An Assessment of the Commercial Trawl Fishery of the Sultanate of Oman using the Ecologically Sustainable Development Framework

By

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Declaration of Originality

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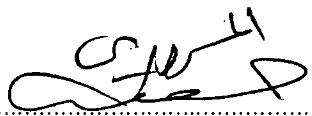

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Abstract

The Sultanate of Oman has devoted particular attention to the development of the fisheries sector as a mechanism to increase fisheries' share in the GDP, foreign exchange, food security and food quality, private sector investment and socio-economic well-being of fishers. However, as a signatory to Agenda 21 Oman has not yet made an attempt to assess the overall performance of her fisheries sector with respect to the core principles of sustainable development. This study aims to assess the performance of the commercial trawl fishery of Oman covering the period 1997-2006 by measuring its impacts on the society and the environment. Considering the relevance and suitability to the fishery, the Ecologically Sustainable Development (ESD) framework was used for this assessment.

A field observation onboard a fishing vessel and a consultation review process involving all stakeholders was carried out to facilitate the identification of the ESD framework components. A set of relevant indicators were then developed to assess the progress with respect to their operational objectives identified from the country's natural resources management policy or, when not available, from the recognized international treaties. This process was structured following the Sustainable Development Reference System (SDRS) guidelines and aimed to gain the acceptance of the fisheries stakeholders.

Multi-Criteria Decision Analysis (MCDA) was then used to assess the progress of each component with respect to its objective toward sustainability. This process involved the calculation and assignment of indicator scores, reference points and weight level (standardization and weighted summation). Following the MCDA results, sensitivity analysis was worked out for five different scenarios representing some adjustment in the MCDA inputs values and the policy preferences of various stakeholders involved. The objectives of this sensitivity analysis were to test the variation in the model in order to increase the confidence and provide new and useful information.

The study period was divided into two periods: the '1998 management scheme' covering the period 1998-2001 and the '1997 management scheme' covering the period 1997 and 2002-2006. Sensitivity analysis results revealed that the year 2001

was the most preferred option for all cases except for the short-term financial preference case, where the year 2006 was the most preferred year. It was observed that with the exception of 2001, which showed the best overall performance, the overall scores aggregated over all components, maintained a similar trend. Close investigation of scores of all options for effects on human revealed that the 1998 management scheme performed weakly with obvious strength and significant performance in the effects on environment. It was also found that the 1997 management scheme mostly targeted short-term financial returns more than any other cases. Contrary to this, the 1998 management scheme was more balanced and favored conservation (long-term preferences) over short-term financial returns.

The results gave special attention and priority to the year 2001 and hence to the 1998 management scheme. Therefore, management schemes practiced in the period 1998-2001, are considered to be the best choice for both long-term financial and conservation preferences and hence they are the best option toward sustainability. In order to give a wider view and determine the status of the fisheries governance, further MCDA was carried out to investigate the effect of the management schemes at indicators and criteria level. This exercise identified the sustainability index of criteria and indicators. The 1998 management scheme was distinguishable from the other by its higher criteria and indicators' sustainability indices.

Based on overall analysis, it was found that the year 2001, which fell within the 1998 management scheme period, was the most preferred year. Therefore, the management measures practiced in the period 1998-2001, are considered to be the most suitable for the advancement towards the ESD principles. However, it is concluded that overall attainment toward sustainability is below par. Based on the key findings (observational as well as analytical), some central policy recommendations have been suggested for better fisheries governance and better attainment of sustainability.

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CHAPTER 1: INTRODUCTION

1.1 General Background

For centuries, human welfare and our continuing existence has profoundly relied upon marine ecosystems and their services. It should be noted that the development of the concept of 'ecosystem services' is mainly to acknowledge our dependency on marine ecosystems in order to meet our basic physical needs and aspirations (Tisdell 1991; Daily et al. 1997; Costanza et al. 1999). It is well recognized by the practitioners in the field that these services have both direct and indirect use value, non-use value and option value which in themselves have great implication to human welfare. These three categories of value are generally combined to estimate the direct and indirect use values even though their measurements are practically and methodologically difficult and have attracted considerable debate among researchers from different discipline areas (Tietenberg 2005). However, despite this debate on the monetization of ecosystem services, Costanza et al. (1998) made an attempt to estimate the global economic value of the ecosystems services which is $US 33 trillion; almost twice the world's Gross National Product (GNP). This is an important attempt because many government agencies require cost-benefit analysis which plays an important role in regulatory decision-making debates on protecting and improving human welfare and the natural environment. For an ecosystem to be healthy and sustainable and to ensure its contribution to human welfare, it must maintain its metabolic activity, its internal structure and organization and be resistant to external stress over relevant time and space scales (Costanza 1992).

While the significance of marine ecosystems is well-founded, there is a growing body of scientific and non-scientific evidence indicating that the health of marine ecosystems is in a state of crisis worldwide (Anon 1994; Kesteven 1996; Costanza et al. 1997; Hilborn 1997; Buckworth 1998; Fogarty and Murawski 1998; Fujita et al. 1998; Long 1998; Schans 2001; Schiermeier 2002; Hilborn 2007). In the context of fisheries, the widespread concern about the state of world fisheries and marine environment formed a formal global consensus at the third United Nations Law of the Sea Convention (UNCLOS III) in 1982. The consensus formally came into force in 1994 (Garcia and Moreno 2001). In particular, the evidence of overfishing of important fish stocks, over-investment, habitat degradation, economic inefficiency and user-group conflicts, amongst others, has provided impetus for the global campaign for the conservation and protection of the marine environment and its resources as the degradation of marine environment would cause significant harm to human well-being. This evidence of a world fisheries crisis also persuaded the Food and Agricultural Organization (FAO) Committee on Fisheries (COFI) in 1991 to recommend to the international institution that new approaches to fisheries management; which encompassed the conservation principles and embraced the consideration of environmental, social and economic issues in the sector; were essential. This recommendation was acted upon and the result was the development of the Code of Conduct for Responsible Fisheries, by FAO, in 1995.

As part of the sustainable development campaign, this evidence of the fisheries crises also led to the development of strategies to ensure the sustainable development of living marine resources and their environment through the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil in 1992. Thus, in the context of marine resources, UNCED reinforced the issue of sustainable use of marine resources and the optimum utilization of fisheries resources through effective and efficient management measures as mentioned in the UNCLOS III. The 1992 Earth Summit in Rio was also followed by the World Scientists' Warning to Humanity (signed by 1700 scientists, including 102 Nobel laureates) statement as: "*We the undersigned, senior members of the world's scientific community, hereby warn all humanity of what lies ahead. A great change in our stewardship of the earth and the life on it is required, if vast human misery is to be avoided and our global home on this planet is not to be irretrievable mutilated*" (Rees 2003; P. 29). This statement further attracted global attention to the significance of the concept of sustainability (Stern 1993), which was first developed at the United Nations Stockholm Conference in 1972 (Green et al. 1991) and received international recognition with the publication of *Our Common Future* (often referred to as 'the Brundtland Report') in 1987 by the World Commission on Environment and Development (WCED 1987).

At UNCED a comprehensive blueprint called 'Agenda 21' has been negotiated for action for sustainable development for the 21st century and beyond with an expectation that it would be followed by all stakeholders to ensure that the needs of the present generation are met without compromising the needs of future generations (UNDSD 1992). To evaluate the achievements and progress made since the 1992 UNCED and Agenda 21, participants from 191 governments, non-governmental organizations, the private sector, scientific community and civil society took part in the World Summit on Sustainable Development (WSSD) held in Johannesburg, South Africa in August 2002. They negotiated a 'Plan of Implementation' that not only makes general reference to the protection and management of a natural resource base to maintain socio-economic development but also makes specific reference to the achievement of sustainability in the fisheries sector (UN 2002b).

Over the last two or so decades, the theory and practice of renewable resources such as fisheries, has taken on a new perspective with global consensus of sustainable development reflected in international policy agendas. Despite the introduction of some innovative approaches such as, adaptive management, co-management, incentive-based management and ecosystems-based management, to manage fisheries resources world-wide, the overall performance of these approaches is not very promising in the sense that there is a distinct lack of progress in articulating the sustainable development principles in totality in a satisfactory manner (Ludwig et al. 1993). Consequently, in the face of this limited progress, researchers and policymakers have engaged themselves in the challenging task of identifying the potential factors of non-sustainability. Although the list is by no means exhaustive, researchers have so far identified some primary factors, such as, lack of good governance, policy inconsistency, conflicts in management objectives, user group conflicts, inadequate information, lack of funding and expertise, socio-economic circumstances of resource users, ineffective incentives, externalities and high market demand, all of which pose as threats in the progression towards sustainability (Hilborn 2007; Grafton et al. 2008).

In addition to this list of primary factors, another source of potential threat identified by the researchers and policymakers is the growth in human population. For instance, over the last 50 years, the world has witnessed a dramatic growth in its population. In March 2007, the world population was estimated to be 6.7 billion compared to 2.5 billion in 1950 (UN 2007c). Hinrichsen (1996) stated that within three decades, if populations continued their recent settlement trends, 75 percent of humanity, or 6.4 billion people, would reside in coastal areas. This indicates a potential shift in the form of in-migration from hinterlands to coastal areas, a common trend in the late 20th century, in most developed countries. The implication of escalating human population and the likely increase in intensity of consumption of fish and seafood products, is that unwise exploitation of fisheries resources represents a serious threat to many fish species in the world (Delgado et al. 2003). The WCED also drew attention to the obvious challenges of population growth, the need for strategies for sustaining food security and the need to conserve natural resources (WCED 1987). The dual pressures of urban and coastal development and population growth have the potential to undermine the long-term viability of the coastal environment (Bryant et al. 1995). The concerns about environmental problems due to population growth should encourage governments to design effective urban and coastal planning systems and minimize potential negative impacts on the coastal and marine environment and ultimately on human welfare.

It should be noted that commercial fishing as an exploitative economic activity is subject to the law of diminishing returns. The law states that if more and more of a variable input (i.e. nominal fishing effort) is applied to a fixed quantity of other inputs, then eventually the resulting increments of output (i.e. catch or yield) will decrease beyond some point. This implies that the marginal product of the variable input will eventually diminish (Cunningham et al. 1984; Tisdell 1982). Experience has shown that by removing an excessively high proportion of a continuously harvested renewable resource its sustainability will be compromised as will the supply of food to future generations (Caddy and Griffiths 1995). It is claimed that for thousands of years humans have had a major impact on target species and their supporting ecosystem to a level where many fisheries have not recovered (Segar 2007). This creates an obvious concern in relation to the pursuits of economic activity and the protection of environment as they are traditionally regarded as opposite to each other. Given this perception, policy makers have had a daunting task reconciling the incompatible objectives of short-term political success, economic growth, social progress, and environmental sustainability in directing the future path of overall society and economy (Molden and Dahl 2007). In the context of fisheries, to meet the expectation of various stakeholders involved in the sector, effective fisheries management should reflect a balance of multiple objectives namely: economic, social, environmental, biological and political. However, these are very often in conflict (Hilborn 2007). In recent years though, researchers and policy makers have put in substantial efforts to remove the environment-economy dichotomy. They have integrated the two in emerging policy framework to support informed and balanced decision making (Coombs 1990; Costanza 1996; Russell 1996). This merger has been forced by the multidisciplinary concept of sustainable development, which demands more prudent use of capital, improved knowledge and effective organizational leadership to ensure human well-being.

Effective management of any living resource requires the maintenance of a dynamic balance between obtaining the benefits of exploitation and minimizing the impacts of exploitation (Brown et al. 1998). It should encourage participation from various stakeholders to achieve meaningful progress in marine resource management to ensure the future well-being of the stock (Krouse 1989).

Following the above-mentioned international initiatives and policy agendas, the Sultanate of Oman (hereafter Oman) has devoted particular attention to the development of the fisheries sector as a mechanism to increase fisheries' share in the Gross Domestic Product (GDP), foreign exchange, food security and food quality, private sector investment and socio-economic well-being of fishers that are reflected in country's economic vision 2020. However, as a signatory to Agenda 21 Oman has not yet made an attempt to assess the overall performance of her fisheries sector with respect to the core principles of sustainable development. This is not unique to Oman as many States (both developed and developing nations) who are signatories to this convention have not been able to make significant progress towards sustainable development because of socio-economic, political, institutional and legal constraints facing them (Imberger 2003; Goodland and Daly 1996; Otterstad 1996). The current situation is clearly reflected in the following statement from the UN report of the World Summit on Sustainable Development, Johannesburg: *"Sadly, we have not made much progress in realizing the grand vision contained in Agenda 21 and other international agreements"* (UN 2002a; P. 157).

1.2 Brief Overview of Fisheries Sector in Oman

Before stating the specific research problems and research objectives it is important to add a brief discussion on the overall fisheries sector in Oman. This discussion will provide a basis for identifying the research problems and the main objectives of this research. However, a detailed discussion about the fisheries sector in Oman will be presented in the following chapter. Under the recent 'Omanization' campaign set out in the Fourth Five Year Plan (1991-1995), fisheries in Oman are considered one of the important natural resources of the country. Like any nationalization campaign, the Omanization program attempts to increase participation by Omanis in the country's socio-economic developmental activities.

In 2006, fisheries contributions to total GDP and non-oil GDP are 0.43% and 0.8% respectively. Despite its low contribution to the country's GDP figures, the sector plays an important socio-economic role in the country. Relative to other natural resources, fisheries is ranked second in regard to their contribution to the national economy. It is estimated that more than one quarter of Oman's population depends on fisheries as a source of living (FAO 2001a). The significance of the fisheries sector to the national economy stems from its contributions to: 1) the national GDP, 2) foreign exchange earnings, 3) sources of food and animal protein, and 4) provision of direct and indirect employment (Al-Oufi 1999). In the FAO country review report in 2004, it is reported that Oman is not only a major producer, but also one of the net exporters of fish and fisheries products in the region (Morgan 2004).

Total fish landing grew considerably from 94,893 mt valued at OMR 25.04 million in 1985 to 151,908 mt valued at OMR 72.49 million in 2006 (MAF 2007). This type of financial return has resulted in increasing pressure on coastal resources. Establishing the causal factor underlying declines in targeted population is a controversial matter and separating the effects of environmentally-induced and human-induced change can be difficult in practice. However, existing evidence indicates that the inshore fisheries resources of Oman have shown symptoms of overfishing especially the high-value commercial species such as kingfish, lobster, shrimp, abalone, sardine and many other demersal species (Al-Oufi 1999; Moore and Dorr 1994; Siddeek 1995; Sultan 1996).

To continue its economic productivity and its significant contributions to socio-economic welfare, it is important that the fisheries sector be managed and developed in a sustainable manner. According to the FAO definition of sustainable development, any development activities associated with land, water, plant and genetic resources, must be environmentally non-degrading, technologically appropriate, economically viable and socially acceptable (Garcia 2000). In this context, fisheries development in Oman should not be allowed to undermine the regenerative capacity of the fisheries resources. For example, under the economic diversification strategies as adopted by the government in Oman, the management authority may encourage technological development in the commercial fisheries sector to increase profitability of the sector. The introduction of new fishing technology or even developing an existing one in a developing country like Oman has the potential to increase the welfare of the present and future generations by increasing the profitability of the sector. However, as experienced by other modern fishing nations in the world, this type of technological sophistication may also generate catastrophic results if left unregulated (Cunningham et al. 1984). More specifically, a variety of problems can appear including substantial change in ecosystem structure; wastage through discards; impacts on endangered species; loss of critical habitats; and increasing conflicts and confrontation over access to fisheries resources and for any targeted subsidies (FAO 1999a).

The Fisheries sector in Oman is divided into two types namely, traditional and commercial (often called industrial). The two types are based on the fishing methods used and their scale of operations. During the period 1985-2006, an average of about 85% of the total landing came from the traditional sector and the remaining 15% came from the commercial sector. However, the commercial sector has attracted attention from the government under the Omanization and economic diversification policies.

Involvement of the commercial fishing fleet in Omani waters was commenced in 1976 when the government entered into a contract with a Japanese fishing company and later, in 1978 with a Korean company, allowing these companies to take a percentage of the catch. In 1989, the government decided to give five private Omani companies a harvesting quota of 28,000 mt of demersal fish species and 50,000 mt of pelagic depending on stock status determined by the ministry.

The commercial vessels which operate in Omani waters can be categorized into three types according to their method of fishing and the species fished: Demersal Trawlers, Longliners and Purse Seiner. Trawlers are licensed to operate along the continental shelf between latitude 21° 40' N, south of Masirah Island and longitude 55° 45' E, North of Halaniyat Island, and at a distance of 10 nautical miles from the shore or at more than 50 meters depth (see Chapter 2 for detail discussion). However, sometimes trawlers are allowed to fish at a distance of 5 nautical miles. This has apparently created resources access conflict between the traditional and trawling sectors.

Trawling contribution to the commercial landing and value averaged 79.92% and 77.41% respectively in the period 1991-2006. In 2006, 28 vessels fished for 4149 fishing days and landed 19,276 mt, which counted for 82.49% of the total commercial landing valued at 10,511,243 OMR (76.72%) (MAF 2007). In this context, the trawl sector plays an important economic role in the overall commercial fisheries sector in Oman. In the management regulatory context, it should be noted that the commercial trawl sector is a highly regulated enterprise compared to the traditional sector. The main management measures used in the trawl sector are a combination of license limitation, area and gear restrictions, output control and a monetary measure (tax/royalties). It should be mentioned that commercial trawlers' economic behavior (the maximization discounted net returns) may lead to over-exploitation of the key trawl species. This is because of the fact that in the absence of any effective regulations the exploitation rate of commercially important species will be influenced by the economic return to resource users (Clark 1973a; Clark 1973). In the absence of effective fisheries governance, this opportunistic behavior will ultimately undermine the objectives of the current strategic visions of the Government. Thus, in order to maintain and/or increase the flow of socio-economic benefits from the trawl fishery and to achieve sustainability in the sector as part of the 'Vision 2020' and 'Omanization' campaign, it is important that the management authority should make every effort to assess the performance of the trawl sector under the sustainable development principles. It also makes sense to assess the progress of a highly regulated industry toward sustainable development. In addition, the choice of the trawl sector in Oman as a relevant case study of sustainable development is not only influenced by its strategic importance in the country's economic development and environmental policy agenda but also by other compelling reasons discussed in the following section 1.3.

1.3 Statement of Problem

Although the share of the trawling sector in relation to total fish landings (traditional and commercial) is on average about 13% in the period 1989-2006, in the context of sustainability of living marine resources it has great influences on the overall management objectives of the fisheries sector in Oman. The following reasons are provided to justify the present research under the headings of environmental, economic, social and institutional dimensions as they together form the core concept of sustainability.

1.3.1 Environmental

- There is a widespread concern among scientists, fisheries managers, industry and the general public about the potential negative effects trawl fishing has on the potential of altering and/or destroying the physical characteristics of marine habitat (Turner et al. 1999; Kaiser et al. 2001; Kaiser et al. 2002; Kennelly 2003). In this context, national fisheries policies that promote environmental sustainability are worth assessing.
- There is also a growing concern that fishing activities such as trawling contribute to the issue of 'by-catch' and 'discards' which are taken incidentally or opportunistically along with other targeted species (Hall 1995; Suuronen 2005; Davis 2002).

1.3.2 Economic

- The trawl sector is export market oriented as a significant amount (sometimes 100%) of trawl landings are intended for foreign markets. Consequently, leaving aside the distributional issue of foreign earnings, there is a clear trade-off between the availability of trawl catch in the domestic market and the foreign earnings. Following the theory of demand, given the local market demand, the non-availability of trawl catch has the potential to create upward pressure in the prices of fish in the domestic market in the short-run.

- The sector provides significant royalty payments to the government.
- The period 1998-2001 witnessed a notable change in the management practices in the form of input control in the trawl sector. Consequently, there was a major shift in landings and therefore the economic return from the trawl sector to the traditional sector.

1.3.3 Social

- The trawl fishery has been experiencing conflict in regard to internal allocation that involves conflict arising between different user groups and gear types (Charles 1992). Under the social dimension of sustainability it is worth considering the impact of such conflict.
- It is also important to assess whether the performance of the trawl sector is consistent with the recent nationalization strategy drawn up by the government. It is important to note the unique feature of the sector being that there are only four fishing vessels which are still fully operated by foreign fishing companies with foreign crews. It should be noted that there is a national youth vessel project led by the Ministry of Fisheries Wealth (MFW) aimed at training Omani youth to replace the existing foreign crews employed in the trawl vessels.
- As the sector is export oriented, it is important to examine the influence of this strategy on domestic food security.
- There is a growing concern from the public about the trawl sector performance under the principles of ecologically sustainable development.

1.3.4 Institutional

- Although it is not specific to the trawl fishery, overall it is important to examine the institutional capacity with particular reference to effective control over marine resources, availability of financial resources, expertise and training, formulation of policy and its review process, transparency in decision making, lack of bias in resource allocation, institutional accountability, information management, promotion of community awareness and other relevant conditions, to ensure institutional sustainability.

All these reasons warrant a systematic approach to assess the performance of the commercial trawl fishery in Oman in accordance with an appropriate sustainable development framework.

1.4 Research Objective

Due to the lack of appropriate and relevant information for the traditional fisheries sector and considering the above-mentioned reasons regarding the commercial trawl sector, the present study mainly focuses on the Omani commercial trawling sector. The main objective of this study is:

- To assess the performance of the commercial trawl sector of Oman covering the period 1997-2006 using the Ecologically Sustainable Development (ESD) framework with particular emphasis on human impact and the environment as proposed by Chesson and Clayton (1998).

To achieve this main research objective, several sub-objectives as listed below should be met:

1. To identify a suitable sustainable development framework from the literature along with its core components;
2. To identify the appropriate objective(s) for each component with specific reference to the overall fisheries management objectives in Oman;
3. To ensure that the objective(s) under each component stated in sub-objective 1 above is (are) relevant by consulting the key stakeholders and by conducting independent field observations;
4. To develop a Sustainable Development Reference System (SDRS) by developing appropriate indicator(s) for each component and subsequently developing appropriate reference point(s) for each indicator; and

5. To assess the progress of each component towards sustainable development in regard to its associated objective(s) identified in sub-objective 2 above. This is performed by examining the strengths and weaknesses of the various management measures that were in place during the study period under different scenario using the Multi-Criteria Decision Analysis (MCDA).

1.5 Scope, Limitation and Significance of the Study

As mentioned earlier in section 1.4, in the context of the commercial trawl fishery in Oman this study mainly investigates how far the concept of sustainable development has progressed in practice. It is important to recognize that the notion of sustainable development is a multidisciplinary and multifaceted concept. Consequently, the task of embracing the concept in its totality is daunting as the definitions and interpretations available in the literature are often ambiguous and very broad in nature (Drummond and Marsden 1995; Otterstad 1996; Mitchell 1997; Molden and Dahl 2007; Potts 2006). Considering the research objective stated in section 1.4, it may be argued that the analytical approach and framework adopted in this study is partial in nature because the study focuses on the trawl fishery only as opposed to the overall fishery sector and also its emphasis on selected sustainability dimensions. However, this is not unusual as the imperfection in operationalizing the concept of sustainable development is also recognized by others (Drummond and Marsden 1995). Furthermore, the lack of relevant and consistent data and information across fisheries sectors (traditional and commercial) limited the scope of this study. However, as identified by Principle 15 of the Rio Declaration, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent over-exploitation of natural resource and environmental degradation (UN 1992).

Thus, it should be emphasized that in applying the principles of sustainable development to the study in hand, it is essential to consider the core dimensions of sustainable development in such a way that is relevant to this particular case study (Bruff and Wood 1995). Keeping this in mind and based on the analysis of existing literature on sustainable development and its operational appropriateness to the case in hand, it has been decided to adopt the Ecologically Sustainable Development

(ESD) framework proposed by Chesson and Clayton (1998). The main reasons for this decision are as follows: 1) the proposed framework has already been applied to assessing the sustainability of similar Commonwealth fisheries in Australia, and 2) the other existing frameworks in the literature were found to be either general and broad or have some specific limitation and thereby were not suitable for the case study in hand.

In addition to the reasons provided in section 1.3, and to provide justification for the significance of this research it should be noted that international conservation policy and practice are undergoing rapid transformation from nature preservation to sustainable use of natural resources for livelihoods (Allison and Ellis 2001; Tisdell 1991). Thus, an understanding of the socio-economic and environmental consequences of the most controversial fisheries sector in Oman has a profound implication for conservation policy making, consistent with the principles of ESD. Furthermore, Agenda 21 has addressed the pressing problems facing the marine resources sector world-wide and aimed at preparing the global community to provide effective solutions to those problems. Although this blueprint reflects a global consensus, the responsibility of its successful implementation resides with the state. Effective strategies, plans, policies and processes are to be developed and implemented to ensure the success of the blueprint in Oman.

It should be noted that no attempt has been made to assess the performance of the fisheries sector in Oman with specific reference to sustainable development. This study, therefore, anticipates satisfying the existing gap in fisheries research and adding new knowledge in the field by focussing on the multidisciplinary contexts of sustainable development and their role in effective management of fisheries resources in Oman. In particular, this study intends to make a major contribution to the existing knowledge in fisheries research through its application of a sustainable development framework in assessing and measuring the impacts of the commercial trawl fishery on human well-being and the marine environment. It is hoped that this study will make a valuable contribution in assessing the sustainability of an important fisheries sector in Oman and that the findings of this study may be useful to the resource managers and fishing industry in designing effective policies to sustain export earnings and maintain resource sustainability. This study should also act as a useful guide to the future research in assessing overall fisheries sustainability in Oman. Further significance of this research is its relevance to Oman in relation to its contribution in identifying the degree of achievement of the country's commitments to the local, national and international community regarding the sustainability of fisheries resources as well as human development.

1.5.1 Further Limitation

In addition to the limitations mentioned above, two other limitations which might have some affect on the accuracy and comprehensiveness of the study are worth mentioning.

1. The dynamic and complex nature of the topic

   As mentioned earlier, sustainability is a complex and dynamic concept. It covers and includes many different themes found in its four core dimensions: environmental, economic, social and institutional. Due to this complexity, it is impossible to cover all dimensional aspects of the concept on equal footing in this study. With this in mind, the study follows a systematic approach based on SDRS and ESD frameworks to identify relevant components (criteria) and indicators.

2. Selection of Indicators

   As mentioned in section 1.3, lack of relevant and consistent data and information limited the scope of this study. In this context, it should be mentioned that the selection of appropriate indicators to measure progress towards sustainability is constrained by the availability of relevant and reliable data. As a result, a majority of indicators have been constructed based on the available data and an attempt has been made to ensure that they are as direct as possible in addressing the identified operational objectives.

1.6 Brief Outline of the Methodology

The overall approach adopted in this research is largely blended and it attempts to combine existing concepts from several scientific discipline areas into an appropriate and flexible framework. More specifically, a diverse range of literature has been used to select, adopt and derive appropriate definitions of the concepts, indicators and frameworks to achieve the main objective of the study. In this context, the methodological framework proposed by Chesson and Clayton (1998) is followed in this study as mentioned in Section 1.5. In selecting and measuring the sustainability indicators, particular attention has been given to make those indicators appropriate, direct, simple, relevant, acceptable to and easily understood by the key stakeholders. This has been achieved through consultation and review with relevant stakeholders. The step by step procedure and methodological approach followed in this study will be further discussed in detail in the relevant chapters of the thesis.

1.7 Thesis Structure

Including this introductory first chapter, the thesis consists of nine chapters organized to follow the research methodology undertaken in this study.

Chapter Two is allocated to reviewing the fisheries and the natural resources of Oman and investigates the presence of the sustainability dimensions on them. Specifically, it aims to provide an overview of the country profile, the fisheries resources and sectors (traditional and commercial) and other natural resources available in the country. It also highlights and discusses the management side and the legal framework of the fishery and the country's attitude toward its sustainability. It gives further attention to the industrial trawling sector, which is the study case of this research.

Chapter Three reviews the literature on the concept of the sustainability and mostly focuses on fisheries sustainable development. It highlights all components (social, economic, ecological and institutional) of the sustainable development. The evolution and the definition of the sustainable development are reviewed. Different international initiatives, instruments and management approaches that tackle the idea of fisheries sustainability are also highlighted and discussed throughout the chapter. Special attention is given to the Australian ESD concept and its sustainability reporting framework.

Chapter Four reviews some of the most important fisheries related technical guidelines behind the development of sustainability indicators. Specifically, it reviews five different conceptual frameworks used to adapt a practical set of indicators and the context of fisheries indicators. Therefore, the main objective of this chapter is to identify the best fit framework to be followed in the assessment of indicators for the trawling sector in the Sultanate of Oman. Different analysis tools used in the sustainability evaluation process are also discussed in order to end up with the one, most applicable to fit the evaluation of the study findings.

Chapter Five aims to design and identify all possible components of the ESD framework that are relevant to the industrial trawling sector in Oman. It also aims to specify objectives for each of the relevant components. This has been achieved through a set of surveys, group discussion and consultation reviews and a field observation to understand and get a clear view of the fishery, aided by the intensive literature review presented in the previous two chapters.

Chapter Six aims to identify a set of practical performance indicators and reference points following the SDRS (FAO 1999a) and the ESD framework. Mostly, the indicators have been chosen based on the available data that directly addresses the operational objectives identified in the previous chapter. This has been achieved through discussion and consultation reviews with relevant stakeholders following an extensive literature search on indicators for fisheries sustainable development.

Chapter Seven aims to assess progress with respect to the specified objective(s) under each component of the ESD framework described in chapter five using the selected list of indicators described in Chapter Six. This assessment is carried out with respect to each component's objective(s) toward sustainability using the MCDA. Furthermore, this chapter provides justification of preferred trends of selected indicators and describes the standardization process and a method of calculating a score for each component.

Chapter Eight is assigned to further sensitivity analysis and options evaluation that might help in any further development in the management framework. It shows the results of sensitivity analysis that highlight strengths and weaknesses of the base case presented in Chapter Seven that influences the overall performance ordering. It also presents the sensitivity analysis of four other cases that represent preferences of different decision makers' attitudes and some adjustment in the inputs values.

Chapter Nine summarizes the overall conclusions and lists some policy implications that will help in improving the legislative framework of the commercial trawling sector.

CHAPTER 2: AN OVERVIEW OF THE FISHERY SYSTEM IN THE SULTANATE OF OMAN

2.1 Introduction

Although the main focus of this study is the sustainability of the commercial trawl fisheries sector in Oman as indicated in Chapter 1, it is important to examine the country's physical features, socio-economic characteristics and administrative structures along with the characteristics of marine habitats and resources. This is because an understanding of these features, structures and characteristics and their likely influences to the conservation of marine environment and resources under different management practices is critical for assessing the trawl sector's progress toward sustainability. In the context of fisheries and marine resources, this chapter presents an overview of the nature, status and characterization of the overall fishery system in Oman under various 'sub-systems' - the natural system (consisting of fish and ecosystem), the human system (involving fishers, post-harvest sector, consumers, community and socio-economic features) and the fisheries management system (which includes fisheries management, policy and planning, fisheries development and fisheries research) - as discussed by Charles (2001). It should be emphasized that the interconnectedness among the elements of these three 'sub-systems' and the nature of potential influence on each other needs to be well-understood by the management authority to ensure fisheries sustainability in Oman. The apparent interactions between components also calls for an 'integrated approach' to fisheries management in the sense that it demands theoretical as well as technical contributions from multiple disciplines that would lead to improved management performances towards sustainable fisheries.

2.2 Country Profile

2.2.1 Physical Features

Oman occupies the southeastern corner of the Arabian Peninsula between latitudes 16° 40′ and 26° 20′ North and longitudes 51° 50′ and 59° 40′ East. The coastline extends 3165 km from the Strait of Hormuz in the North to the borders of the Republic of Yemen in the South with a total land area of 309,500 square kilometers, making it the third largest country in the Arabian Peninsula (National Survey Authority, Ministry of Defense). The Sultanate of Oman shares a land border with three countries namely; the United Arab Emirate and the Kingdom of Saudi Arabia to the west and Yemen to the southwest. On the other hand, it is bordered by three different oceans: the Arabian Gulf off the western shore of Musandam; the Gulf of Oman which forms the northeastern coast from Musandam to Ras Al-Hadd; and the Arabian Sea which borders the long southern and central coast from Ras Al-Hadd down to the Yemen border. All these waters provide the country with access to the world's oceans (Oman 2004; Oman 2005). It is indicated that marine waters that border Oman have the potential for development (Feidi 2001; Feidi 2006).

Oman is composed of varying topographic areas consisting of plains, wadis (dry river valleys) and mountains. The most important area is the plain overlooking the Gulf of Oman and the Arabian Sea with an area constituting about 3% of the total land area. Oman's coast along the Arabian Sea in most areas is barren and rocky, while along the Gulf of Oman it is sandy except in Musandam and few areas in Muscat and Al-Sharqyiah. The mountain ranges occupy about 15% of the total land area, the most important of which is Hajar, extending in the form of an arch from Ras Musandam in the North to Ras Al-Hadd and Al-Qara in the southwestern corner of Oman. The remaining area, which includes part of Ar-Rub Al-Khali (Empty Quarter) and occupies about 82% of the total area, is mainly sand and desert. Some tropical vegetation grows along the coast in Dhofar, a region in the south affected by the southwest Monsoon (Oman 2004; Oman 2005; World-Book 1999).

Oman is considered one of the hottest countries in the world. The climate differs from one area to another. It is hot (often exceeding 50 °C) and humid in the coastal areas in summer and hot and dry in the interior. The exception is the higher mountains, which enjoy a moderate climate throughout the year and low temperatures, down to -4 °C, in the winter. Generally, Oman experiences light and irregular rainfall (less than 15 centimeters of rain each year) with the exception of Dhofar region, where heavy and regular rains, up to 63.5 centimeters annually, fall between June and October because of the Indian Ocean (Oman 2004; Oman 2005). The monsoonal activity results in extensive upwelling along the coast and high marine productivity. The climatic features have been limiting the agricultural production in the country and as a result have shifted attention to the exploitation of the potential of marine resources.

2.2.2 Country's Administrative Structure

As a gateway between the Indian Ocean, east Africa and the Arabian Gulf, Oman's geographical location has always been strategically important in relation to the socio-economic development and political affairs of the region. For example, in 2003, Oman was ranked fifth in regard to capture fisheries production in the Arab region (Feidi 2006). In 2005, two neighboring countries United Arab Emirates (UAE) and Saudi Arabia were ranked first and second respectively as importers of fish and fishery products from Oman (see Table 2. 8 in Section 2.5.2). In addition, since 1970, Oman has developed close ties to its neighboring countries and in 1981 joined the six-member Gulf Cooperation Council (Oman 2005). Oman is divided, as per Royal Decrees No. 6/1991 and 108/2006 sanctioning the administrative regions of Oman, into nine administrative divisions of which four, Muscat, Musandam, Dhofar and Al-Buraimi, are called Governorates. The other five Al-Batinah, Al-Dhahirah, Al-Dakhiliyah or Interior, Al-Sharqiyah and Al-Wusta, are called Regions (Oman 2004). Figure 2. 1 presents the location of each administrative region. The administrative divisions are further subdivided into 61 provinces (Wilayah; plural: Wilayat). The division between Governorates and Regions is based on the administrative profile, geographic location and economic importance of each administrative division, briefly discussed below (Omanet 2007).

Muscat Governorate is situated on the Gulf of Oman. It is the central administrative centre of the country and hence it is entrusted with the preparation and formulation of projects, programmes and plans aiming at realizing progress and prosperity for the whole population and in all regions of the country. It is characterized by high population density and substantial socio-economic developmental activities.

The Governorate of Musandam lies in the far north of Oman. It is separated from the rest of the country by a strip of United Arab Emirates land. Its rough mountains rise to 1800 m above sea level. It is distinguished by its strategic location, with part of it, known as Ras Musandam, overseeing the international water passage called the Strait of Hormuz, the gate to the Arabian Gulf. The Musandam area also provides huge potential for tourism.

Dhofar Governorate occupies nearly one third of the country's total area and is one of the very few areas in the Arabian Peninsula with a wide range of topographic variations. The coast of Dhofar is considered a haven for the fishing industries and sardines, lobsters and abalone constitute most of the catch (Oman 2005). Its climate is dramatically different to the rest of Oman due to the effects of the Southwest Monsoon, which arrives during the summer months, creating humidity and moderate temperatures of around 30°C.

The Governorate of Al Buraimi is situated in the north west corner of the country, adjacent to the borders with United Arab Emirates. It is a new governorate initiated by Royal Decree number 108 issued in 2006.

The principal activities of the population of Al-Batinah Region are agriculture and fisheries. Its coastal plain occupies the frontier with the United Arab Emirates for a distance of 270 km south east of the Muscat Governorate. It is situated between the coast and the western Hajar mountain range and is one of the most industrialized and urbanized region in Oman.

Al-Sharqiyah Region is the north east front of Oman over looking the Arabian Sea from the east and is famous for shipbuilding. It can be divided into two areas: the eastern Hajar Mountains and the sandy plain penetrated by wadis. It is bordered by the Arabian Sea to the south east and by Wahiba Sand to the south. It has unspoiled coastline in the east and the south, which abounds with dolphins and turtles. The fish resource provides a livelihood for the coastal people.

Al-Wusta Region is important for its abundant oil and fisheries resources, which are the major export commodities of Oman. Fishing and animal husbandry are the main occupations of the population of the area. The region is also characterized by its unique and special environment including the Arabian Oryx sanctuary, which was registered on the International heritage list. This region contains the permitted fishing area for the commercial trawling sector.

Al-Dakhliyah (Interior) Region is a central plateau running from Al-Jabal Al-Akhder in the north towards the desert in the south. It is bordered on the east by Al-Sharqiyah and on the west by Al-Dhahirah, a semi-desert plain sloping from the southern flanks of Western Hajr in the direction of Ar-Rub Al-Khali.

2.2.3 Population and Economy

According to the 2003 general census of population, housing and establishment, the total population of Oman was 2.341 million, with 23.9% non-Omani (MNE 2004). By 2006 the population had increased to about 2.577 million (Anon 2007a).

At present, the Omani economy's main sources of revenue are the promising oil and natural gas sectors. Before the discovery of oil reserves in the country[1], agriculture and fisheries dominated the Omani economy with around 80% of the population depending on these two sectors (Al-Oufi 1999). Now, Oman is an open and oil-based economy. In 2006 the estimated per capita Gross Domestic Product (GDP) was 5320 OMR (MNE 2007a) and the 2004 estimated unemployment rate was 15% (World-Factbook 2007). Oman's Ministry of Information stated that the macroeconomic environment of Oman has been robust since 2000, driven by high oil prices, development of Liquefied Natural Gas (LNG), increase in public investment in infrastructure development and growing diversification of the national economy (Oman 2005).

[1] Oil exporting began in 1967.

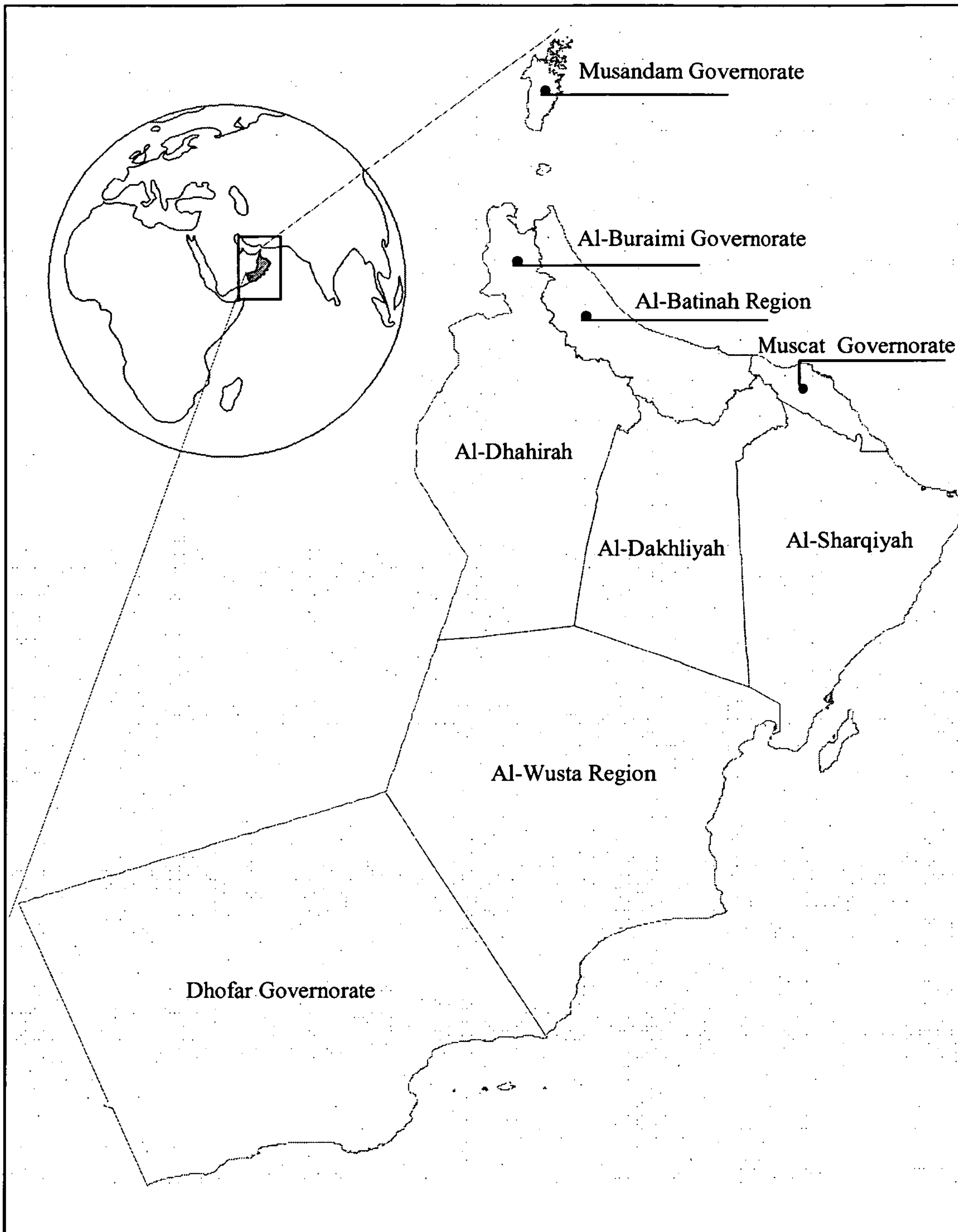


Figure 2. 1 Map of the Sultanate of Oman showing its Governorates and Administrative Regions

Oman's economic policy making draws on a series of five-year plans that set objectives for all government sectors. By 1995, Oman had completed four five-year plans. In 1995, drawing on past experience and international commitments, a new vision for Oman's economic future was outlined. The conference called "Vision for Oman's National Economy: Oman 2020" held in June 1995 outlined proposals for the country's sustainable development over twenty-five years to 2020. The following fundamental goals were outlined (Omaninfo 2006; Oman 2004):

1. To develop and upgrade Omani human resources in order to cope with technological progress and attain international competitiveness.
2. To develop a private sector capable of optimum use of human and natural resources in an efficient and ecologically sound way, in close collaboration with the government.
3. To utilize the geo-strategic location of the country, optimize the use of its natural resources and promote economic diversification.
4. To distribute the fruits of development among all regions and all citizens.
5. To preserve, safeguard and develop the achievements accomplished in the past twenty five years.

According to the Vision 2020 statement the crude oil's contribution to GDP is predicted to drop to around 9% in 2020, compared to its 41% in 1996. Compared to the less than 1% it generated in 1996, by 2020 natural gas is expected to generate 10% of GDP The fishing sector, on the other hand, is expected to grow from 1% in 1995 to 2% by 2020. Table 2. 1 below presents the quantity, value and share of crude oil production, natural gas production and fish resources to total GDP in 2006. Table 2. 1 clearly demonstrates the economic significance of the crude oil sector of the economy.

2.2.4 Role of Financial Institutions in Economic Development

Oman's banking sector is supervised and directed by the Central Bank of Oman (CBO) established in December 1971. With all other commercial and specialized banks, the CBO plays an important role in the economic development through its monetary policy and investing strategies. Financial institutions in Oman play a major role in the country's economic development. In addition to commercial banks, there are also three specialized banks; among them is the Oman Development Bank (ODB). This bank is an Omani joint-stock company created in April 1997 in a merger between the ODB, and the Oman Agriculture and Fisheries Bank (OAFB), which had been playing a special role in the development of marine sector in Oman. It supports small, limited cost projects and encourages investment from aspiring entrepreneurs. ODB enjoys exemption from all taxes and the government subsidizes the interest rate on the soft loans it advances. ODB finances private sector projects in several fields including industry, agriculture, fisheries, animal resources, exports, tourism and self-employed and workshop projects through the provision of medium and long-term loans and participation in capital investment. It offers technical assistance and consultancy services to Omani companies. ODB is also responsible for the provision and recovery of government-backed soft loans, export credit guarantees and distribution of proceeds from the Fisheries Research Fund (FRF), which was established in 1991 for the development of fisheries research.

Table 2. 1 Production and income of oil, gas and fish resources in year 2006

Parameter	Quantity (Unit)	Value (Mn. OMR)	Share of GDP (%)
GDP	-	13,709.7	-
Crude Oil	269.2423 (Mn. BBL)	3,225.9	23.53
Natural Gas	1,051,755 (Mn. t^3)	613.5	4.47
Fish Resources	151,908 (mt)	58.5	0.43

Source: (MNE 2007a)

2.3 Conservation of Natural Environment

The conservation of the environment and natural resources have always been of key importance to Oman. Since 1970, His Majesty the Sultan of Oman has expressed on many occasions, his clear commitment to environment protection and conservation. On the 15th anniversary of the country's National Day (1985), an address by His Majesty stated that (Omanet 2005; P. 118):

"As a result of our great concern for the protection of the natural environment and our achievements in this respect, Oman has gained a respectable position among nations concerned with environmental protection; yet, we still have to exert more effort and consider the special conditions relevant to this issue, when

we come to plan and implement development projects. We must proceed to develop contacts with regional and international organizations concerned. It is a duty which must be undertaken by each citizen, to guarantee the protection of our natural resources and public health against any harmful effects and protect the beautiful and distinguished nature which God Almighty granted to our beloved Oman."

2.3.1 National Commitment

It is important to note that 2001 and 2002 were designated Years of the Environment, stressing the crucial link between environmental protection and human dimensions of development with a view to promoting sustainable development. It also demonstrates the country's commitment to environmental issues. At the Earth Summit in Rio de Janeiro, Brazil in 1992, it was announced that His Majesty Sultan Qaboos would offer a bi-annual Award for Environmental Conservation, to be administered by UNESCO (Oman 2004). The representative of His Majesty at the World Summit on Sustainable Development held in Johannesburg confirmed Oman's commitment to the implementation of the basic principles adopted in the Earth Summit.

It should be noted that in the context of marine environment, the FAO Code of Conduct for Responsible Fisheries states that: "*States should apply the precautionary approach widely to conservation, management and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment*" (FAO 1995; P. 12). Influenced by these type of international environmental initiatives, Oman has adopted an anticipatory and precautionary approach to environmental management (MRME 1992). The main goal of this national approach to environmental management is to integrate environmental considerations into all developmental plans and activities. Thus, necessary institutions have been established, legal frameworks have been developed to ensure effective monitoring, assessment and response to the potential negative impacts of developmental activities on the environmental resource base.) Several projects and programmes, described below, have been planned, financed and implemented in order to fulfill regional and international obligations.

The objectives of the national economic development process were indicated by the Development Council established in 1975. The policies governing those objectives reflect the great determination and confidence based on the country's background of its old civilization, Arab tradition and a firm faith in God as reflected in the above-mentioned National Day address (MRME 1992).

2.3.2 Regional and International Commitment

Oman's foreign policy since 1970 has been influenced by His Majesty Sultan Qaboos bin Said's determination to remove the political and economic isolation of the country and integrate Oman both regionally and internationally. Therefore, Oman's foreign policy is driven by this vision and guided by the following principles:

1. Development and maintenance of good relations with Oman's neighbors and all countries.
2. Outward-looking and internationalist outlook, as befits long-standing maritime traditions.
3. Pragmatic approach to bilateral relations, emphasizing underlying geo-strategic realities rather than temporary ideological positions.
4. Search for security through cooperation and peace, rather than conflict.

Oman is a member of several regional and international organizations. On 7th October 1971, Oman joined the United Nations. Since then, Oman has joined many international organizations including the Food and Agriculture Organization (FAO), United Nations Industrial Development Organization (UNIDO) and United Nations Educational, Scientific and Cultural Organization (UNESCO). Oman has also assumed membership of key international bodies such as the United Nations Security Council (UNSC), United Nations Economic and Social Council (UNESC) and the Council of the International Seabed Authority (CISA).

At regional level, Oman joined the League of Arab States in 1971 and became a member of the Arab Gulf Cooperation Council (AGCC) on its formation in May 1981. In 1997, Oman, along with 13 other nations, founded the Indian Ocean Rim Association for Regional Cooperation (IORARC), which aimed to improve links through the Indian Ocean region, from Australia, through South East Asia, India, Africa and the Arabian Peninsula. Table 2. 2 documents Oman's membership, since 1971, on international and regional organizations responsible for ocean governance in general and fisheries research and development in particular.

Oman has also signed, at both international and regional level, many commissions, conventions and protocols that deal with environment and fisheries such as the voluntary FAO Code of Conduct for Responsible Fisheries and the UN Fish Stocks Agreement. Table 2. 3 categorizes the name of commissions, conventions and protocols specific to fisheries and marine environment both at the regional and international levels.

Table 2. 2 Oman's membership of international and regional organizations dealing with marine environment and fisheries research and development

Level	Organization	Abbreviation	Year of Membership
International	United Nation Organization	UN	1971
	Food and Agriculture Organization	FAO	1971
	United Nations Educational, Scientific and Cultural Organization	UNESCO	1972
	International Fund for Agricultural Development	IFAD	1977
	International Maritime Organization	IMO	1974
	International Union for Conservation of Nature	IUCN	1975
	International Whaling Commission	IWC	1980
	Indian Ocean Rim Association for Regional Cooperation	IORARC	1997
Arab	League of Arab States	LAS	1971
	Arab Organization for Agricultural Development	AOAD	1972
	Arab League Educational Culture and Scientific Organization	ALECSO	1973
Muslim	Islamic Education, Scientific and Cultural Organization	IESCO	1982
Gulf	Arab Gulf Cooperation Council	AGCC	1981
Other	Regional Organization for Protection of the Maritime Environment	ROPME	1979

Sources:
1. Office of the Permanent Representative of the Sultanate of Oman to the United Nation
2. Ministry of Information - Sultanate of Oman
3. Ministry of Agriculture & Fisheries - Sultanate of Oman
4. Ministry of Regional Municipalities, Environment & Water Resources - Sultanate of Oman
5. Ministry of National Economy - Sultanate of Oman
6. (MRME 1992)
7. Organizations websites

Table 2. 3 Oman's commitment to programmes, commissions, conventions and protocols dealing with marine environment and fisheries research and development

Organization	Programme, Commissions, Conventions and protocols
UN	United Nations Environment Programme (UNEP)
	United Nations Convention on the Law of the Sea
	Agreement Relating to the Implementation of Part XI of the United Nations Convention on the Law of the Sea
	International Convention for The Regulation of the Whaling
	Convention on Biological Diversity
	International Seabed Authority
	United Nations Framework Convention on Climate Change
	United Nations Fish Stocks Agreement
FAO	FAO Code of Conduct for Responsible Fisheries
	Regional Commission for Fisheries
	Indian Ocean Fishery Commission
	Indian Ocean Tuna Commission
IMO	International Convention for the Prevention of Pollution from Ships (MARPOL)
	International Convention Relating to Intervention on the High Seas in Case of Oil Pollution Casualties and its Protocol
	International Oil Pollution Compensation Funds
	International Convention on Civil Liability for Oil Pollution Damage and its Protocol
	International Regulation for Preventing Collision at Sea
AGCC	Council for Arab Ministers in Charge of Environmental Affairs
ROPME	Protocol Concerning Marine Pollution Resulting from Exploration and Exploitation of the Continental Shelf
	Protocol for the Protection of the Marine Environment against Pollution from Land-Based Sources
	Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution

Sources: Same as in Table 2. 2

2.3.3 Overall Legislative Structure

Oman's government is a bicameral (State Council and Legislative Council) system. The Basic Statute of the State provided for the establishment of the Council of Oman which was created by Royal Decree No. 86/97 in 1997. It comprises the Majlis A'Shura (Consultative Council), whose members are elected by Omani citizens every three years, and the Majlis A'Dawla (State Council), whose members are appointed by the Sultan.

The Sultan of Oman legislates by Royal Decree and appoints a Cabinet to assist him in governmental affairs. The Cabinet is comprised of several ministries and selected special advisors. Law-making begins with either an instruction from the Sultan or a request from a ministry to the Cabinet of the Deputy Prime Minister for Legal Affairs. Throughout the law-making process, concerned ministries are involved and extensive reviews are sought. All legislation proposed by any ministry as well as the regulations promulgated by each ministry are reviewed by the legal experts in the Ministry of Diwan Affairs (MDA). MDA is an administrative body which has an over-riding relationship with each and every other ministry in the country (Grinyer 1980). Legal instruments thereafter will emanate from the Sultan as Sultanic (Royal) Decrees or Sultanic Decisions or from the responsible minister as Ministerial Decisions.

To ease administrative complexity, Oman is divided into Wilayat (governorate or districts) under the jurisdiction of the Ministry of the Interior (see section 2.2.2). It is an important ministry because of its supervisory role over Walis, whom are regional administrative officers or Governors who serve as his Majesty's representatives throughout the country. A Wali is appointed to each Wilayah, whereas Muscat (the capital), Musandam, Dhofar and Al-Buraimi all have Governors. Each Wali or Governor aided by appropriate channel is in charge of ensuring that the laws are followed in the local communities in a peaceful and strife-free manner. The Walis also serve as a conduit through which the local population can make their wishes known to any of the national ministries.

Royal Decree 34/74 issuing the Marine Pollution Control Law brought to light Oman's early concern for the safety of the marine environment. Very early, His Majesty the Sultan realized the importance of conserving Oman's natural heritage and, in 1974, established the Office of the Adviser for Conservation of the Environment. In the same year, Royal Decree 68/79 established the Council for Conservation of the Environment and the Prevention of Pollution under the chairmanship of His Majesty (see section 2.3.4). This enabled much early action to be taken to bring awareness of environmental matters to the new and expanding ministries. Legislation was passed by various ministries, such as a law to ban the hunting of certain wildlife species. In 1982 the Oman Natural History Museum was established in the Ministry of National Heritage and Culture (MNHC), bringing yet another ministry into the broadening field of consultation.

In 1979, the Law on National Parks and Protected Nature Areas was issued by Royal Decree No. 26/79. This was then replaced by the Law on Nature Reserves and Wildlife Conservation issued by Royal Decree No. 6/03. In 1982, Royal Decree No. 10/82 'The Law on Conservation of the Environment and the Prevention of Pollution' and its Amendments (Royal Decree No. 63/85) were issued, addressing offences against the environment, which is defined broadly to include air, water, soil, land life, marine life and factors and natural materials with which man deals in his place of work. They include the requirement that all development projects should undergo environmental scrutiny prior to the issue of a mandatory environmental permit. A full Environmental Impact Assessment (EIA) study is required to be carried out for larger projects or those in environmentally sensitive areas. This law was then replaced with Royal Decree 114/2001 "The Law of Conservation of the Environment and Prevention of Pollution".

In 1992 a National Conservation Strategy (NCS) for sustainable development was drafted, with extensive consultation among the ministries and organizations with responsibility for biodiversity conservation, or whose development projects could present a threat to the habitat of flora and fauna (MRME 1997). The exercise was concluded with a major seminar to extend this consultation. The document was finally ratified by the Cabinet as a guideline document and issued in 1996.

The formulating of the National Biodiversity Strategy and Action Plan (NBSAP) in 2000 has promoted awareness and understanding of the fields of responsibility, establishing much growing and beneficial dialogue between the various ministries and agencies involved in biodiversity conservation. In addition to NBSAP and NCS, the preparations of the National Coastal Zone Management

Programme, the National Coral Reef Management Plan and the establishment of 12 Natural Reserves (MRMEWR 2003) have been important milestones in national conservation efforts.

Some other important legislation and laws applicable to fisheries and marine resources are discussed in Section 2.6.2.

2.3.4 Authorities

Oman's environmental strategy is based on the principle of co-operation between all relevant government and private institutions, both at home and abroad, and the regional and international organizations involved with the environment. It' aims to maintain a balance between essential development and the well-being of the environment and public health.

Following the legislation system (Section 2.3.3), there are various official authorities holding responsibility for management, development, planning, research, education, decision making and consultation, for general environmental matters (MRME 1992) including marine environment and fisheries related issues.

2.3.4.1 Council for Conservation of the Environment and Prevention of Pollution (CCEPP)

This council was created in 1979 by Royal Decree No. 68/79. Its initial purpose was to oversee the control of marine pollution pursuant to Oman's responsibilities under the Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution (MRME 1992) (see Table 2. 3 above). In 1984, these responsibilities were expanded to cover protection of the environment and prevention of pollution generally as per Royal Decree No. 46/1984.

2.3.4.2 Ministry of Regional Municipalities, Environment and Water Resources (MRMEWR)

By Royal Decree No. 45/1984, Oman created a Ministry of Environment, the first Arab country to do so. In 1991 according to Royal Decree No. 177/1991, it was amalgamated with the Ministry of Regional Municipalities to form the Ministry of Regional Municipalities and Environment (MRME) a single large Ministry with a presence throughout all regions of the country. In 2001, Royal Decree No. 47/2001 revises the name of the Ministry of Regional Municipalities and Environment to Ministry of Regional Municipalities, Environment and Water Resources (MRMEWR). Recently, by Royal Decree No. 90/2007, a Ministry for Environment and Climate Affairs (MECA) was established to which environment related work, allocations and assets shall be transferred from the MRMEWR making it the principal authority for environmental protection and nature conservation. It is represented by the Directorate General for Environmental Affairs who addresses environmental protection and the adverse impacts of development by:

- Drafting and implementation of laws, regulations and national plans for environmental conservation
- Preparation and execution of national plans for protection of the environment
- Pollution monitoring and control networks and programs
- Research programs and environmental impact assessments
- Implementation of special projects
- Maintaining environmental databases
- Public awareness campaigns and technical training of staff
- Issuing of environmental permits and emission licenses
- Nationwide inspection schedules and response to incidents
- Ratification of international conventions
- Participation in domestic and foreign environmental conferences
- National focal point for international organizations

The Directorate General of Nature Conservation is another directorate, which promotes the protection and conservation of nature and biodiversity as well as increasing awareness of it through the designation of protected areas, the establishment of ranger units, research, and the evaluation of development projects. It is the national focal point for the Convention of Biological Diversity (CBD) signed following the Rio Earth Summit in 1992 (see Table 2. 3 above).

2.3.4.3 Office of Advisor for Conservation of the Environment (OACE)

OACE was created in 1974 within the Diwan (Office) of the Royal Court. It is a noteworthy authority which concentrates on matters related to, and affecting, the conservation of nature and wildlife resources and adapting some specific national projects and work in contact with MECA.

2.3.4.4 Ministry of Fisheries Wealth

The Fisheries Department formed in 1972 became a Directorate General in 1974. In 1975 Royal Decree No. 26/1975 formed the Ministry of Agriculture, Fisheries, Petroleum and Minerals. In June 1979, this Ministry was split into two: the Ministry of Agriculture and Fisheries (MAF) and the Ministry of Petroleum and Minerals. The Directorate General of Fisheries Resources in MAF practices its duty through seven departments and centers: department of fisheries development, department of extension & fisheries research, department of inspection, marine science & fisheries center (MSFC), quality control center, aquaculture center and fishermen training center.

In the context of a 'Fishery System Approach' as mentioned in the introduction of this chapter, the following sections are arranged to describe the various components of the three 'sub-systems' namely: natural system, human system and fishery management system.

2.4 Natural System

2.4.1 Marine Habitats and Resources

Oman has always struck a sensible balance between the needs of development and the environment. Today, even with an oil driven economy, marine resources are still of great economic importance to the country (see Section 2.5.1 for further details). In this section, characteristics of some key marine habitats and resources are highlighted. These characteristics are fundamental to understanding the importance of their protection and importance of habitat quality in relation to the life cycle of marine species.

2.4.1.1 Mangrove

Mangrove forests are critical marine habitats acting as a genetic reservoir. They provide a nursery ground harboring juvenile stages of commercially important fish and Penaeid shrimp as well as refuge and breeding areas. The only mangrove species occurring in the country is the highly saline-tolerant *Avicennia marine*, but *Rhizophora stylosa* and *Lummnitzera racemosa* were artificially transplanted by Japan International Cooperation Agency (JICA) in the early 1980's (Shoji 2002). There are four main important sites associated with mangrove communities; three of them found along the Al-Batinah coast with a total area of around 11.1 km^2 and the fourth is the best forest in Oman which covers 60% of Mahout Island in Al-Wusta Region (Al-Muharrami 1994; MRMEWR 2003).

2.4.1.2 Coral Reef

In Oman, major coral growth occurs mainly in four areas: the Musandam Peninsula (Arabian Gulf, Strait of Hormuz and Gulf of Oman); the capital area coast (with the Daymaniyat Islands) to Ras Al-Hadd; Masirah Island and some isolated sheltered locations in Dhofar and Al-Hallaniyate Islands (Arabian Sea) (MRMEWR 2004). Other coastline of the country either lacks corals or has limited growth of small, scattered colonies due mainly to the absence of suitable substrate (e.g. along the sandy Al-Batinah coast) or due to seasonal upwelling of cold water along the Arabian Sea coast. Different scientists in the period from 1986 to 1995 suggest that between 70 and 90 coral species and about 50 genera may exist in Omani waters. Distribution maps generated from previous reports by Veron (2000) indicate that over 100 species may exist.

2.4.1.3 Sea Grass and Seaweed

Four species of seagrass have been found in Oman, dominated by the smaller species *Halodule uninervise* and *Halophila ovalis* with occasional beds of the larger species *Syringodium isoetifolium* and *Thalassodendron ciliatum* (Jupp et al. 1996). Seagrasses of the area form an important diet for the endangered green turtle *Chelonia mydas*. They also provide important habitat for fish and crustaceans such as the commercially significant *Penaeus semisulcatus* (Mohan and Siddeek 1996). Over 230 taxa of macroalgae (seaweeds) have been identified (Jupp 2000; Wynne and

Jupp 1998). Along the coast of the Arabian Sea, upwelling triggered by the southweast monsoon fuels dense growth of phaeophytes dominated by *Nizamuddinia zanardinii* and *Sargassum* spp. (MRMEWR 2003).

2.4.1.4 Turtles

Of the total of seven species of marine turtles in the world, five species are found in Oman (MRMEWR 2003). Four of them nest along the Omani coast and islands; the Loggerhead turtle *Caratta caretta*, Green turtle *chelonian mydas*, Hawksbill turtle *Eretmochelys imbricata* and Olive Ridley turtle *Lepidochelys olivacea*. All five species of turtle are listed in the IUCN Red Data Book either as "endangered species" or as "critically endangered species" (Baillie and Groombridge 1996). Oman is the only country in the area with sea turtle populations of worldwide importance. The loggerheads are found on Masirah Island, greens at Ras Al-Hadd and hawksbills on the Daymaniyat Islands (Ross and Barwani 1981). The green turtles nesting population of Ras Al-Hadd (Arabian Sea) is the largest in the Indian Ocean with 13,000-20,000 individuals nesting annually (Baldwin and Al-Kiyumi 1999). There are some turtle mortalities reported against trawlers (see Chapter 5 for further details).

2.4.1.5 Marine Mammals

Aside from one single recording of an elephant seal (*Mirounga leonine*) discovered on a beach in the Dhofar Region in 1989, the only marine mammals known to regularly occur in Omani waters are cetaceans. To date, three species of mysticeti (baleen whales) and 15 species of odontoceti (toothed whales, dolphins and porpoises) have been confirmed as occurring in Omani waters (MRMEWR 2003).

2.4.1.6 Khawrs (Coastal Lagoon or Saline Creeks)

At the mouth of wadis, khawrs are found with or without mangrove, separated from the sea by a sand bar. They are of high conservation value as wader and migratory bird feeding areas (Clarke et al. 1986) and important reservoirs of biodiversity including fish, invertebrates and macrophytes including reeds (MRMEWR 2003). Most of the khawrs can be found in Dhofar Governorate, where

44 khawrs were identified by Fouda (1995) extending along about 100km of sandy coastline.

2.4.1.7 Wadis (Dry River Valleys)

There are no major rivers in Oman, however, flat alluvial plains around the coast have wadis, which may run down from interior mountain ranges and then fill with deposited sand and gravel material during infrequent rainstorms. A wadi system enhances conditions for expansion of terrestrial communities of fauna and flora by the occasional nutrients flows into these ecosystems.

2.4.2 Fishery Resource

A total of 1,142 species have been identified in Oman's territorial waters, of which more than 400 are demersal, 511 from coral reefs and coastal lagoons, 2 mesopelagic, 157 pelagic, 30 bathypelagic and 7 are bathydemersals (Fouda et al. 1998). Al-Abdessalaam (1995) describes 280 species with emphasis on commercial species. Demersal fisheries of the Arabian Sea, Gulf of Oman and Arabian Gulf include over 350 commercial fish species as claimed by Siddeek et al. (1999). Randall (1995) describes 930 coastal fishes from shelf areas, excluding deep-sea, flying and lantern fishes.

The richness and diversity of the fish resources in the country may be attributed to several factors such as the country's diverse coastal habitat, huge Economic Exclusive Zone (EEZ) (300,333 km^2), wide climatic spectrum and its unique geographic location in the Northwest Indian Ocean with a strong upwelling zone (MRMEWR 2003). In fact, the JGOFS Arabian Sea Expedition during 1994-1996 classified the seas off the coast of the country among the most highly productive areas in the world in terms of primary and secondary production (Milliman and Smith 2001). The Indian Ocean in general has attracted the attention of world fishing interest due to the increasing trend of fish production as against the stagnation and depletion of the production from the world's other oceans (Milliman and Smith 2001). The Arabian Sea, especially the semi-enclosed Northwest region is considered to be one of the richest ecosystems in the area with a mosaic of fauna and flora that includes some economically important fish stocks. In addition to the semi-enclosed nature of the sea, the other reasons considered for the diverse and rich fauna and flora are the large number of river systems joining the sea, specialized water currents such as the Somalia current and the upwelling phenomena driven by monsoon winds (Varghese and Somvanshi 2001).

2.4.2.1 Stock Assessment

Effective fisheries management relies heavily upon, amongst other things, accurate information on stock status. In its simplest terms, stock assessment can be defined as the process of assembling, analyzing and interpreting biological information on fish stocks, which serves as an important input to the fisheries management decision making process (Schnute and Richards 1994). Thus, to ensure sustainable production over time from fish resources it is essential to have an estimate for individual stock. Oman has adopted various surveys and special projects to assess the stock size of various fisheries and/or key species. As an example, during December 1999-2002 a special project on the kingfish fishery was run to estimate the key biological parameters and assess the socio-economic importance of the kingfish fishery (Al-Oufi et al. 2004). Recently on August 9, 2007, MAF (known now as MFW) signed a contract with a New Zealand-based company to conduct surveys on fisheries resources. The project will run for 26 months to cover all seasons. It includes surveying surface and deep fisheries resources in addition to the fish resources in the country's territorial waters. The survey area covers the area from southern Masirah Island to the country's border with Yemen at a depth that ranges from 20 - 1,200 meters.

A Trilateral workshop on Lantern fish in the Gulf of Oman was organized by the FAO Fishery Industries Division in cooperation with the Ministry of Agriculture and Fisheries on 7-9th May 2001 and was hosted by Oman (FAO 2001b). It was attended by 43 participants from Oman, the Islamic Republic of Iran and from FAO. The Omani delegation felt that more research is needed for gathering biological and ecological information and data. This was supported by FAO and therefore it was decided not to exploit the lantern fish resources until further research is done with FAO technical support.

There are three other fishery-independent surveys carried out in Oman which determine the potential yield of fish stock. The first was carried out in the period

1976-1979 by the Research Vessel Dr. Fridjoft Nansen[2] in the Arabian Gulf and the Gulf of Oman at a depth of 10-300 m (Aglen and Tilseth 1981). The second was also carried out by the same vessel in the period 1983-1984, which covered the area from Ras Al-Hadd to Ras Marbat in the Dhofar Region (Siddeek et al. 1999). The third survey was conducted by the Research Vessel Rastrelliger (Johannesson 1995). It carried out an acoustic and trawl fishing survey from 15th November 1989 to 15th November 1990 under the joint arrangement between FAO and the Government of the Sultanate of Oman Fish Resources Assessment Survey Project (Al-Abdessalaam 1991). The survey took place in the Omani Exclusive Economic Zone (EEZ) at a depth between 15 to 200 meters (Mohan 1994) covering pelagic, mesopelagic (lantern fish) and demersal fish resources. A total of 150 species and species groups were documented during the Rastrelliger survey. Only 99 species from 15 families were considered to be of commercial interest. Total fish resources were estimated to be 5,307,000 tons (MAF 2001) (Table 2. 4).

Of the estimated total 5,307,000 tons of fish and seafood resources during the survey in 1989-1990 (Table 2. 4), 4,278,357 tons was estimated as the total potential yield that could be harvested in a sustainable manner (MAF 2001) (Table 2. 5). It should be noted that sharks, rays, crustaceans and molluscs were included in the estimates of pelagic and demersal fish resources in Table 2. 4 below. Of the 126,000 tons of potential yield of demersal resources only 67,000 tons was categorized as commercial with the remaining 59,000 tons categorized as non-commercial (Mohan 1994). Mohan (1994) also claimed that the total potential yield estimate of the demersal resources was later revised upwards to about 139,000 tons.

[2] This survey was one part only of different surveys carried out by Research Vessel Dr. Fridjoft Nansen from 1975 to February 1981 (Aglen and Tilseth 1981).

Table 2. 4 Estimates of fish resources in Oman from Research Vessel Rastrelliger survey (1989-1990)

Fish	Gulf of Oman		Arabian Sea		Total	
	Quantity (Ton)	%	Quantity (Ton)	%	Quantity (Ton)	%
Pelagic	63,020	1.50	189,062	17.08	252,082	4.75
%	25.00		75.00		100	
Demersal	96,083	2.29	469,113	42.37	565,196	10.65
%	17.00		83.00		100	
Lantern Fish	4,040,750	96.21	448,972	40.55	4,489,722	84.60
%	90.00		10.00		100	
Total	4,199,853	100	1,107,147	100	5,307,000	
%	79.14		20.86			100

Table 2. 5 Total potential yield of Oman fish resources from Research Vessel Rastrelliger survey (1989-1990)

Fish	Amount (ton)	Percentage (%)
Large Pelagic	70,000	1.64
Small Pelagic	63,000	1.47
Demersal	126,000	2.95
Sharks & Rays[3]	10,000	0.23
Crustacean & Mollusc	9,357	0.22
Lantern Fish	4,000,000	93.49
Total	4,278,357	100

From Table 2. 4 and Table 2.5 above, it can be seen that, excluding lantern fish, only 43% of the total potential yield was harvested in 1990. It should also be noted that in 2006 the actual harvest was only 54.6% of the 1990 potential yield estimate. The harvesting however, has concentrated on the exploitation of high-valued species, such as, kingfish, grouper, tunas, shrimps and other known species (MAF 2001). Thus it can perhaps be said, that apart from some high-valued commercial species, the symptom of overexploitation is not common across all species in Oman.

[3] Sharks, Rays, Crustacean and Mollusk were included within Pelagic and Demersal fish resources in Table 2. 4

Furthermore, there is a sign of declining catches in the coastal waters due to the high concentration of fishing efforts compared to the offshore waters. However, it is believed that increases in fish production are possible with the development of appropriate scientific guidance, effective management and the application of modern technology that will enable the country to extend its fishing operation within the EEZ (Feidi 2006). It is also important to note that experimental studies on the feasibility of shrimp, finfish and abalone culture are being carried out in Oman (Anon 2006c).

2.5 Human System

2.5.1 Fisheries Socio-economic Role

Fisheries represents the second most important sector in the national economy after oil and gas and has the potential to meet human nutritional needs by supplying food from the sea (Oman 2005). The historical importance of fisheries in the country, coupled with the potential long-term contribution of the fisheries sector to the national economy, led the government to seek development of this valuable resource base. His Majesty the Sultan recognizes the need to strengthen the Government's institutional capabilities to assist traditional fishermen and to manage and develop the country's vast marine resources. In general, fisheries are described as a multi-million dollar industry and the traditional fishery in particular is also of great social significance in creating employment. It is also reported that more than a quarter of Oman's population depend directly or indirectly in one way or another on fishing for their livelihood. As mentioned earlier in Section 2.2.1, the country's long coastline has significant resource potential and as a result the fisheries sector could play a major role in the country's socio-economic development program. Because of the EEZ, Oman has fishing access to 300,333 km^2 of inshore and offshore waters (MRMEWR 2003). The realization of the socio-economic importance of the sector was reflected in the overall goals of the country's modernization process in the early 1970s. These goals aimed to increase the supplies of fish for local consumption, to increase export earnings, to increase employment and to increase fishers' income.

Table 2. 6 below presents the contribution the fisheries sector made to the national economy for the period 1980-2006. It should be noted that the fisheries sector's contribution to the GDP (at market prices) exhibited a significant growth in

the period 1980-2006 with a Coefficient of Variation (CV) of about 41%. The calculated value of the CV measures the variation in the GDP figures as a proportion of its overall mean as following:

CV = 100 (Standard Deviation / Observed Mean)

It is also noted from Table 2. 6 that the year 1995 witnessed a significant growth (208.88%) compared to the base year (1980 = 100%) level. This increase in the GDP figure in 1995 was attributed to the increase in landings (see Table 2. 10). It should also be mentioned that the particular reference to the year 1995 was mainly due to the fact that the fisheries contribution in the year 1995 was used as a reference year in the country's 'Vision 2020' statement. Under the "vision 2020" statement, declared in 1995, the fisheries sector is expected to contribute around 2% to the total GDP in 2020 which is twice the 1995 figure. Based on the simple index value presented in column 3 of Table 2. 6, it can be seen that the year 2005 recorded the highest GDP value with 252.07% above the base year (1980=100%) value. It is noted that the year 2005 experienced an increase in the price of fish products due to strong demand on international markets (see Figure 2. 2). As a result, this price increase has contributed to 2005 having the highest GDP figure.

During the period 1980-2006, the relative contribution of the fisheries sector to the non-oil GDP (at current market prices) ranged from 1.92% in 1980 to 0.8% in 2006. As a proportion of the total GDP, the fisheries sector's GDP during the same period ranged between 0.43% and 1.0%. However, it should be noted that the sector's contribution to total GDP has experienced a downward trend since 1995, which has important policy implications and indicates the fact that the gap between the expected value (under the Vision 2020) and the realized values has been widening since 1995. However, MAF Fisheries Deputy indicated that the reasons for this widening gap are due to factors such as the rise in oil price during the period, which was higher than the rise in fish price and the underestimation of the fisheries GDP figures during the period as the calculation failed to include the contribution of value-added products (Personal communication, October 14, 2006). A similar trend can also be noted in relation to the sector's share to the non-oil GDP (Table 2. 6). Furthermore, discrepancies in inflation figures may have had some affect in the calculation of the GDP figures as some references indicate an inflation rate varying between 3.2% (World-Factbook 2007) up to 6% (Anon 2007b), whereas the official authority records show a rate of only 1% (MNE 2007c).

Table 2. 6 Key indicators of the Fisheries Sector (1980 – 2006)

Year	Fisheries Sector GDP (at Current Market Price) (Mn. OMR)	Index of Fisheries Sector GDP (1980 = 100)	Share of Oil & Non-oil GDP (%)	Share of Non-oil GDP (%)
1980	16.9	100	0.8	1.92
1981	19.7	116.57	0.7	1.76
1982	21	124.26	0.8	1.62
1983	24.8	146.75	0.8	1.68
1984	24.1	142.60	0.7	1.42
1985	22.1	130.77	0.6	1.21
1986	21.6	127.81	0.7	1.12
1987	28.3	167.46	0.9	1.54
1988	25.3	149.70	0.8	1.26
1989	27.3	161.54	0.8	1.3
1990	28.1	166.27	0.6	1.17
1991	22.1	130.77	0.5	0.85
1992	26.7	157.99	0.6	0.93
1993	26.9	159.17	0.6	0.88
1994	30.9	182.84	0.6	0.96
1995	52.2	308.88	1	1.55
1996	46.2	273.37	0.8	1.3
1997	52.8	312.43	0.9	1.4
1998	50.9	301.18	0.9	1.3
1999	52.3	309.47	0.9	1.4
2000	48.7	288.17	0.6	1.2
2001	51	301.78	0.66	1.12
2002	53.1	314.20	0.68	1.13
2003	56.6	334.91	0.68	1.12
2004	57.6	340.83	0.60	1.02
2005	59.5	352.07	0.50	0.95
2006	58.5	346.15	0.43	0.80
Average	37.23			

Source: (MNE 2007a; MD 1997)

Another significant role played by the fisheries sector is through the creation of employment opportunities for Omani people. The fisheries sector provides thousands of employment opportunities for Omani nationals, especially for people in coastal communities. In 2006, the sector provided direct employment for 32,476 fishermen. Another 7,500 people were engaged in fisheries-related activities, such as fish handling, selling, processing and distribution as well as ancillary industries like workshop mechanics and selling of fishing gear and spare parts (Anon 2007a). Therefore, in 2006 the fisheries sector directly and indirectly employed 40,000 Omani nationals, about 1.6% of the total population. In future more employment opportunities are expected to be created in the fisheries-based industry of the country through infrastructure development initiatives such as the establishment of new fishing ports. There would also be more employment opportunities for the Omani people under the Omanization program that is, if the commercial fleet were to be fully Omanized. By 2020 the fisheries sector is expected to directly employ about 50,000 fishermen compared to the recorded 32,476 fishermen in 2006. Although the 2006 figure may indicate a good achievement so far, it should be recognized that to make the program effective and to maintain its credibility the government has to do more to match the expected level of direct employment in 2020. The Sixth Five Year plan (2001-2005) had aimed at achieving a 3.9% annual growth rate by Omanizing the commercial fishing fleets by the end of 2005 (Oman 2005).

With regard to social contributions, it should be noted that the fisheries sector in Oman is noted for its contribution to human health through the supply of nutrition and to human capital through the national investment in fisheries related education to develop skills and expertise in Omani people. The contribution towards the development of human capital is now considered as a part of economic development and an indicator of social sustainability (Goodland and Daly 1996).

2.5.2 Domestic Consumption, Export and Post-harvest Sector

For centuries, fish has been an important staple food for the Omani coastal inhabitants and has provided a large portion of their protein requirements. Even the inland populations have long been dependent on fish landed along the coasts of the Arabian Sea and the Gulf of Oman. These fish were processed (dried and salted) and transported to the inland regions using camel and donkeys. At present fish is transported chilled with ice or in refrigerated trucks to the inland regions using national highways.

As stated by Jenkinson (1987), based on 1983 FAO Yearbook of Fisheries statistics, per capita fish consumption in Oman was 20.3 kg, which then rose to 36.7 kg in 1995 (Feidi 1998). The per capita figure then declined to 20.3 kg in 1997 (Al-Oufi 1999) and maintained an average level of 25.8 kg during the period 1999-2001 (NOAA 2003). In 2003 the per capita fish consumption increased again to 24.1 kg (FAO 2006b). It should be mentioned that, Feidi (2006) calculated the per capita consumption figure for Oman which in 2003, was 37.42 kg (the highest in the Arab countries). This apparent discrepancy was due to the fact that calculations by Feidi (2006) included imports. Table 2. 7 below provides an estimated figure of the per capita fish consumption in Oman in 2005. The figure represents the quantity of fish that was available to each person in Oman in 2005 after exports to international markets and losses due to poor handling (about 30%). This figure was then adjusted by employing a generic flesh yield coefficient of 70% as used by Al-Oufi (1999). Furthermore, as shown in Table 2. 7, the per capita fish consumption in 2005 was 14.04 kg per person, which apparently indicates the fact that the per capita consumption in 2005 declined significantly compared to the corresponding figure in 1995. However, it should be noted that this comparison may not be appropriate as the calculation of the 2005 figure includes losses due to poor handling and yield coefficient. In any case, if there has been a genuine reduction in per capita fish consumption in recent years, it is perhaps indicative of the fact that high purchasing power due to oil revenue in the country has influenced consumer to demand for other protein substitutes (Feidi 2006). Al-Oufi (1999) stated that this sharp decline from 83,000 mt to 73,863 mt was due to the reduction in the quantity of fish available for local consumption caused by the sharp increase in fish exports (see Figure 2. 2). This indicates a clear trade-off between export earnings and domestic consumption, which undermines national food security.

Table 2. 7 Apparent consumption of fish in Oman in 2005

Item	Amount (mt)
Total fish landings	157,339
Exports	-83,476
Balance	73,863
Losses due to poor handling @ 30%	-22,159
Amount available to be consumed by the population of 2.577 million	51,704
Yield coefficient @ 70% of the 51,704 metric tons available in the country	36,193
Fish consumption per capita	14.04 kg/person

The sector also contributes to foreign exchange earnings of the country, and ranked second after oil and gas exports and first among the non-oil exports. Table 2. 8 below, presents a list of the top ten countries importing Omani fish and seafood in 2005 along with their rank in terms of value. In terms of both quantity and value, it can be seen that Oman's fisheries sector plays an important role in the economy through foreign exchange earnings. Although there are noticeable fluctuations in foreign exchange earnings, quantity, total value and unit value of fish exports all have experienced overall positive trends during 1981-2005 (see Figure 2. 2 and Table 2. 9). The year 1995 witnessed a substantial increase in the value of fish exports, reaching 41.2 OMR million, which was 117% above the 1994 level. This rise was due to the increase in both the quantity and in the fish price. In 2004 both quantity and value of the exported fish and fisheries products reached their highest levels. The quantity and value recorded in 2004 were 85,055 mt and 62 OMR million being 860% and 2254% higher respectively than the corresponding values in 1981. It is important to note that the calculated CV values for export quantity, total value and unit value are 53.76%, 69.07% and 30.21% respectively (see Table 2. 9). These figures indicate the fact that variation in quantity, relative to price, is the dominant factor that contributed to the variation in total value during 1981-2005.

Table 2. 8 Top ten major Importers of Omani fish for year 2005

Rank	Country	Quantity (mt)	Value (OMR)	Quantity Percentage[4]	Value Percentage
1	UAE	33000.6	18528.4	39.5	31.6
2	Saudi	13274.6	5773.9	15.9	9.8
3	Italy	3559.2	5380.1	4.3	9.2
4	Hong Kong	786.7	3229.9	0.9	5.5
5	Thailand	3882.4	2819.5	4.7	4.8
6	China	3139.5	2754.0	3.8	4.7
7	Greece	2515.4	2686.2	3.0	4.6
8	Spain	2344.5	2074.8	2.8	3.5
9	France	1443.2	1913.7	1.7	3.3
10	Libya	2154.0	1518.3	2.6	2.6

Al-Oufi (1999) also claimed that any reduction in both quantity and value of fish exports observed in a particular year relative to previous years, during 1981-2005, can be attributed most likely to the reduction in landings from the traditional sector as the largest share of total landings (85%) comes from this sector. There could be other specific events which might contribute to the fact of a reduction in quantity and value in particular year. For example, technical restrictions imposed by the European Union (EU) in July 1998 on fish imports from Oman have definitely contributed to the decline in the quantity and value of the fish export. These restrictions have been brought about due to detection of non compliance with the EU standards.

To address this import ban issue, the government put significant effort into enacting a quality assurance system for the fish processing companies. Since 1998, Oman has adopted a Hazard Analysis and Critical Control Point (HACCP) system in seafood operations in the country. At presents 24 out of 39 seafood processing facilities have adopted the HACCP system under the guidance of the National Quality Control Centre. To maintain food quality and safety and to enforce required quality standards, the centre monitors and conducts periodical analysis of samples from the processing facilities (Anon 2006a; Anon 2006b). Consequently, successful results have been achieved as the EU lifted the ban in October 1999 (Al-Oufi 2002).

[4] Quantity and value were calculated relative to the overall export quantity (83,476 mt) and value (58,637,000 OMR). The amount of the catch was exported to a total of 50 countries.

By September 2002, around 50% of existing processing plants were upgraded to meet the international standards (Al-Oufi 2002).

Table 2. 9 Export quantity, value and unit price for the period 1981-2005

Year	Quantity (mt)		Value (OMR Million)		Price (OMR/mt)	
	Unit	Index	Unit	Index	Unit	Index
1981	8861	100	3	100	299	100
1982	12509	141	3	104	220	73
1983	14216	160	8	317	590	197
1984	17774	201	8	313	466	156
1985	19462	220	8	293	399	133
1986	18472	208	11	405	580	194
1987	20669	233	12	447	573	192
1988	35150	397	19	714	538	180
1989	28137	318	15	563	530	177
1990	33854	382	17	652	510	171
1991	29403	332	13	501	451	151
1992	29598	334	13	508	455	152
1993	45810	517	20	747	432	144
1994	44587	503	19	718	427	143
1995	59148	668	41	1555	697	233
1996	38526	435	37	1393	958	320
1997	36476	412	27	1024	744	249
1998	34847	393	28	1061	807	270
1999	45632	515	35	1338	777	260
2000	46409	524	37	1403	801	268
2001	52464	592	39	1482	749	250
2002	62250	703	46	1751	745	249
2003	69009	779	52	1977	759	254
2004	85055	960	62	2354	733	245
2005	83476	942	59	2213	702	235
2006						
Average	38871.77		25.37		597.82	
Std. Dev. (SD)	20897.86		17.52		180.60	
Coefficient of Variation (CV)	53.76		69.07		30.21	

Source: (MAF 2004; MAF 2005; MAF 2006a, b; MAF 2007)

Although, Oman has experienced an increase in both the quantity and value of fish exports since 2002 in international markets (see Figure 2. 2), the domestic market has experienced a shortage of supply. Following the basic theory of demand and given the local market demand, this type of shortage in supply increases the local market price of fish thereby reducing the quantity demanded by the local consumers. This is not surprising as the CV estimate for the unit value of the traditional sector for the period 1985-2006 shows relatively larger fluctuation compared to that of the commercial sector (see Section 2.5.3 for further discussion). The implications of this issue will be discussed further in the context of sustainable development in the next chapters.

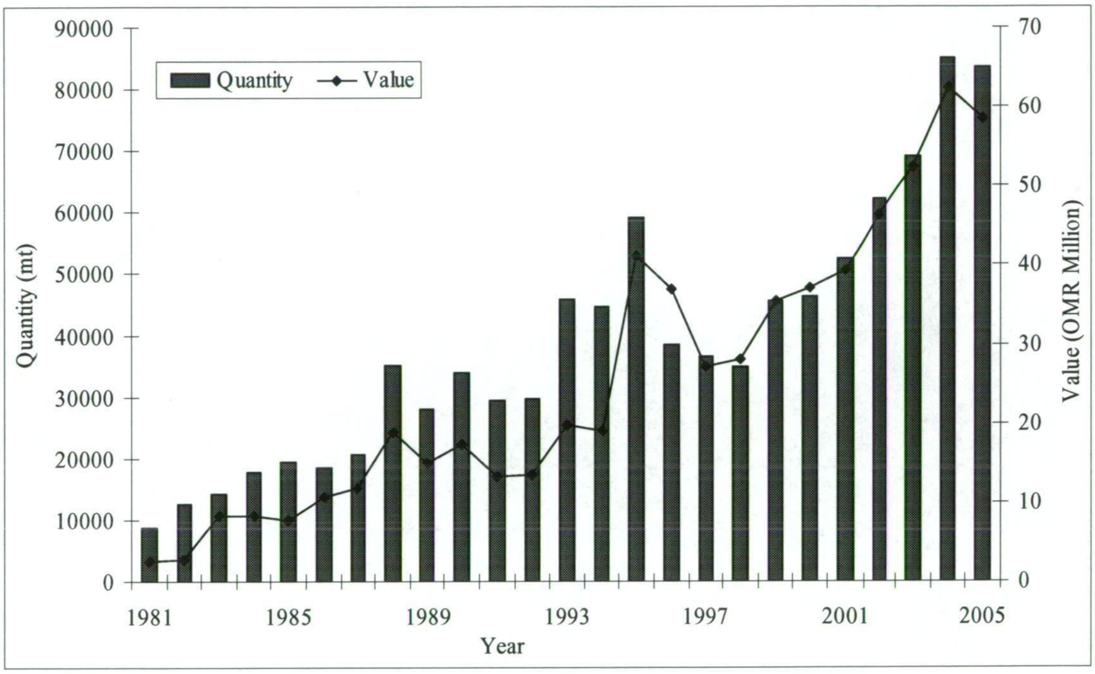


Figure 2. 2 Quantity and value of fish exports (1981 – 2005)

2.5.3 Landing and Value

Total fish landing grew considerably from 94,893 mt, valued at OMR 25.04 million, in 1985 to 151,908 mt, valued at OMR 72.49 million, in 2006 (see Table 2. 10 and Table 2. 11) (MAF 2007). Over the period 1985-2006, an average of 85% of the total landing came from the traditional sector and the remaining 15% came from the commercial, or so called industrial, sector. This indicates that the traditional sector is the dominant sector in the country. However, it should be mentioned that the quality of the landings statistics has varied considerably during the past two decades or so (Morgan 2004). Statistical reports showed that landing generally peaks in the period from September to May and then declines due to the effect of the monsoons in the Southern part of the coastal areas and the migration of fish. In 2006, 29.8% of the total traditional landing (128,542 mt) came from the Al-Sharqiyah Region followed by Muscat with 22.1% and then Al-Batinah and Al-Wusta with 16.5% and 14.1% respectively. Dhofar contributed 12.8%, while Musandam only contributed 6.1%. The high landing recorded in Muscat could be due to good market conditions which attracted many fishermen to land and sell their catch for higher capital return.

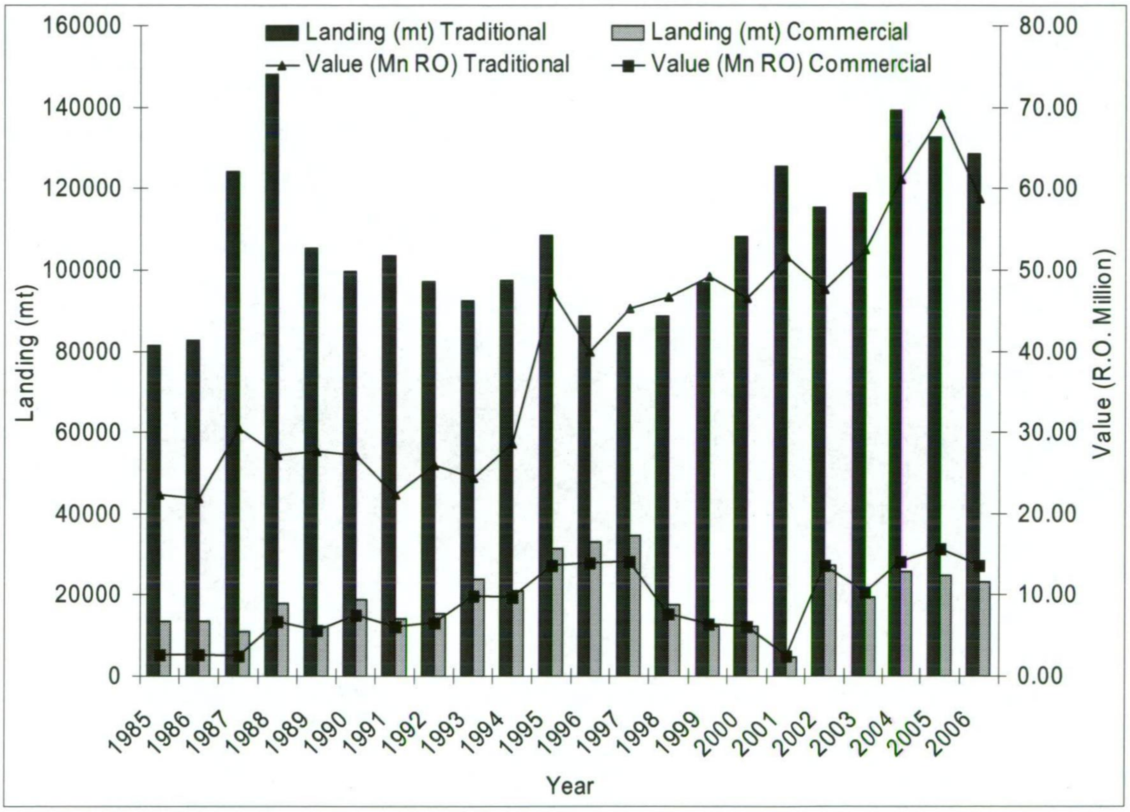


Figure 2. 3 Traditional and commercial fish landings and values (1985 – 2006)

Fish landings in Oman are generally categorized according to types such as large pelagic, small pelagic, demersal, sharks and rays and crustacean as shown in Table 2. 11 below. All statistical reports issued by MAF, show details of the most common species listed under the above-mentioned fish categories (see Table 2. 11). It can be seen from Table 2. 11 that in 2006, the highest landing contribution came from small pelagic (32%) followed by large pelagic (27.2%) and then by demersal species (26.6%). Crustacean and elasmobranches (shark and rays) contributed only 7.7% and 3.8% respectively, however, they command higher value per unit of weight. For instance, crustaceans' share in total value is about 18.2% despites their low share in total landings. In the context of high-value species, these high economic returns influence fishers' harvesting behavior that lead to high fishing effort and subsequently low landings over time. The apparent decline in the landing of high-value species such as kingfish, abalone, lobster, shrimp and cuttlefish has become a great concern to the fisheries managers and policy makers in Oman. It is claimed that stocks of many high-value species of fish and shellfish in Omani waters are severely depleted, and their fisheries appear to be heading towards collapse (Moore and Dorr 1994). There is growing concern among managers and policy makers about the economic viability of those fisheries and hence the future livelihoods of those fishermen involved in those fisheries (Al-Oufi 1999). For these reasons, various studies and research have been carried out during the last few years in the area of stock assessment and population dynamics of those high-valued species.

Table 2. 10 presents the landings and the corresponding values of the fish resources from both traditional and commercial sectors for the period 1985-2006. Index numbers for total landings and values were also calculated using 1985 as the base year (1985=100) as presented in Table 2. 10. The main purpose of the construction of those index numbers is to measure the changes in landings and values over the period 1985-2006. It may also be helpful in judging the effect of certain policies adopted by the government during the period 1985-2006. For example, based on the landing index it can be seen that the highest increase (75.02%) in total landings was in 1988. This increase can perhaps be attributed to the steady increase in the number of fishing vessels and investments in fishing gear during the 1980s as a result of the Government initiated fisheries development programs which targeted the traditional sector (Al-Abdessalaam 1993; Al-Oufi 1999). However, it is noted that the period 1989-1994 experienced a reduction in total landings compared to 1988. This was considered the first sign of overfishing brought about by the excessive pressures on the coastal fisheries resources resulting from the development program of the 1980s (Siddeek 1995; Sultan 1996). It should also be mentioned that the relatively lower landing figures in the period 1989-2001 were either due to lower catches from the traditional sector or lower catches from the commercial sector or both. This was probably influenced by the combination of two factors, namely, the expansionary program in the traditional sector and the introduction of regulations in

the trawl sector. The observed sign of coastal fisheries overfishing as indicated by Al-Oufi (2002) was attributed to the increase of the fishing effort during the same period.

It should be noted that the CV figures were calculated for combined landings (traditional and commercial), total value and unit value as 15.97%, 35.96% and 28.45% respectively. Based on these calculated figures it can be said that variation in domestic price, relative to landings, is the dominant factor contributed to the variation in total value during 1985-2006. In addition, the CV figures were calculated for landings, total value and unit value, for each sector separately. The values for the commercial sector are 40.32% (landings), 50.06% (total value) and 25.87% (unit value) respectively. This implies that variation in landings, relative to price, is the dominant factor contributed to the variation in total value for the commercial sector during 1985-2006. On the other hand, the values for the traditional sector are 17.79% (landings), 36.29% (total value) and 30.89% (unit value) respectively. This implies that variation in price, relative to landings, is the dominant factor contributed to the variation in total value for the traditional sector during 1985-2006.

Based on a cross-sectoral comparison, it can be said that the commercial sector's landing and value figures show higher variation than that of the traditional sector. On the other hand, the variation in unit value is higher for the traditional sector compared to the commercial sector. These cross-sectoral comparisons, perhaps, indicate the following facts: 1) landings from the traditional sector are relatively stable compared to that of the commercial sector; and 2) price fluctuation in the international market (as the commercial trawl sector was significantly export oriented) was relatively lower than that of its domestic counterpart during 1985-2006.

The high figures of both quantity and value since 2002 may indicate the influence of strong export market growth in recent years as discussed in Section 2.5.2. As stated by Al-Oufi (2002), the overall positive trend in landings from 1999 onward might also be attributed to the positive effects of environmental factors, such as availability of food and good water temperature.

Table 2. 10 Total (traditional and commercial) fish landings (mt) and values (OMR million) for the period 1985–2006.

Year	Landing (mt)	Landing Index (1985 = 100)	Value (OMR million)	Value Index (1985 = 100)	Unit Value (OMR/mt)
1985	94893	100	25.04	100	263.88
1986	96337	101.52	24.56	98.08	254.94
1987	135089	142.36	32.98	131.71	244.14
1988	166079	175.02	33.95	135.58	204.42
1989	117537	123.86	33.43	133.51	284.42
1990	118641	125.03	34.62	138.26	291.80
1991	117765	124.10	28.35	113.22	240.73
1992	112313	118.36	32.62	130.27	290.44
1993	116469	122.74	34.31	137.02	294.50
1994	118572	124.95	38.27	152.84	323.60
1995	139861	147.39	60.87	243.09	435.22
1996	121615	128.16	53.82	214.94	442.54
1997	118994	125.40	59.41	237.26	499.28
1998	106165	111.88	54.42	217.33	512.58
1999	108809	114.66	55.52	221.73	510.22
2000	120421	126.90	52.77	210.74	438.17
2001	129904	136.90	54.06	215.89	416.18
2002	142668	150.35	61.15	244.21	428.62
2003	138485	145.94	62.85	251.00	453.84
2004	165018	173.90	75.23	300.44	455.87
2005	157339	165.81	84.85	338.86	539.28
2006	151908	160.08	72.49	289.50	477.21
Average	127040		48.44		377.36
Std. Dev. (SD)	20289.40		17.42		107.32
Coefficient of Variation (CV)	15.97		35.95		28.44

Source: (MAF 2004; MAF 2005; MAF 2006a, b; MAF 2007)

Despite the variations in landings, total value and unit value, it should be noted that each experienced an overall positive trend during the period 1985-2006 (see Table 2. 10). It is claimed that the overall positive trend in fish value during the period was also influenced by the improvement in the quality of the landings and reduction of waste due to bad handling and storage, amongst others (Al-Oufi 2002).

Table 2. 11 Landing and value of each fish category in 2006

Fish category[5]	Landing		Value		Value (RO) per unit of weight
	(mt)	%	(RO 1000)	%	(kg)
Large Pelagic	41342	27.2	22391	30.9	0.542
Small Pelagic	48563	32.0	12804	17.7	0.264
Demersal	40405	26.6	18051	24.9	0.447
Sharks & Rays	5702	3.8	4541	6.3	0.796
Crustacean	11760	7.7	13172	18.2	1.120
Unidentified fish	4136	2.7	1533	2.1	0.371
			Average		0.590

With specific reference to the commercial sector, it can be seen that this sector caught an average of 15% of the total fish landed during the period 1985- 2006 with an average value of 18%. A total of 23367 mt (15.4% of the total landing) was landed in 2006 with a 5.4% reduction from the previous year (Figure 2. 4). These catches were landed by a total of 100 fishing vessels having undertaken 208 fishing trips with an average catch of 112341.3 kg/trip.

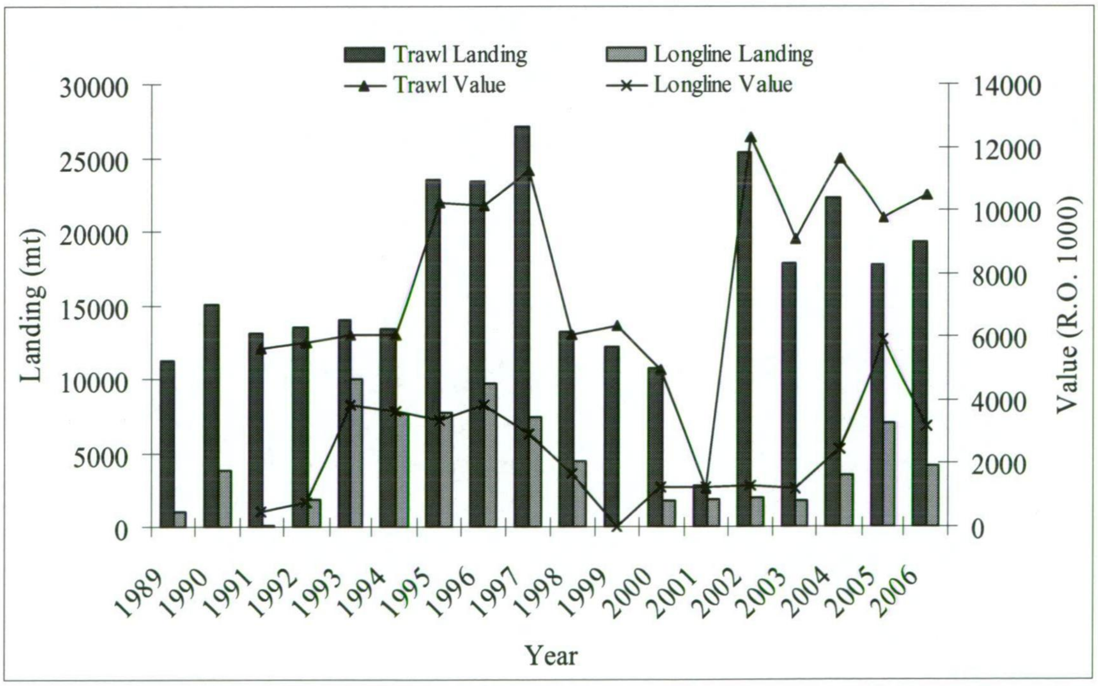


Figure 2. 4 Landing and value of the commercial sector

[5] It should be noted that Lantern fish and Mollusc catches were nil.

Figure 2. 4 shows an obvious decline in the landing of the commercial sector (both trawling and longlining) in the period 1998-2001. This was due to the abstention of the foreign fishing vessels contracted with Omani local fishing companies to fish. It came about as a reaction to the regulations issued by MAF to manage the fishing season and discarding of by-catch, which was seen at that time as a bold step toward sustainable development. Although researchers suggested that this closed season of 3-4 months/year would be insufficient to ensure sustainability (Mathews et al. 2001), it did not last for long and as a result the MAF Minister was dismissed and the season opened again. This gives an indication of the political interference and of the weakness in enforcement and management regulations and in turn suggests a communication gap between relevant stakeholders. This issue is further discussed in Chapter 5.

Although, the Government encourages the country's youth to work in the fishing industry and subsidizes them with soft loans from the Oman Development Bank, 100% of the 3,416 fishermen recorded in this sector in 1997 were non-Omani. There is a running project created by MAF aimed at training Omani youth to use big and moderate fishing vessels in order to replace the existing foreign employment (MAF 2001). In addition, 2 Omani fishing vessels started fishing as commercial trawlers in 2001 followed by another one in 2003 and another one in 2005 giving a total of only 4 vessels up to 2006. However, the vessels are still operated by foreign fishing companies with completely foreign crew.

2.5.4 Classification of Fisheries Sector

2.5.4.1 Traditional Sector

Traditional sector refers to groups of small-scale fishermen, employing a variety of traditional fishing gear and vessels. Prior to 1970, exploitation was limited to traditional small boats. Today, however, the outboard engine, modern fishing boats and more effective fishing gear have enabled the fishermen to increasingly explore the water masses both vertically and horizontally.

As mentioned in Chapter 1, in realizing the importance of the fisheries sectors in Oman and the value of fisheries resources, the Government has made an effort to manage the fisheries by introducing different management regulations, facilitating scientific research and infrastructure development. The initial impetus for the expansion of the traditional fishing fleet occurred in 1978 when the government launched the Fishermen's Encouragement Fund, which provided financial assistance to replace old vessels with new mechanized vessels. However, despite such boat improvements and a large recruitment of new fisherman (from 19306 fishermen in 1990 to 32476 in 2006), an overall downward trend is noted in catch per unit of effort figures during the period 1990-2006. Table 2. 12 presents data relating to number of fishermen, landings and catch per unit of effort in the traditional sector from 1990-2006. Prior to 1990 there was no data available for the number of fishermen. Although fishing effort has increased significantly during the past two decades, there has been very little modification in the design of the fishing gear used in the country in an attempt to improve efficiency or selectivity. It should be noted that the traditional sector is not a highly regulated sector compared to the commercial sector.

Table 2. 12 Number of fishermen, landings and catch per unit of effort (fisherman) in the traditional sector (1990 – 2006)

Year	Landing (mt)	No. of fishermen	CPUE (mt/fisherman)
1990	99798	19306	5.17
1991	103536	20377	5.08
1992	97046	20571	4.72
1993	92434	22330	4.14
1994	97535	22330	4.37
1995	108566	24489	4.43
1996	88514	25575	3.46
1997	84444	26096	3.24
1998	88557	26944	3.29
1999	96664	27516	3.51
2000	108019	28578	3.78
2001	125275	29331	4.27
2002	115308	30421	3.79
2003	118877	31587	3.76
2004	139236	32434	4.29
2005	132629	32744	4.05
2006	128542	32476	3.96
Average	107352	26653	4.08

Source: (MAF 2004; MAF 2005; MAF 2006a, b; MAF 2007)

2.5.4.2 Commercial Sector

In contrast to the traditional sector, the commercial sector refers to a group of fishermen working in large and modern fishing vessels that operate in designated zones within the EEZ and in high seas (see Figure 2. 6) and is a highly regulated enterprise. Each vessel has a trained observer allocated by the Ministry to monitor the vessel's activity and to ensure that the vessel is working in accordance with the Ministry's rules and restrictions for instance relating to catch quotas. However, during field trips it has been found that this observer program is mostly practiced by relatively inefficient operators (see Chapter 5).

As mentioned in Chapter 1, the commercial vessels operating in Omani waters can be categorized into three types according to the method of fishing and the species fished. The are, demersal trawlers, longliners (target large pelagic species such as yellow fin tuna found in open seas) and purse seiners. Operation of the industrial fishing fleet in Omani waters was first started in 1976. In 1989, the Government decided to give five private Omani companies a production quota of 28,000 mt of demersal fish and 50,000 of pelagic depending on the stock size and some relative parameters determined by the Ministry.

Commercial fishing by trawler began in 1976 when MAF entered into a contract with a Japanese fishing company and later on with a Korean company (see Section 2.5.4.4). Trawlers are licensed to operate along the continental shelf between latitude 21° 40' N, south of Masirah Island and longitude 55o 45' E, north of Halaniyat Island, and at a distance of 10 nautical miles from the shore or at more than 50 meters depth (Figure 2. 6). However, occasionally trawlers are allowed to fish at a lesser distance of 5 nautical miles from shore.

On the other hand, commercial fishing by longliner began in Oman in late 1989. The number of longliners has greatly increased from an initial fleet of 19, recorded in 1990, to about 184 in 1994. The number then decline to 18 vessels in 2000 rising again to 67 in 2006 (MAF 2006a-b). They are allowed to perform fishing operations in areas between latitude 24° 45' N and longitude 54° 00' E, at a distance not less than 20 nautical miles from the coast line and discard of any catch is strictly prohibited. Longliners contribution to the commercial landing and value averaged 20.08% and 22.59% respectively in the period 1991-2006. In 2006, 67 vessels landed

4091 mt, which counted for 17.5% of the total commercial landing valued at 3,190,000 OMR (23.3%).

Oman Fishing Company (OFC) is a leading commercial company which was established in 1989. 24% of its equity is owned by the Government and the rest is owned by other shareholders. OFC gets more than 64% of the production quota but it has been contracting out this harvesting right to Korean and Chinese trawl operators and, large pelagic Taiwanese longliners. The fishing effort in this sector has varied since 1989 as has the sharing system employed in exchange for fishing authorization. The percentage of the catch retained by the local companies, for example, has varied from 39% in 1988 to its current range of about 18%-20%.

As mentioned above, 28,000 mt of demersal fish is allocated as a production quota for commercial trawling. The highest landing figure was recorded in 1997 (27,123 mt), which counted for 96.87% of the given quota, whereas the lowest figure was recorded in 2001 (2,741 mt), which counted for only 9.79%. This lower catch record in 2001 suggests that the production quotas were non-binding as the total annual catch of species fell short of the production quota (the sum of the individual quotas) in that species. One reason could be attributed to the introduction of the new fishing regulations in the period 1998-2002. If this serious discrepancy continues in the fishery, it would undermine the economic efficiency criterion of the sustainable development principle. In addition, the gap between the actual landing (excluding discards) and the allocated quota has introduced the problem of overcapitalization, with more fishing companies requesting to enter the fishery than the quota allowed. Chapter 7 will discus some of the effects of this structural change on the fishery.

When the quota was assigned, it was intended to cover both landed and discarded catch. The fishing companies after a while demurred and requested not to count the discards within the quota. At that time, there was no legislation regulating discarded fish. This objection then forced MFW to establish a legal framework managing the by-catch issue (see Chapter 5). Although the issues of bycatch and discard in a multi-species fishery can not be fully avoided, the level of bycatch and discard particularly in the commercial trawl sector has received the significant attention of the Government as it hampers management control on harvested species.

This in turn contradicts the conservation objectives in the fisheries legislation in Oman (see Section 2.5.4.4 for further discussion).

2.5.4.3 Fishing Gear and Its Use

Fishing gear in Oman consists of trawls, bottom and surface gill nets (drift and set gill nets), traps (wire mesh and plastic types), barrier traps, hand lines, and bare hands and knives (to dislodge abalone) (Siddeek et al. 1999). In addition to that, there are longlines, beach seines, trolling, cast nets for shrimp and sardine, harpoons for cuttlefish and encircling nets (Al-Masroori 2002). Beach seines are widely used in the coastal waters of various countries to catch sardines, anchovies, other small coastal pelagic fish and juveniles of many pelagic and demersal species (Siddeek 1999). Encircling nets are used only to catch the small pelagic fish in Muscat and Al-Batinah such as, sardine, Indian mackerel and some large pelagic fish such as kingfish. The most common gear used along the entire coast is the gill net, with its mesh size varying according to the target species. Traps, also known as pots, creels and baskets are mainly used to catch crustaceans, molluscs and demersal fish (Rafeet 1999) in the coastal demersal fisheries of Oman (El-Etreby et al. 2001). The trap shape is roughly hemispherical with a side funnel entrance. The circular base is attached with a round steel rod to maintain stability against water circulation (Al-Masroori et al. 2004).

Traditional fishermen set their fishing gear anywhere in the coastal waters. Some fishermen claim an area of the sea, either initiated by them or inherited from their fathers and grandfathers. The property is created by constructing some artificial reefs, locally known as *Shadood* in a specific area and no other fishermen are allowed to fish there. This kind of sea property is controlled and managed by *Senat Al-Bahar* (see Section 2.6.3.2) and by the Ministry.

In the multiple user context, problems arise due to conflict between the use of active fishing gear (such as drift nets) and passive fishing gear (such as traps) when they are deployed in the same fishing ground (Al-Masroori 2002) and between the local traditional fishermen and the commercial foreign fishermen (Al-Oufi 1999). Under the Omanization campaign, this particular type of conflict is seen as one of the key indicators that highlights the impact of the commercial sector on the local community under the ESD framework (see Chapter 5 for further discussion).

Most of the 32476 fishermen recorded in 2006 were part-timers, who fish only on weekends or after work hours. In 2005, MAF conducted a traditional sector fishing boats census. This census revealed that there were 32744 fishermen using 13560 fishing vessels of five types: fiberglass skiff, shashah, huri, launch and aluminum skiff (Table 2. 13). Fiberglass skiffs fitted with outboard engines are 3 to 10 m in length and are commonly used in all regions. The aluminum skiffs are transom sterned hard-chine boats with an average length of 5 m (Mohan 1994). The other three are of wooden construction and the shashah is about 3 to 5m and totally made of fronds (palm tree leaf). Horis are wooden dugout canoes which vary in length from 4 to 10 m. Nowadays they are fitted with outboard engines. The launches (dhows) are the largest traditional boats being between 12 and 16 m in length and fitted with inboard engines. Dhows are commonly used for offshore trips that might last for several days.

Table 2. 13 Number of traditional fishermen and fishing boats in 2005, by region

Region	Number of fishermen	Number of boats					
		Fiber-glass	Hori	Launch	Aluminum	Shashah	Total
Musandam	3483	1191	1	58	4	0	1254
Al-Batinah	10663	3892	55	36	18	272	4273
Muscat	4167	1565	15	4	3	0	1587
Al-Sharqiyah	7349	2559	122	209	20	0	2910
Al-Wusta	3404	1536	4	56	1	0	1597
Dhofar	3678	1856	0	70	11	2	1939
Total	32744	12599	197	433	57	274	13560

Source: (MAF 2006a, b)

2.5.4.4 Commercial Trawling

Only a single cod-end trawl is allowed in Oman and the mesh size for the main net, including the wing, should not be less than 210 mm, and cod-end stretched mesh size should not be less than 110 mm. In addition, trawlers must provide a catch report which is to include details of the species caught by area and by day, following each fishing trip. As stated above, each trawler should have a trained observer allocated by MAF. However, some trawlers depart the port for the fishing grounds without an observer and some observers will leave the vessel after several days without a replacement joining the vessel. Keeping in mind that there are neither By-Catch Reduction Devices (BRD) nor Turtle Excluder Devices (TED) imposed, trawlers are allowed to discard 16 kinds of non-commercial fishes (some with size limit). During an onboard field trip and interviews with some observers and captains of the vessels it was found that there is a strong tendency to discard any catch of low economic value and permission is asked of the onboard observer before discard. This observation is supported by Hare (1990). It gives clear indication of the fishermen's attitude toward the by-catch and thus the recorded figures of by-catch are definitely underestimated. Total fish discarded in 1993 was 3596.2 mt of which 50.5% was commercial catch (Figure 2. 5). In 1996, trawler discards declined sharply by 271% compared to that of 1993. As claimed by the Head of the Commercial Department, this reduction was attributed to some new discards regulations (personal communication, October 14, 2006). Close investigation of the regulations show no clear and logical reason behind this sharp reduction, which indicate an underestimation and/or misreporting of the discards (see Chapter 5 for further discussion). Hare (1990) revealed a yearly discard rate of 39.1% by the trawling sector with maximum rate of 53.8%. A study by FAO, claimed that total discard in the Omani fishery in the period 1992-2001 was 1,384 mt at a rate of 1% of the total landing (Kelleher 2005). This figure seems to be greatly underestimated.

Table 2. 14 below shows annual fishing effort of the trawling sector and Table 2. 15 shows 2004 trawler specification parameters.

The reduction in the commercial landing in the period 1998-2001 (Figure 2. 4 and Section 2.5.4.2) positively affected the landing of the traditional sector especially those of Al-Wusta Region as both sectors interact in close fishing grounds. Mathews et al. (2001), support this trend as high industrial landings, driven by international prices, reduce traditional landings when both fleets fish the same species. The same reference stated that the high industrial effort probably also reduces net traditional fishermen revenue an area which needs further research (see Chapters 5 and 7 for more discussion).

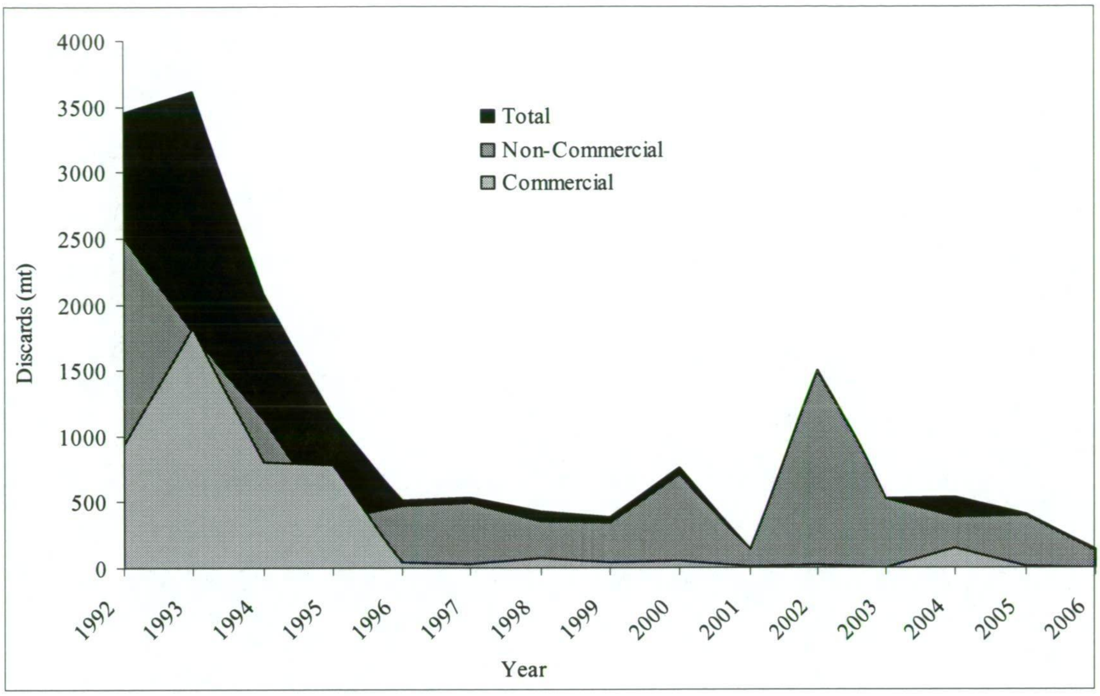


Figure 2. 5 Fish discards of trawling sector

Table 2. 14 Annual effort of the trawling sector

Year	No. of Vessels	Fishing Days	Season Duration	Average Catch per Vessel per Year (mt)	Average Catch per Fishing Day (mt)	Average Fishing Days per Vessel
1995[6]	14	3744	12	1681.79	6.29	267
1996	15	2844	12	1557.73	8.22	190
1997	21	4139	12	1291.57	6.55	197
1998	18	1795	7	733.22	7.35	100
1999	11	1628	7	1104.09	7.46	148
2000	10	1288	10	1068.20	8.29	129
2001	7	304	8	391.57	9.02	43
2002	23	3303	12	1104.43	7.69	144
2003	22	2596	12	811.91	6.88	118
2004	31	4760	12	718.71	4.68	154
2005	36	4752	12	491.26	3.72	132
2006	28	4149	12	688.42	4.65	148
Average	20	2942	11	970.24	6.73	147

Source: (MAF 2004; MAF 2005; MAF 2006a, b; MAF 2007)

[6] It should be noted that the years 1990-1994 are not included due to absence of information.

Table 2. 15 Trawler specifications in 2004

Parameter	Length (m)	GRT	hp	Crew No.
Min.	39	226	1000	6
Max.	62	927	3400	40
Average	47	478	1825	32

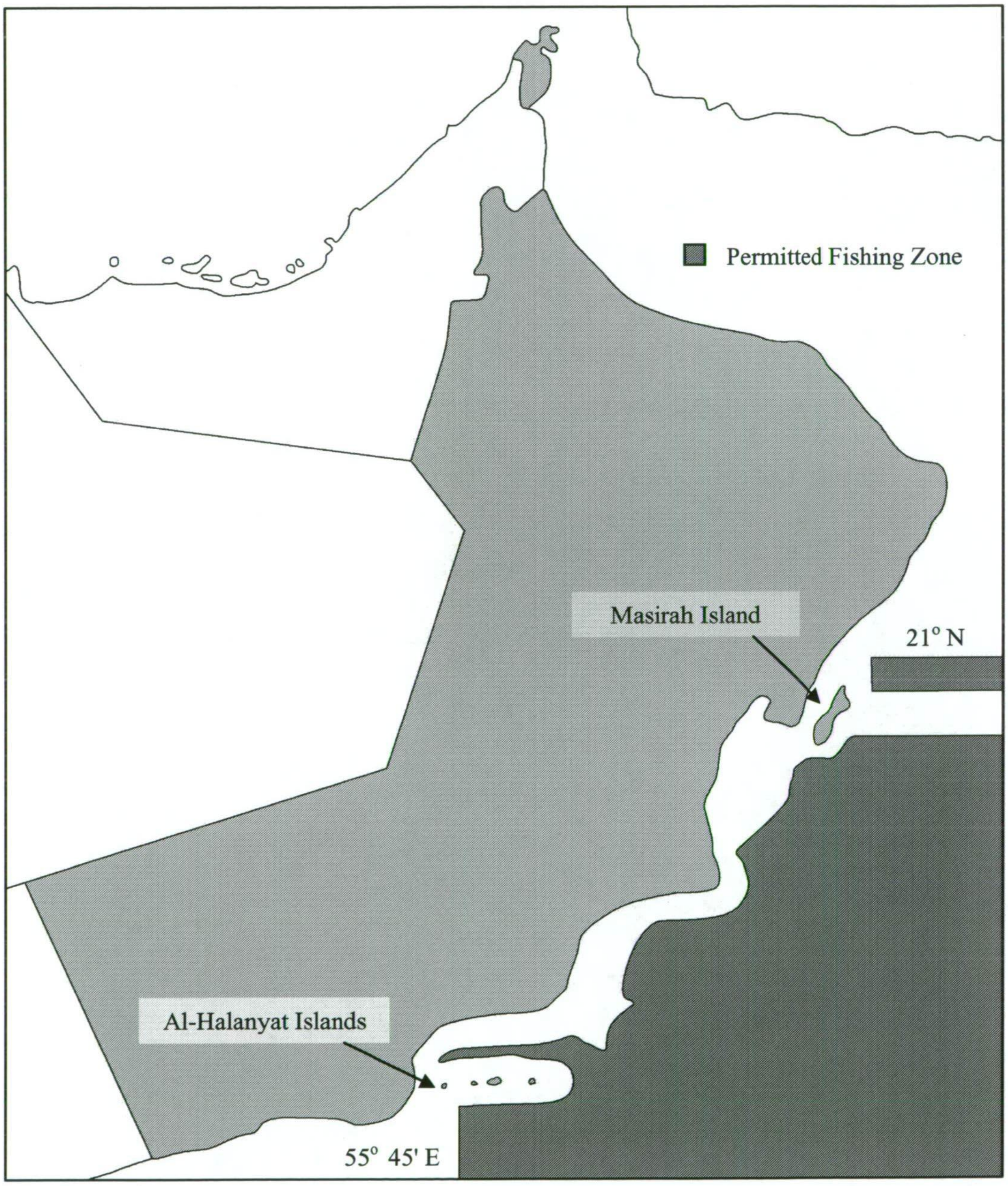


Figure 2. 6 Permitted trawling area in the Omani water

2.6 Fishery Management System

It is well recognized that to avoid the occurrences of over investment and over-exploitation of resources, which are common with an open-access regime in fisheries, it is essential to have a fisheries management plan that imposes regulations on the fishery which in turn restricts fishers' activities. It should also be recognized that a sound fisheries management plan should reflect ecological, socio-cultural, economical and political realities influencing the sector. It should also be recognized that decisions to comply or not to comply with the existing or proposed management regulations mainly depend on perception and attitudes of user groups of fisheries resources. It is worth mentioning that the effective implementation and cost-effectiveness of management regulations depend upon the acceptability of the regulations by the affected party. It is perceived that the lower the degree of acceptability of proposed regulations by the affected parties, the higher the transaction costs (Van der Burg 2000; Abdullah et al. 1998). Therefore, cost-effectiveness of fisheries management regulations relies heavily upon the effectiveness of the associated compliance program put into practice in the fishery as non-compliance is often cited as the principle cause of fisheries management failure (Sutinen et al. 1990). The importance of fisheries compliance has been well documented in international policy documents including the Code of Conduct for Responsible Fisheries, United Nations Convention on the Law of the Sea (1982) and United Nations Fish Stock Agreement, to name few.

2.6.1 Fisheries Development Plan

Through a series of successive Five Year Plans beginning in 1976, the government has laid down the foundation of a self-sustaining economy. For example, the formulation of Vision 2020 in 1995 was guided by three basic principles namely; economic diversification, achievement of economic efficiency through privatization and development of human resources and capacity building. Since 1967, due to the commencement of lucrative petroleum production and export together with the industry's attractive high employment income, the fisheries sector was experiencing an out-migration of its labor force to the petroleum sector. Furthermore, the economic development campaign was also largely influenced by the increased revenues from oil. However, oil is a non-renewable resource and therefore it is necessary for Oman to examine its potential for future development without oil. This urgency is reflected in the current economic diversification program as the Government is now determined to develop and manage its fisheries resources wisely so that over time fisheries would occupy a major role in the national economy (Grinyer 1980). This national commitment to the development of the fisheries sector in Oman is evident from the following example. In 1972, the Sultanate formed a Fisheries Department which was later absorbed into the Ministry of Agriculture and Fisheries (MAF). However, due to the current focus on the fisheries sector the Sultanate has decided to provide independent administrative support by forming a separate Ministry by dividing the MAF into two, namely, the Ministry of Fisheries Wealth (MFW) and the Ministry of Agriculture (MOA).

Due to a lack of scientific and technical expertise at present, the Ministry has been seeking the guidance (in the form of expert consultancy) and assistance from different international organizations to ensure sustainable development in the sector. Such technical services have been received from either international organizations such as the United Nations and specifically the Food and Agriculture Organization (FAO) or from some other specialized international non-governmental organizations.

In 1999, new organizational framework was designed for MAF by Royal Decree No. 83/99. Four sectors (research, extension, management and development) were identified under the Directorate General of Fisheries Resources (DGFR) to simplify administrative tasks and facilitate achieving its targeted objectives. The fisheries extension is a very important department as it provides the official link between the fishermen and the ministry. It communicates the output of the research to the fishermen and reports problems and concerns faced by fishermen to the research centers where the problems will be addressed.

The development plans of the Ministry could be determined from its objectives indicated by the Minister in his speech to Majlis A'Shura, Consultative Council (see Section 2.3.4) in 2000 as:

1. Reinforcing a sustainable fishing concept through:
    - Conservation and development of the fisheries and marine resources;
    - Coastal fisheries management;

- Ensuring the development of post harvest technology and quality control regulation/s;
- Conducting scientific research;
- Increasing the awareness of the fishermen toward sustainable fishing; and
- Establishment of fisheries development centers throughout the country.

2. Contribution to the national income from diversity of resources through:
    - Increasing the value-based contribution of the fisheries resources based on scientific methods;
    - Developing the fisheries export;
    - Developing the fishing industry and processing industry;
    - Importing advanced knowledge of fishing technology from developed nations; and
    - Developing appropriate infrastructures to increase efficiency in the fisheries sector.

3. Improving and maintaining the standard of living of, and services to, the fishing community through:
    - Improving career conditions through modernizing the traditional sector and through Omanization (substituting foreign employees for Omanis) of the industrial sector;
    - Encouraging and insuring collaborative work; and
    - Enhancing women's participation in the related food industry.

4. Increasing the contribution of the fisheries sector toward national food security through:
    - Developing an efficient marketing system;
    - Ascertaining a significant revenue from fisheries exports; and
    - Involving the private sector in the production and marketing sector.

The above-mentioned detailed list of fisheries objectives also encompasses the broad listed objectives stated by Morgan (2004). It is apparent that the MAF plans and associated objectives are well intentioned toward sustainable development and incorporate the elements from the core dimensions of sustainability; economic, environment and social in addition to the institutional dimension.

2.6.2 Fisheries Legislation

Prior to 1981, there was no national legislation to provide the legal mandate for fisheries management measures for Oman's EEZ. There were no frameworks available to reflect the mission of the Ministry with regard to the country's fisheries resources. Although a Draft Maritime Code was prepared in 1974, it was not approved by His Majesty and did not appear as a Royal Decree (Grinyer 1980).

In 1981, the first Fisheries Act called the Law of Marine Fishing and Conservation of Living Aquatic Resources was issued by Royal Decree No. 53/81 (MAF 1994) to govern the activities of the fisheries sector. It authorizes the designation of areas where fishing will be permanently forbidden, and other areas where fishing will be allowed only within defined seasons and for specific species (Lausche 1986). It consists of six sections and 31 articles covering definitions and terminologies, fishing regulation, protection and development, marketing and processing, penalties and general provision.

Royal Decree No. 53/81 was then followed by Ministerial Decision No. 3/82, of 1982 which includes executive regulations for laws on marine fishing and conservation of living aquatic resources (MAF 1994). This was then replaced with an updated regulations list under Ministerial Decision No. 4/94 issued in 1994. It includes 51 articles classified within 8 chapters addressing specific executive regulations that manage, develop and protect marine wealth. However, some of its regulations were again revised and modified through other Ministerial Decisions. In 1994, regulations governing commercial fishing were prepared and unofficially issued and some of them are to be included when dealing with permits given to any fishing vessel. Since 1994, MFW has been preparing to issue a list of comprehensive official regulations to manage the fishing sector similar to Ministerial Decisions 36/04 and 64/04. Chapter 5 examines the effectiveness of the fisheries legal and regulatory framework with particular attention to the commercial trawl sector.

Table 2. 16 below illustrates some important ministerial decisions issued by MFW to manage relevant matters that fall within its responsibility.

In 2006 a position of Deputy was assigned for the fishery sector in the Ministry framework by Royal Decree No. 80/2006. Recently, a Ministry for Fisheries Wealth (MFW) responsible for the day-to-day management of the fisheries in Oman, was established by Royal Decree No 91/2007.

Table 2. 16 Some related Ministerial Decisions (MD) regulating fisheries resources

No.	Year	MD No.	Title	Comments
1	1983	3/82	Executive Regulations for Law of Marine Fishing and Conservation of Living Aquatic Resources	
2	1994	4/94	Executive Regulations for Law of Marine Fishing and Conservation of Living Aquatic Resources	Replaced MD 3/82
3	1997	4/97	Quality Control Regulations for Omani Fishery Export	
4	1998	42/98	Amendment to MD 4/94	Canceled in 2000
5	1998	43/98	Defining Fishing Season for the Trawling Sector	Canceled in 2000
6	1998	121/98	Conditions and Specifications of Commercial Fishing Vessels Prepared to Store Fishery Product	
7	1998	136/98	Quality Control Regulation for Omani Fishery Export	Replaced MD 4/97
8	1999	71/99	Organizing Censorship on Commercial Fishing Vessels Landing	
9	2000	24/2000	Regulations Organizing Senat Al-Bahar Local Committees Responsibilities (see section 2.6.3.2)	
10	2004	36/04	Regulations of Aquaculture and Quality Control of Cultured Fish	
11	2004	64/04	Regulations Managing Fishing Ports	

2.6.3 Fisheries Management

The Ministry of Fisheries Wealth (MFW) (see Section 2.3.4) is the official authority responsible for conservation, protection and development of the fisheries resources on behalf of the Omani community. In addition to His Majesty's Royal Decrees, it issues all required Ministerial Decisions to enforce regulations to facilitate achieving its management objectives.

2.6.3.1 Management Tools and Approaches

From the discussion in Section 2.5.3, it is evident that the development of both the traditional and industrial sector has exerted excessive pressure on fish stocks. Unfortunately, most of the development efforts have been, and still are, directed toward the accumulation of fishing efforts in coastal waters (Al-Oufi 1999). On the other hand, enforcement of management regulations for both sectors is the greatest challenge in the country. There are, for example, encroachments practiced by the industrial trawlers, where they access the artisanal fishing grounds (<50 m depth) (Siddeek et al. 1999) and it is common for illegal fishing to be practiced by the traditional sector (Morgan 2004). This weakness in enforcement could be attributed to the lack of financial resources, inconsistencies in the legal framework and political influences, which will be discussed in detail in Chapter 5. However, as claimed by Sheppard et al. (1992), the fisheries sector in the region faces two potentially serious problems namely, pollution and loss of nursery areas. Current laws and regulations are attempting to minimize the potential impacts of those threats on the marine environment. In recent years, management of fisheries resources in Oman have been influenced by international and regional commitments and policy agendas as discussed in Section 2.3.2.

As mentioned in Section 2.5.4, in management regulatory context, the commercial trawl sector is a highly regulated enterprise compared to the traditional sector. The main management measures used in the trawl sector are a combination of license limitation, area and gear restrictions, output control and a monetary measure (tax/royalties). It is noted that a system of restricted licensing (or called limited entry) is in place for both traditional and commercial fisheries sectors in Oman. However, it remains basically un-enforced particularly in the traditional sector. Prior to 1992, obtaining a license was not a problem for those who wanted to enter the fishery sector, however the Ministry discontinued issuing new licenses in 1993 as the authorities realized that the number of fishermen was too high compared to the capacity of the resources to support them. However, in 1995 a census conducted by MAF revealed that there were 7,000 unlicensed fishermen working with 4,500 fishing boats. In April 1997, the Ministry changed its original policy to restrict the number of fishermen. This is a challenging policy making task as this action was criticized as inconsistent with the Ministry's policy to increase the number of fishermen to 50,000 in 2020 as targeted by the Vision for the Oman Economy 2020. The apparent reason behind this non-enforcement is the lack of financial resources to effectively monitor a vast area of coastline (3165 kilometers) and several fishing villages. This is not unique to Oman as it is quite a common symptom in developing nations (Schurman 1996).

Furthermore, this centralized approach of imposing regulations (such as restrictive licensing) failed to recognize the existing informal rules among traditional resource users and thus limits the effectiveness of the regulations (Al-Oufi 1999). Al-Oufi (1999) recommended that different management approaches needed to be considered by MFW for resources that give low economic returns.

Although the licensing program has provided some useful management information, overall the program has been ineffective in the sense that, it does not regulate the activities of the fishermen. It is important to note that as a standalone fisheries measure it is not adequate enough to control all dimensions of fishing effort, identified in the literature as composite input, because of the possibility of input substitutions. Therefore, if left unmonitored, the symptom of so-called capital stuffing may develop in fisheries over time (Pearse 1994). In the case at hand, the limited success of the program is very likely due to weaknesses in its implementation. It should be noted that there are some fishing regulations awaiting enforcement in the kingfish fishery as a result of a continuous three year project concentrating on this species (Al-Oufi et al. 2004). Another similar project was carried out for shark fisheries, which suffer from excessive fishing pressures due to strong market demand for shark-fin. It is expected that new fishing regulations will be developed following the recommendations from these specialized research projects.

Under the present coastal overfishing conditions, user group conflicts and ineffective regulatory enforcement regimes, an open access type of situation does prevail in some coastal fisheries cases in Oman. Only three shellfish fisheries are exceptions; the shrimp fishery in Mahout Island, the lobster fishery and the abalone fishery in Dhofar Region. These three fisheries are managed with a combination of closed season and area, size limit and gear restrictions. It should be noted that the inherent problems of over-exploitation (a conservation problem) and economic inefficiency (an economic problem) associated with the open access regimes, which

Hardin (1968) labeled as 'The Tragedy of the Commons' are now well-understood by managers and policy makers around the world. Hardin's (1968) use of the term 'Commons' has been criticized by several studies focusing on the characteristics of local level common property institutions (Van der Schans 2001; Berkes 1989; McCay and Acheson 1987). The main reason behind this criticism is that property in common does not mean open access.

In regard to the traditional sector in Oman, Morgan (2004) stated that political influences of local tribal and regional community make it difficult to enforce centralized regulations, which are inconsistent with traditional regulations. Since most of the current regulations in Oman were initiated only after the 1970 renaissance as mentioned in Section 2.3.1, the Omani coastal communities are finding it difficult to sacrifice the autonomous decision-makers' power in fisheries resources management issues. Historically, the community built an efficient and well-organized local policy and regulations based on Islamic beliefs and principles, old civilization and Arab traditions. This policy is called "Senat Al-Bahar", literally the "code of the sea". This is not unique to Oman, as in most countries in the Asia-Pacific region, traditional sea tenures and exercise of fisheries rights reflect the characteristics of the local level community organization in a broader administrative power structure (Ruddle 1989). In most cases, it is found that entitlements to use common property resources are informal, unwritten and protected by tradition or customs. These characteristics do exist in the traditional fisheries sector in Oman.

Thus, from the above discussion, it is evident that open access characteristics and common property institutions co-exist in the traditional fisheries sector in Oman. Therefore, any regulatory effort by the government must be directed to overcome these two problems through the determination of conditions under which the proposed regulatory measures conserve stock and improve socio-economic performance of the sector. Centralized initiatives must be adapted to local-level needs and aspirations to be effective. The effectiveness of any partnership approach will depend on the decision making power of the two parties involved.

Senat Al-Bahar as identified by Al-Oufi et al. (2000) is an institution, normally chaired by an experienced fisherman who is well respected within the community, addresses technological externalities and assignment of tasks as well as in some cases, management of stocks by restricting harvests. Although this institution does not have a system of monitoring in place, fishermen themselves enforce some of the rules propounded. Lack of a monitoring system is considered to be one of the limiting factors affecting the effectiveness of traditional fisheries resource management by Senat Al-Bahar. Al-Oufi et al. (2000) also highlighted that moral norms play a key role in the success of the Senat. However, it appears that Senat Al-Bahar is unable to withstand the current changes in the fishery, even though some of its rules are adhered to and it is supported by the national legal framework.

The importance of the traditional user group involvement and their active participation in the decision making process has been recognized by the Government. Consequently, the Government issued a Ministerial Decision No. 24/2000 to approve the regulations organizing the Senat Al-Bahar local committees. In each Wilayah, this committee consists of the Wali as chair, Majlis A'Shura member (see Section 2.3.3), the Director of the Fisheries Office and 3-6 experienced and well respected fishermen. These committees have the following responsibilities:

1. Developing management systems and supervising the fisheries resources.
2. Providing propositions in:
    a. Current fishing rules and mechanisms for their enforcement.
    b. Marine environment protection and fisheries sustainability.
    c. Supporting inspection and enforcement obligations.
    d. Development of fisheries products and markets and their management.
    e. Diminishing the foreign employees and local labor-saving in the traditional sector.
    f. Current fisheries projects and advising any new projects that might develop the fishing sector.
    g. Extension programmes and their execution.
3. Contemplating fishermen status, proclaiming their necessities and priorities and resolving conflicts.

This step is considered as a good step toward the concept of sustainability as the involvement of the Senat Al-Bahar in the fisheries development process is one of the fundamental basics of the sustainable development. Although, governmental legislation and management tools do now exist, Senat Al-Bahar is still active and practiced by some fishermen. Al-Masroori (2002) noted from a field survey that out of 92 trap fishers, only 11.5% complied with the traditional rules although 29.4% of the sampled trap fishermen were aware of the rules. The remaining 70.6% were not aware of the rules. However, the result from this field survey can not be generalized as the sample size only cover a small proportion of traditional fishermen using particular fishing methods.

2.6.4 Fisheries Research and Development

The Marine Science and Fisheries Centre was set up in 1986 on the coast near Muscat, with the consultative support of UNESCO and FAO. In cooperation with Sultan Qaboos University, its role includes studies of different stocks of resources and the future development and management of the vast range of marine species found in Omani waters. In addition, it also conducts research on the general ecology of the marine environment, with particular emphasis on the conservation of ecosystems and endangered species such as turtles.

To prepare young Omanis academically and technically, to foster scientific research and to undertake research in the fields of technology, economics, the sciences and humanities, Sultan Qaboos University (SQU), consisting of seven colleges, opened in 1986. The College of Agricultural and Marine Sciences (CAMS) and College of Science are the two colleges concerned with the environment. Within CAMS, the Department of Marine Science and Fisheries (MSF) is the official educational and research authority in the country and the consult member to MFW, MECA and other official authorities dealing with environmental sectors amongst others.

2.7 Conclusion

The present chapter provides an overview of the country's physical features, socio-economic characteristics and administrative structures along with the nature, status and characteristics of the overall fishery system in Oman under the various 'sub-systems' - the natural system, the human system and the fisheries management system. The critical information provided in this chapter will be used in the following chapters of the thesis for developing sustainability indicators to facilitate the assessment of the trawl sector's progress toward sustainability. This chapter also highlighted the interdependency of various 'sub-systems' as part of a whole 'fishery system'. The recognition of this interconnectedness feature will form the basis for encompassing the various dimensions of sustainability namely, ecological sustainability, social (community) sustainability, economic sustainability and institutional sustainability. Given the obvious dichotomy between the traditional and commercial fisheries sectors in Oman as discussed above, it is important to find a balanced approach for progress towards a sustainable development path.

CHAPTER 3: FISHERIES SUSTAINABILITY AND ECOLOGICALLY SUSTAINABLE DEVELOPMENT

3.1 Introduction

To fulfill the research objectives stated in Chapter 1, the main objective of this chapter is to review the literature on the concept of the sustainable development with particular relevance to the fisheries sector. It should be mentioned that it is not the intention of this chapter to debate whether or not sustainability should be incorporated into all national developmental plans as a key policy objective. Rather, it is taken as given that sustainability is considered necessary world-wide, as the objectives of community well-being, economic development and environmental conservation are all integrated into the concept of sustainability. The desirability of achieving sustainability is reflected in various international forums and national policy decisions.

It should be emphasized that particular attention is given to the Ecologically Sustainable Development (ESD) framework proposed in the National Strategy for Ecologically Sustainable Development (NSESD) in Australia (Australia 1992). The reason for this particular attention is that the framework will be used in sustainability assessment of the commercial trawl fishery in Oman.

3.2 Evolution of Sustainable Development

Broadly speaking, during the past four decades or so, sustainable development has been a highly debated topic among natural and social scientists, governments and policy makers due to concern about the interaction of economic growth and natural environment. It is noted that a great deal of confusion exists in the literature regarding sustainable development's precise meaning and operational content (Lele 2000; Murcott 1997; Morita et al. 1993; Garcia 2000; Drummond and Marsden 1995; Mitchell 1997). Despite this debate and confusion, in recent years, sustainable development has been a widely accepted guiding principle for the national and international policy process.

Prior to listing some of the conceptions of sustainable development identifiable in the literature, it would worthwhile to discuss briefly the evolution of the concept of sustainable development.

In 1798, the relationship between population growth and economic development was explained by Malthus (1798) in his famous writing 'Essay on the principle of population as it affects the future improvement of society'. Drawing on the concept of diminishing returns, Malthus (1798) suggested that the growth in food supplies could not keep pace with the population growth. As a result, per capita incomes would have a tendency to fall which would affect the standard of living of a population. This suggestion indicates the limit to natural capital (i.e. natural environment) by the fact that population growth, if left unchecked, has the potential to limit the sustainability of economic growth. Later, in economic development literature, this idea became known as 'Malthusian population trap'. Like Malthus (1798), Ricardo (1817) also expressed his pessimistic view on the prospects of economic growth in the long-run.

In the mid 19th century, Mill (1848) in his publication 'Principles of political economy' considered the race between technological progress and diminishing returns in examining the future prospect of economic growth and introduced the concept of 'stationary state', which simply indicates a stationary condition of capital and population in the economy. In other words, this condition also gave an indication of the possible limits to economic growth. However, towards the end of the 19th century an optimistic view prevailed mainly influenced by scientific and technological advances. This view dominated until the 1950s.

However, despite this optimism, there was scientific evidence that indicated signs of considerable environmental damage. Since the 1960s, several publications have been written which raised concern about the extent of environmental damage caused by human activities. Publications including, 'The silent springs' by Carson (1962), ' The limits to growth' by Meadows et al. (1972), 'A blueprint for survival' by Goldsmith et al. (1972) and 'Small is beautiful' by Schumacher (1975) are but a few. This acute environmental concern received enormous media publicity and significant attention from the community which initiated the environmental movement in the 1960s. This movement was successful in receiving international recognition with the United Nations Conference held in Stockholm in 1972. At this conference a milestone was reached in the development of international environmental policy which then resulted in the establishment of the United Nations Environment Program (UNEP).

The realization of the significant risks associated with the rapid and irreversible environmental changes necessitated a shift in the natural resource management paradigm to a new paradigm called sustainable development. This new paradigm called for a balance between conservation and development and shifted the focus, amongst other things, from profitability towards sustainability, from growth towards balance, from control towards integration and from domination towards harmony with nature (Clarke and Clegg 1998).

3.3 Conceptualizing Sustainable Development

To make the notion of sustainable development operational it is important to identify its precise meaning. As mentioned above, there are several views existing in literature which can be summarized as follows:

1 Development that ensures the fulfillment of basic needs of both present and future generations[1] (WCED 1987).

2 Development that ensure per capita income and consumption are non declining over time (Pearce et al. 1989; Perman et al. 2003).

3 Development that ensures natural capital stock is non declining over time (Perman et al. 2003).

4 Development that ensures that the protection of the human race is maximized (Georgescu-Roegen 1971; Daly 1980).

5 Development that protects community and community relations (Douglass 1984).

6 Development that promotes consensus building and building of institutional capacity (Perman et al. 2003).

[1] Within it, two key concepts are contained; (1) the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given, and (2) the idea of limitation imposed by the state of technology and social organization on the environments ability to meet present and future needs (Potts 2003).

7 Development that maintains biological diversity and ecological process and protects the condition of ecosystem resilience (IUCN 1980).

The first six concepts primarily originate from social scientists (economist and sociologist), while concept seven is associated with natural scientists. There are other definitions available from different international bodies with particular relevance to fisheries and marine resources (see Box 1). It is clear that there are two distinct camps engaged in the debate in identifying the precise meaning of the concept of sustainable development. For further discussion and critical reviews on the sustainable development concept, see Tisdell (1994), Lele (2000) and Pisani (2006).

Furthermore, opposing views have also been reflected in the further debate on substitutability of man-made capital (economic) for natural capital (environment). Depending on individual views on the extent of substitutability, this debate has divided sustainability into four categories, namely: very weak sustainability, weak, strong, and very strong. It is important to note that the very weak and very strong categories represent the two poles in the debate as they suggest the possibility of 'perfect substitution' and 'no substitution' respectively. On the other hand, the notions of weak and strong substitutability highlight the possibility of trade-off between man-made capital and natural capital. For further discussion see Goodland and Daly (1996).

Although the concept of sustainable development can be variously defined, based on a specific discipline's area, it has some common threads that bring different views together namely, that environmental quality and resource base of future generations must not be compromised, the recognition of integration between environmental and socio-economic development, preserving ecological integrity and adopting a precautionary approach in the face of scientific uncertainty (Dovers and Lindenmayer 1997).

Box 1: Sustainable Development Definitions

World Conservation Strategy (IUCN 1980):

For development to be sustainable it must take account of social and ecological factors, as well as economic ones, of the living resource base, and of the long-term as well as short-term advantages and disadvantages of alternatives actions.

FAO Committee on Fisheries (FAO 1995):

The management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner to ensure the attainment and continued satisfaction of human needs for present and future generations. Such development conserves land, water, plant and genetic resources, is environmentally non-degrading, technologically appropriate, economically viable and socially acceptable.

The National Strategy for Ecologically Sustainable Development (Australia 1992):

Using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained and the total quality of life now and in the future can be increased

It is important to note that to meet the goal of sustainable development, a fulfillment of economic, social, environmental and institutional sustainability in a simultaneous fashion is fundamental (Charles 2001; Barbier 1987). This integration and priority towards environmental protection is depicted in Figure 3. 1 below. Part a of the figure indicates that the concept of sustainability is an interface between ecological conservation, economic and social development. Part b of the figure highlights the facts that the environment encompasses both social and economic elements of sustainable development as the socio-economic wellbeing relies upon the health of the natural environment. By considering the changing paradigms in fisheries management, Charles (2001) postulated that through the following 'sustainability triangle' as depicted in Figure 3. 2, economic, social and ecological sustainability would be held together by institutional sustainability. It should be emphasized that this concept, introduced by Charles (2001) has practical application as it provides a frameworks for sustainability assessment.

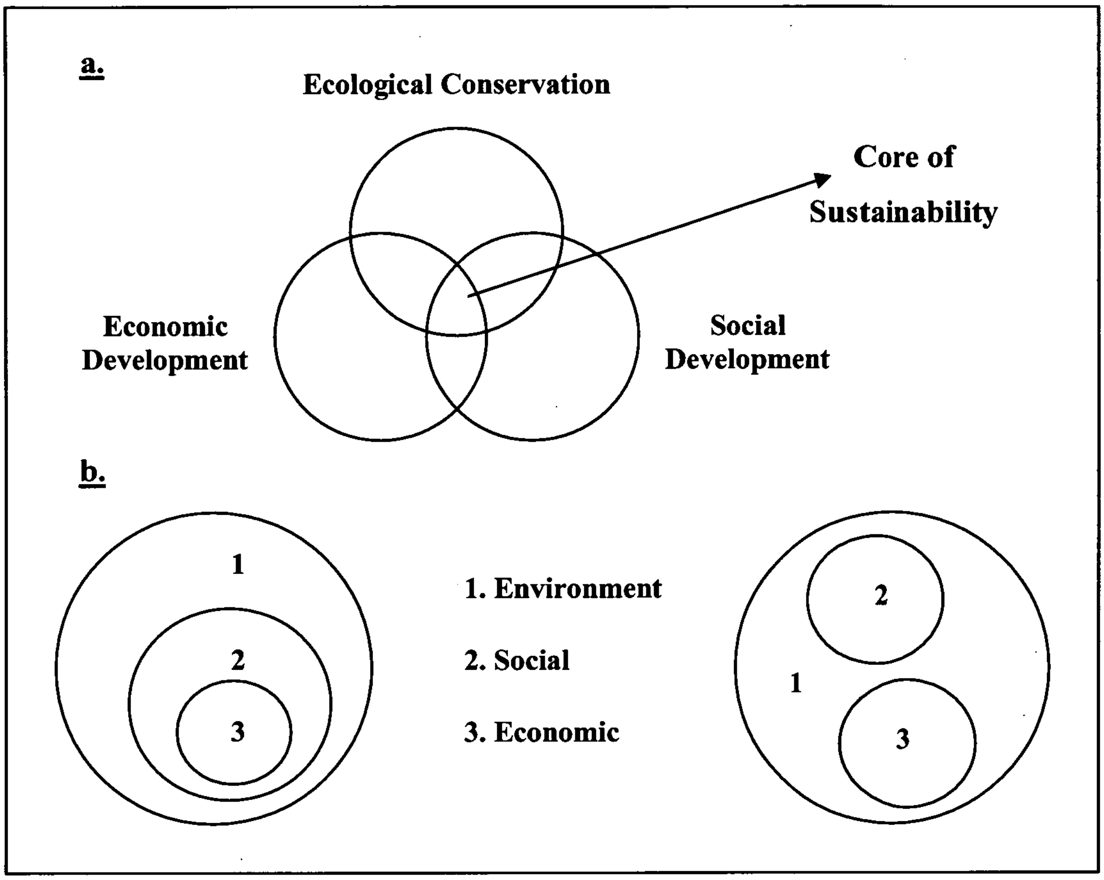


Figure 3. 1 a. Scheme of sustainable development; b. Ways of conceptualizing sustainable development (Hodge 1997)

It should be noted that in the 1970s and early 1980s, the main focus of the sustainable development campaign was on the conservation of non-living natural resources (minerals and fossil fuels) and the control of pollution. However, at the beginning of the 1980s the focus shifted towards the conservation of living resources influenced by the World Conservation Strategy (IUCN 1980). This influence was indicated by the addition of the word 'ecologically' to the concept of sustainable development.

It should be noted that in recent years, there has been growing recognition of the fact that religions can make a significant role in sustainable development. Religious precepts tend to influence the community's ways of making a living. Most religions teach human spiritual wellbeing through prayer or meditation or in work, as work disciplines our soul. This discipline presents itself as moral duties to make the best use of talents (human capital) and resources endowed by God. It should be noted that religion, in its modest form, is compatible with development as it is associated with a belief in experiment, in rationality, in community welfare and development, productive investment and honesty in commercial relation (Gyekye 1997; Lewis 1955). This crucial relationship between religion and sustainable development is highlighted by the existence of the Senat Al-Bahar and its influence on the attitude towards community development in Oman as discussed in Chapter 2. (For further discussion on Islamic philosophy and its relation to sustainable development see Bagader et al. (1994) and Chatel (2003)). Gottlieb (1996) and Mebratu (1998) state that historically religious beliefs and social traditions and laws that shape a community's command for sustainability and conservation and environment.

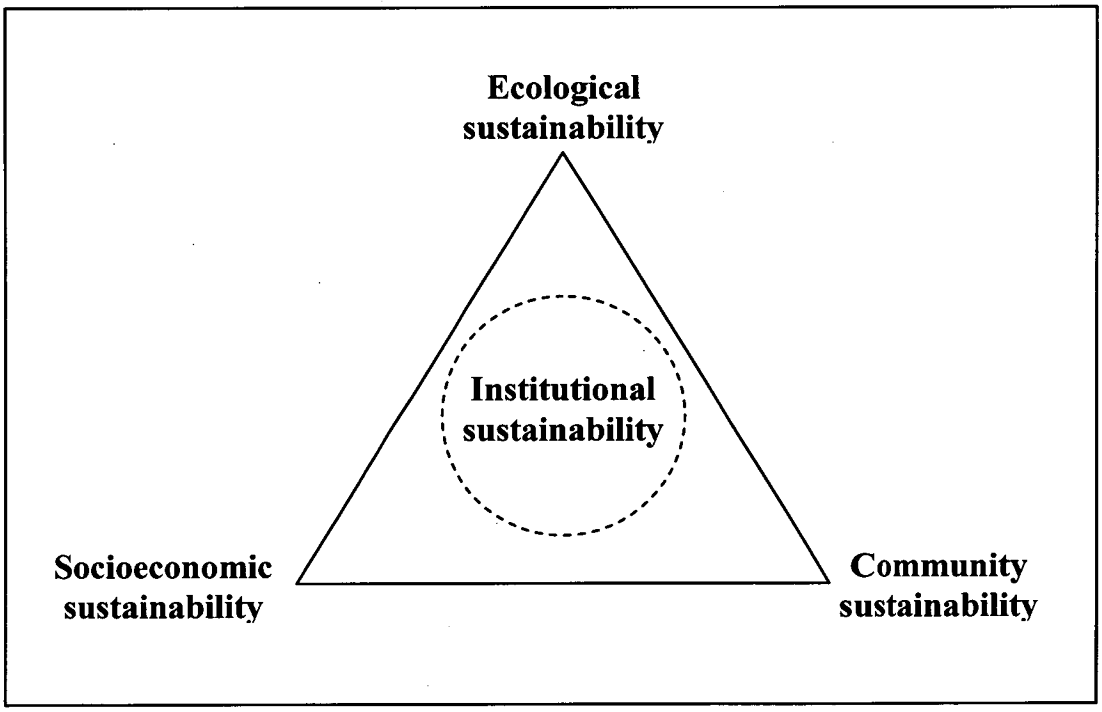


Figure 3. 2 The sustainability triangle for sustainability assessment (Adapted from Charles 2001)

3.4 International Development and Fisheries Sustainability

3.4.1 World Conservation Strategy

As mentioned above, in 1980, the World Conservation Strategy (WCS) was formed by the World Conservation Union (formerly called the International Union for the Conservation of Nature and Natural Resources, IUCN)) in cooperation with the United Nations Environment Programme (UNEP), the World Wildlife Fund

(WWF), FAO and UNESCO. It was developed over a three-year period with the involvement of more than 450 government agencies, international bodies, and nongovernmental organizations from over 100 countries (IUCN 1980; Saunier 1999).

The aim of the World Conservation Strategy is to help advance the achievement of sustainable development through the conservation of living resources. Saunier (1999) stated that WCS was intended to stimulate a more focused approach to living resource conservation and to provide policy guidance on how this could be carried out. It provided both an intellectual framework and practical guidance for the necessary conservation actions (Potter 1985). It called for global coordinated efforts, for concerted action at national and international levels, and for global solidarity to implement its programs. WCS is considered to be the first attempt to carry the concept of sustainability beyond a simple renewable resource system (Lele 2000).

The World Conservation Strategy identified three objectives fundamental to the ecological tier of sustainable development (IUCN 1980; Saunier 1999):

1. Conservation of essential ecological processes and life support systems;
2. Preservation of genetic diversity; and
3. Sustainable utilization of species and ecosystems.

The environment debate pre-WCED focused mainly on the impact of economic growth on the environment, where the impacts of a degraded environment on development prospects were largely ignored before the emergence of the WCED (Pezzoli 1997; WCED 1987).

3.4.2 World Commission on Environment and Development (WCED)

In the 1983 United Nation General Assembly (38/161), a recommendation was made to form a special commission on the environmental perspective to the year 2000 and beyond (UN 1983; Pezzoli 1997). After a three year period (1984-1987), the commission conducted a meeting at foreign ministers level that brought the discussion of sustainable development to literally millions of people around the world (Pezzoli 1997). The World Commission on Environment and Development (WCED), also known as '*Our Common Future*', was published in 1987, which alerted the world to the urgency of making progress toward economic development that could be sustained without depleting natural resources or harming the environment. The commission came to be known as the Brundtland Commission, or Report, after the Commission's chairwoman, Gro Harlem Brundtland. It developed guiding principles for sustainable development as generally understood today and defined sustainable development as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED 1987; P. 8). It outlined the condition of the global affairs in terms of environmental degradation, economic inequality and poverty and reviews the incapability of the nations to effectively secure equity for future generation. It is considered as the starting point for most of the current discussions on the concept of sustainability and sustainable development.

Therefore, the WCED Commission report has moved discussions of sustainable development from the WCS strategy of conservation to long-term environmental strategies in three major areas (Saunier 1999):

1. Management of the commons;
2. Peace, security, the environment and development; and
3. Institutional and legal changes.

The key issues and common challenges the commission would investigate were (WCED 1987; Segschneider 2001):

- Population Control;
- Human Resources;
- Food Security: Sustaining the potential;
- Species and Ecosystem: Resources for development;
- Energy: Choice for environment and development;
- Industry: Producing more with less; and
- The urban challenge.

In 1989, the report was debated in the United Nation General Assembly (44/228), in which it was decided to organize a UN Conference on Environment and Development. This decision was clearly stated in the Assembly Resolution in Article 2 as "Decides to convene the United Nations Conference on Environment and Development, which shall be of two weeks' duration and shall have the highest possible level of participation, to coincide with World Environment Day, on 5 June 1992" (UN 1989). This Assembly Resolution, which established the conference, listed around 23 objectives to be achieved by this Conference.

3.4.3 United Nations Conference on Environment and Development (UNCED)

In 1992, more than 100 heads of state met in Rio de Janeiro, Brazil, for the United Nations Conference on Environment and Development (UNCED). The Conference met to address urgent problems of environmental protection and socio-economic development. Nearly 50,000 official observers and citizens from around the world, who met in a wide range of official and community-based councils and seminars at a Global Forum, also attended the Earth Summit. The Earth Summit or Rio Conference, as UNCED was also known, was the conclusion of two years of negotiations by four International Preparatory Committees (PrepComs) (Mebratu 1998).

Five major agreements on global environmental issues were signed at the UNCED namely: Agenda 21; the Convention on Biological Diversity (CBD); the Framework Convention on Climate Change; the Rio Declaration; and the Statement on Forest Principles. Agenda 21, the CBD and the Rio Declaration are of major concern to the fisheries and marine resources and will be briefly elaborated on in this section.

To monitor the implementation of the above mentioned five agreements, a major institutional output of this conference was the creation of the UN Commission on Sustainable Development (CSD). Another objective for the CSD was to act as a forum for the ongoing negotiation of international policies on environment and development as a functional commission of the United Nation Economic and Social Council (UNESC) (UNCSD 2006; Saunier 1999). The CSD monitoring objective is planned to be achieved through (Saunier 1999):

- Ensuring effective follow-up of UNCED;
- Enhancing international cooperation and rationalization of intergovernmental decision-making capacity; and
- Examining progress in the implementation of Agenda 21 at the local, national, regional and international levels.

3.4.3.1 The Convention on Biological Diversity

The Convention on Biological Diversity, known informally as the Biodiversity Convention was signed in 1992 and came into force in December 1993 (CIESIN 2006; Yamin 1995). It is an international agreement that provides a legal, institutional and normative framework for international efforts to conserve biodiversity for its 118 parties, including Oman (Yamin 1995; MRME 1997). CBD is considered a landmark in the environment and development field, which recognized for the first time that the conservation of biological diversity is of common concern to mankind (Pimbert 1997).

This biological diversity of the CBD includes genetic diversity (the variation of genes within a species); species diversity (the variation of species within a region); and ecosystem diversity (the variety of ecosystems within a region) (Yamin 1995). The CBD was signed to achieve the following objectives (CIESIN 2006):

- To conserve biological diversity;
- To promote the sustainable use of its components; and
- To encourage equitable sharing of the benefits arising from the utilization of genetic resources.

3.4.3.2 The Rio Declaration on Environment and Development

The Rio Declaration on Environment and Development, often shortened to the Rio Declaration, is a short document produced at the UNCED. This declaration consists of 27 guiding principles intended to guide future sustainable development around the world and specifically focusing on the rights and obligations of sovereign states with respect to environment and development (Dykstra and Heinrich 1996).

One matter specifically related to the fisheries and marine resources sustainability issue in the Rio Declaration is Principle 15, which introduced the Precautionary Approach. This approach is further discussed in Section 3.4.3.

3.4.3.3 Agenda 21

Agenda 21 sets out actions that nations, communities and international organizations can take to contribute to the goal of global sustainability in the twenty-first century. Acting on the problems of today it also aims at preparing the world for the challenges of the next century. Agenda 21 reflects a global consensus and political commitment at the highest level on development and environment cooperation (UNDSD 1992). In sharing similar guidance responsibilities, Agenda 21 and UNCLOS set forth rights and obligations of States and provide the international basis upon which to pursue the protection and sustainable development of the marine and coastal environment and its resources (UNDSD 1992). This requires new approaches to marine and coastal area management and development at the national, sub-regional, regional and global levels, and approaches that are integrated in content and are precautionary and anticipatory in ambit, as reflected in the following program areas (UNDSD 1992):

a. Integrated management and sustainable development of coastal areas, including exclusive economic zones;
b. Marine environmental protection;
c. Sustainable use and conservation of marine living resources of the high seas;
d. Sustainable use and conservation of marine living resources under national jurisdiction;
e. Addressing critical uncertainties for the management of the marine environment and climate change;
f. Strengthening international, including regional, cooperation and coordination; and
g. Sustainable development of small islands.

Agenda 21 is divided into four main sections, or elements, including socio-economic dimension, resources conservation, community involvement and implementation measures (Gardiner 2002). Table 3. 1 below shows details of the elements of the Agenda and it has been the basis for action by many national and local governments. For example, over 150 countries have set up national advisory councils to promote dialogue between government, environmentalists, the private sector and the general community. Many have also established programs for monitoring national progress on sustainable development indicators. At the local government level, nearly 2000 towns and cities worldwide have created their own Local Agenda 21 plans (UNESCO 2002).

Table 3. 1 Elements of Agenda 21 (Gardiner 2002)

Elements	Issues
Social and economic dimension	Poverty, Production and Consumption, Health, Human Settlement, Integrated Decision Making
Conservation and management of resources for development	Atmosphere, **Oceans and Seas**, Land, Forests, Mountains, Biological Diversity, Ecosystems, Biotechnology, Freshwater resources, Toxic Chemicals, Hazardous Radioactive and Solid Wastes
Strengthening the role of major groups	Youth, Women, Indigenous Peoples, Non-Government Organizations, Local Authorities, Trade Unions, Business, Scientific and Technical Communities, Farmers
Means of implementation	Finance, Technology transfer, Information, Public Awareness, Capacity Building, Education, Legal Instruments, Institutional Frameworks

Oman is one of the countries which has shown great progress toward adoption of Agenda 21. Its Arabian Oryx Sanctuary (see Chapter 2) is included, by the United Nations Educational, Scientific and Cultural Organization (UNESCO), on the World Heritage List. Oman's present integrated system of protected areas, which includes six sites, is an early implementation of the convention on biodiversity and Chapter 15 of the Agenda (UN 1997). Oman's Government has also given special attention to the desertification problem in the Arabian Peninsula. Having demonstrated its commitment to Agenda (UN 1997). Chapter 2 includes details on Oman's commitment toward some international treaties.

Local Agenda 21 has become well embedded as a mechanism for promoting sustainable development strategies at the municipal level. Quantitative studies indicate an impressive rate of progress on strategy production and adoption (Selman

1998), however, the world has not gone far enough in translating the documents into concrete actions (Wapner 2003). Therefore, the world started to review Agenda 21 with the aim of providing more operational plans of action towards practical and secure sustainable development.

3.4.4 World Summit on Sustainable Development (WSSD)

The 10 years era after the Rio Conference points out the paradox of how the Rio process launched a number of successful institutional processes, without, however, producing tangible global results (Sachs et al. 2002). Progress in implementing sustainable development has been extremely disappointing since the 1992 Earth Summit, with poverty deepening and environmental degradation worsening (UN 2006a).

In December 2000, the UN General Assembly decided, in Resolution 55/199, to hold the World Summit on Sustainable Development (WSSD) in Johannesburg, South Africa (UN 2006a). Then, and ten years after the Earth Summit, the WSSD, commonly known as Rio +10, was held in Johannesburg, South Africa from 26 August to 4 September 2002. It was held to review the Agenda 21 implementation and to make concrete plans of action for sustainable development (Masaharu and Akiyama 2003).

The Johannesburg Summit brought together tens of thousands of participants, including 100 heads of State and Government, more than 10,000 national delegates and 8,000 leaders from non-governmental organizations (NGOs), businesses and other major groups. They all met to focus the world's attention and direct action toward meeting difficult challenges, including improving people's lives and conserving the natural resources in a world that is growing in population, with ever-increasing demands for food, water, shelter, sanitation, energy, health services and economic security (UN 2002a). The WSSD resulted in a new Declaration and action plan, the Johannesburg Plan of Implementation (UN 2002b) reaffirmed the international commitment to the goal of sustainability.

The WSSD Plan of Implementation is designed to further build on the achievements made since UNCED and to expedite the realization of the remaining goals. Critics have argued that the plan does not go far enough to securing concrete outcomes but it does make significant commitments in several key areas including oceans (Potts 2003).

In June 2001, the United Nations Secretary called for an international work program designed to meet the needs of decision makers and the public for scientific information concerning the consequences of ecosystem change for human well-being and options for responding to those changes (UN 2006b). This program - The Millennium Ecosystem Assessment (MA), which was completed in March 2005, has involved the work of more than 1,360 experts worldwide. Their findings on the condition and trends of ecosystems, scenarios for the future, possible responses, and assessments at a sub-global level are set out in technical chapters grouped around these four main themes.

MA founds that at least one quarter of marine fish stocks are over harvested and the quantity of fish caught by humans is now declining because of the shortage of stocks since the 1980s. Numerous references support and indicate as well as strengthen the criticism of failure in securing sustainable fisheries (see Section 3.5).

3.5 World Commitment toward Fisheries Sustainability

After the Second World War, the fleets of the Northern Hemisphere were ready to take on the world to re-establish food production (Garcia and Grainger 1996; Pauly et al. 2002). Accompanied with the rapid expansion and progress in fisheries technology, fishing industries were discovering new fishing grounds and expanding their fishing both horizontally and vertically. Thereafter, stress in several large-scale fisheries start to appear, and some fisheries, such as that of the Peruvian anchovy in 1971–1972 collapsed with global repercussions (Pauly et al. 2002; Hannesson 1995). At that time, natural causes (El Niño event) were claimed to be the reason for the Peruvian anchovy collapse, however, as claimed by Pauly et al. (2002) overfishing was found to be a significant factor.

Regardless of latter major collapses and stocking signals, the fishing pressure and high levels of effort continued (Potts 2003). Pauly et al. (2002; P. 689) stated that "*literature supports the claim that, historically, fisheries have tended to be non-sustainable, although not unexpectedly there is a debate about the cause for this, and the exceptions*". Based on an examination of historical catch and abundance data, together with experimental studies and surveys, Longhurst (2007) suggests that all sea fisheries could collapse by the middle of this century unless action is taken to prevent this from happening. In a recent study, Worm et al. (2006) predicted that all fisheries will have collapsed by 2048. This prediction was criticized by Branch (2008). However, literature gives many examples and different scenarios of the collapse of fisheries concluding that overall, the main cause is a failure by fisheries management to sustain fisheries resources (see Chapter 1). Therefore, as stated by Pauly et al. (2002; P. 689) "*Fisheries have rarely been 'sustainable'. Rather, fishing has induced serial depletions, long masked by improved technology, geographic expansion and exploitation of previously spurned species lower in the food web*". On the other hand, assuming good signs, a success in one fishery sector may be seen as a failure in another due to the conflict in objectives (Hilborn 2007).

All the above mentioned crises of geographical spread of the fishing fleets, development in fishing technologies and stress signals in stocks, lead to maritime jurisdiction (EEZ) and evoked the idea of global fisheries management. Thereafter, different international initiatives, instruments and management approaches were initiated to unify the protection of the world marine resources especially, the shared one. Some relevant global concensuses, of the main fisheries, are discussed in the following sections.

3.5.1 The United Nation Convention on the Law of the Sea

Triggered by the competition between governmental authority over the sea and the idea of the freedom of the sea, and more specifically its jurisdiction, power, food and mineral resources, the world struggled to compile a law for the sea (Jones 1972; O'Connell 1982). The first official attempt to codify the law of the sea was the Hague Conference 1930 (Glasgow 1930), which failed to reach an agreement and therefore no convention was issued (Opeskin 2005). O'Connell (1982) claimed that the Hague Conference failed for political reasons, however, it drew some legal lines. Since then, three conferences have been convened: UNCLOS I in 1958, UNCLOS II in 1960 and UNCLOS III in 1973 (UN 2007b).

The first international collaboration in marine resources management started with the signing of the UN Law of the Sea Convention (UNCLOS) on December 10th, 1982 and came into force in 1994 (Garcia and Moreno 2001; Potts 2003). The

UN Law of the Sea Convention marked the culmination of more than 14 years of work involving participation by more than 150 countries representing all regions of the world, all legal and political systems and the spectrum of socio/economic development (UN 2007). From the last UNCLOS conference in 1973 to 1982, nations spent seven sessions finalizing the Law of the Sea (Opeskin 2005). The convention comprises 320 articles and nine annexes, governing all aspects of ocean space, such as delimitation, environmental control, marine scientific research, economic and commercial activities, transfer of technology and the settlement of disputes relating to ocean matters (UN 2007). UNCLOS is considered one of the main bases, with Agenda 21, (see Section 3.3.1.3) for fisheries sustainable development. It should be noted that Oman is a ratified member on the UNCLOS (see Chapter 2).

One of the most important articles of the UNCLOS mentioned is article 87. This raises the notion of the 'freedom of high seas', that part of seawater that lies beyond the jurisdiction of coastal states. In this article, the rights have been granted to the nation to fish in this area (Potts 2003). A poorly defined management regime in the high seas has been noted to contribute to the overexploitation of marine resources and resulted in a lack of incentive to conserve resources and generate minimal cooperation between states (Emerson 1995; Potts 2003). As an open access system (Hardin 1968) is well known to lead to an abuse of resources, institutions such as the FAO recognized the problem and the threat to the sustainable development of resources (Potts 2003). As an international action, the International Conference on Responsible Fishing held in 1992 has formed the United Nation Conference on Environment and Development and Agenda 21 (see Section 3.3.1.3). One critical outcome from Chapter 17 of Agenda 21 (UNDSD 1992) was the recommendation to convene a conference on the issue of the management of high seas stocks, which produced The United Nation Fish Stock Agreement (UNFSA) (Potts 2003).

3.5.2 The United Nation Fish Stocks Agreement

The United Nation Fish Stock Agreement (UNFSA) or the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (Anderson 1996) was developed over six sessions between 1993 and 1995 with 148 states, UN agencies, international bodies and non-government organizations (Potts 2003). It brought forth an agreement that was designed to address and alleviate a worldwide resource management crisis and focussed on the so-called straddling and highly migratory fish stocks (Munro 2000). The objectives of the agreement were to agree on clarifying the responsibilities of fishing states, to provide coordination for management via Regional Fisheries Management Organizations (RFMOs) and to strengthen fisheries management on the high seas (Potts 2003). The agreement provided measures that regulate the interaction between the RFMOs and Distance-Water Fishing Nations (DWFNs), however, instability is found to appear, which raises conflict such as the case of Northern Atlantic Bluefin Tuna Fisheries (Brasao et al. 2000).

The Agreement can be broken down into four parts: general principles; measures for strengthening regional and sub-regional cooperation; measures for monitoring, surveillance and enforcement; and the settlement of disputes (Ocean-Law 2007). According to Nandan (2005), UNFSA is built on three essential pillars, which are designed to ensure that the agreement achieves its objective of long term conservation and sustainable use of straddling fish stocks and highly migratory fish stocks:

1. To state the principles and practices on which better management of stocks should be based;
2. To ensure that the conservation and management measures are adhered to and complied with, and that they are not undermined by those who fish the stocks; and
3. The provision of peaceful settlement of disputes.

The UNFSA declares that states should apply the precautionary approach to the conservation, management and exploitation of straddling and migratory fish stocks (Herriman et al. 1997; Potts 2003; Smith 2000). The precautionary approach is embodied in the UNFSA to improve decision making in the face of uncertainty (Garcia 1994; Richards and Maguire 1998).

3.5.3 The Precautionary Approach

Predicting ecosystems' behavior cannot be done with absolute certainty, regardless of the amount of scientific effort invested (Panel 1999). Therefore, uncertainty can be considered as a fundamental characteristic of the fisheries and they can only be managed within the limits of their predicted certainty. In addition, the process of management and authority themselves suffer uncertainty, models for stock assessment are oversimplifications and errors do exist in fisheries data (Potts 2003). As a result of such complexity in a fishery, a management concept termed as 'precautionary approach' has emerged and gained acceptance as a basis for fishery management (Richards and Maguire 1998). However, it should be noted that it was first incorporated into environmental policy in Germany in1980 (Barrett 2000).

Principle 15 of the Rio Declaration states: "*In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation*" (UN 1992). The first part of Article 7.5 (Precautionary Approach) of the FAO Code of Conduct for Responsible Fisheries (see Chapter 4) states that: "*States should apply the precautionary approach widely to conservation, management and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment*" (FAO 1995).

As claimed by O'Riordan and Jordan (1995), the precautionary principle is neither a well defined principle nor a stable concept. It has become the repository for a jumble of adventurous beliefs that challenge the status quo of political power, ideology and civil rights (O'Riordan and Jordan 1995). Smith (2000) has described the precautionary approach as a logical extension of commonsense concepts that guide daily life. It is therefore a moral and political principle, which is most often used to minimize the impact of human actions on the environment and human health when scientific facts are missing. "*At its core, the principle calls for preventive, anticipatory measures to be taken when an activity raises threats of harm to the environment, wildlife, or human health, even if some cause-and-effect relationships are not fully established*" (Smith 2000; P. 263). Kriebel et al. (2001) has identified four central components for the precautionary approach: taking preventive action in the face of uncertainty; shifting the burden of proof to the proponents of an activity; exploring a wide range of alternatives to possibly harmful actions; and increasing public participation in decision making. Overall, the precautionary approach emphasizes guidelines intended to prevent overfishing, for rebuilding stock and therefore maintaining sustainability (Potts 2003).

As per article 6.3*b* of the UNFSA, states shall "*determine, on the basis of the best scientific information available, stock-specific reference points and the action to be taken if they are exceeded*". This article specifies the primary mechanism for applying the precautionary approach (Richards and Maguire 1998). It is to identify and develop reference points for fisheries that identify desired states (targets) or undesirable states (limits) for a particular variable or indicator (Garcia 1994; Potts 2003). It should be noted that the assessment of the commercial trawling in this study is based on identifying and developing reference points as targets or limits to be achieved or avoided. Reference points have been generally defined in term of fishing mortality rate F, and expressed as targets rather than limits such as with the Maximum Sustainable Yield (MSY) and Maximum Economic Yield (MEY).

Once reference points have been established, fishery management strategies shall ensure that risk of exceeding limit reference points is very low and that target reference points are not exceeded on average (Richards and Maguire 1998). Risk assessment is also of great importance in fisheries management. To succeed in fisheries management and to maintain stable fishing communities, risk has to be managed (Hilborn et al. 2001). For this purpose, different precautionary approaches were developed to assess risk and certainty. Figure 3. 3 shows a simple performance measure to assess a variable over time in relation to the reference points as illustrated by Sainsbury and Sumaila (2001). Another example is the ICES precautionary approach to management (Figure 3. 4) (Cury et al. 2005).

Uncertainties and risks can be higher in data-poor situations in the new and developing fisheries such as the case in Oman, where best information available is simply inadequate for determining meaningful reference points (Richards and Maguire 1998). Therefore, very conservative management measures are required for such cases under the precautionary approach. For such cases and as per Article 6.6 of the FAO Code of Conduct for Responsible Fisheries, states are required to adapt as soon as possible cautious conservation and management measures. Such precautionary measures include catch and effort limits including area closure or marine protected areas and Total Allowable Catch (precautionary TAC) (Richards and Maguire 1998; Saunders et al. 1998; Ward et al. 2002; Horwood et al. 1998; Jaworski et al. 2006; Baelde 2005).

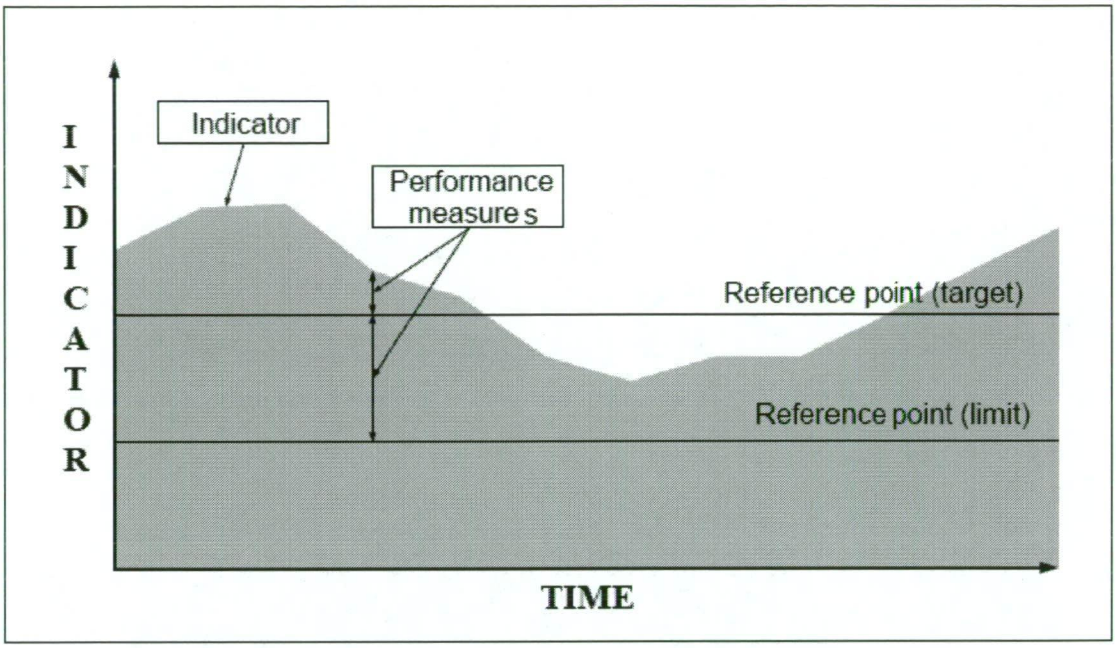


Figure 3. 3 The use of an indicator and reference points to define simple performance measures (from Sainsbury and Sumaila 2001)

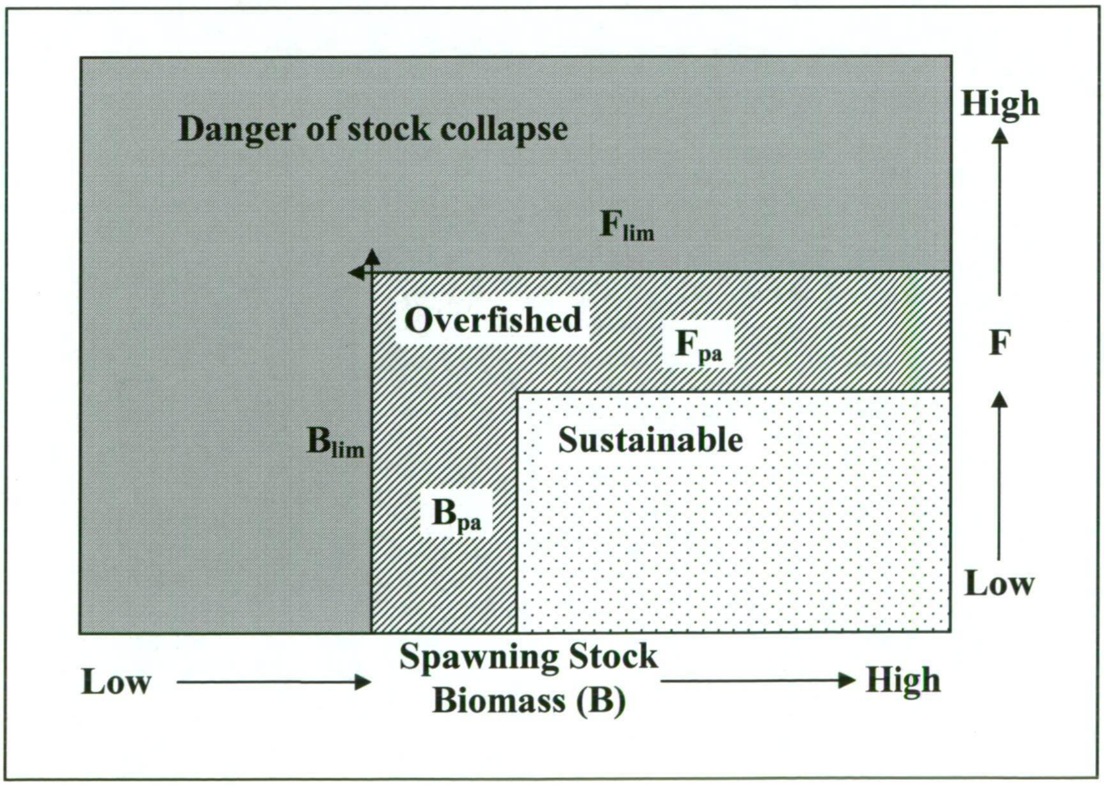


Figure 3. 4 ICES precautionary approach adapted from (ICES 2007)

Most of the initial determined target and limit reference points are based on fish stock assessment models, which are inherently uncertain and based on a single species approach (Caddy and Mahon 1995; Potts 2003). Therefore, further conceptual development has shown the need for wide inclusion of biological diversity, ecological integrity and policy decision making and monitoring of all context including ecological, socio-economic and institutional parameters; the principals of sustainable development. All these issues and limitations bring the world toward the implementation of an Ecosystem Approach to Management (EAM) or Ecosystem-Based Management (EBM) to focus on different management priorities and to consider the ecosystem as a whole rather than single target species (Potts 2003; Sainsbury and Sumaila 2001; UNEP/GPA 2006; Garcia and Cochrane 2005).

3.5.4 Ecosystem-Based Fisheries Management

Limitation of single-species approach, target species effects on ecosystem (Pauly et al. 2002; Pauly et al. 2000), socio-economic concerns (Bowen 1996; Potts 2003) and human induced factors on land and in the ocean (Sherman and Muda 1999) all are limitations in fisheries management and are threats toward the ecosystem in its holistic concept. As a result, the relatively new approach, Ecosystem-Based Management (EBM) or Ecosystem-Based Approach (EBA) (Witherell et al. 2000) was then followed to achieve both ecosystems and human healthy communities. EBM is an innovative management approach to address these challenges. It considers all ecosystem components in an interrelating mode, including humans and environment, rather than managing one issue or resource in an isolated way.

In fisheries, EBM is most commonly referred to as Ecosystem-Based Fisheries Management (EBFM) considering the considerable influence that fisheries now have on fish abundance (Christie et al. 2007). EBFM is "*a new direction for fishery management, essentially reversing the order of management priorities to start with the ecosystem rather than the target species*" (Pikitch et al. 2004; P. 346). From 'conservation of the parts' of system, EBFM acknowledges that fisheries operates within broader ecological and socio-economic systems that influence each other (Potts 2003). On the other hand, the study of fishing gear impacts, which is the case for this research has also moved from effect on target species toward effects on ecosystem and communities (Hall and Mainprize 2004; Gislason 2002). Therefore, EBFM is the interacting effect of fishery on ecosystem and of ecosystem on fishery (Potts 2003; Sainsbury and Sumaila 2001; Ward et al. 2002). It is worth noting that the aim of this study is to assess the impact of the commercial trawling in Oman on humans and the environment.

Lackey (1998) has listed seven pillars that define and bound the concept of EBM: values and priorities, boundaries, health, stability, diversity, sustainability and scientific information. However, objectives of the EBFM will vary from one ecosystem to another and setting of conceptual objectives is important for identifying the actions required to implement the ecosystem management (Potts 2003). Defining proper long-term, ecosystem-related objectives is one of the difficulties in developing an operational basis for a fishery ecosystem approach (Cury et al. 2005). Slocombe (1998) has provided a set of procedural goals and objectives that would facilitate the development and implementation of substantive goals for ecosystem-based management. Cury et al. (2005) suggested that the mathematical 'viability' concept, developed by Aubin (1991), can be used to assist in the definition, selection of, and interaction among, long-term objectives at an ecosystem level. According to (Pikitch et al. 2004), the overall objective of EBFM is to sustain healthy marine ecosystems and the fisheries they support. In particular, EBFM should:

1. Avoid degradation of ecosystems, as measured by indicators of environmental quality and system status;
2. Minimize the risk of irreversible change to natural assemblages of species and ecosystem processes;
3. Obtain and maintain long-term socioeconomic benefits without compromising the ecosystem; and
4. Generate knowledge of ecosystem processes sufficient to understand the likely consequences of human actions.

Expansion from a single-species concept to a holistic approach raises questions about information, governance mechanism and the need for trans-discipline (Murawski 2000; Potts 2003; Slocombe 1998). Due to the complexity of the ecosystem, and therefore great uncertainty, a precautionary approach and a wide range of objectives should be involved in this kind of management. To achieve any objective, specific practical tools and measures have to be defined (Potts 2003) including indicators and reference points. This certainly will require a new set of reference points that cover the whole ecosystem. However, single-species targets and limit reference points are still appropriate, but will need to be modified in the context of the overall state of the system, habitat, protected species and non-target species even when there are no biological interactions between the species (Pikitch et al. 2004; Arnason 2000). Although that fisheries management to date has not been highly successful (Schrank 2007), there is still hope that the EBFM approach might be able to unlock some of the impediments that conventional management has experienced (Garcia and Moreno 2001).

The process of establishing set of sustainability indicators is explored in details in Chapter 4.

3.6 Ecologically Sustainable Development

The concept of Ecologically Sustainable Development (ESD) officially entered the Australian environmental policy lexicon in the 1980s with the formation of the ESD working groups (Australia 1992). In 1989, following the release of the Brundtland Report (see Section 2.3.1.2), the Prime Minister released a policy statement on the environment entitled *Our Country Our Future* (Fletcher 2002a). Thereafter, the Commonwealth Government as well as the international community (ENRC 2000) adopted ESD, and took on board the Australian concept for Sustainable Development which emphasized the importance of the environment in sustainable development. It has been considered as a useful concept in pursuing sustainability consistent with a balanced approach in dealing with environmental, social and economic issues (ENRC 2000; Fletcher 2002a). The term was formally transferred to the Council of Australian Governments (COAG) endorsed National Strategy of Ecologically Sustainable Development (NSESD) in 1992 and now the principles are incorporated in recent environment legislation – the *Environment Protection and Biodiversity Conservation Act* (EPBC) 1999 (ENRC 2000; Curran 2003).

The National Strategy on ESD (Australia 1992) was agreed by all Australian Governments and most states have incorporated ESD into their fisheries legislations

(Whitworth et al. 2002). It defines the ESD as *"using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained and the total quality of life now and in the future can be increased"*. This definition is obviously reflecting WCD and other international conventions. The goal of the NSESD is towards development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (Australia 1992). NSESD core objectives are (Australia 1992):

1. To enhance individual and community well-being and welfare by following a path of economic development that safeguards the welfare of future generations;
2. To provide for equity within and between generations; and
3. To protect biological diversity and maintain essential ecological processes and life-support systems.

Another fundamental element of the NSESD is a series of 'guiding principles' (ENRC 2000), which are:

1. Decision making processes should effectively integrate both long and short-term economic, environmental, social and equity considerations;
2. Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. This is a noteworthy precautionary principle and should be considered in the application of ESD principles in managing fisheries;
3. The global dimension of environmental impacts of actions and policies should be recognized and considered;
4. The need to develop a strong, growing and diversified economy which can enhance the capacity for environmental protection should be recognized;
5. The need to maintain and enhance international competitiveness in an environmentally sound manner should be recognized;
6. Cost effective and flexible policy instruments should be adopted, such as improved valuation, pricing and incentive mechanisms; and

7. Decisions and actions should provide for broad community involvement on issues which affect them.

Whilst ESD has often been wrongly assumed to address only environmental issues, this set of guiding principles along with the three objectives recognize that continued development is a necessary element in meeting the overall objectives (Fletcher 2002a). They are required to be considered as a package and no objective or principle should predominate the others. A balanced approach is required that takes into account all these objectives and principles to pursue the goal of ESD. However in practice, the objectives of optimizing economic efficiency in Australian fisheries management take precedence over social objectives.

Although Australian state governments had agreed on the National Strategy on ESD, fisheries agencies were often unclear on how to implement ESD on fisheries management (Whitworth et al. 2002). To facilitate the implementation of the ESD Strategy into fisheries management, directors of all fisheries management agencies along with representatives from industry, non-government organizations, Environment Australia and other relevant stakeholders had organized the Standing Committee on Fisheries and Aquaculture (SCFA). In June 2000 SCFA then developed the National ESD Reporting Framework for Australian Fisheries (Whitworth et al. 2002) and agreed on the following three core objectives for sustainable fisheries (Fletcher 2002a):

1. To protect biodiversity and maintain essential ecological processes;
2. Enhancement of individual and community well-being by following a path of economic development that safeguards the welfare of current and future generations; and
3. Provision of effective legal, institutional and economic frameworks for ecologically sustainable development.

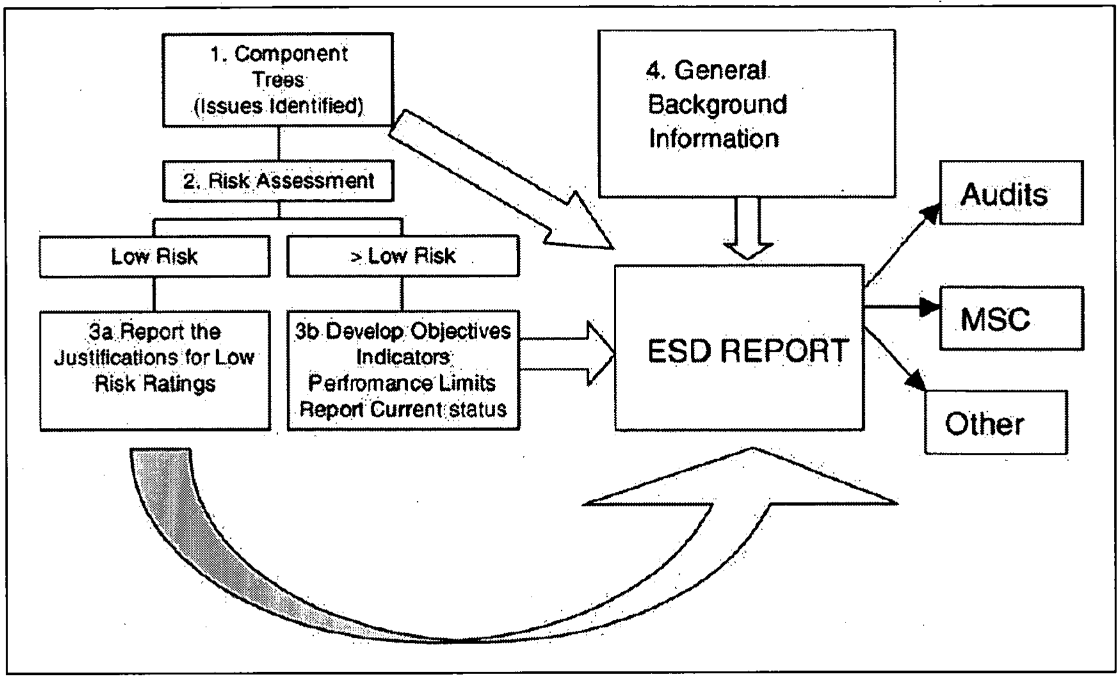


Figure 3. 5 Summary of the National ESD Reporting Framework (Chesson and Clayton 1998)

From the above mentioned three core objectives, ESD is then divided into eight major components (within three main categories). These are relevant to fisheries and cover the ecological, social, economic and institutional areas (Fletcher 2002b; Fletcher et al. 2005). The eight major components are:

- **Contributions of the fishery to ecological well-being**

    1. Retained species: cover the impact of the fishery on all species that are kept and used even if caught incidentally and whether primary or by-product species.

    2. Non-retained species: cover the impact of the fishery on species that are caught or directly impacted but neither kept nor used.

    3. General Ecosystem: cover all other impacts of the fishery on the ecosystem mainly - effects from removing fish, benthic biota and other biological and physical effects.

- **Contributions of the fishery to human well-being**

    4. Indigenous well-being: cover the effects of the fishery on the indigenous communities.

5. Community and regional well-being: cover the effects of the fishery on any local or regional community.

6. National social and economic well-being: cover the contribution of the fishery to the consumers, fishers, associated industries and national economy.

- **Ability of the fishery to contribute**

7. Impact of the environment on the fishery: cover all issues that affect the performance of the fishery and are outside the direct control of the management agency or industry.

8. Governance: cover the management processes and arrangements that support the performance

Each of the eight major components of the ESD is further subdivided into more specific sub-components to form a series of generic component trees (Whitworth et al. 2002). Figure 3. 6 provides an example of a generic component tree of general ecosystem effects.

Figure 3. 6 An example of a generic component tree for the general ecosystem effects (Fletcher et al. 2005)

Once all lower sub-components for a fishery are identified, a performance report is required. There are four main elements in the process which complete an ESD report (Fletcher et al. 2002; Fletcher et al. 2005):

1. Identifying the issues relevant to the fishery:

   This is achieved by expanding (splitting) or contracting (removing/lumping) the number of sub-components as required depending upon fishing methods, area of operations and the species involved (Fletcher et al. 2004). It aims also at maximizing the consistency and minimizing the chance of missing, issues or impacts (positive or negative) related to the fishery.

2. Prioritizing issues using risk assessment:

   As the importance of identifying often large number of issues varies greatly, risk assessment methodology is used to prioritize the issues and specify an appropriate level of management response. This method has also to include justification for the level chosen to enable review and facilitate future amendment. To facilitate gaining a realistic and consistent estimate of risk, SCFA has developed a risk matrix of six consequences levels (negligible, minor, moderate, sever, major and catastrophic) with values ranging from zero to five respectively. These consequences are related to another six categories of likelihood of occurrence (remote, rare, unlikely, possible, occasional and likely) and are assigned levels ranging from one to six respectively. The mathematical calculation of the consequence and likelihood show that the resultant risk values range from zero to 30 (Risk = Consequence x Likelihood) (Table 3. 2). For full details on risk assessment methodology see Fletcher (2002a).

3. Completing component reports:

   A suitable detailed report on the performance of the fishery is required mainly for issues requiring explicit management. To ensure consistency of focus and attention across all issues, a set of standard report headings has been developed (Fletcher et al. 2005). A full performance report should address: objectives, indicators, performance measure, data, evaluation, robustness, fisheries management response, comments and action and any external drivers that might affect performance against objective (Fletcher 2002b).

4. Compiling a report:

The final step is to compile all information, in an appropriate format, into a comprehensive report including summary background material on the fishery, the major species affected and the environments within which the fishery operates. In addition to the basic biological and ecological characteristics, the report should also include social and economic information and the methodology followed (Fletcher et al. 2002a).

Table 3. 2 Risk ranking definition and outcomes (Fletcher 2002a)

Risk ranking	Risk scores	Likely management response	Likely reporting requirement
Negligible	0	Nil	Short justification only
Low	1-6	None specific	Full justification needed
Moderate	7-12	Specific management needed	Full performance report
High	13-18	Possible increase to management activities needed	Full performance report
Extreme	> 19	Likely additional management activities needed	Full performance report

With respect to fisheries, ESD concept means that the effect of the fishery on the target species and also the direct and indirect effects that the fishery may have on the broader ecosystem, must be managed. Furthermore, the ESD concept recognizes a number of different scales of positive and negative social and economic effects. In a wider approach, the integration of the economic, social and environmental implications, within decision-making processes, is the cornerstone and major innovation of ESD (Fletcher 2002a). This is why, ESD is considered an Ecosystem-Based Management framework.

The Fisheries Management Act 1991 (Australia 2006; P. 1) states, as an objective, *"that the exploitation of fisheries resources and the carrying on of any related activities are conducted in a manner consistent with the principles of ecologically sustainable development..."*. To determine how well the management requirements for sustainability are met, and how performance progresses over time, Chesson and Clayton (1998) have developed a generic framework to answer this question. This framework consists of a structure and a set of procedure to apply to that structure.

The Chesson and Clayton (1998) ESD framework is a comprehensive structure, which includes environmental, economic and social components used to evaluate the progress of SD over time. This evaluation is done by examining the effect of fishing in terms of impacts on the ecological process (effect on environment including effect on the resources (FAO 1999a) and on total quality of life (effect on humans). The structure is designed to organize information about the fishery, avoiding omission and duplication (Chesson and Clayton 1998). The issues addressed within ESD are not fixed but are likely to have an ongoing evolutionary. In this respect, ESD should be seen as a means not an end (Fletcher 2002a). The next chapter investigates ESD framework for assessing fisheries in addition to four other conceptual frameworks for sustainable development.

3.7 Conclusion

This chapter provides an overview of the evolution of the concept of sustainable development and reviews literature relevant to fisheries sustainability. It can be concluded from the reviews of the growing amount of literature on the subject that sustainable development has had a substantial impact on the intellectual thoughts and has, since the 1970s, infiltrated all levels of government activities from local to international.

However, the task of how to make the sustainability concept operational appears increasingly challenging. Keeping this in mind, the ESD framework developed in Australia has been discussed as it has particular relevance to the fisheries sector. In addition, the framework has been used in assessing the various Commonwealth fisheries in Australia.

The identification of the various dimensions of sustainability, together with the fisheries information provided in Chapter 2, will form the basis of determining the suitable framework for the fishery sector in Oman. This is discussed in detail in the next chapter.

CHAPTER 4: FISHERIES INDICATORS AND CONCEPTUAL FRAMEWORKS FOR SUSTAINABLE DEVELOPMENT

4.1 Introduction

From the review of the concept of sustainable development in Chapter 3, it is clear that the concept is multi-dimensional in nature. To examine the overall contribution of the commercial trawl sector of Oman to ESD, it is important to identify all relevant issues and categorize them under economic, social, environmental and institutional dimensions of sustainable development. This is important, because of the fact that as a commercial enterprise, the trawl sector needs to position itself well nationally, regionally and internationally. This would allow it to meet community expectations of environmental, social and economic outcomes and to at least maintain or enhance market access in the context of regional and international rules, for example in the area of trade agreements and also in regard to consumer preferences. To address these issues in a coherent and cost-effective manner a systematic approach, which generally results in a comprehensive operational framework, needs to be established. This operational framework is useful for a number of reasons, amongst them: a) it explicitly integrates all dimensions of sustainability; b) it potentially leads to effective multi-objective policy analysis; c) it establishes linkages and relationships between different components of sustainable development and their corresponding levels; and d) it permits policy analysts to compare management performances over a period of time. Furthermore, fisheries managers require an operational framework to monitor and manage sustainability in the sector. Keeping this in mind, the main purpose of this chapter is to review the existing sustainable development frameworks in fisheries literature and to choose one particular framework with which to assess the sustainability performance of the commercial trawl sector in Oman. In selecting the framework for the case in hand, particular attention has been given to a number of criteria such as, organizational goals and objectives, fishery characteristics, suitability to local conditions and availability of data and information.

This chapter also reviews some important fisheries related technical guidelines behind the development of appropriate sustainability indicators which are one of the fundamental ingredients of the *Sustainable Development Reference System* (SDRS).

4.2 Sustainable Development Reference System

In the context of capture fisheries, the concept of the Sustainability Reference System (SRS), sometimes referred to as Sustainable Development Reference System (SDRS), was introduced and adopted as a means of selecting and organizing appropriate indicators by the Australian-FAO Technical Consultation on Sustainability Indicators in Marine Capture Fisheries (Sydney, Australia, 18-22 January 1999) (FAO 1999a; Garcia and Staples 2000b). It should be noted that the consolidated effort put forward in the Technical Consultation forum of 1999 to develop a series of technical guidelines to serve as a basis for integrating a set of indicators in accordance with sustainable development principles was influenced by the Agenda 21 as it specifically calls for the harmonization of efforts to develop the indicators at the national, regional and global levels including incorporating and updating accessible databases (UNDESA 2001). Garcia et al. (2000b) also indicated that experience in many sectors and countries has demonstrated failure to implement any indicators developed outside a reference system.

SDRS is defined by FAO (1999a; P. 30) as "*a means of representing the sustainability of a system of exploitation (e.g. a fishery or a fishery sector), composed of reference points (selected on the basis of objectives, constraints and limits) and indicators*".

As stated by Garcia and Staples (2000b), an SDRS is a referencing system used to study, assess and report on the sustainability of a sector. It is a system of developing, organizing and using a set of indicators to track progress with respect to sustainable development (FAO 1999a). SDRS also provide a means to aggregate the indicators and visualize them for effective communication (Garcia et al. 2000b). In the context of selecting, organizing and using sustainable development indicators for capture fisheries, FAO (1999a) in its technical guidelines for responsible fisheries, has stated that an efficient SDRS should reflect the following seven characteristics. That is, an efficient SDRS should:

1. Be capable of delivering meaningful information about the achievement of sustainable development and policy objectives (including their legal basis) at the desired scale;
2. Be inexpensive and simple to compile and use;
3. Optimize the use of information;
4. Handle different levels of complexity and scales;
5. Facilitate integration and aggregation of indicators;
6. Provide information that is readily communicable to stakeholders; and
7. Contribute directly to improve decision-making processes.

4.2.1 Development of SDRS

According to the existing literature, the development of an SDRS involves five key steps along with a range of expertise form relevant stakeholders (FAO 1999a; Garcia and Staples 2000b; Garcia et al. 2000b). The key steps are detailed below:

1. Specifying the scope of the SDRS:

   As stated by FAO (1999a) and Garcia et al. (2000a), the scope of an SDRS will depend on the fishery's size and complexity and on the intended uses and users of the information. Therefore, decisions will need to be made on the overall purpose of the SDRS, human activities to be covered, issues to be addressed and the system's geographical boundaries in relation to its components.

2. Developing a framework for indicator development (or selecting an existing one):

As mentioned in the introduction, to address the multi-dimensional complexity of sustainable development in a coherent manner, a framework is a necessity and must be developed in a convenient way to organize indicators in relation to sustainable development (FAO 1999a). This framework has to show the dimension of the system, factors and their relationships and criteria[1] for which

[1] A criterion as stated by Garcia and Staples (2000b; P. 385) is "*an attribute of the sustainability information system in relation to which indicators and reference points may be elaborated*".

indicators will be established and monitored (Garcia and Staples 2000b). As stated by Garcia et al. (2000b), the type of adapted framework is not critical as long as it encompasses the scope and purpose of the SDRS.

Table 4. 1 below presents six existing frameworks generally used in developing and grouping indicators as revealed by FAO (1999a) and Garcia et al. (2000b). It also presents the corresponding dimensions associated with each framework. It should be noted that these frameworks are mutually non-exclusive.

3. Specifying criteria, objectives, potential indicators and reference points:

   As mentioned above, each sustainable development framework has its own dimensions, which will determine the criteria and their selection of objectives, indicators and reference points (FAO 1999a; Garcia et al. 2000b). In other words, indicators, through reference points, will indicate whether the objectives of any dimension's criterion are achieved and if so, to what extent. This highlights the importance of choosing representative indicators and reference points that are meaningful and describe objectives efficiently (FAO 1999a). This topic will be discussed in detail in Section 4.5.

   The selection of criteria and the identification of their corresponding objectives usually involves all stakeholders and experts in the field. It requires detailed operational and technical knowledge of the system, its dimensions (social, economic, ecological and institutional) and the inter-dimensional and intra-dimensional interactions with regard to elements under each dimension (FAO 1999a).

   Table 4. 2 presents some examples of criteria for the core dimensions of sustainability discussed in Chapter 3. Updating and/or developing the criteria and indicators is required as objectives might change over time. Therefore, an SDRS framework should have the ability to develop relationships and trade-offs between objectives (FAO 1999a). Objectives such as maintaining fish stock might be well-defined at national level and/or objectives, such as minimizing pollution, well-defined at international level. On the other hand, some objectives such as promotion of local community development (FAO 1999a) may be vague (Garcia et al. 2000b) and never

have been clearly articulated or agreed upon. It should be noted that, in contrast to goals –which are ideals – an objective is specific and in most cases a quantifiable statement and has a time frame and indicator(s) attached to it through which management activities can be evaluated for progress and effectiveness (Barber and Taylor 1990).

4. Choosing set of indicators and reference points:

Literature reviews have identified listed numerous candidate indicators (FAO 2003a; Garcia 2003; Lack 2004; Ward et al. 1998; Ward et al. 2002). SDRS frameworks help in identifying a set of reliable indicators based on the identified criteria. Identifying a set of agreed indicators will be based on criteria such as data availability, feasibility, cost-effectiveness and accuracy and precision (Garcia et al. 2000b). This topic will also be discussed in detail in Section 4.5.

Once indicators have been selected and agreed upon, they need to be standardized, well documented and their applications cleared and widely understood (Garcia et al. 2000b). As in the case of criteria, indicators also need to be updated and interpreted accordingly to accommodate dynamic elements and any uncertainty involved in the fisheries sector (FAO 1999a).

5. Specifying the method of aggregation and visualization:

Once the SDRS is developed, each part of the framework and the indicators should be tested using an appropriate method. Indicators and their interpretation need to be presented in an easily understood form as a simple value (Garcia et al. 2000b). In order to read the result, the indicators should be scaled according to the criterion's objectives to obtain a sustainability score to judge the status of the fishery according to its contribution to ecological and human well-being. The methods used in assessment of a system toward sustainability are discussed in Section 4.4.

Table 4. 1 Some SDRS frameworks and their dimensions. Adapted from (FAO 1999a; Garcia et al. 2000b)

No.	Framework[2]	Dimensions
1	FAO Code of Conduct for Responsible Fisheries	Fishing operations Integration into ICAM[3] Aquaculture development Fisheries management Post-harvest practices and trade Fisheries research
2	FAO definition of sustainable development	Resources Environment Institution Technology People
3	General sustainable development framework	Human subsystem Environment subsystem
4	Pressure-State-Response	Pressure Response State
5	Ecologically Sustainable Development (ESD) framework	Environment Social Economic Institution
6	Commission of Sustainable Development (CSD) indicator framework	Environment Social Economic Institution

For an effective communication, the scores of the indicators should be clearly represented in graphical form to potential users. A range of visualization approaches were adopted in the literature to effectively communicate the measure of sustainability. Some of the common approaches are mentioned below.

1. The two-dimensional Barometer of Sustainability presented in Figure 4. 1 was proposed by Prescott-Allen (1996). The barometer measures sustainability performance based on indicators. The indices of ecological well-being and human well-being are measured on the y and x -axes

[2] It is important to note that all the above mentioned frameworks focus on both human and ecosystem wellbeing.
[3] Integrated Coastal Area Management.

respectively and the indices are scaled in five class intervals ranging from sustainable to unsustainable.

2. The two-dimensional bar chart proposed by Chesson and Clayton (1998) as in is shown in Figure 4. 2 below. In this case, the *y*-axis measures scores scaled from 0 to 1 and the *x*-axis represents the key components of the ESD. It can be seen that the performance of various key components of the ESD may be compared over time. Figure 4. 2 provides an example of time trends in aggregated indicators for the human components of the ESD framework. This framework employ a hierarchal structure which allows aggregation to whatever level is necessary or desirable (Garcia et al. 2000b). The visualization approach followed by Chesson and Clayton (1998) is used in this study (Chapters 7, 8 and 9).

3. The multidimensional representation of the Kite Diagram as shown in Figure 4. 3 (Garcia and Staples 2000b) demonstrates the multivariate properties of a system. It can be used to compare performances of two fisheries. It should be noted that all parameter values used to measure the performance of a fishery are grouped in two dimensions namely, ecological well-being and human well-being.

4. Other visualization techniques such as the Egg of Wellbeing Diagram and Maps of Sustainability Diagram (Figure 4. 4) are also used. For the discussion on those techniques as well as others along with their strengths and weaknesses see Guijt et al. (2001), Garcia et al. (2000b) and Rice and Rochet (2005).

Table 4. 2 Example of criteria for the main dimensions of sustainability (FAO 1999a; Garcia et al. 2000b)

Dimensions	Criteria
Economic	Harvest Harvest value Fisheries contribution to GDP Fisheries exports value Investment in fishing fleets and processing facilities Taxes and subsidies Employment Income Fishery net revenues
Social	Employment/participation Demography Literacy/education Protein/consumption Income Fishing traditions/culture Indebtedness Gender distribution in decision-making
Ecological	Catch structure Relative abundance of target species Exploitation rate Direct effects of fishing gear on non-target species Indirect effects of fishing Direct effects of gear on habitats Biodiversity (species) Change in area and quality of important or critical habitats Fishing pressure: fished vs. unfished area
Governance & Institutional	Compliance regime Property rights Transparency and participation Capacity to manage

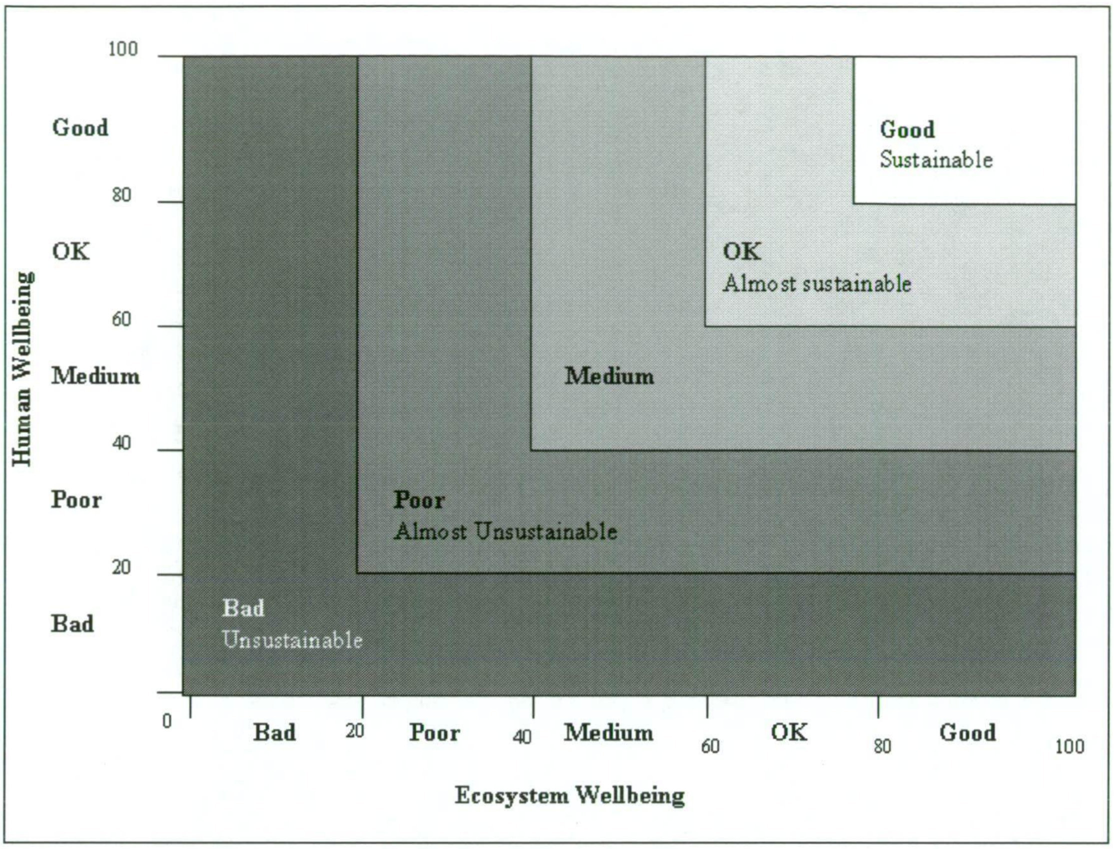


Figure 4. 1 The Barometer of Sustainability (Guijt et al. 2001)

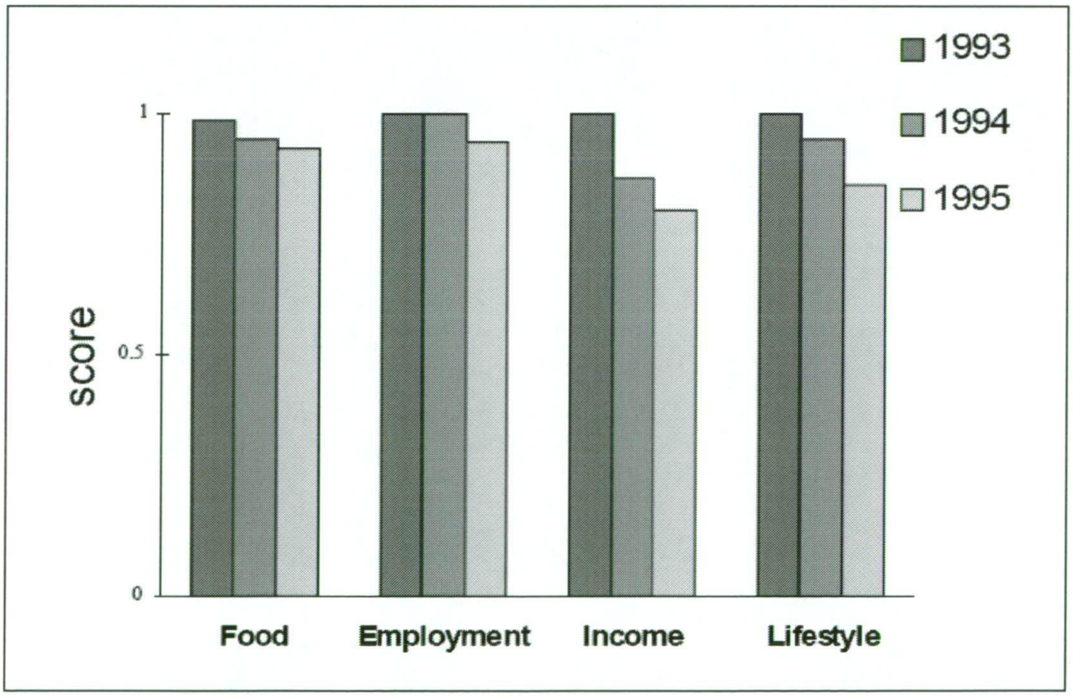


Figure 4. 2 Trend in aggregated indicators for the human component of the ESD framework (Chesson and Clayton 1998)

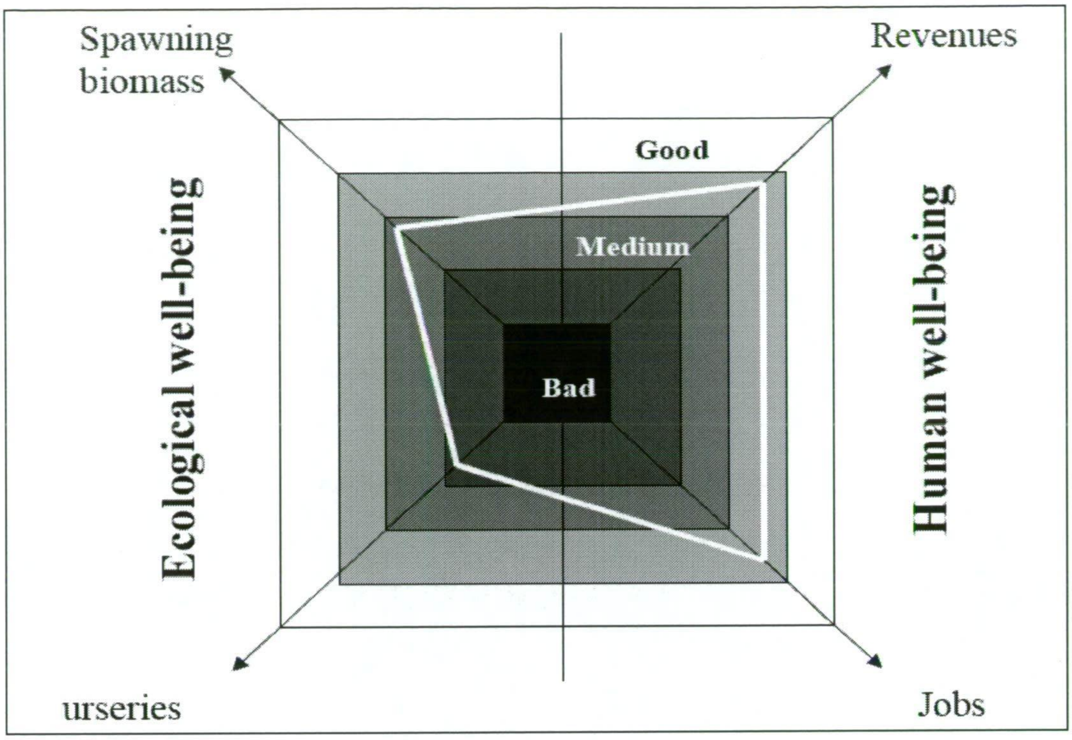


Figure 4. 3 An example of Kite Diagram (Garcia and Staples 2000b)

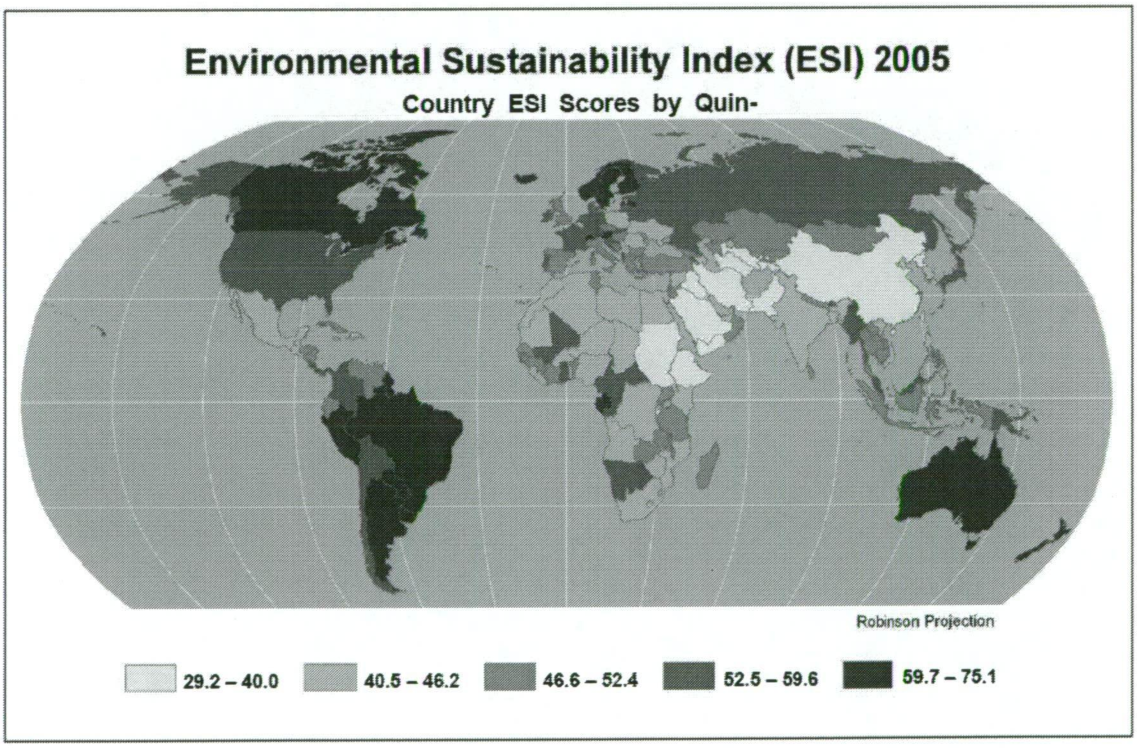


Figure 4. 4 Environmental Sustainability Index (Daniel et al. 2005) as an example of Map sustainability diagram

4.3 Conceptual Frameworks for Sustainable Development

Garcia and Staples (2000b) stated that a comprehensive framework for sustainable development needs to incorporate the various dimensions of sustainable development (as discussed in Chapter 3), associated elements and their relationships, as well as the key criteria associated with each dimension (see Table 4. 2) for which indicators will need to be established and monitored. Such framework should also be flexible enough to allow choice from a long list of diverse potential indicators (Rice and Rochet 2005).

In the following sections, five potential frameworks, relevant to fisheries sustainability will be investigated. They are: 1) the FAO Code of Conduct for Responsible Fisheries; 2) the FAO definition of sustainable development; 3) the general framework for sustainable development; 4) Pressure-State-Response (PSR) framework and its variants; and 5) the Ecologically Sustainable Development (ESD).

4.3.1 FAO definition of sustainable development

As reviewed by Garcia and Staples (2000b), the FAO definition of sustainable development identifies five main components: 1) the multiple resource in; 2) its environment to be conserved; 3) the social and economic human needs to be satisfied; 4) the technology to be controlled and 5) the institutions to be established through the general management process. As shown in Figure 4. 5, resources and environment address the environmental well-being (E) sector of sustainable development while the people, technology and institutions address the human well-being (H) sector (FAO 1999a). Although indicators can be easily identified to track more than one criterion, the FAO definition of sustainable development is considered to be very general and broad and is applicable to all development sectors (Garcia and Staples 2000b). For this reason, the framework gives no prescriptive details to identify specific targets, criteria and/or indicators (FAO 1999a).

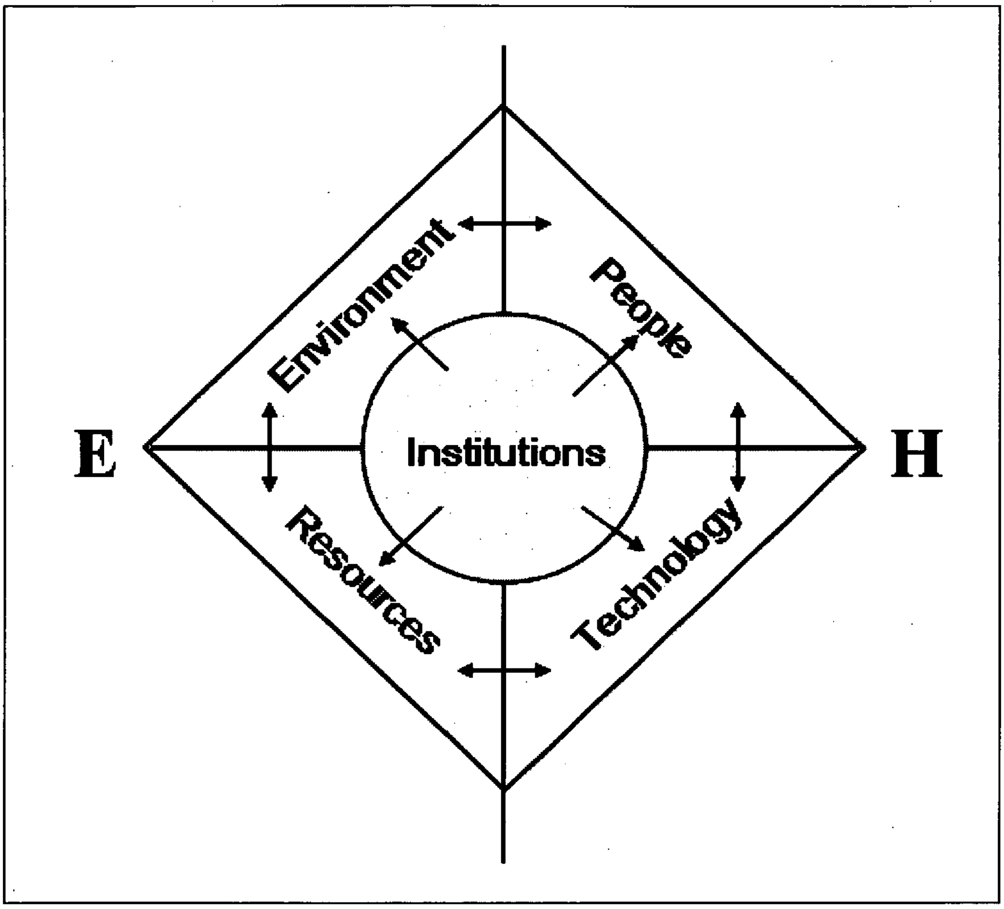


Figure 4. 5 FAO sustainability framework adapted from (Garcia and Staples 2000b)

Garcia (2000) analyzed the FAO definition framework's related principles, criteria and indicators with the FAO Code of Conduct for Responsible Fisheries framework. Three principles were distinguished from the FAO definition framework: 1) conservation of a resource in its environment; 2) satisfaction of human needs and 3) management. To improve operational usefulness, these principles were further classified into a number of sub-principles (Garcia 2000). This detailed classification will help and guide identification of criteria and indicators through the provisions and criteria of the FAO Code of Conduct framework.

4.3.2 FAO Code of Conduct for Responsible Fisheries

The FAO Committee on Fisheries (COFI) at its Nineteenth Session in March 1991 and the subsequent International Conference on Responsible Fishing, held in 1992 in Cancún (Mexico), called for development of new concepts which would lead to responsible and sustained fisheries (FAO 1995). This was also supported by the 1992 United Nations Conference on Environment and Development (UNCED); in particular its Agenda 21. In a non-mandatory manner, and consistent with international instruments, FAO then established principles and standards applicable to cover conservation, management and development of all fisheries known as FAO Code of Conduct for Responsible Fisheries (FAO 1995). Providing a necessary framework for national and international efforts to ensure sustainable exploitation of aquatic living resources in harmony with the environment, this was adopted on 31 October 1995 by all FAO members (FAO 1995),

Compared to the FAO definition of "sustainable development framework", FAO Code of Conduct for Responsible Fisheries framework as the name implies, focusses on the sustainability of the fisheries sector. Instead of showing the balance between environmental and human well-being, its structure has an operational focus on six areas: 1) fishing operations; 2) fisheries management; 3) integration of fisheries into coastal area management; 4) post-harvest practices and trade; 5) aquaculture development and 6) fisheries research (FAO 1999a) (Figure 4. 6). The wide application of this framework to different principles of fisheries and aquaculture makes it very broad although numerous provisions are identified for a number of specific targets, criteria and indicators (FAO 1999a) that were integrated by Garcia (2000) to work with the FAO definition of a sustainability framework.

The six general principles listed in Figure 4. 6 are assisted by a series of technical guidelines produced by FAO to support the implementation of the framework. Such implementation is anticipated from various groups of stockholders (fishermen, managers, processors, traders, fish farmers and scientists) (Garcia and Staples 2000b).

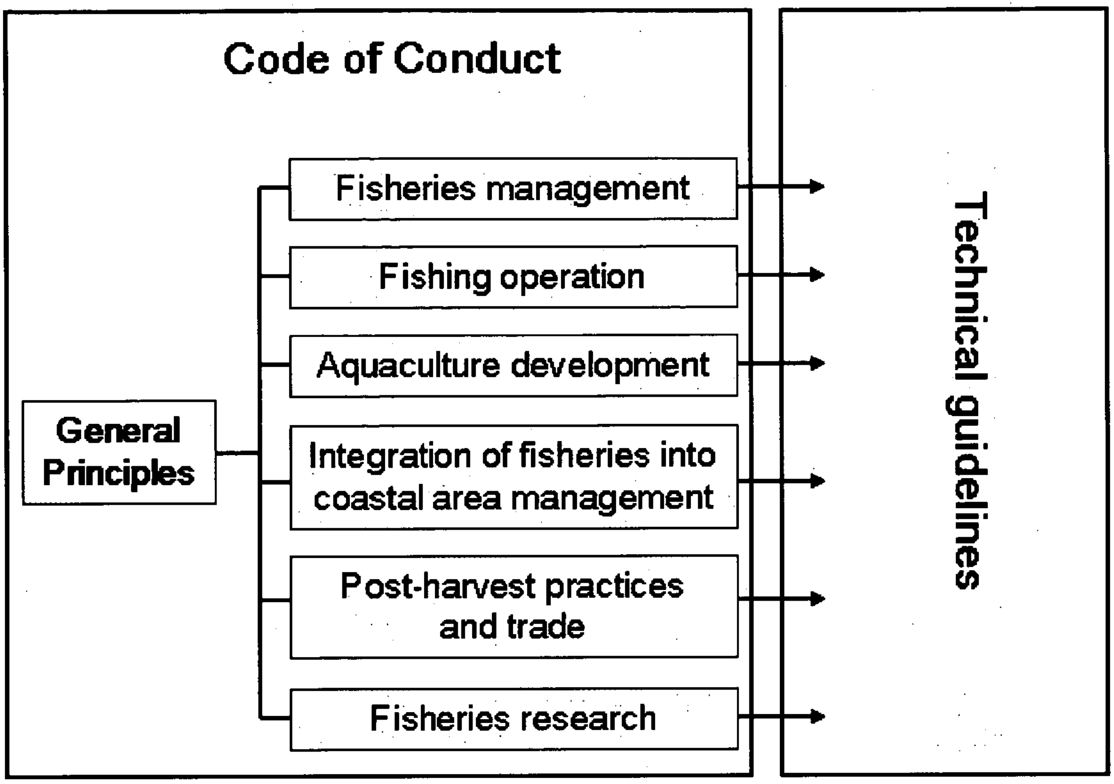


Figure 4. 6 FAO Code of Conduct framework adapted from Garcia and Staples (2000b)

4.3.3 General Framework for Sustainable Development

The general framework for sustainable development was first reported in 1995 (RIVM/UNEP 1995) and has been adapted by many nations for indicators development (Schomaker 1997). The structure of this framework, organized as a human sub-system, exerts complex pressure on the environment sub-system through pollution and depletion, for example, and receives feed-back signals from it (Garcia and Staples 2000b) followed by responses by way of mitigation and regulation (Figure 4. 7).

As stated by FAO (1999a) and Garcia and Staples (2000b), the general framework for sustainable development is less detailed than the FAO Code of Conduct because it has been designed for general application. The same references also stated that it has the advantage of explicitly identifying both environmental and human well-being domains and their relation to each other. It fails however to identify linear linkages between the two well-being domains and therefore can not properly reflect the real world (Schomaker 1997).

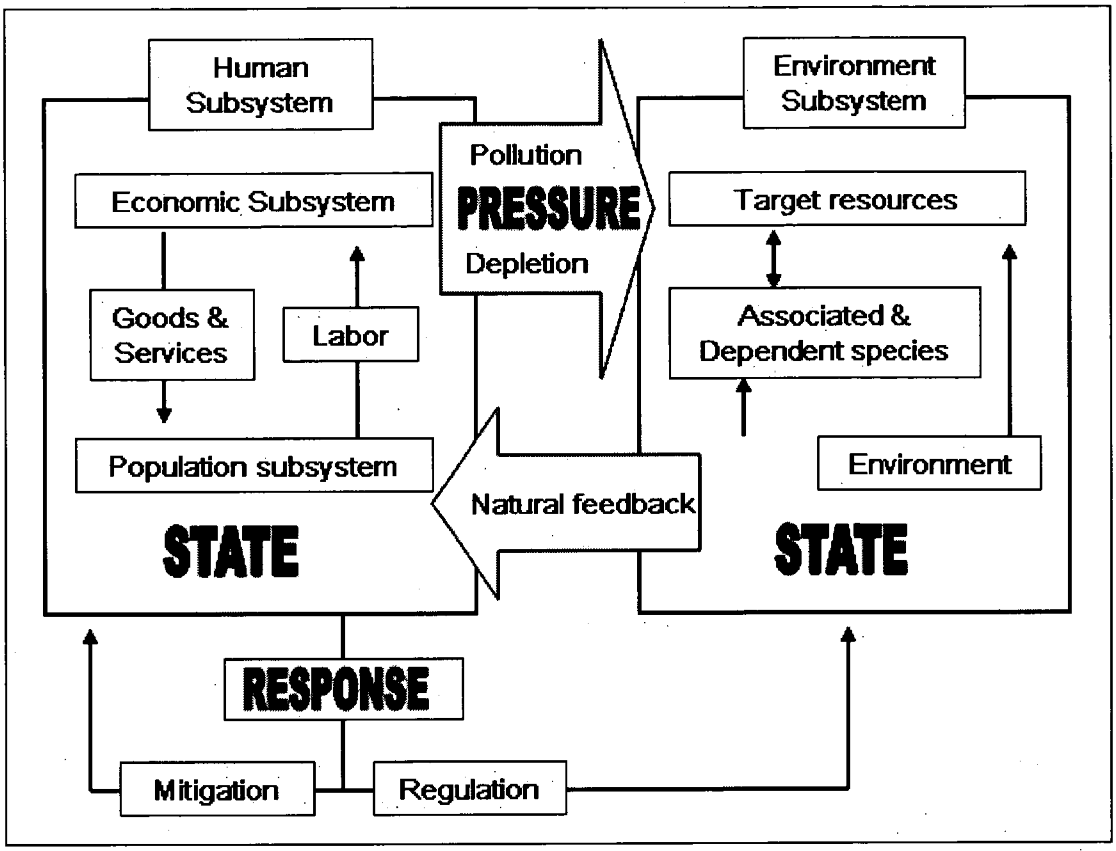


Figure 4. 7 General framework for sustainable development (Garcia and Staples 2000b)

4.3.4 Pressure-State-Response Framework

The pressure-state-response (PSR) framework was developed by the Organization for Economic Cooperation and Development (OECD) and other international bodies (FAO 1999a). The PSR framework (Figure 4. 8), as stated by OECD (1993b), is based on a concept of causality, where human activities exert pressures on the environment and change its quality and the quantity (state) of natural resources, which is then followed by society response. These responses form a management strategy, which includes problem perception, policy formulation, monitoring and policy evaluation (OECD 1993b).

As indicated by OECD (1993b), FAO (1999a) and Garcia and Staples (2000b), the PSR framework has three types of indicators: pressure, state and response. OECD (1993b) and (2000b) raised two points with regard to the response indicators and the complexity mentioned above. The first point distinguishes between indicators of environmental pressures and indicators of social responses. Sometimes this area becomes blurred when response indicators capture the feedback effect of society's responses on environmental pressures. "*A reduction in greenhouse gas* *emissions or improvements in energy efficiency could, for example, be interpreted both as a pressure and as a response indicator for climate change. Ideally, the response indicator should reflect society's efforts in tackling a particular environmental problem*" (OECD 1993b; P. 8). An increase in the demand for fish might also be seen as a sign of improvement in human wealth as well as a potential signal for a potential increase in the pressure to fish (Garcia and Staples 2000b). The second point has to do with the qualitative nature of most of the social responses such as the ratification of international agreements and the absence of measurable character. Therefore, it is very important to distinguish between these sets of indicators and the indicators required for the purpose of evaluation and reporting (OECD 1993b) (see Section 4.5).

The PSR framework, in its way, is very broad, vague and lacking operating details. Some variants were introduced in order to split and expand it. Driving forces (D) for example were distinguished from the pressure they generate and State (S) was split into Impact (I), Effort (E) and Stock (ST), which lead to a more complicated structure (Garcia and Staples 2000b). The Driving-Force-Pressure-State-Response (DPSR) and Driving-Force-Pressure-State-Impact-Response (DPSIR) frameworks are examples of such expansion in the PSR framework (Figure 4. 9). However, the PSR framework still has some limitation as a model of how the world works and as a guide to decision-making. Garcia and Staples (2000b) stated that the linear cause-effect relation in the PSR framework oversimplifies reality and ignores many of the linkages between issues and feed back within the socio-ecological system. This limitation in the linkage could be overcome by introducing some assistance tools such as modelling (Garcia and Staples 2000b).

Overall, the PSR framework has limitation in the human activity-environment interaction, which can not capture the more complex and dynamic nature of the processes (Bossel 1999; OECD 1993a; Willmann 2000). Another limitation, stated by Farsari and Prastacos (2002), is the inability to measure a very long list of indicators, as it proposes only three sets of indicators: pressure, state and responses.

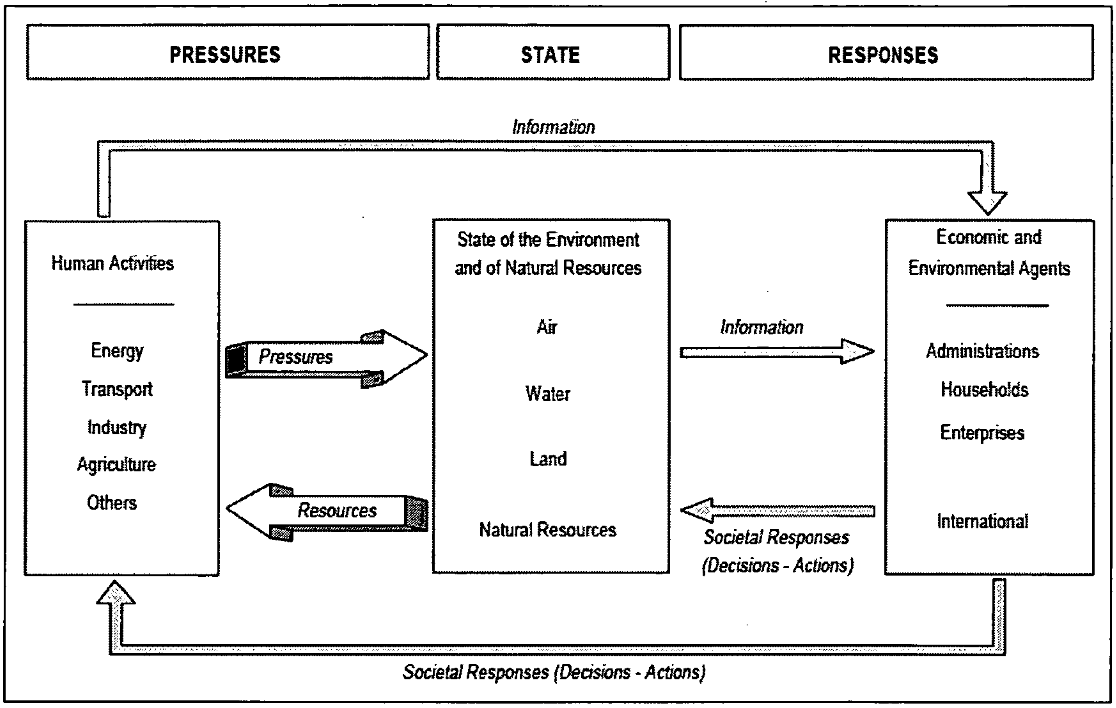


Figure 4. 8 Pressure-State-Responses framework (OECD 1993b)

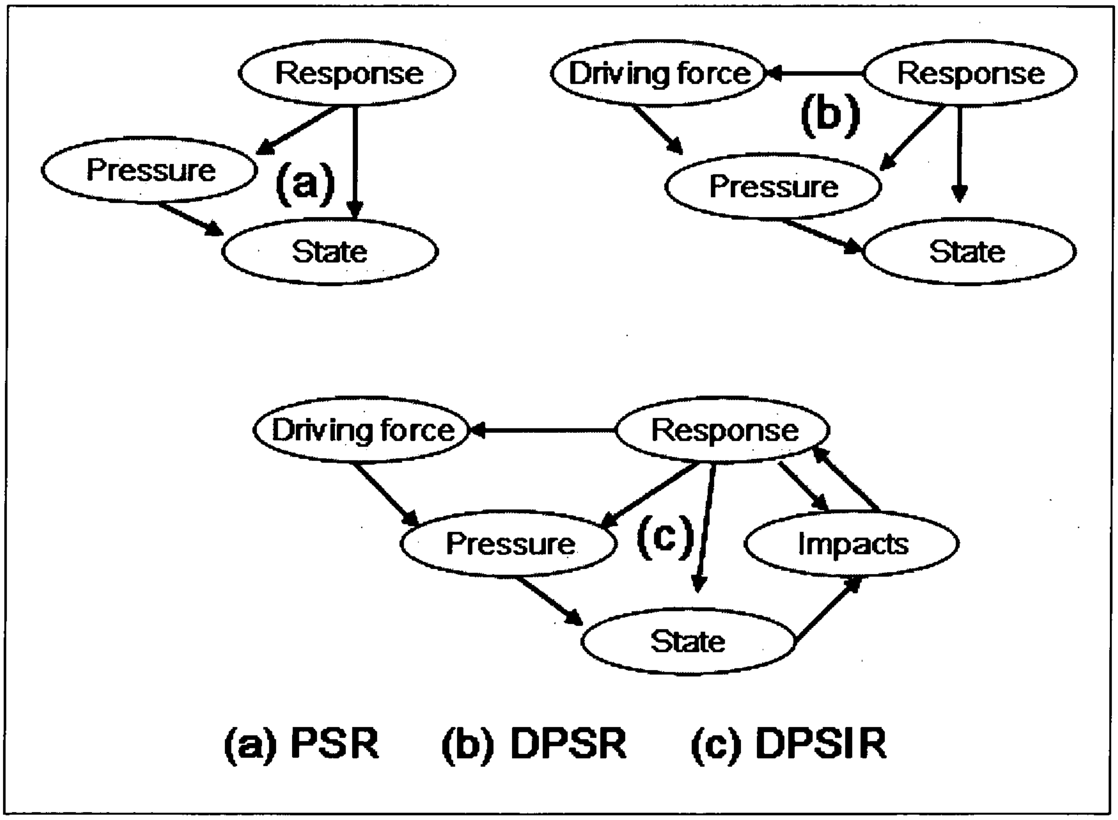


Figure 4. 9 PSR framework and its variants (Garcia and Staples 2000b)

4.3.5 Ecologically Sustainable Development Framework

As mentioned in Chapter 3, the concept of Ecologically Sustainable Development (ESD) officially entered the Australian environmental policy lexicon in the 1980s with the formation of the ESD working groups (Australia 1992). It was the first formal Government initiative aimed at institutionalizing sustainable development in decision making. It has been adapted by Australia, and was formally transferred to the Council of Australian Governments (COAG) endorsed National Strategy of Ecologically Sustainable Development (NSESD) in 1992 and now the principles are incorporated in recent environment legislation – the *Environment Protection and Biodiversity Conservation Act* (EPBC) 1999 (ENRC 2000; Curran 2003). The National Strategy on ESD (Australia 1992) was agreed by all Australian States (see Chapter 3 for details).

Following the NSESD and its definition of sustainable development, Chesson and Clayton (1998) have developed a generic framework to assist in determining how well the management requirements for sustainability are met and whether or not progress is being made over time. Compared to the above mentioned general frameworks, the ESD framework proposed by Chesson and Clayton (1998) is specific to the fisheries sector. It considers costs and benefits from the overall perspective of the community rather than from the limited perspective of a management agency or particular interest group (Chesson and Clayton 1998). It has the same top dichotomy as that of the general framework for sustainable development (human and environment) (Garcia and Staples 2000b) and that is why it is considered a variant for the general framework for sustainable development (FAO 1999a).

The ESD framework is a comprehensive structure with a set of procedures that include environmental, economic and social components used to evaluate the progress of SD over time. This evaluation is done by examining the effects of fishing on ecological processes; effects on environment[4], including effects on resources (FAO 1999a) and on total quality of life (effects on humans) (Figure 4. 10). The effects on both humans and the environment are further subdivided into several

[4] The term environment here is consistent with the ecological definition of environment, which defines environment according to Begon et al. (1996) as "everything outside the particular organism under consideration" (Chesson and Clayton 1998; P. 6).

components in a hierarchical fashion to the level desired (Chesson and Clayton 1998).

The effects of fishing on humanity could be directly related through socio-economic effects (food, employment, income and lifestyle), which are considered the main components of the effects on humanity (see Figure 4. 10). These components can be further sub-divided into other sub-components based on the existing circumstances of the fishery under consideration (Figure 4. 11).

On the other hand, effects on the environment are divided into three components: effects on the primary commercial species, effects on non-target species and effects on other aspects of the environment, which can also be further subdivided into specific sub-components (Figure 4. 12). Chesson and Clayton (1998) stated that some ambiguity is expected in the effects on the environment component. "*For example, it may be unclear whether a particular species of fish should be regarded as a 'primary commercial species' or a 'non-target species', but this should not really matter as long as it is included in one and only one category*" (Chesson and Clayton 1998; P. 8).

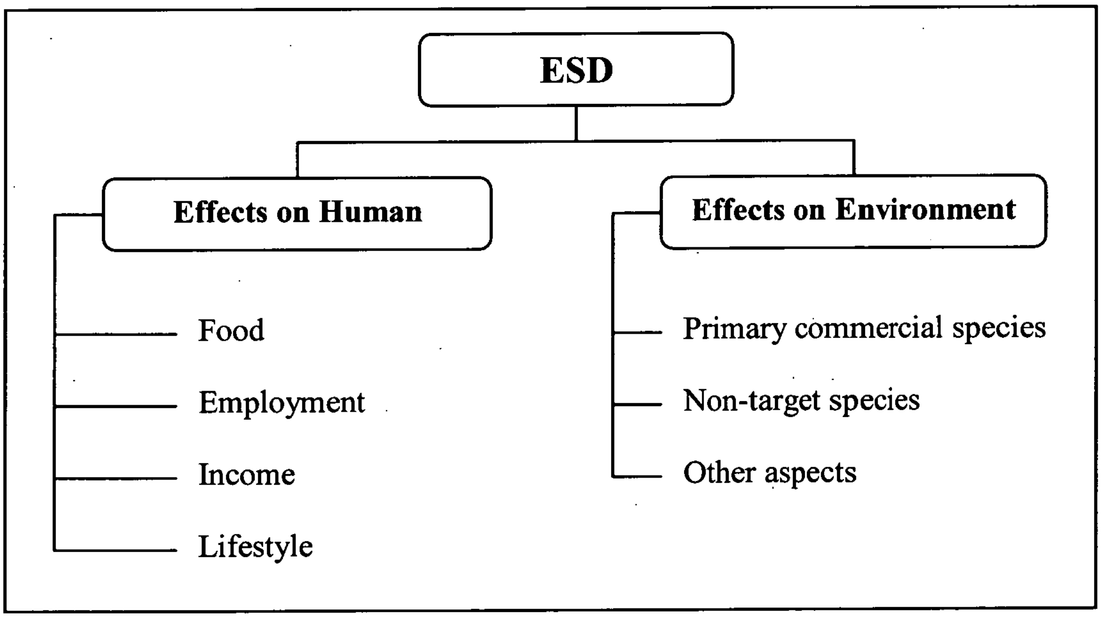


Figure 4. 10 Ecologically Sustainable Development (ESD) framework (Chesson and Clayton 1998)

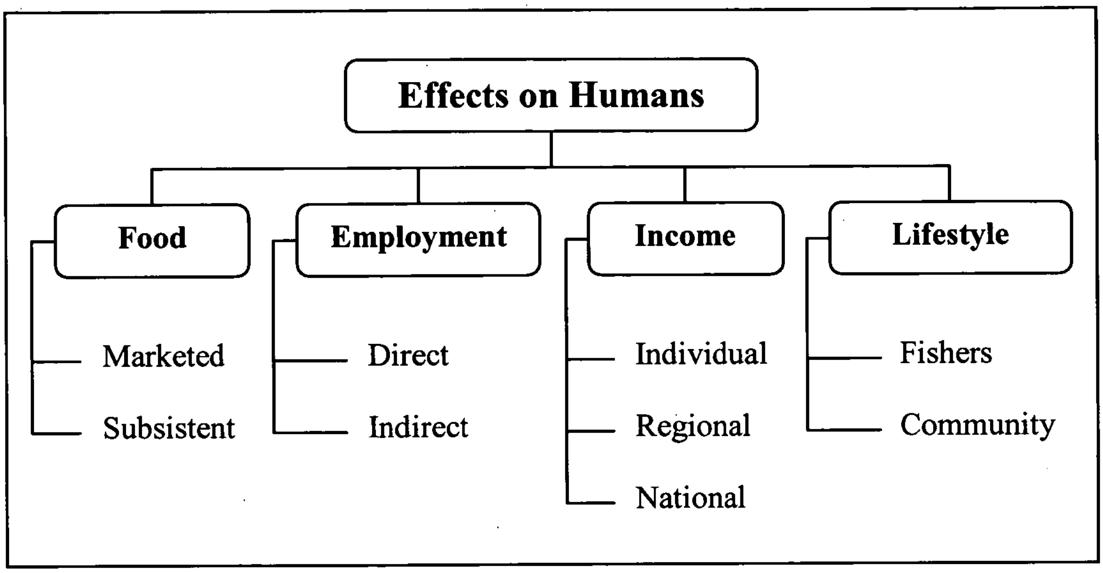


Figure 4. 11 Effects on human component of the ESD framework (Chesson and Clayton 1998)

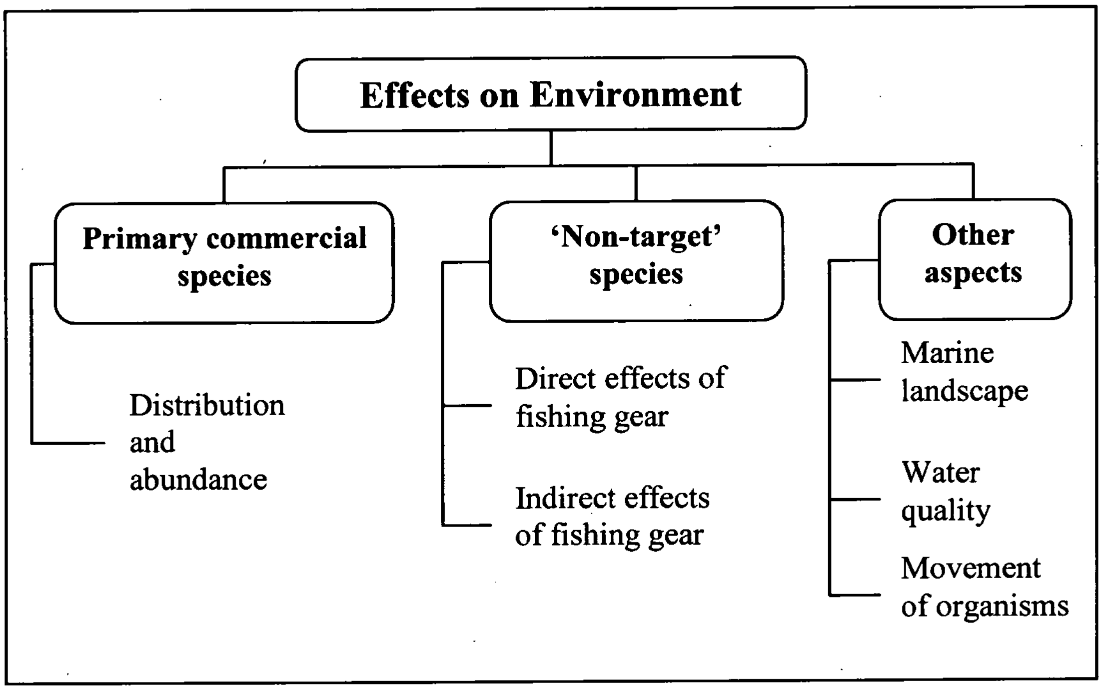


Figure 4. 12 Effects on environment component of the ESD framework (Chesson and Clayton 1998)

The ESD framework structure is designed to organize information about the fishery, avoiding omission and duplication (Chesson and Clayton 1998). The issues addressed within ESD are not fixed; they are likely to be an ongoing process of evolution, therefore in this respect, ESD should be seen as a means rather than an end (Fletcher 2002). Chesson and Clayton (1998) stated that the link of the framework to the NSESD does not restrict the application of the framework to other fisheries and it can be adapted to the specific circumstances of any fishery through further subdivision to whatever level is desired.

Chesson and Clayton (1998) have identified four basic steps to apply the structure in order to assess the progress toward sustainability. The four basic steps are:

1. Identifying the components of the hierarchical structure that are relevant to the fishery under consideration:

   As the ESD framework structure is intended to be comprehensive, major changes to the lower levels of the hierarchy are anticipated (Chesson and Clayton 1998).

2. Specifying objectives for each of the relevant components:

   Once all relevant components of the ESD framework are identified, it is important to specify an objective for each component. The specification of the objective is the main point, which will translate the concept of ESD. Therefore, the objectives need to capture the essential elements of sustainability. Objectives are a critical process, which will affect the identification of a practical set of indicators and thereby will affect the assessment process. If more than one objective is identified, then the component should best be handled by further subdivision into sub-components (Chesson and Clayton 1998).

3. Assessing progress with respect to the identified objectives:

   This step will require an analytical framework for organizing information on the economic and social consequences of alternative environmental policies. Chesson and Clayton (1998) have proposed a non-traditional application of Multi-Criteria Decision Analysis (MCDA) technique, which is well-suited to the task of assessing progress with respect to multiple objectives. The MCDA is further discussed in the next section.

4. Evaluating options for improving progress:

For further advancement toward sustainability, progress needs to be evaluated. Such evaluation will require a mechanism allowing response to the result and seeking ways to improve future performance. Failing this, there will be little value in progressing (Chesson and Clayton 1998).

As mentioned earlier, each step is intended to be part of a consultative process involving all stakeholders or at least a means of making each process transparent so that it can be scrutinized by all interested parties. Fletcher et al. (2002a) proposed six possible consultative methods that could be used to generate the modified 'trees' to suit a particular fishery, which are:

1. The manager/scientist himself;
2. A small group of agency staff;
3. A sub-committee of a Management Advisory Committee;
4. A focussed group containing representatives of all stakeholder groups;
5. An open, public meeting; or
6. A combination of some of the above.

The most efficient process was found to be a combination of two methods, where a manager/scientist came up with an initial draft version of the component tree, which was then finalized through a workshop that included representation from each of the main stakeholder groups (Fletcher et al. 2002a). The most important point to be considered here is to include all components relevant to the fishery even if it bears no relation to the management agency and is considered to be outside its responsibility.

4.4 Decision Analysis Techniques

It should be noted that rational decision making is a dynamic and sequential process. Thus, any rational analytical decision making model must take into consideration the interdependent nature of multiple objectives of fisheries management that are associated with the core dimensions of sustainability (Lane and Stephenson 1996), as discussed in Chapter 3. In the context of fisheries, fisheries managers have to make strategic decisions that involve a process of comparing objectives systematically and choosing between alternative courses of action. It should also be noted that the existence of a realistic and sound fisheries management plan ultimately gives direction to strategic and operational decision making in fisheries. However, as discussed in Chapter 2, Oman whilst outlining specific fisheries objectives to be achieved, is lacking a definitive management plan for its fisheries.

Theoretical and empirical research in different fields of science have provided a number of useful analytical frameworks for organizing information on the economic and social consequences of alternative environmental policies. Some well-known approaches in environmental decision making are: Cost-Benefit Analysis (CBA), Multi-Criteria Analysis (MCA) and Cost-Effectiveness Analysis (CEA). For more details on other approaches see NCER (1997) and Communities (2000). It is important to note that unlike MCA, CBA is restricted to numerical (monetary) magnitude (Beaumont and Hadley 2004). Use of mathematical techniques such as linear programming or dynamic programming in fisheries management decision making is not uncommon (Mardle and Pascoe 1999). However, given the lack of a fisheries management plan, data limitations and other particular local conditions as discussed in Chapters 1 and 2, the actual application of such mathematical techniques including CBA to analyze the case in hand becomes impracticable. Furthermore, these mathematical techniques are criticized in the literature as they do not provide a Pareto Efficient Solution (Mardle and Pascoe 1999).

Munda (2005) also stated that "to measure sustainability of a natural system with a set of multi-dimensional indicators, a multi-criterion analysis framework is required". Given the need to evaluate the best management option on the basis of a set of variables that are expressed in a mixture of units of measurement, MCA has gained popularities in recent years in the context of fisheries (Mardle and Pascoe 1999; Soma 2003; Leung et al. 1998).

4.4.1 Multi-Criteria Analysis

Multi-Criteria Analysis (MCA), an established decision support technique, is well-suited to the task of assessing progress with respect to multiple objectives (RAC 1992). Another interpretation of this, as stated by Dodgson et al. (2000) is that "it can be used to describe any structured approach to determine overall preferences among alternative options, where the options accomplish several objectives". Communities (2000) stated that MCA techniques can be used to identify a single option; to rank option; to short-list a limited number of options for subsequent detailed appraisal; or simply to distinguish acceptable from unacceptable possibilities. It's purpose is based on different theoretical foundations including optimization, goal aspiration or outranking (Linkov et al. 2004). With regard to this research, MCA technique is used to compare performance at different points in time. Therefore compared to typical MCA analysis, years will be ranked instead of criteria so that the output is a trend over time reflecting progress of sustainability over time.

As a tool for conflict management, MCA has demonstrated its usefulness in many environmental management problems. From an operational point of view, the major strength of multi criteria methods is their ability to address problems marked by various conflicting evaluations (Martinez-Alier et al. 1998). MCA is not a single rigid procedure, but a general approach which provides choices in term of types of data (qualitative, quantitative or a mixture of both) and methods for analyzing the data to arrive at a decision (Chesson and Clayton 1998). Janssen (1992) reviews some of the more common methods. A typical application of MCA involves a fixed number of alternatives and a set of criteria that are to be satisfied. Different alternatives satisfy each criterion to a different extent and the aim is to select the best alternative (Chesson et al. 1999).

Multi-Criteria Decision Analysis (MCDA) is a form of MCA that provides an overall ordering of options from the most preferred to the least preferred (Communities 2000). From the literature, it is noted that MCA, based on the nature of the decision space (continuous or discrete) and the number of decision alternatives (Leung 2006), is often classified into two categories namely: Multi-Objective Decision Making (MODM) and Multi-Attribute Decision Making (MADM). As mentioned above, MCDA has been proposed by Chesson and Clayton (1998) to be used with the ESD progress assessment following the MADM approach (Leung 2006).

A full application of MCDA involves eight steps following Analytical Hierarchy Process (AHP)[5] (Communities 2000). This hierarchal process was also followed by Chesson and Clayton (1998). These steps include identifying concept aims, overall objectives, indicators and criteria, method of aggregation and result presentation. It is worth noting that the above mentioned SDRS and ESD framework share these steps with MCDA. This suggests that SDRS, ESD framework and MCDA work together in a linear application method toward assessing sustainability indicating analogous and persistent relationship. The details and steps of MCDA application are shown in Figure 4. 3 below.

The decision to use MCA is based on the following reasons, which have particular relevance to the commercial trawl fishery in Oman:

1. The trade-offs among the various management objectives are explicitly analyzed (Leung 2006). It is important to note that the decision-makers' attitude toward risk is reflected by their approach to this trade-off.

2. This approach has the ability to combine quantitative as well as qualitative information to analyze complex fisheries management problems in assessing sustainability. In this context, it encourages stakeholders' participation as a source of qualitative information. Given the lack of fisheries management plans and data limitations in Oman, a stakeholders' participation in this regard would provide legitimacy to the decision making process.

3. The MCDA with reference to AHP allows decomposition of a decision problem into a hierarchical structure. This approach helps fisheries managers to specify interdependency and interaction amongst elements associated with the core dimension of sustainability as discussed in Chapter 3. This hierarchical process is also followed by others in evaluating fisheries management decisions toward sustainability (Chesson and Clayton 1998; Leung et al. 1998; Soma 2003).

[5] The Analytical Hierarchy Process (AHP) is a MCA method originally developed by Saaty (1980). It develops a linear additive model that derives weightings and assigns scores achieved by alternatives, which are based on pair-wise comparisons between criteria and options (Communities 2000).

4.5 Indicators of Sustainable Development

Although there are various definitions of the concept of indicators existing in literature, the commonality lies in its legitimate role in performance monitoring (INDECO 2004). As a result, development of appropriate indicators to measure performances of various dimensions of sustainability based on a reference point is important. The fourth statement of Chapter 40 (40.4) of Agenda 21 states: "*Indicators of sustainable development need to be developed to provide solid bases for decision-making at all levels and to contribute to the self-regulating sustainability of integrated environment and development systems*" (UNDSD 1992; P. 346).

Therefore, an indicator is a variable or an index, related to a criterion, whereas a reference point is a target or a limit point within an indicator. In other words, a reference point represents an indicator within a criterion in a system (Figure 4. 13). There could be more than one reference point for each indicator and more than one indicator for each criterion. For example; Maximum Sustainable Yield (MSY) is a reference point for the catch indicator of the fishing capacity criterion in the ecological dimension of sustainability.

Table 4. 3 Steps in Multi-Criteria Decision Analysis (MCDA) application (Communities 2000)

No.	Step	Detail
1	Establish the decision context	• Establish aims of the MCDA, and identify decision makers and other key players. • Design the socio-technical system for conducting the MCDA. • Consider the context of the appraisal.
2	Identify the options to be appraised	
3	Identify objectives and criteria	• Identify criteria for assessing the consequences of each option. • Organize the criteria by clustering them under high-level and lower-level objectives in a hierarchy.
4	Scoring: • Assess the expected performance of each option against the criteria. Then assess the value associated with the consequences of each option for each criterion	• Describe the consequences of the options. • Score the options on the criteria. • Check the consistency of the scores on each criterion.
5	Weighting	• Assign a weighting for each of the criterion to reflect their relative importance to the decision.
6	Combine the weights and scores for each option to derive an overall value	• Calculate overall weighted scores at each level in the hierarchy. • Calculate overall weighted scores.
7	Examine the results	
8	Sensitivity analysis	• Conduct a sensitivity analysis: do other preferences or weightings affect the overall ordering of the options? • Look at the advantage and disadvantages of selected options, and compare pairs of options. • Create possible new options that might be better than those originally considered. • Repeat the above steps until a requisite model is obtained.

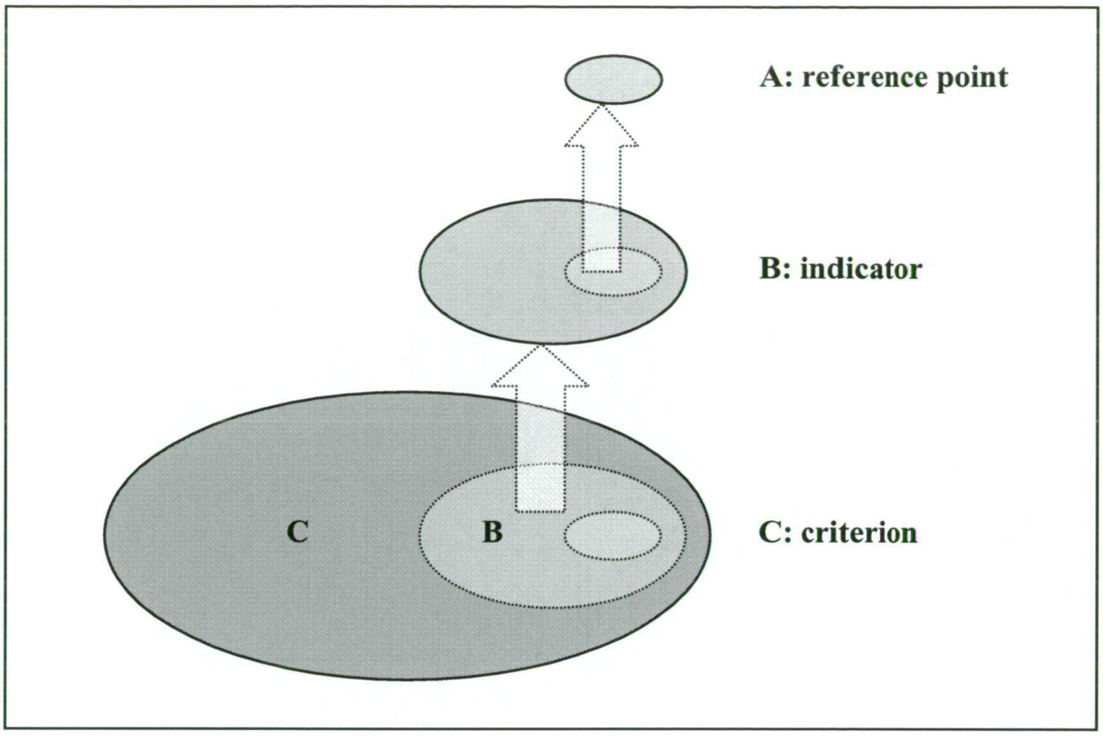


Figure 4. 13 Scheme and order of reference points and indicators of a criterion within any sustainability dimension

As stated by Dahl (1995; P. 8), "*one way to express the concept of sustainability without failing into value judgments about development will be to produce "vector" indicators* which *basically show the direction of movement towards or away from a goal and the speed of that movement*". This indicates that the success on sustainable development will heavily depend on the indicators. This is true as indicators depend on an effective sustainable development which in itself requires a significant amount of information and research capacity (Garcia and Staples 2000a). This also leads to the point of considering sustainability indicators instead of the old traditional indicators such as Gross Domestic Product (GDP). GDP for example has been used as the single indicator on status of national growth. However, it has been seen in recent years to be simple and does not account for other dimensions (social and environmental) of growth in a national economy (Bossel 1999). This also highlights the importance of exercising caution while aggregating information and developing indicators to capture the complexity of a system.

Considering the international commitment of the nations presented in chapter 40 of Agenda 21, the Commission on Sustainable Development (CSD) approved in 1995 a five-year (1995-2000) Work Programme on Indicators of Sustainable Development (ISD). The main objective of the CSD Work Programme was to make indicators of sustainable development accessible to decision-makers at the national level, by defining them, elucidating their methodologies and providing training and other capacity building activities (UNDESA 2001). At the end of this programme, and after extensive testing and improvement, a list of indicators developed by CSD, was issued (UN 2007a). As stated by UN (2007a), the third revised CSD indicator set was finalized in 2006 by a group of indicator experts from developing and developed countries and international organizations. It consists of a set of 50 core indicators, which are part of a larger set of 96 indicators of sustainable development.

In the context of the fisheries and marine resources, the Work Programme on ISD has identified three indicators following Chapter 17 of Agenda 21 on oceans, seas and coasts. Two of them deal with coastal zone: algae concentration in coastal area and percent of total population living in coastal areas. The third is annual catch by major species for fisheries.

4.5.1 Conceptualizing Sustainable Development Indicators

As mentioned above, based on international commitments[6] and on national policy, views and plans[7], countries normally initiate a set of practical objectives within their legislation arrangements. Therefore, as mentioned in Section 4.2 and to maintain, achieve, evaluate and develop such objectives, a set of reliable tools or system of measurement is required. As stated by Hart (1998; P. 36), an indicator is "*a way to measure, indicate, point out or point to - with more or less exactness - something that is a sign, symptom or index of something used to show visually the condition of a system*".

Performance indicators reflect a simple concept that provides information about a single phenomenon or a complex system such that usable information could be used in decision-making (Bossel 1999; Dahl 1995; Potts 2003). Various institutions and authors have proposed different definitions for the concept of indicators (INDECO 2004). The Organization for Economic Co-operation and Development (OECD) has defined indicator as "*a parameter, or a value derived from parameters, which points to, provides information about, describes the state of*

[6] International commitments and agreements are discussed in Chapter 3.
[7] Oman's Commitments to the International agreements in addition to its policy, views, plans and legislation dealing with marine recourses are discussed in Chapter 2.

a phenomenon, environment or area" (Linster 2003; P. 169). Fletcher et al. (2002a; P. 120) define an indicator as "*a quantity that can be measured and used to track changes with respect to an operational objective. The measurement is not necessarily restricted to numerical values*". More specific to fisheries, it can be defined as "*a variable that measures the state of the fishery and can assume discrete values believed to represent critical situation*" (Seijo and Caddy 2000; P. 477).

As indicated by the International Institute for Sustainable Development (IISD), indicators are aggregates of raw and processed data, but they can be further aggregated to form complex indices (IISD 2007). Usually, any set of indicators are developed based on a set of criteria (Charles 2001) to provide a bridge between objectives and actions (FAO 1999a). They are normally developed from raw data (Potts 2003), where the data is processed and condensed into smaller amount of meaningful information in a systematic flow as in the metaphor of an information pyramid or iceberg (Jesinghaus 1999) (Figure 4. 14).

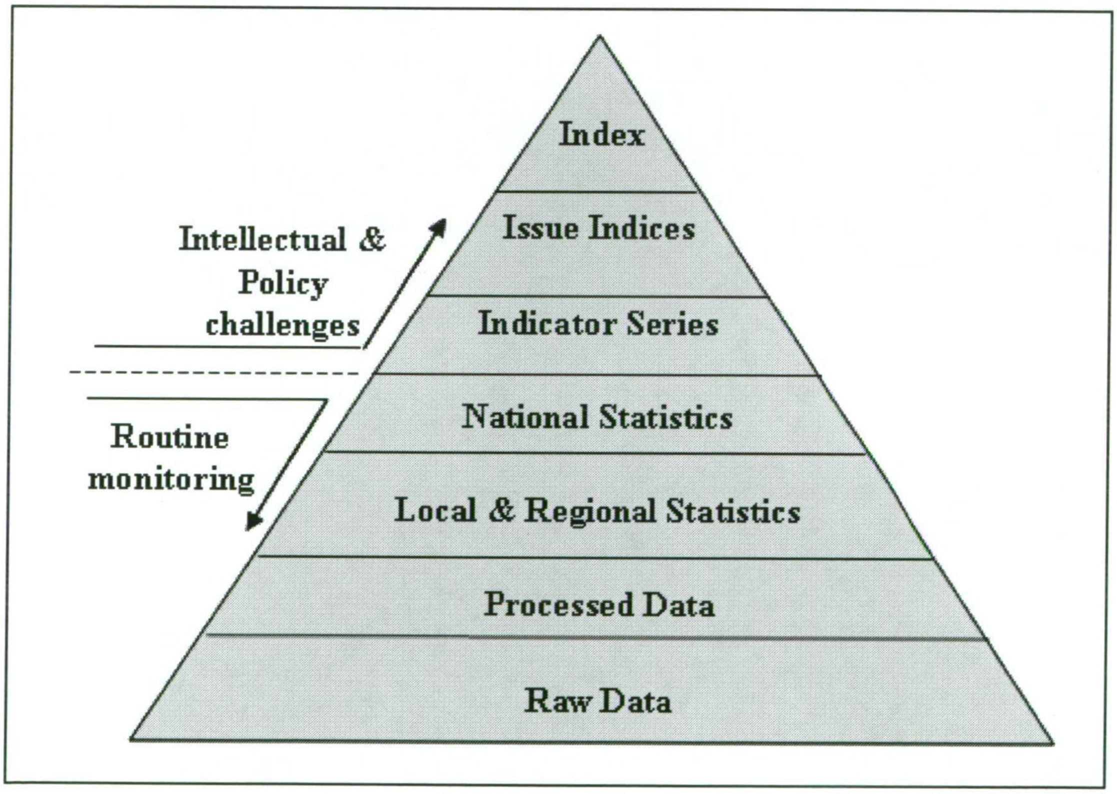


Figure 4. 14 The information pyramid (Potts 2003)

4.5.2 Role, Types and Specifications of Indicators

Whatever sustainable development framework (discussed in Section 4.3) is selected, a set of indicators will need to be identified and developed (Garcia and Staples 2000b). As a middle ground between science and policy, indicators must be simultaneously pragmatic and scientifically valid (Jesinghaus 1999; Potts 2006). Potts (2003) has reviewed the literature and listed four overall functions implemented by indicators:

1. Linking goals and objectives to management actions;
2. Reporting and performance assessment;
3. Building consensus, participation and understanding amongst stakeholders; and
4. Forming linkages and integrating scientific and policy disciplines.

Although indicators have specific objective/s to achieve, they might have different names due to the method used for classification. This classification, as stated by INDECO (2004), could be according to the level of management system, to which the indicators refers or just due to the fact that different groups working on indicators have approached the subject in slightly different ways. Therefore, indicators could have very broad identities if directly listed under the sustainability dimensions (Garcia and Staples 2000b) or system components (Charles 2001; Garcia and Staples 2000b). They could also bear the name of their state as in the case of the PSR framework. More specifically, they could also bear the name of their characteristics such as evaluation and reporting (Garcia and Staples 2000b). The Scientific Committee on Problems of the Environment (SCOPE) of the International Council of Scientific Unions (ICSU) has identified three classifications of indicators based on four categories of environmental indicators: resource, pollution, ecosystem and impact on human welfare (Garcia and Staples 2000b). Table 4. 4 lists each type of indicator according to its method of classification.

Sustainability indicators have been consistantly developed since the 1980s (Potts 2003) and there are several important and influential international initiatives helping sustainability indicators. WCED, Agenda 21, UNDP, OECD, UNEP, World Bank, SCOPE, IISD and most importantly the United Nation CSD are all examples of international initiatives toward sustainability indicators that in the long term assist the sustainable development of fisheries along with those indicators developed by FAO such as the frameworks discussed in Section 4.3.

Table 4. 4 Types of indicators according to method of classification

Method of classification	Type of indicator
Sustainability dimensions & system components	Ecological indicators: Resource indicators Environmental indicators Socioeconomic indicators: Social indicators Economic indicators Institutional indicators Technological indicators
Environment of indicator	State indicators Pressure indicators Response indicators Driving force indicators Impact indicators
SCOPE classification	Source indicators (what is taken) Sink indicators (what is dumped) Life-support indicators (what protects life?)
Characteristics of indicators[8]	Indicators of level Indicators of change Operational indicators Measured indicators Derived indicators Quantitative indicators Qualitative indicators Predictive indicators Retrospective indicators Indicators of risk and vulnerability

As stated by Garcia and Staples (2000b), for indicators and reference points to be acceptable and effective, they should meet a number of technical specifications. According to the Institute for European Environmental Policy (IEEP), indicators can be developed based on their norms and/or processes through a conceptual framework (such those mentioned in Section 4.3). Literature gives examples of different criteria and standards required to be considered in developing a set of potential indicators.

[8] For more explanation see Garcia and Staples (2000b) and INDECO (2004).

Three international checklists worth mentioning belong to: CSD Work Programme (Box 1), ICES (Box 2) and FAO (Box 3).

Bakkes et al. (1994) points out that indicators of biological diversity are poorly developed and that they are strongly based on species and away from the ecosystem as a whole (Saunders et al. 1998). Charles (2001) stated that in fishery systems, there have been relatively few attempts to develop sets of indicators that are quantitative and reflect an integrated, interdisciplinary, multidimensional view of sustainability, including assessment of both natural and human sub-system. Similarly, Dahl (2000) found that with only five indicators in the CSD context, ocean indicators are poorly represented. This clearly indicates a gap to be filled in future versions. Alternatively, there is a substantial amount of literature covering the integrated treatment of sustainability concepts, policy issue and the social and economic valuation of aquatic resources and ecosystems (Charles 2001). Thus, more effort was employed in developing different frameworks and guidelines which plan and help in identifying the indicators, than in identifying sets of indicators. This could be advantageous in the early stages of sustainable development, in which laying the foundations for good indicators is of high priority, as applying the wrong indicators could devastate the system by giving wrong signals.

Currently, following Agenda 21 (UNDSD 1992) and works from CSD and OECD, there are many indicators used on a national scale which enable a country to report on its progress toward sustainable fisheries development (Chesson 2006). Attempts however, to develop indicator sets often fail to gain broad support because they invest too much effort in specifying the indicators and not enough in understanding the objectives (Chesson 2006). This reinforces the importance of the SDRS (Section 4.2) and the related frameworks as foundations and as a tool for best harmonizing between indicators of the system components (economic, environment and social) and the operational objectives necessary to achieve sustainable development. Rice and Rochet (2005) classified methods found in literature under three categories that help in selecting final indicators: standardization, weighting and combining. On the other hand, numerous lists of candidate indicators exist already (FAO 2003a; Garcia 2003; Lack 2004; Ward et al. 1998; Ward et al. 2002).

Literature review and discussion on specific candidate indicators related to this study are included in Chapter 6 following the identified components of the ESD framework adapted by the trawling fishery in the Sultanate of Oman as presented in Chapter 5.

Box 1: Criteria of indicators according to CSD Work Programme (UNDESA 2001)

- Primarily national in scope;
- Relevant to assessing sustainable development progress;
- Understandable, clear, and unambiguous, to the extent possible;
- Within the capabilities of national governments to develop;
- Conceptually sound;
- Limited in number, but remaining open-ended and adaptable to future needs;
- Broad in coverage of Agenda 21 and all aspects of sustainable development;
- Representative of an international consensus to the extent possible; and
- Dependent on cost effective data of known quality.

Box 2: Criteria of indicators according to ICES (INDECO 2004)

- Relatively easy to understand by non-scientists and those who will decide on their use;
- Sensitive to a manageable human activity;
- Relatively tightly linked to that activity;
- Easily and accurately measured with a low error rate;
- Responsive primarily to a human activity (e.g. fisheries), with low responsiveness to other causes of change;
- Measurable over a large proportion of the area to which the indicator is to apply (e.g. EU policy area); and
- Based on an existing body or time series of data to allow a realistic setting of objectives

Box 3: Criteria of indicators according to FAO (FAO 1999a)

- Policy priorities;
- Practicality/feasibility;
- Data availability;
- Cost-effectiveness;
- Understandability;
- Accuracy and precision;
- Robustness to uncertainty;
- Scientific validity;
- Acceptability to users/stakeholders (consensus among parties);
- Ability to communicate information;
- Timeliness;
- Formal (legal) foundation; and
- Adequate documentation.

4.6 Conclusion

This chapter provides a brief review on the SDRS and a discussion on the use of MCA in fisheries decision making process. From the discussion of various sustainable development frameworks and considering their suitability and the degree of relevance to the commercial trawl fishery's conditions in Oman, the ESD framework is found to be better suited to address the research objectives stated in chapter 1. The chapter also highlights the process of developing indicators according to the chosen ESD framework.

Based on those review and discussion, the next chapter will be devoted to identify relevant ESD components and their corresponding objectives with particular reference to the commercial trawl sector in Oman.

CHAPTER 5: ESD FRAMEWORK FOR THE COMMERCIAL TRAWLING SECTOR IN THE SULTANATE OF OMAN

5.1 Introduction

In Chapter 4, based on a broad review, it was decided to follow the ESD framework developed by Chesson and Clayton (1998) to analyze the present case study. However, for the case in hand, selecting a suitable framework alone is not sufficient for the purpose of producing a credible assessment of ESD. Therefore, as the next step, an attempt should be made to modify the framework (if necessary) to ensure its practical relevance to Omani fisheries conditions and issues. Chesson and Clayton (1998) stated that the framework structure can be adapted to the specific circumstances of any fishery through further subdivision to any desired level. It should be noted that rigidity in framework may result in inadequate assessment of ESD in fisheries (Staples 1996).

Therefore, the two main objectives of this chapter are: 1) to modify the selected ESD framework to provide a perspective on the issues relevant to the commercial trawling sector in the Sultanate of Oman; and 2) to specify objectives for each of the relevant components and sub-components of the modified ESD framework. To facilitate the process of modifying the framework and specifying the objectives, discussions and consultation review with key stakeholder and field workers were conducted. These are later described in this chapter.

5.2 Methodology in Modifying the ESD Framework

With respect to fisheries, the concept of ESD means that the effect the fishery has on the target species and also the direct and indirect effects that the fishery may have on the broader ecosystem, must be managed. Furthermore, the ESD concept recognizes a number of different positive and negative scales and their social and economic effects. In a wider approach, the integration of economic, social and environmental implications within the decision-making processes is the cornerstone and major innovation of ESD (Fletcher 2002).

As mentioned in Chapter 4, in the context of the natural resources sector in Australia, Chesson and Clayton (1998) have developed a framework, as depicted in Figure 5.1, which determines how well the management requirements for sustainability are met, and how performance progresses over time. The framework presented in Figure 5. 1 is a comprehensive structure, which includes environmental, economic and social components used to evaluate the progress of SD over time. This evaluation is done by examining the effects of fishing in terms of impacts on ecological processes (effect on the environment including effect on resources) and on total quality of life (effect on humans). Fletcher (2002) stated that the issues addressed within ESD are dynamic in nature as they are subject to an ongoing process of evolution. Thus, in this context, ESD should be seen as a means not an end.

The rationale for the selection of a research method depends on the research questions (Frankfort-Nachmias and Nachmias 1997). Once a research question has been decided, a plan or schedule (research design) must be developed to answer it (Christensen and Stoup 1986). Although there are many similarities between qualitative and quantitative research methods, some procedures are very different because of the different nature and assumptions of the data and of the question to be answered (Malterud 2001; Myers 1997). Quantitative studies are frequently based upon consistent instruments that are administered to randomly selected sample populations and issues of reliability and validity can be assessed in a relatively forthright manner. In contrast, qualitative studies are not usually based upon consistent instruments and thus utilize smaller, random samples, which makes the assessment of the accuracy of its finding less straightforward. Different techniques and approaches were utilized and used to evaluate qualitative findings and to enhance trustworthiness (Guba and Lincoln 1981) such as triangulation and following literately reviewed systematic ways and guidelines for discussing the findings (Altheide and Johnson 1994; Malterud 2001).

As the aim of this study is to assess the effect of the commercial trawl sector in the Sultanate of Oman, the Australian ESD framework was found to be the best tool to be used to achieve this goal (see Chapter 4). The ESD framework evaluates the sector by measuring its impacts on the society and environment. Chesson and Clayton (1999) stated that each step of the evaluation process is intended to be part of a consultative process involving all stakeholders or, where consultation is not practicable, at least a means of making the process transparent so that it can be scrutinized by all interested parties.

Following the investigation and review of the fishery system in Oman and the status of the fisheries and environmental resources presented in Chapter 2, the Australian ESD framework (Chesson and Clayton 1998) was first drafted by the researcher to reflect the circumstances of the Omani commercial trawl fishery. This fishery specific information along with the discussion on sustainable development presented in Chapters 3 and 4 has facilitated the identification of components for the adapted framework. In addition, an onboard field observation was conducted and interviews were held with some observers (surveillance officers) to gather relevant information for this study. A consultation review with key stakeholders was then carried out to finalize the modified ESD framework.

Therefore, this Chapter is devoted to the adoption of the Australian ESD framework and its modification to fit within, and its ability to be used to evaluate, the commercial trawl sector in Oman. This has been achieved through a consultation process with academics, researchers, decision-makers and industrial stakeholders concerned with the fisheries in the Sultanate of Oman aided by a field observation and the comprehensive literature review presented in Chapters 3 and 4.

The method followed in this chapter is a qualitative research method (Mason 1998). It includes field observation and consultation review as described in detail below.

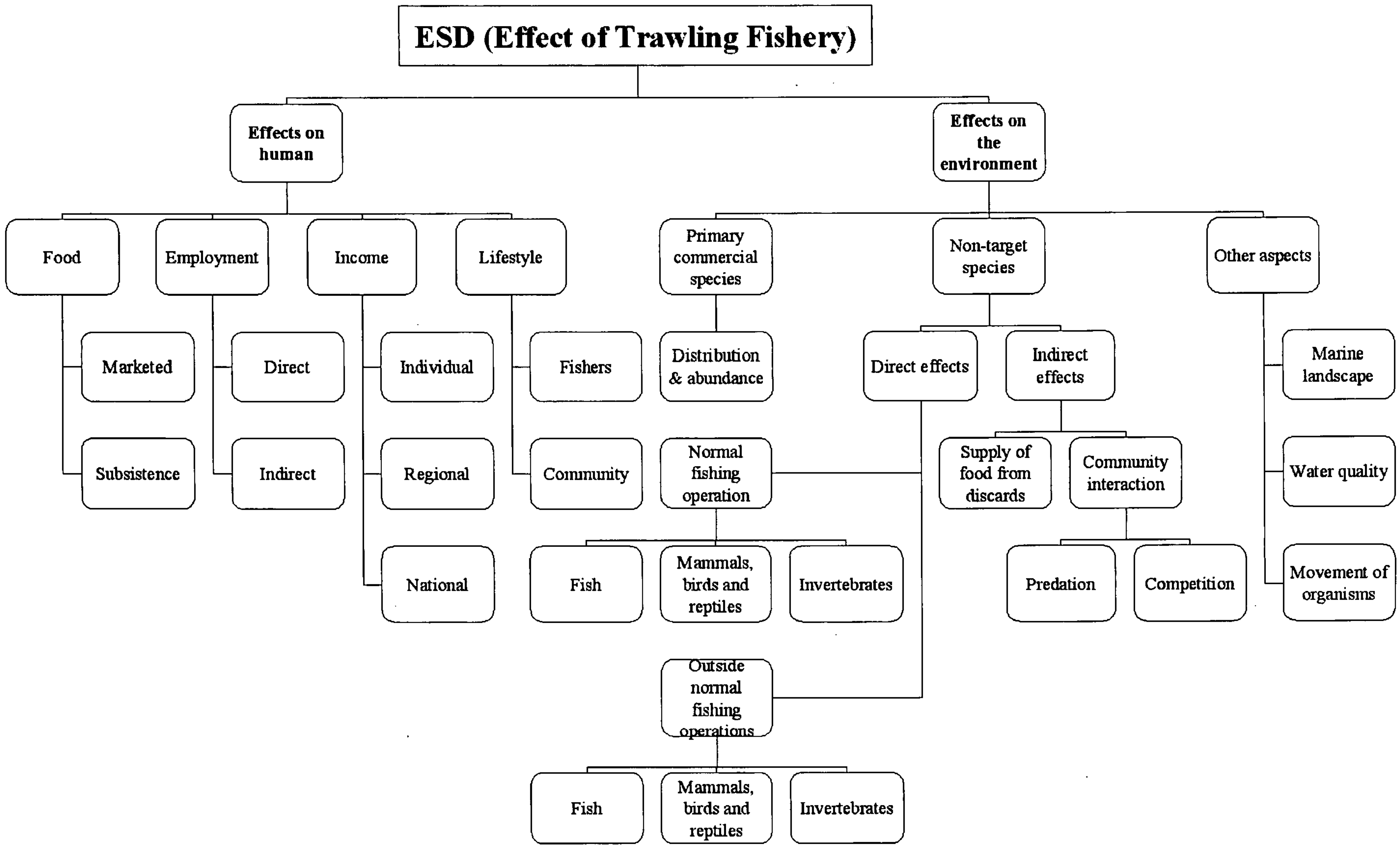


Figure 5. 1 Framework for ESD assessment (Chesson and Clayton 1998)

5.2.1 Field Observation

This part of the study is considered to be an *ethnography* (Brewer 2000) as it mostly aims to study the behavior and attitude of a social group (Daymon and Holloway 2002) in a mixture of observational and interview techniques as well as document analysis. Atkinson (1992) states that the word *ethnography*, derived from Greek, means a description of a people or, literally, 'the writing of culture' (Daymon and Holloway 2002). Ethnography as defined by Jackson (2006; P. 77) is "*the study of people in naturally occurring setting or 'field' by means of methods which capture their social meanings and ordering activities, involving the researcher participating directly in the setting, if not also the activities, in order to collect data in a systematic manner but without meaning being imposed on them externally*".

As claimed by Daymon and Holloway (2002), arguably, observation is the fundamental basis of all research methods. No matter which method you use, in any situation, you will always be looking about you in order to gather more evidence to help you understand the research context. "*The term 'observation' and in particular 'participant observation' is usually used to refer to methods of generating data which involve the researcher immersing herself or himself in a research setting and systematically observing dimensions of that setting, interactions, relations, actions, events and so on*" (Mason 2002; P. 84). It has been used in a variety of disciplines as a tool for collecting data about people, processes and cultures in qualitative research (Kawulich 2005). Participant observation involves social interaction between the researcher and informants in the milieu of the latter. The idea behind this being to allow the observer to study first-hand the day-to-day experiences and behaviors of subjects in particular situations and if necessary to talk to them about their feelings and interpretations (Waddington 2004). This is of great importance as social values play an important role in the sustainable development concept.

Burgess (1984) cited in (Waddington 2004) identified four possible research identities or master roles as also proposed by Gold (1958):

1. The complete participant, who operates covertly, concealing any intention to observe the setting;
2. The participant-as-observer, who forms relations and participates in activities but makes no secret of an intention to observe events;

3. The observer-as-participant, who maintains only superficial contacts with the people being studied; and

4. The complete observer, who merely stands back and eavesdrops on the proceeding.

In this study, the researcher acts as an (observer-as-participant), where some interactions are carried out in order to explain and clarify some actions and events as explained below.

The field observation was carried out in the third week of September 2005 onboard a fishing vessel. The aim was to observe at least three trawlers, but due to weather conditions, it was not possible nor allowed under Occupational Health and Safety (OH&S) obligations, to move from one vessel to another at sea. However, this limitation was addressed by interviewing observers onboard the other working trawlers through VHF radio facility. During that week, 12 trawlers were fishing and 6 of them had observers on board. The observers onboard those trawlers communicated with each other through the VHF radio facility in the morning and afternoon to discuss all issues faced by them. In addition to daily activities, they further reported any problems to the officer in the MAF control room. In the afternoon, all observers spoke with each other at the same time and it was decided to use this period to hold a series of interviews with other observers to overcome the limitation of the field observation.

This participant observation was mainly aimed at gathering and clarifying new information about the Omani commercial trawling sector which might be of support to the study and to facilitate the process of identifying the components of the ESD framework.

The objectives of this field observation were to:

1. Investigate the whole channel of the fishing operation carried out onboard the demersal trawlers in order to understand its bonds with and impacts on humans and the environment;

2. Investigate the implementation of the legal and regulatory framework applied by MAF;

3. Investigate the attitude and practice of the fishermen toward the environment, catch and marine resources;
4. Investigate the condition of the ships and their adherence to the Conditions and Specifications of Commercial Fishing Vessels Prepared to Store Fishery Product, Ministerial Decision number 121/98;
5. Investigate the behavior and performance of the observers onboard the fishing vessels; and
6. Determine social values of relevance to this sector.

5.2.2 Consultation Review

Identifying the issues of a component tree in the ESD hierarchical structure normally involves a discussion workshop or a series of meetings among all concerned stakeholders within the fisheries (Fletcher et al. 2002a). However, as this study used the ESD framework identified by Chesson and Clayton (1998), the principle aim of this consultation review was to ensure that the context of the ESD framework tree would be functional within the Omani commercial trawling sector. This was achieved by expanding (splitting) or contracting (removing/lumping) the number of sub-components as suggested by Fletcher et al. (2004). It also involved adding any new related components, as it will be applied to a different fishery. Gaining the acceptance of the Omani stakeholders was the final step in adapting and finalizing the ESD framework.

Fletcher et al. (2002a), proposed six possible consultative methods that could be used to generate the modified trees to suit a particular fishery as discussed in Chapter 4. The most efficient process was found to be a combination of two methods, with a manager/scientist coming up with an initial draft version of the component tree which would then be finalized through a workshop that would include representation from each of the main stakeholder groups (Fletcher et al. 2002a).

Organizing a workshop was not possible due to resources and time constraints. Therefore, the researcher modified this method with a consultation review. The modified ESD framework was then shown to a panel of 30 experts made up from amongst those concerned stakeholders (Table 5. 1) (Appendix 1). It is worth noting that this review covered virtually the entire number of concerned academic personnel, researchers in the field and directors and upper managerial personnel from management and industry groups. The review was submitted to the concerned personnel by the researcher after explaining its aim and considering any ambiguous issues around it. The review was then collected after few days by the researcher and any outstanding issues were discussed with the respondents. This consultation review, with a response rate of 70%, was carried out in January 2006. (Table 5. 1).

Table 5. 1 Expert panel

Stakeholder	Number of Experts	Response	
		Number	Rate (%)
Academic	13	10	77
Management	10	7	70
Industry	7	4	57
Total	30	21	70

The review aimed to identify all possible components of the hierarchical structure relevant to the fishery. It aimed at maximizing consistency and minimizing the chance of missing issues or impacts (positive or negative) related to the trawling sector in the Sultanate in a comprehensive and structured manner as suggested by Chesson and Clayton (1998), FAO (1999a) and Fletcher et al. (2004). This step was never involved any discussion of the importance but rather evaluated or scaling of any issue. Any related issue raised by participants has been added to the relevant section for follow-up assessment. Communication effort was extended between the researcher and the expert panel to explain, discuss and clear up any ambiguous point or issues.

5.3 Findings

The findings of the field observations and the consultation review are discussed under two main headings; *The legal and regulatory framework* and *The impact on fishing imposed by the trawling on the fish stock and environment* according to the objectives as mentioned in Section 5.2.1:. The findings will be discussed with specific relevance to some related Ministerial Decisions that regulate the fishery.

5.3.1 Legal and Regulatory Framework

As discussed in Chapter 2, the trawlers and their crews who are 100% non-Omani, use the fishing rights of the Omani national companies according to contracts between them. In 2004, the nationalities of the foreign trawlers were mostly Korean, Chinese and Iranian. Those trawlers get a fishing vessel license for each voyage (Appendix 2). This license only indicates the permitted restricted closed fishing area and minimum mesh size. In addition to the Executive Regulations for Law of Marine Fishing and Conservation of Aquatic Resources (MD 4/94), this fishing vessel license is the only legal document within the commercial fishing sector. Other Ministerial Decisions that are of concern here and which influence the trawl fishery sector are: Quality Control Regulations for Omani Fishery Export (MD 4/97) and Conditions and Specifications of Commercial Fishing Vessels Prepared to Store Fishery Product (MD 121/98).

Although there clear legislative structures exist for the management of living marine resources in Oman, as discussed below, some limitations and weaknesses in the enforcement of regulations were identified during the field observation.

Regulations which include more specific and comprehensive rules and guidance that deal with trawling and longlining and which organize commercial fishing were drafted by the relevant section in the MAF in 1994. Issuing and enforcing such regulations will have no legal status as they are included in the Royal Decree No. 53/81 or the Executive Regulations for Law of Marine Fishing and Conservation of Aquatic Resources (MD 4/94). As stated by MAF Fisheries Deputy new legislation to include such regulations is now in process (personal communication, October 14, 2006). Therefore, the regulations organizing commercial fishing were never officially issued by a Ministerial Decision and have never been adopted by the authorities (see Chapter 2). Furthermore, some of those regulations, suggesting shortcoming in legal framework, were found in some official reports concerning fisheries management regulation of the country (FAO 2006a),. For example, the following regulation, which are not official nor being imposed were found in the FAO Country Profiles and Mapping Information System (FAO 2001a) and in some other technical papers including FAO (2006a):

- No vessel is allowed to continue fishing operations in one section for more than five consecutive days;
- Fishing operations are not allowed to be performed simultaneously in the same section by more than one vessel. Distance between adjacent vessels during fishing operations should be at least 5 nautical miles;
- The maximum duration of a fishing trip is 35 days;

Overall, the Executive Regulations (MD 4/94) organizing the Law of Marine Fishing and Conservation of Aquatic Resources issued by Royal Decree No. 53/81 is the only legal document that organizes the fishing in general for all sectors: traditional, commercial and recreational. There are only four articles and sub-articles that could be imposed on the fishing practice of the commercial trawlers: Articles 17, 20-I and 20-K and Article 42-C. Each will be listed and discussed under applicable headings in this chapter.

One of the key weaknesses in the regulation worth mentioning occurs in the by-catch and discard issues in the trawling sector. For 18 years from 1976 to 1994, there was no single rule regulating by-catch and discard of non-target species and vessels were allowed to discard catches that had no commercial value to them. They were not fined for discarding, but it was deducted from their quota. The only rule was Article 17[1], (Chapter 4) of the MD 4/94 that states: *"Fishing vessels are not allowed to return any fishes that has a marketing value except as specified by the concerned authority"*[2]. In 1994, MAF issued a decision, listing 15 teleost species and various elasmobranches, including all rays and guitar fish (Table 5. 2) that are allowed to be discarded back into the sea during fishing operations. In 1998 however, a new Minister (see Chapter 2) amended Article 17 by MD 42/98 which states: *"Discarding of any kind of fish is totally prohibited"*. As a result, five fishing companies objected to this action and against another two Ministerial Decisions: (43/98), which applies a closed fishing season from 15 July to 15 November and (121/98), which states certain specifications for fishing vessels (discussed below). This complaint was raised with the Ministry of National Economy and Ministry of Trade and Industry and as a result, in 2000, MDs numbers 42/98 and 43/98 were

[1] This article was found in MD 3/82, the one replaced by MD 4/94.
[2] There was no guideline of fishes with or without marketing value.

amended and cancelled in 2002. Further discussion on discards issues as an impact of trawl fishing is presented in Section 5.3.2.1.

Some other weaknesses and limitation are listed under the applicable headings in the following sections.

5.3.1.1 Enforcement and Compliance

Compliance with fisheries management rules, necessary to ensure the sustainable use of the world's fisheries resources, can only be achieved if an effective Monitoring Control and Surveillance (MCS) regime is in place (Cacaud 1999). Implementing the fishing regulations monitoring task for the commercial sector vessels in Oman is done through an onboard observers program and satellite monitoring system (Vessel Monitoring Systems - VMS). The enforcement of a closed fishing area is monitored by satellite; however there is still some breach of this "enforcement" as confirmed by observers. The Argos/GPS transmitter system, VMS, has been used since 2001 under contract to the French ARGOS company (CLS Group). Table 5. 3 shows the cumulative number of trawlers that use the system. This system is used to:

1. Identify position and direction of the fishing vessels;
2. Specify the distance and depth of the vessel fishing area;
3. Give early warning when a vessel breaches the fishing zone;
4. Give early warning in case of an emergency;
5. Frequently report the catch data to the Authority through the observer and;
6. Provide daily reports on the fishing vessels activities.

Table 5. 2 List of fishes that are allowed to be discarded

No.	Fish Name	Species	Importance[3]				IUCN Red List Status[4]
			Fisheries	Aquarium	Bait	Gamefish	
1	Spotted sicklefish	*Drepane punctata*	commercial	commercial	-	-	Not in the list
2	Crocodile flathead	*Cociella crocodila*	-	-	-	-	-
3	Whitecheek monocle bream	*Scolopsis vosmeri*	commercial	-	-	yes	-
4	Striped piggy	*Pomadasys stridens*	commercial	-	occasionally	-	-
5	Indian threadfin	*Polynemus indicus*	commercial	-		yes	-
6	Redtoothed triggerfish	*Odonus niger*	minor commercial	commercial	-	-	-
7	Masked triggerfish	*Sufflamen Fraenatus*	minor commercial	commercial	-	-	-
8	Birdbeak burrfish	*Chilomycterus orbicularis*	subsistence fisheries	-	-	yes	-
9	Long-spine porcupinefish	*Diodon holocanthus*	minor commercial	commercial	-	-	-
10	Reticulated leatherjacket	*Stephanolepis diaspros*	minor commercial	-	-	-	-
11	Greater lizardfish	*Saurida tumbil*	commercial	-	-	-	-
12	Giant seacatfish	*Arius thalassinus*	commercial	-	-	yes	-
13	Mauritius gurnard	*Pterygotrigla guezei*	-	-	-	-	-
14	Olive grunt	*Pomadasys olivaceum*	commercial	-	usually	-	-
15	Moontail bullseye	*Priacanthus hamrur*	minor commercial	commercial	-	-	-
16	All Rays and Guitar fish e.g. Giant guitarfish	*Rhynchobatus djiddensis*	commercial	public aquariums	-	yes	Vulnerable (VU)[5]

[3] According to IUCN (2006).
[4] Source: Ibid.
[5] See: http://www.redlist.org/search/details.php?species=39394.

Table 5. 3 Cumulative number of trawlers that apply VMS

Year	No. of Trawlers
2001	7
2002	18
2003	20
2004	28
2005	32

The enforcement of gear restriction, by-catch and any other regulations and criteria can only be observed and investigated by the observer on-board the fishing vessels. Using this format, many breaches have been observed. In 1994 for example, 116 breaches were brought to court (Table 5. 4), with 32 (27.6%) of them for breaching the fishing zone specification of less than 50 meter depth or within the 10 Nm zone. This figure decreased to 6 breaches (10.3%) in 2005 due to the introduction of the Argos/GPS transmitter system. However, the breaching of discard regulation increased to 60% (Table 5. 4). Further cases included breaching the gear restriction (using double code-end or less than 110 mm mesh size) and the majority were for discarding catches. The third column of breaches illustrated in Table 5. 4 indicates those unidentified breaches including some rare breaches including:

1. Killing turtle: 16 turtle were reported killed in 2000 and 586 individual turtle were included in the 1989 catch as reported by Hare (1990). These figures are based on observation of 8 months catch, where 50% were estimated to be dead or had no chance of survival;
2. Discarding oil barrels;
3. Cutting fins from elasmobranches and disposing of the flesh;
4. Not reporting some fish species in the catch report and;
5. Employing unregistered employees or transferring them from one vessel to another without permission.

Sacrilege records indicate that the Coast Guard is a significant authority, which helps MAF in fisheries monitoring and, along with other environmental authorities, is authorized to issue penalties. Al-Kharousi (1999) listed three governmental bodies assisting in and contributing to surveillance activities: the

Royal Oman Police, represented by the Coast Guard; the Royal Navy of Oman (Anon 1999) and the Royal Air Force of Oman.

Table 5. 4 Listed fishing breaches brought to the courts

Year	Type of Breach								Total
	Prohibited gear		Prohibited zone		Discarding catch		Other		
	No.	%	No.	%	No.	%	No.	%	
1994	10	8.6	32	27.6	9	7.8	65	56.0	116
1995	20	9.9	26	12.9	96	47.5	60	29.7	202
1996	2	13.3	10	66.7	3	20.0	0	0.0	15
1997	7	15.9	22	50.0	0	0.0	15	34.1	44
1998	0	0.0	0	0.0	0	0.0	125	100.0	125
1999	2	0.9	3	1.3	68	30.0	154	67.8	227
2000	0	0.0	2	1.1	44	24.6	133	74.3	179
2001[6]	0	0.0	0	0.0	7	100.0	0	0.0	7
2002	2	11.1	0	0.0	16	88.9	0	0.0	18
2003	0	0.0	1	6.3	12	75.0	3	18.8	16
2004	1	4.5	0	0.0	21	95.5	0	0.0	22
2005	15	25.9	6	10.3	35	60.3	2	3.4	58
2006	4	40.0	2	20.0	1	10.0	3	30.0	10
Total	63	6.1	104	10.0	312	30.0	560	53.9	1039

The observer on board a fishing vessel is the authorized person to issue fines. As claimed by the Head of the Commercial Fishing Department (personal communication, October 14, 2006), the observer follows a mechanism (Figure 5. 2) drawn up by MAF based on the Report of the Regional Workshop on Fisheries Monitoring, Control and Surveillance (FAO 1999b) and the International Plan of Action. This action aims to prevent, deter and eliminate illegal, unreported and unregulated fishing (FAO 2001c). A fine is normally preceded by a written warning in the case of gear and fishing zone breaches. The written warning is also preceded by an oral warning for specific and/or frequent discard breaches. Although there is specific direction as to the basis on which oral, written warning or a fine is issued,

[6] There was no single case raised in the court in the period from 2001-2004 due to an administrative decision at a high level. This is an indication of the intrusion of some external influences in the enforcement of the regulation (Chapter 2).

penalties records show for example that an oral warning was issued for discarding 150 kg of catch, while the mechanism declared a written warning for discards of more than 50 kg. This indicates a weakness and hurdle in the monitoring program resulting in an underestimation of the environmental desecration.

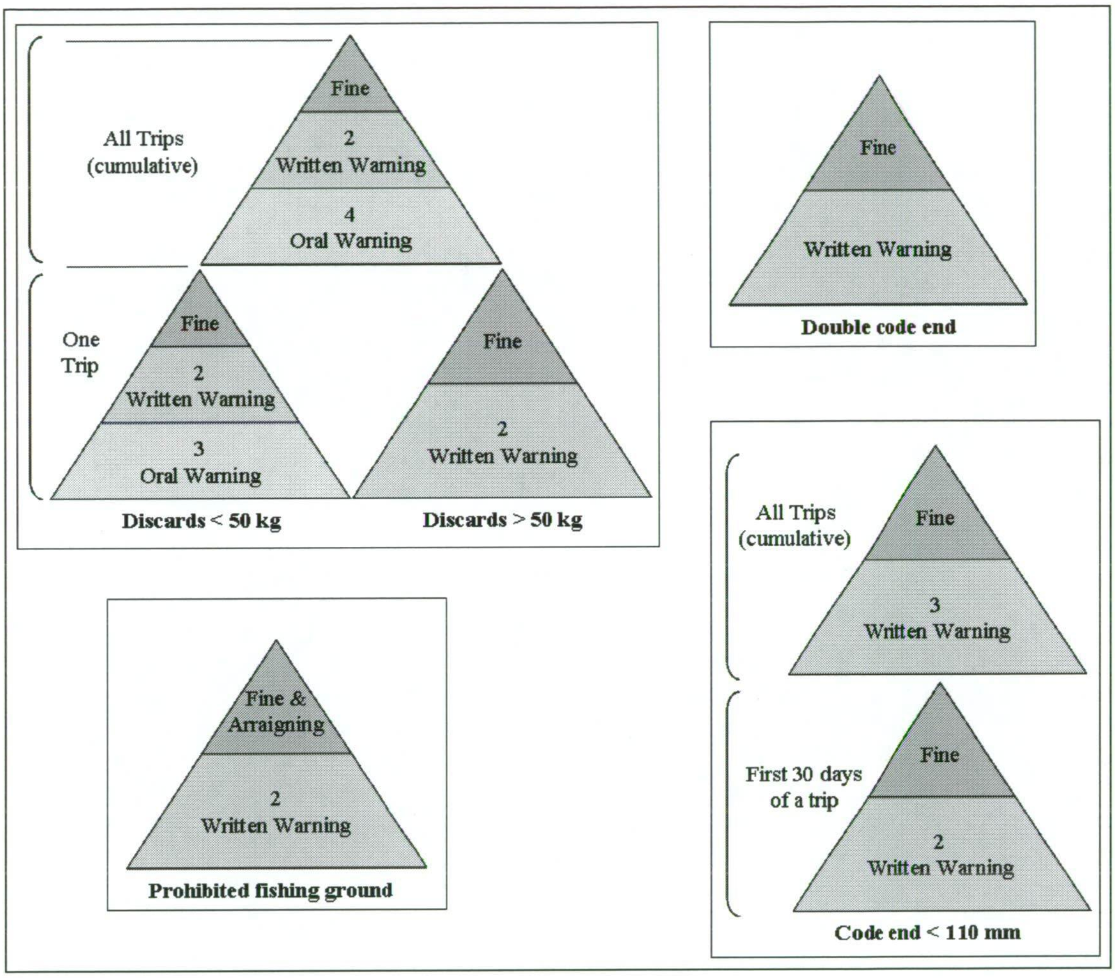


Figure 5. 2 Penalties mechanism for trawling fisheries sector

The breaches often occurred in the presence of an observer, but on some occasions, the fishing vessels had no observer onboard. Sometimes, the observer would leave the vessel without any replacement. This activity was not the objective of this study, but may indicate under-reporting of breaches within the legal framework and therefore underestimation of fishing mortality and the effect of fishing gear. The availability and attendance of the observer to investigate the fishing activities, sorting and processing of the catch was the only activity examined.

5.3.1.2 Quality Control and Occupational Health & Safety

Article 20-I, Chapter 4 of MD 4/94 states that: *"The concerned authority is endorsed to specify the conditions of conserving and circulation of catch to grant its quality and not to be spoiled"*. In this regard, in September 26th 1998, MAF issued Ministerial Decision (MD 121/98), which determines the conditions and specifications of commercial fishing vessels prepared to store fisheries products. This decision was implemented and applied to the vessels in 2000. However, as observed by the researcher, six out of 16 conditions that deal with requirements for fish processing are not complied with by vessels, indicating a weakness in inspection and rule enforcement.

As observed by the researcher, the facilities available for fish processing are of low quality and not consistent with MD 121/98. MD 121/98 states that "*hand washing and disinfection materials, automatic washing tap and onetime-use towel should be provided and made available in the processing area*" (Articles 2-G see also 1-G). None of these was provided nor applied onboard any of the working fishing vessels. Although the researcher remained on one fishing vessel, the best of all vessels, observers (either through personal communication or use of VHF radio facility onboard fishing vessel) support the above finding indicating poor compliance among the fishing fleet in relation to food safety.

Other significant issues observed include the poor living standard on board the fishing vessels. As the vessel was very old (23 years), the living standard was very low and sanitary facilities were generally unsatisfactory for a typical crew of 32 persons[7]. In addition, the quality of sanitary facilities was generally below normal standards required for human habitation (for example, drinking water was observed to be tainted with rust).

On the other hand, there is no single local official document that governs crew living standards. There are no regulations or rules found within the appropriate authority (Ministry of Human Power) that outlines working conditions. The only applicable statement is the one found in the Omani Labor Law, issued by Royal Decree 35/2003. It states that "*the employer... should provide convenient living places, rations, and drinking water...*" (Article 34). Although the Sultanate of Oman

[7] Average crew number for years 2002 and 2003 was 32 persons ranging from a minimum of 6 to, a maximum of 40..

is a member of the International Labor Organization (ILO), there is a lack of regulatory rules and weakness in their enforcement (see sections 5.5.1.1 and 5.5.1.2). This also suggests a low level of Occupational Health and Safety (OH&S), the area concerned with protecting the safety, health and welfare of employees, organizations and others affected by the work they undertake.

In order to cover the living conditions of the foreign crew working on board vessels, a fishers' sub-component of lifestyle, under human component is further divided into two sub-components: traditional and foreign (Figure 5. 3). However, as there is no data available to be used as an indicator, thus this component will not be used in this study analysis, but listed in the framework for future consideration.

As discussed in Chapter 2, Oman has failed to Omanize the trawling sector, therefore, the employment component is classified according to the nationalities of the employees. This is also done to ease the investigation of the impact on employment with accordance to MAF plans and views (Figure 5. 4).

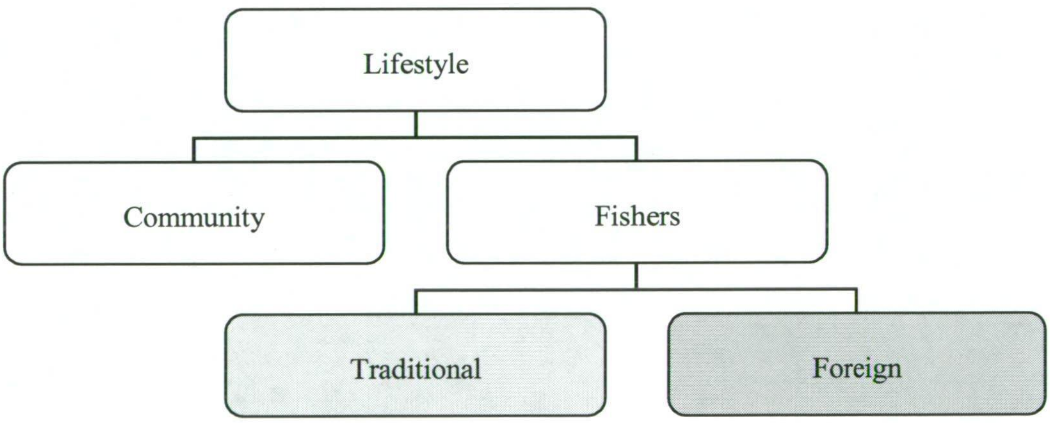


Figure 5. 3 Effect on Lifestyle of the human component

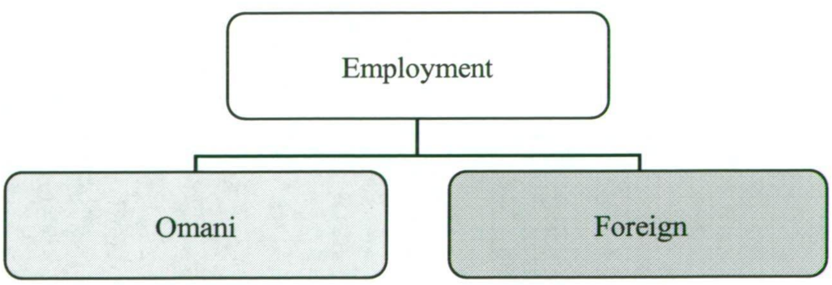


Figure 5. 4 Effects on Employment of the human component

5.3.1.3 Resource Access Conflict

Article 42-C, Chapter 7 of MD 4/94 states that: *"No fisherman is allowed to compete with other fishermen in any place in a fishing ground"*. This article refers to an "area" in a fishing ground and this place or area is not limited or restricted by dimension. Therefore, the vessels can fish in one place, only just maintaining the minimum distance for safe navigation and fishing. This will extend the disturbed area and increase the recovery rate of the ecosystem (Kaiser et al. 2001; FSBI 2004). On one occasion for example, eleven vessels were observed by the researcher trawling in an area 3.8 Nm in diameter. The shortest distance between two vessels was less than 0.3 Nm as confirmed by radar screen. In addition, there is no regulation organizing the maximum period or interval of trawling in the one area.

Some secondary data in the form of court cases and breaches brought to court (Table 5. 4) indicate a clear resource access conflict between the traditional and the commercial trawling sector as they are both competing for same resources (Chapter 2). The reduction in the commercial landings in the period between 1998 and 2001 positively affected the landings of the traditional sector, specifically those of Al-Wusta Region. Mathews et al. (2001), claimed that high commercial landings (driven by international prices) reduce traditional landings when both fleets fish the same species and similarly, the high commercial effort probably also reduces net traditional fishermen revenue. Negative correlation ($r = -0.27$, $n = 12$ years observation, P value = 0.39) was found between the demersal fish landings from the trawling sector and those from the traditional fishermen in Al-Wusta. There is no clear evidence that both fisheries share the same stock, as the traditional fishermen are protected with closed area of 10 Nm and 50 meter depth restrictions. The conflict rises mainly due to the sacrilege of the trawlers operated by foreign fishermen, which is of intense annoyance to the local fishermen.

Similar resource access conflicts between trawl operators and small-scale artisanal fishers occurred in Western Indonesia and led to a ban on trawling in 1980 (Nurhakim 2003). An Ecopath with Ecosim software (a dynamic multi-species model) (Pauly et al. 2000) and economic impact analysis used by Buchary (1999) to evaluate the economic implications of a trawl ban revocation, recommend not to revocate the ban as was suggested in late 1999 by a new government.

To allow sustainable development and as traditional and commercial sectors in Oman are both fishing in overlapping fishing grounds, the resource conflict should be researched and evaluated. To highlight this conflict, an additional component has been added under the effect on human component (Figure 5. 5).

Most of the trawlers' catch is exported, leading to a reduction in the variety of fish landed by both sectors. Around 80% of the landing is exported directly by the foreign fishing company (their share) with no added value gained by Oman except through port tax. This figure needs to be minimized for two reasons: first to satisfy the local market and then to gain added value. Marketing of the catch also influences local nutrition and the declining scenario of per capita fish consumption (Chapter 2). This is mostly due to increased fish exports leading to a low supply for the local market. Therefore, to assess the quality of life and to examine the trade-offs between domestic consumption and export earning, a nutrition component was added under the Effect on food of the human component in Figure 5. 6 below. The marketed component on food of the human component is further subdivided into: Domestic and Export (Figure 5. 6).

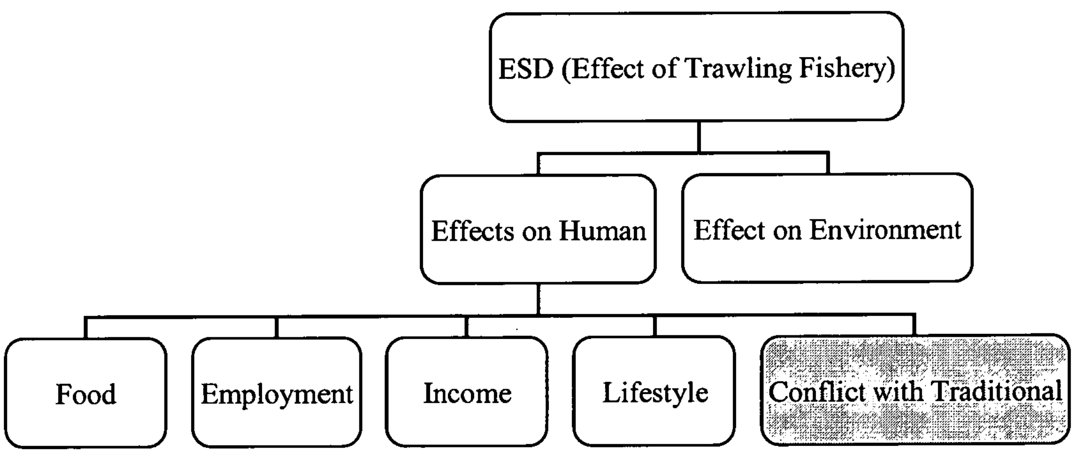


Figure 5. 5 Effect on human component

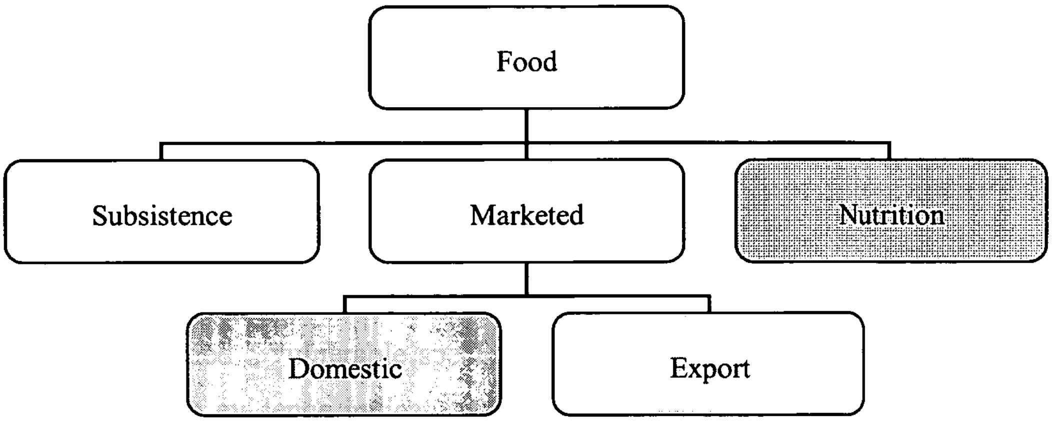


Figure 5. 6 Effect on food of the human component

5.3.2 Impacts of Fishing

Fishing impacts will be discussed under two main heading: 1) discards; and 2) marine pollution and environmental damage. The behavior and attitude of the fishers and observers regarding these two issues will be highlighted.

5.3.2.1 Discards

Total fish discarded in 1993 was 3619.042 mt of which 50.41% was commercial catch (see Figure 2.6 in Chapter 2) and within three years, by 1996, trawlers discards declined sharply to 513.887 mt. As claimed by the Head of the Commercial Department, this reduction was attributed to some new discards regulations (Personal communication, October 14, 2006). Close investigation of the regulations show no clear or logical reason behind this sharp reduction, when the only discards regulation (MD number 42) was issued in 1998. This narrows the reason behind this sharp reduction to underestimation and misreporting of the discards (see Chapter 2).

Most of the breaches of fishing regulations were in the areas of by-catch and the discarding of catches that had market value. Seven of the species, in addition to *Rhynchobatus djiddensis* (Giant guitarfish), are of commercial importance as described by Froese and Pauly (2006). *Rhynchobatus djiddensis* is on the IUCN red list and is classified a vulnerable species (Figure 5. 7). A taxon is vulnerable when the best available evidence indicates that it meets any of the five criteria listed in

IUCN (2001), and it is therefore considered to be facing a high risk of extinction in the wild (IUCN 2006).

Although there is a clearly reported reduction in the amount of discarded catch since 1993, the actual figures could be much higher than the reported catch. This conclusion is derived from two main factors: attitude and intention of the fishermen and the availability of an observer on board fishing vessels as it is this observer, who is the formal reporter of such figures.

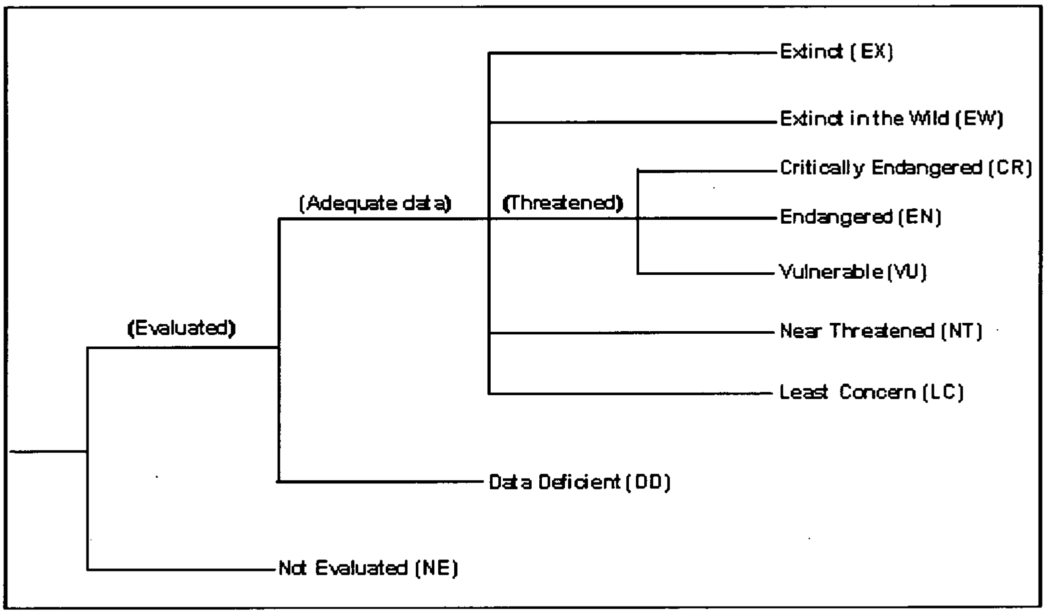


Figure 5. 7 Structure of IUCN Red List categories (source: IUCN 2002).

Captains and high rank crew of the vessels have a strong incentive to discard any catch of low economic value not on the list (Table 5. 2). This action is clearly evident to the observers with the crew undertaking this illegal activity in the presence of the researcher. Observers confirmed that this behavior is common in cases of low-value catches. Although there is no official report, observers often state the occurrence of bribes offered to them in order not to report any illegal incidents. This suggests poor attitudes and manner of the fishermen towards catch discard when there is no official observer onboard the trawler. It can explain the high number of breaches discussed in Section 5.3.1.1.

Another significant and critical issue was observed during net haul back. When the net reached the surface, the captain would stop the hauling operation and allow most of the net body to drift in the water for around 5-15 minutes enabling small fish to escape. Although this allows the escape of non-target species (Suuronen

2005), the observed mortality rate is high. This mortality is classified as a kind of drop out mortality, defined by ICES (2004) as mortality due to captured fish dying and dropping out of the gear, prior to the catch being landed on deck. Such drop out mortality normally occurs accidentally, but in this case, it was purposeful. Large amounts of catch were observed overflowing from the net and floating on the surface of the water demonstrating high mortality rates. This is a type of misreporting resulting in unaccounted fish mortalities (Bray 2000), which affect the reliability of stock assessment and environmental impacts.

It was observed that there was no responsibility for washing off the codend in a timely manner, which increased the chance of drop out mortality. An observer stated that this is legal practice and there is no breach of the regulation. This could be true as there is no clearly stated regulation in this regard, but it does give an indication of the low educational level of the observers and the low understanding and awareness of the principle of illegal fish discards and mortalities.

It is clear that discards from commercial fisheries are a key food resource for many seabird species around the world (Votier et al. 2004). There is evidence that populations of scavenging seabirds have increased considerably where discards are plentiful (Furness 2000). Scavenging species are affected directly in terms of foraging ecology, breeding biology and overwinter condition (Votier et al. 2004). Indirect effects include increased depredation of smaller seabirds by scavengers facing a shortfall in their energy budgets (Votier et al. 2004). Unfortunately, there is no information on such relationships and impacts on this fishery.

The mortality of discards (dropped out or escaped from the fishing gear) is one of the most significant issues affecting marine fisheries management today (Davis 2002). The main factors affecting the stress, injury and mortality of discarded fish are related to capture stresses, fishing conditions and biological attributes. Light conditions, air exposure, temperature, difference in pressure and anoxia (lack of oxygen) are all sources of mortality.

Studies on the mortality of fish discarded from the decks of fishing vessels generally show high mortality rates (Suuronen 2005). In the Omani commercial trawling sector and due to late or delayed catch sorting, the discard mortality rate was observed and rated by the researcher to be as high as 100%.

Discussion with a fishing gear expert indicated that the catch was top-graded i.e. just the best fish removed, and at least 50% of the catch was discarded, which means that there are gross underestimates for the amount of discard. Certainly there are no reports or references available beyond the MAF statistics.

The absence of By-catch Reduction Devices (BRD) in the fishing gear is one of the causes of the high rate and underestimated discards. All of the above indicate high rates of accounted and unaccounted fish mortality associated with the commercial trawling sector and therefore demonstrate a need for urgent management interaction.

Observers onboard the trawler spend 8-10 hours sleeping and resting. During this time, fishing is still carried out and the amount of by-catch is not monitored. Add this factor to the intention and incentive of discarding some of the low value catch and the amount of discarded catch will increase. (This is of course will not be reported to the authority and considered as unaccounted mortality). This action was observed by the researcher several times.

Through the above mentioned discussion, the by-catch problem in this sector could be classified under the critical by-catch category or ecosystem level impacts, which may cause major alterations of the system (Hall 1995).

5.3.2.2 Marine Pollution and Environmental Damage

Article 20-K, Chapter 4 of MD 4/94 states that: *"The concerned authority is endorsed to specify the materials that are not allowed to be disposed to the seawater………"*. In this regard, it is observed that all waste and residue (hard or soft), damaged fishing accessories and their residue, polluted water (diesel) were dumped over board. It was noticed that the fishermen had poor education on the environment and the observer noticed no action or concern about environmental impact.

Trawl gear, as identified by Jones (1992), affects the environment in both direct and indirect ways. Direct effects include scraping and ploughing of the substrata, sediment resuspension, destruction of benthos and dumping of processing waste. Indirect effects include post-fishing mortality and long-term trawl-induced changes to the benthos (Jennings and Kaiser 1998). Recovery rates can vary greatly between different habitats, gears and areas that experience different levels of natural disturbance (FSBI 2004).

In the fishery under study, trawling is allowed in the area between latitude 21° 40' N, south of Masirah Island and longitude 55° 45' E, North of Halaniyat Island (see Chapter 2). This area is characterized by strong water currents including the Somalia current and the upwelling phenomena driven by monsoon winds, (Varghese and Somvanshi 2001), which means that recovery from fishing effects can be as short as several days to weeks (FSBI 2004). In contrast, recovery rates appear most rapid in less physically stable habitats, which are generally inhabited by more opportunistic species (Collie et al. 2000). However, defined areas that are fished in excess of three times per year are likely to be maintained in a permanently altered state (Collie et al. 2000). In the Gulf of Maine (Northwest Atlantic), the sandy habitat required 3,650 days(= 10 years)to recover from otter trawling disturbance (Auster et al. 1996).

The upwelling does have an impact on recovery of the ecosystem trophic level or food web (Pauly et al. 1998), which can accelerate the recovery of the habitat seabed. However, this would not be the case with slow growing habitat-forming fauna and corals, which were found to be present in the study area (MRMEWR 2003). These indicate the call for more ecological research on this topic, as there is no single study to be found in the literature about the ecosystem recovery rate of this particular study area.

As an effect of trawling it was suggested that a shift in marine biomass might happen. There is no clear and direct indication of such an effect found within the components of the original framework. Therefore, a shift in biomass component was added under the 'effect on other aspect' of the 'environment component' to give a direct consideration to such change (Figure 5. 8).

Further expansion to the 'marine landscape' component effect on other aspects of the environment was done. This will reduce the chance of missing any affected landscape segments and also will help in identifying specific objectives for each relevant component. Therefore, the "marine landscape" component was further sub-divided into sediment, rocks, coral and algae components (Figure 5. 8). This reflected the results of the observation field work and discussion with ecosystem experts.

The 'water quality' component was also further sub-divided into turbidity and chemistry components (Figure 5. 8) to distinguish each factor responsible for each component and facilitate objective identification.

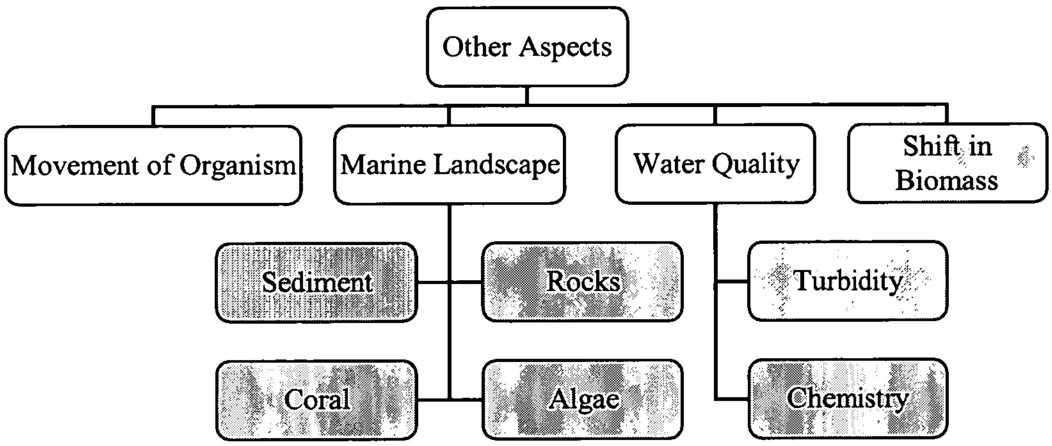


Figure 5. 8 Effect on other aspects of the environment component

Since this framework is intended to evaluate the effect of trawling fishing gear, no effect of trawling is found to be exerted on birds as a direct effect of the normal fishing operation (Figure 5. 9). The only effect shown on birds is under the 'outside normal fishing operation' when they feed on discards. Therefore, mammals and reptiles, as by-catch were found to be the only organisms that could be affected by trawling under normal operation. Due to this finding, the related sub-components were modified.

Based on the above observations and their relationship with ESD, Table 5. 5 shows all issues identified, from field observations and discussion with experts, and also the ESD component that highlights them. As a final step, Figure 5. 10 presents the modified ESD framework incorporating key issues discussed in this chapter.

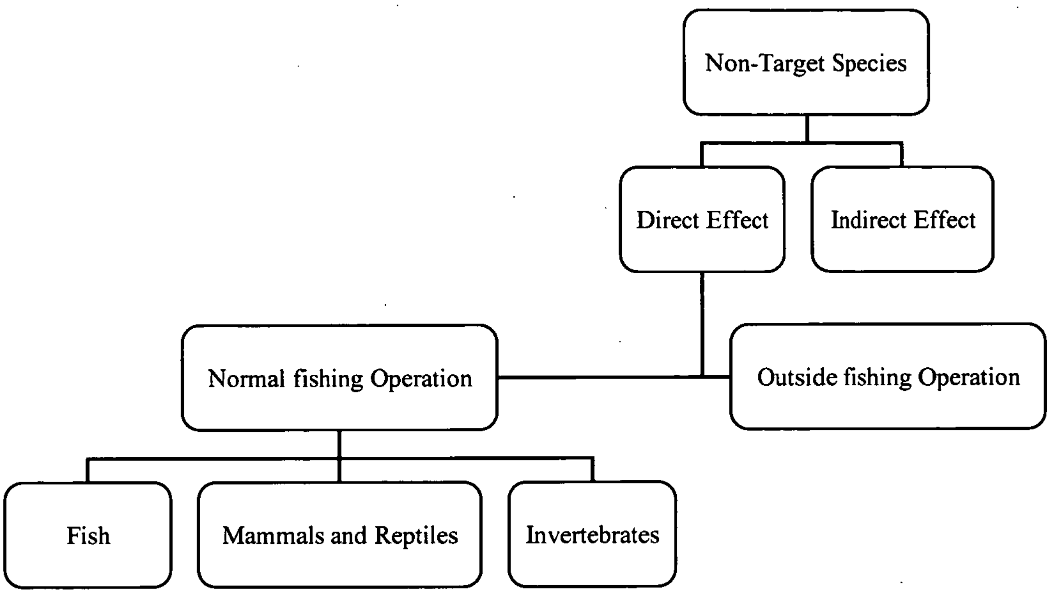


Figure 5. 9 Effect on non-target species of the environment component

Table 5. 5 Newly identified issues and their relation to ESD components

No.	Issue	ESD Component
1	High level and underestimation of accounted and unaccounted fish mortality	Primary commercial species & Non-target species
2	Catch high grading	Primary commercial species & Non-target species
3	Incentive to discard catch	Primary commercial species & Non-target species
4	Physical and chemical environmental pollution	Marine landscape & Water quality
5	Ecosystem recovery rate	Other aspect
6	Low living standards onboard fishing vessel	Foreign
7	Resource access conflicts between traditional and commercial sector	Conflict with traditional
8	Shift in biomass	Shift in biomass
9	Declining scenario of the per capita fish consumption	Nutrition
10	Reduction in the variety of landed fish	Domestic & Export

5.3.3 Policy Implications

Effective enforcement of fisheries rules and regulations and fishers' compliance towards them rely heavily on the comprehensiveness of fisheries legislation. Any limitations in fisheries legislation will lead to deficient fisheries management and thereby pose a threat to the sustainability of living marine resources. Although the purpose behind the development of the FAO code of conduct for responsible fishing is noble, being a voluntary instrument it becomes flexible in its application.

The findings in relation to the difficulties in enforcing compliance of legislative rules (discussed in Sections 5.3.1 and 5.3.2) have important policy implications in the sense that the apparent lack of enforcement of laws designed to protect and conserve living marine resources in Oman, will undermine national development plans. Furthermore, observed non-compliance in the fisheries sector in Oman undermines the attainment of, amongst other things, the following main goals stipulated in the development plan: a) conservation and development of resources; b) economic efficiency and cost-effectiveness of fisheries management; and c) legitimacy of regulations, which are coherent with the Ecologically Sustainable Development (ESD) principles advocated by national plans and international treaties.

It is also found that the current enforcement effort by the authority to combat illegal fishing activities (Table 5. 4) is ineffective. The policy implication of this finding is that the authority must take necessary action through the adoption of either a deterrent approach (i.e. by increasing the chance of detection, arrest, conviction and prosecution), or a voluntary approach (i.e. educating fishers). By combining the two, a mixed approach could strengthen the existing enforcement strategies so that the fishers who comply with regulations would not perceive that the illegal behavior is legitimized (Charles et al. 1999).

The extent of discarding, currently experienced by the trawl sector, has some serious policy implications as it undermines the sustainable development principles in relation to economic efficiency (it diminishes the potential economic benefit from the fishery) and ecosystem integrity (it creates imbalance in the marine community and disrupt the food web). Furthermore, discard activities contribute to erroneous data thereby undermining the true nature of fishing mortality as experienced by the fishery. In this regard, to support conservation objectives of the fisheries development plan, the authority should devise management policies to reduce discards associated with the trawl fishery.

It is also observed that human-induced activities such as the dumping of fish and other waste materials poses a substantial threat to the environmental sustainability campaign proposed by the country. Strict enforcement of existing regulations under Royal Decree 34/79, which prohibits marine pollution, is essential to protect the wealth of the marine environment.

Broadly speaking, the main concern with regard to non-compliance in fisheries for the regulatory authorities is that it undermines the attainment of, amongst others, the following key management objectives: a) conservation of resources; b) economic efficiency and cost-effectiveness of regulations; and c) legitimacy of regulations, which are coherent with the Ecologically Sustainable Development (ESD) principles advocated by national plans and international treaties. To achieve effectiveness and legitimacy in fisheries management, management authorities, experts, researchers and policy makers have been putting their effort into designing strategies to achieve optimal levels of compliance in the fisheries sector around the world.

However, in recent years design of effective compliance strategies under a partnership approach in the form of co-management has been promoted. This is to ensure that regulators' views on effective and efficient resource management are not contradictory to those of the resource users. It should be noted that the greater the convergence of views between the regulators and resource users of the source, the nature and significance of non-compliance, the higher will be the chance of fostering cooperation and forming the basis for improved management strategies.

5.4 Objectives of the ESD Components

The policy of MAF to manage and develop the fisheries sector is built on two main strategies: 1) Vision Oman 2020, a 25 year plan (1995- 2020) (see Chapter 2) and 2) a Five Year Plan (MAF 2006b). Vision Oman 2020 counts on the fisheries sector to support the national economy by raising its GDP contribution from 1.1% in 1995 to 2% in 2020. To achieve this target, MAF had put in action a strategy to develop the traditional sector and build it into a modern one with seven objectives (Box 1) and five policies (Box 2). The broad view and development plans of the Ministry are previously listed in Chapter 2.

Box 1: Objectives of Vision Oman 2020

1. To develop the export fisheries
2. To provide more productive employment and careers for Omanis
3. To increase the contribution of the fisheries sector toward food security
4. To develop the fish-related industry
5. To improve the living level of traditional fishermen
6. To increase the annual growth and contribution of the sector to the GDP
7. To encourage and motivate the national private sector to work in the sector

Box 2: Policies to achieve Vision Oman 2020 objectives

1. Providing the basic infrastructure: fishing ports and extension and statistics centers; and supporting facilities including: roads, electricity, water, ice and freezing factories, processing factories, transport facilities and fuel stations.
2. Protecting fisheries resources from overfishing
3. Developing fisheries research through providing data and statistics to help in decision making, drawing up production and marketing policies.
4. Providing a fishing fleet with new fishing technology and good fish preserving and safety equipment and capable of utilizing the resources
5. Encouraging the private sector and enhancing its responsibilities in adapting the fisheries projects and increasing production through processing, marketing and aquaculture

The Government prepares a plan every five years, in which it draws up a strategy to be followed in the ensuing five years. MAF drew up its own objectives and policies for the fisheries sector, to be achieved in the current (7th) five year plan (2006– 2010) (Table 5. 6).

Although not explicitly stated, it is clear and apparent that MAF plans and views are well framed and organized toward sustainable development and encompass all three dimensions of welfare – economic, environmental and social (see Chapter 2). However, as can be seen in Boxes 1 and 2 and Table 5.5, MAF objectives did not include the environment dimension and only cover the social and economic dimensions. This explains the availability of clear operational objectives for the components under the 'effects on human', but not for the components under the 'effects on environment' (Table 5. 6).

The protection and preservation of fisheries resources is only stated in the policies, which are drawn up as tools to achieve the social and economic objectives and not treated as a target objective. This could curtail the importance of the fisheries resources or even prioritize the social and economic dimensions over the environment, which is against the sustainable development principles. Therefore, this issue needs to receive much attention in the drawing up of any new legislation which is in process as stated by MAF Fisheries Deputy (personal communication, October 14, 2006).

On the other hand, the objectives and policies are broad and touch on general topics only. Operational objectives were often not stated explicitly although they may exist implicitly. This is because the Sultanate does not adapt any sustainable development framework although it considers international legislation and conventions such as the FAO Code of Conduct for Responsible Fisheries, in its policies.

As the Sultanate is a developing country, the research is limited to the past few years and a lot of fields are not yet covered and specific objectives are not yet issued. Terms like "sustaining" and "conserving" (Whitworth et al. 2002) are mostly used in the statements of objectives or policies, which are the target of any specific operational objectives. Some of the available management objectives are based on precautionary decisions as a result of lack of knowledge.

Table 5. 6 Objectives and policies of the fisheries sector for the 7th five year plan (2006 – 2010):

Objectives	Policies
- To provide and reinforce basic infrastructure	- Utilizing fisheries resources in the EEZ through motivating investment in youth project[8] and developing fisheries boats
- To achieve an annual growth of 3% in the domestic production sector	- Supporting fisheries research - Developing aquaculture
- To increase the productivity and quality of fisheries resources	- Increasing the quality of the sector through safety standards and quality control
- To develop human resources and Omanize the sector	- Increasing the quality of fisheries management and developing fisheries extension
- To achieve an annual growth of 5% of the value of fish export	- Developing fish marketing by activating the role of wholesale market and production market within the fishing ports - Developing post-harvest technology and trading through paying attention to transporting, distributing, storing and marketing
- To reinforce the contribution of fishermen in the management and development of the fisheries sector	- Preserving and developing fish resources through surveillance technology and legislation
- To reinforce private sector contribution in the development activities	- Encouraging the converting industry to increase the added-value of the fisheries products

In general, the broad objectives adapted by MAF have been found to agree with the two core objectives of the ESD National Framework for sustainable development, which target the biodiversity, ecological processes and individual and community well-being. This eases the process of identifying the operational objectives for the Omani commercial trawling fishery.

Each component of the ESD framework requires an agreed operational objective, which must be an outcome-based objective, not a process or data gathering

[8] A running project created by MAF aimed at training Omani youth to use large and moderate fishing vessels in order to replace the existing foreign employment.

objective, i.e. "*What, specific to this issue for this fishery, is needed to be achieved?*" (Fletcher et al. 2002a). Establishing accepted operational objectives for the components of the ESD framework was extremely challenging in this research. In this case, an initial version of objectives was drafted by the researcher based on the available local objectives in a way which did not clash with the plans, views and policies of MAF. International legislation and conventions were reviewed and used to fill any gap in the local objectives. The objectives of the ESD framework components were also used to support this process. The initial draft was then presented to the MAF Fisheries Deputy, as a representative of the responsible authority of fisheries management and legislation, to gain his comments.

A discussion was held with the MAF Fisheries Deputy on 14th of October 2006 to establish and prepare a final draft of operational objectives for the framework (Table 5. 7). After viewing the listed objectives in Table 5. 7, it might be argued that an essential element called a 'specific' is missing from some objectives. It is important to emphasis that lack of such specific does not undermine the achievement of this study objective. This is because the main objective of the study is to use the ESD framework to assess trends in progress of a specific management option (regulation) toward sustainability as stated in Chapter 1.

Table 5. 7 Operational objectives for the ESD components

Component	Objective (Time frame: 2020)
Effects on Humans	
1. Food (Quantity)	To increase the contribution of the fisheries sector toward food security and achieve subjective satisfaction
a. Marketed	
Domestic	To achieve subjective satisfaction and enhance the variety of seafood
Export	To achieve 5% annual growth To minimize the non-added value export[9]
2. Employment	To provide more productive employment and careers for Omanis
b. Omanis	To increase the number of workers
c. Foreign[10]	To decrease the number of workers
3. Income	
d. Individual	To improve the living standard of the traditional fisherman
e. Regional	
f. National	To achieve 3% annual growth
4. Lifestyle	
g. Community	To encourage and motivate the national private sector to work in the sector
h. Fishers	
Traditional	To improve the living level of the traditional fishermen
Foreign	
5. Conflict with Traditional	To minimize the resource access conflict To protect small scale fisheries interests (FAO Code of Conduct)
Effects on Environment	
1. Primary commercial species	To maintain a production quota of 28,000 mt
2. Non-target species	
a. Direct effects	
Normal fishing operation	To reduce mortality rate of escapees and discards
b. Indirect effects	
Supply of food from discards	To develop by-catch industry
Community interaction	To maintain natural relation and interaction
3. Other aspect	
c. Shift in biomass	
d. Movement of organisms	To be kept as natural as possible and minimize any negative impacts
e. Marine landscape	
f. Water quality	

[9] Around 80% of the landing is exported directly by foreign fishing companies with no value adding gained by Oman. This figure need to be minimized for two reasons: firstly to satisfy the local market and secondly to gain added value.
[10] Foreign segment is not targeted by MAF objectives and policies.

5.5 Conclusion

A modified framework for assessing the management initiative and industry performance toward sustainability has been developed. In developing the modified framework, a series of consultations was held with key stakeholders to ensure legitimacy and credibility of the final product. The advantage of using this type of framework is that it allows analysts to consider the full spectrum of fisheries issues related to core dimension of ESD principles. It also facilitates transparent discussion with key stakeholders in relation to obvious trade-offs between multiple objectives. This is a crucial element in fisheries management decision making and in the management of living marine resources.

While the focus has been on the trawl sector, with the availability of appropriate levels of resources, the framework can be readily extended to assess the overall performance of the fisheries sector in Oman.

Based on the review of existing legal framework and field observation, some important policy issues were raised. These should be taken into account by the fisheries management authority to ensure credibility of the existing regulatory framework.

The chapter also presents the objectives of each key component and sub-component of the framework that are consistent with the national legislation, international treaties and ESD principles. These objectives were presented to the key official of management authority for review and comments before finalizing the process of developing appropriate objectives.

After the identification of objectives, the next step was to develop a suitable set of indicators following the process discussed in Chapter 4. This task is outlined in the next chapter.

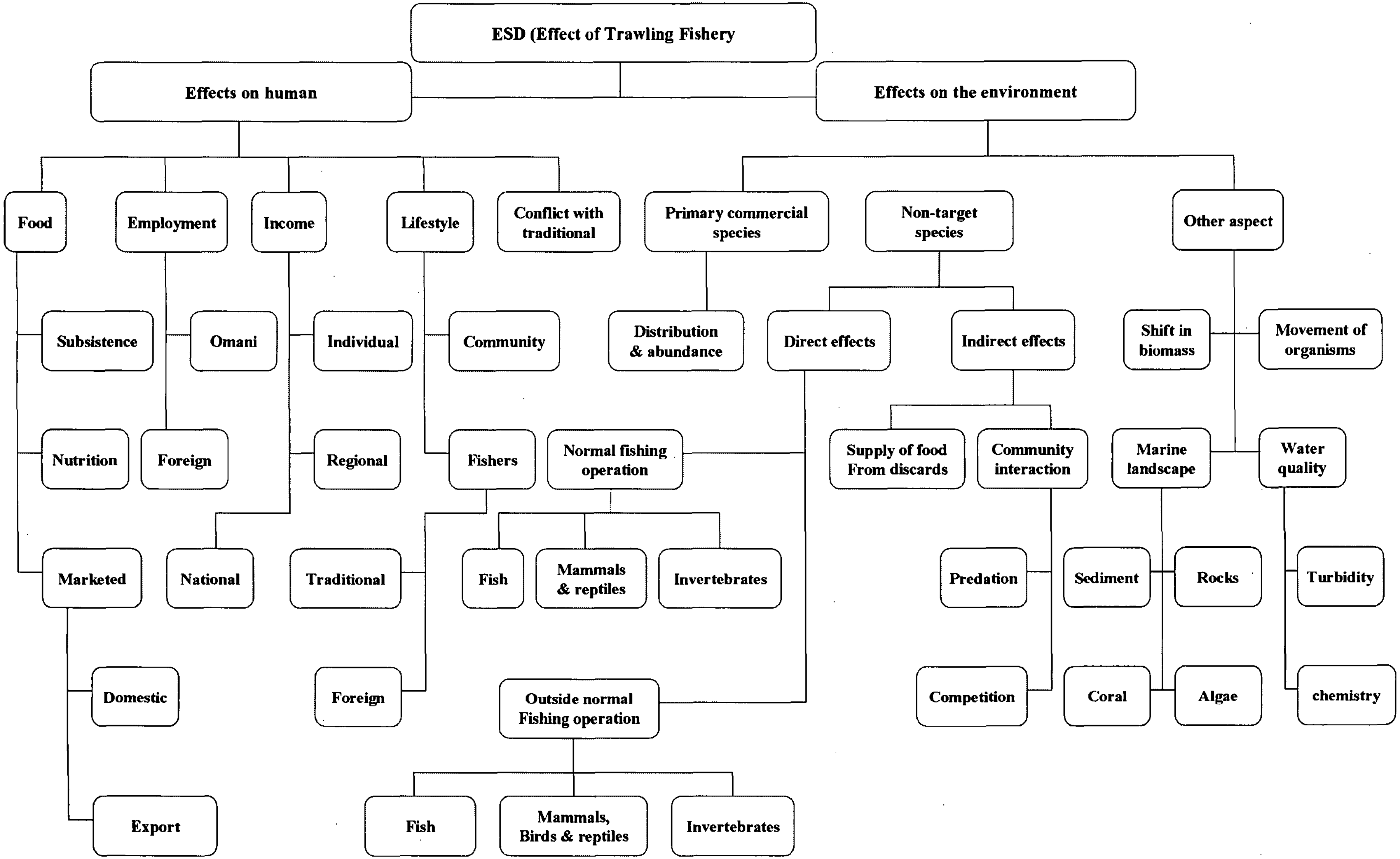


Figure 5. 10 Modified ESD framework for Oman commercial trawling sector

CHAPTER 6: ESD INDICATORS FOR THE COMMERCIAL TRAWLING SECTOR IN THE SULTANATE OF OMAN

6.1 Introduction

The main objective of this chapter is to identify a set of practical performance indicators and reference points following the Sustainable Development Reference System, discussed in Chapter 4, and the proposed ESD framework suitable to Oman, as discussed in Chapter 5. The indicators have been mostly chosen based on that data available that directly addresses the operational objectives identified in the previous chapter. This has been achieved through discussion and consultation reviews with relevant stakeholders following an extensive literature search on indicators for the sustainable development of fisheries.

Some of the indicators identified in this chapter will not be used in this analysis as their data is erroneous. They have been listed as applicable indicators for future consideration.

6.2 Fisheries Indicators

As middle ground between science and policy, indicators[1] must be simultaneously pragmatic and scientifically valid (Jesinghaus 1999). They provide a bridge between objectives and actions (FAO 1999a). They are normally developed from raw data (Potts 2003), where the data is processed and condensed into smaller amounts of meaningful information in a systematic flow as in the metaphor of an information pyramid (Jesinghaus 1999).

Bakkes et al. (1994) pointed out that indicators of biological diversity are poorly developed and that they are biased strongly toward species and away from the ecosystem as a whole (Saunders et al. 1998). In fishery systems, Charles (2001) claims that there have been relatively few attempts to develop sets of indicators that

[1] 'Indicator' is defined in Chapter 4 as *"a quantity that can be measured and used to track changes with respect to an operational objective. The measurement is not necessarily restricted to numerical values"*.

are quantitative and reflect an integrated, interdisciplinary, multidimensional view of sustainability, including assessment of both natural and human sub-system. Similarly, Dahl (2000) found that ocean indicators are poorly represented in the United Nation Commission on Sustainable Development (UNCSD) context, with only five indicators, clearly indicating a gap to be filled in future versions. Alternatively, there is substantial literature covering the integrated treatment of sustainability concepts, policy issues and the social and economic valuation of aquatic resources and ecosystems (Charles 2001). Thus, rather than identifying sets of indicators more effort was employed in developing different frameworks and guidelines, which plan and help in identifying the indicators. This could be advantageous in the early stages of sustainable development in which drawing the foundation for good indicators is of high priority. Applying the wrong indicators could devastate the system.

Currently, following Agenda 21 (UNDSD 1992) and works from CSD and Organization for Economic Co-operation and Development (OECD), there are many indicators used on a national scale which enable a country to report on its progress toward sustainable development (Chesson 2006). Attempts to develop indicator sets however, often fail to gain broad support because they invest too much effort in specifying the indicators and not enough in understanding the objectives (Chesson 2006). This reinforces the importance, in the past, of the SDRS and the related frameworks as a foundation and as a tool for best harmonizing between indicators of the system components (economic, environment and social) and the operational objectives necessary to achieve the sustainable development. Rice and Rochet (2005) classified the methods found in literature under three categories that help in selecting a final set of indicators: standardization, weighting and combining. On the other hand, numerous lists of candidate indicators exist already (FAO 2003a; Garcia 2003; Lack 2004; Ward et al. 1998; Ward et al. 2002). This issue is discussed in more detail in Chapters 3 and 4.

It is clearly indicated above that there are diverse groups of indicators applicable to ESD of marine resources. Due to the availability of data, this is mostly true for developed countries but not for developing countries (Garcia and Cochrane 2005). The Sultanate of Oman like other developing countries suffers a shortage of relevant statistical raw data making it difficult to develop performance indicators applicable to ESD. As mentioned in Chapter 1, the selection of appropriate indicators to measure progress towards sustainability is constrained by the availability of relevant and reliable data. As a result, the majority of indicators have been constructed based on the available data and an attempt has been made to ensure that they are as direct as possible in addressing the identified operational objectives. This process also involved consultation review and discussion with the target stockholder in quantitative approaches. As recommended by Chesson and Clayton (1998), the indicators will be developed within the structured set of objectives and will be structured with accordance to the ESD framework components achieved in Chapter 5 and following the SDRS guideline.

Following the ESD framework, the effects of the Omani commercial trawling sector were classified into two components: effects on human and effects on the environment as shown in Figure 5.10 in Chapter 5. Therefore, the indicators were classified, investigated and discussed under the above two components and their further subcomponents.

6.3 Effect on Humans

The commercial trawling activity is mainly focused on targeting fish species for commercial gain. This commercial practice has a multiple effect on both humans and the environment. Effects on humans are divided into five components: food, employment, income, lifestyle and conflict with the traditional sector as shown in Figure 5.10 in Chapter 5.

6.3.1 Food

Fish has been an important staple food for the Omani coastal inhabitants and the interior populations for centuries, providing a large portion of their protein requirements. One of the four objectives of the MAF development plans listed in Chapter 2 is:

Increasing the contribution of the fisheries sector toward food security through the following policies:

- *Developing an efficient marketing system;*
- *Ascertaining a significant value from the export of fish;*

- *Enhancing the private sector in production and marketing.*

This objective highlights the importance of food security or to be more specific, the fisheries food security. Before discussing the food component and its possible indicators, it is worthwhile discussing the concept of food security.

Food security is a flexible concept with about 200 definitions (FAO 2003b; Hoddinott 1999). It was first defined in the 1974 World Food Summit as (FAO 2003b; P. 27):

"Availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuation in production and prices"

Then in 1983, FAO (1983) expanded the definition to include securing access by vulnerable people to available supplies (FAO 2003b; P. 27):

"Ensuring that all people at all times have both physical and economic access to the basic food that they need"

In 1986, the World Bank (World-Bank 1986) defined the concept of food security as (FAO 2003b; P. 27):

"Access of all people at all times to enough food for an active, healthy life"

From the above definition, it can be noted that food security is not only the availability of food in a country during war, as the term security may reflect and as some decision makers may believe, but also during times of peace[2]. Food security is the physical and economic availability of food for all people at all times and as claimed by (FAO 2003b), attention should be balanced between the demand and supply side of the food security equation. This point gives attention to the allocation of the available supplies to the population. In general, the concept of food security and the above mentioned objective, highlights two main issues: the availability of food (fish) and marketing. Marketing, which is mentioned in the objective, is of two kinds: domestic and export. These issues represent the three sub-components, Nutrition, Domestic Market and Export, of the food category identified in the ESD components as shown in Figure 5.10 in Chapter 5:.

[2] In personal communication with some decision makers, it appears that they believe that food security is the ability of the country to provide food during wars. This misperception may affect the decisions with regard to food security in the country and the export of seafood products.

6.3.1.1 Nutrition

Normally, and in the majority of cases, annual landed catch and diversity of landed catch are used as indicators of food quantity and variety (Chesson and Clayton 1998). As discussed in Chapter 2, most of the landing from the trawling sector in the Sultanate (about 80%) exits the country, with no added value, as part of the foreign fishing company's share. Unpublished data (personal communication, October 14, 2006) indicated a decline, from 39% in 1988 to a current level of 20%, in the catch retained by the local companies. The landed catch is not sufficient to support the increase in the population and there is a need to retain more of the catch to be sold in the local market.

As food security exists when all people at all time have physical, social and economic access to sufficient, safe and nutritious food; food insecurity exists when people do not have adequate physical, social or economic access to food (FAO 2003b). In the past few years, the population of Oman has had difficulty gaining access to fish products, suggesting weak domestic food security. This reflects the increase in exports of fish products accompanying high international demand and concomitant high prices. Similarly, the shortage of fish products was also accompanied by high prices on local markets.

Although there are many indicators that can be used to measure food security (Hoddinott 1999; Hoddinott and Yohannes 2002; Riely et al. 1999) or nutrition and marketing as mentioned above, there is a shortage of data that can be used to build such indicators. The obvious market phenomenon of a shortage of fish available for local supply (see Chapter 2), suggests fish per capita to be the best indicator to measure the effect of trawling on the nutrition component. On the other hand, as nutrition or nutritional science by definition includes processes, living body and food (Beauman et al. 2005), exclusion of humans as a part of the indicator will produce a biased judgment. Therefore, retained landed catch and population will be used to determine the indicator for the nutrition sub-component. As per capita fish consumption is a function of catch and population, it will be used as an indicator for nutrition.

Change in per capita fish consumption is an important criterion that relates to the significance of the contribution of fisheries to the livelihood of coastal communities (FAO 1999a). Indeed, the per capita fish consumption is used as an indicator for sustainable development (Bossel 1999), as an indirect pressure indicator on fish resources (Gallic 2003), as socioeconomic indicator for nutrition (UNESCO 2003) and as a food security indicator (Riely et al. 1999).

The data required for per capita fish consumption is: the amount of catch retained by the local companies that is sold in the local markets[3] and the total population of the country.

The preferred trend of this indicator should be positive as a higher share is required to be retained by the local companies in favor of nutrition.

6.3.1.2 Food Variety

Another indicator used for food component in addition to the above food quantity, is diversity of landed catch (Chesson and Clayton 1998; Chesson et al. 1999). Species diversity indices are used for this purpose. Chesson and Clayton (1998), used the Shannon diversity index[4] to calculate the diversity of seafood landed from the fishery and this diversity index along with other indices are used to measure species diversity in ecological communities (Krebs 1989).

The fishery examined in this study is different as the landed species are shared between two fishing companies (foreign and local). The Omani people gain access to only about 20% of the catch, therefore, the seafood diversity here should be the diversity of fish in the share and not the diversity of fish in the total catch. The diversity of catch in the local companies' share is measured as the ratio of species in the share to the total number of species in the total catch of the foreign fishing companies.

The preferred trend of this indicator is positive and the reference point if required will be 1 (maximum standardized index), representing a share of all landed fish species.

[3] Imported fish quantity will not be counted in the calculation of the per capita fish consumption as this study is targeting only the commercial trawl fishery.
[4] Shannon diversity index is discussed in detail in Chapter 7.

6.3.1.3 Domestic Market

As mentioned above, catch retained by the local companies that is sold in the local markets will be used to calculate the per capita fish consumption. The figure will also be used as an indicator to measure the commercial effect of trawling on the domestic market and the amount it contributes in satisfying local market demand which is considered an economic and social indicator.

The preferred trend of this indicator is positive as the local companies are required to retain a higher amount of the share that is sold in the local market to favor nutrition, supply and prices.

If a reference point is required, 20% (the recent share of the local companies) will be used as an absolute value (20% of the total catch).

6.3.1.4 Export

The amount of exported catch will be used as an indicator to assess the contribution of the export component of the trawling sector. The exported catch of the trawling sector is of two kinds. The first is the share of the foreign fishing companies, which is not landed and therefore has no direct contribution to the community[5]. It counts for around 80% and needs to be reduced to allow more direct benefits to the community and to satisfy the local markets. The second is the export by the local companies, which counts for around 20%. This type of export needs to be developed in order to achieve the 5% annual growth as required by objectives of MAF. The following formula explains distribution of the total catch by the commercial trawling sector:

Total Catch = EF + (EL + RL)

Where:

EF: amount of Exports by Foreign fishing companies

EL: amount of Exports by Local fishing companies

RL: amount of fish Retained by the Local companies in the local market

[5] It should be noted that fishers may not receive direct benefits from such export earnings. However, the 'trickle-down' effects of such export activities may exist with limited potential in terms of taxes for the local community.

As this sub-component is intended to assess the food components, the amount of exports by foreign fishing companies will be used as an indicator. Therefore the preferred trend of this indicator should be negative as higher share is required to be retained by the local companies for more benefits to the community and for local markets to be satisfied. This negative trend could be seen as an opposite view to the 5% annual growth required to be gained from the export sector. The reality is that this export has only a commercial price value as a tax paid to MAF and port authority but no added value, which could be gained if this amount is landed. Therefore, its reduction will be consistent with the ESD framework to enhance the economic and the social wellbeing of the community.

6.3.2 Employment

Employment or unemployment rates are good candidate indicators for human benefits and well-being (Chesson and Clayton 1998; Garcia 1996). Different sustainable development frameworks have used them as indicators for both social and economic status of a population (FAO 1999a). They are used as a direction for decision making (Jesinghaus 1999) and could also indicate the effectiveness of the political process. Employment is a source of income and a means for accessing goods and services and it enhances human capabilities, skills and experience (Chesson and Clayton 1998).

Increasing or maintaining employment is a key national socio-economic objective. One of the four objectives of the MAF development plans discussed in Chapter 2 is:

To improve or maintain standard of living and services of the fishing community through for example:

- *Improving career conditions through modernizing traditional sector and Omanization (substituting the foreign employee with Omanis) of the commercial one.*

6.3.2.1 Omani and Foreign Employment

The fisheries sector provided direct employment for 31,587 traditional fishermen in 2003. Another 4,500 people are engaged in fisheries-related activities, such as fish handling, selling, processing and distribution as well as ancillary industries like workshop mechanics and selling of fishing gear and spare parts. The sector is expected to employ around 50,000 fishermen in 2020 compared to a level of 31,587 fishermen in 2003. Although the sector provides direct employment for about 35,000 Omani nationals, or 1.5% of the total population, commercial trawling fails to employ Omanis directly in the fishing operation. There were about 800 foreign fishermen working onboard 31 trawlers in 2004. According to MAF policy under the Omanization objective, foreign labor should be replaced by Omanis. Therefore, to provide employment opportunities for Omanis, the foreign employment figures should decline to zero.

In this study, the number of Omani and foreign employees will be used as indicators for Omani and foreign employment respectively. Therefore, the required data to calculate those indicators are the number of employees working directly in the fishing vessels or indirectly in fishing companies. Although the companies' production also involves the traditional sector, the number of workers will not affect the evaluation as the aim is to investigate the Omanization trend over time.

Data for the number of Omani and foreign personal working in the sector are required for the indicator. A positive trend is required for Omani employment and a negative trend for foreign employment based on the Omanization plan. As a reference point, zero number of foreign personal working in the sector will be used to evaluate the social impacts (in term of employment) of the fisheries management initiatives in Oman.

The employment figure in the Omani youth fishing vessels project created by MAF (see Chapter 2) will be excluded from the indicator calculation. This is because those vessels are not allowed to trawl and indeed, the project is shown to be an enormous failure.

6.3.3 Income

As discussed in Chapter 2, fishing is an important socio-economic activity in Oman as it contributes to the socio-economic well-being of Omani people. Following Garcia and Staples (2000b), income is used as a criterion in the ESD framework to measure the social and economical dimensions. One of the objectives of Vision

Oman 2020 is to increase the annual growth and contribution of the fisheries sector in the national GDP.

Although employment is a good indicator of human benefits and well-being, income is the basis for obtaining goods and services. For humans, income is the acknowledgment of efforts, skills and talents (Anand and Sen 2000). Income is a strong indicator of socioeconomic potential (Bonzon 2000; FAO 1999a; INDECO 2004; Willmann 2000; UNESCO 2003) and also of poverty (UNDESA 2001). Therefore, the distribution of income is considered to be an important issue in developing countries (Jesinghaus 1999; Bossel 1999; UNDESA 2001) and the ratio of average income to poverty level or top to bottom income is of great concern to many researchers (Bossel 1999; UNDESA 2001).

Chesson and Clayton (1998) used the annual gross value of the fishery as an indicator for the income component. This gross value includes different local economic benefits to individuals, companies and the country. It ranges from personal salary, which is not applicable in this sector as fishing is done by foreign fishing companies, to government advantage through taxes and levies. Local fishing companies get landing share of about 20% and the remainder, 80% of the catch, is retained by foreign companies. The 80% gives no benefit to the country and sometimes the entire catch goes directly overseas and therefore there is no added value gained by the country apart from port tax. This compromises income distribution gained by commercial trawling, as profit is the target of any commercial fishing. Relevant costs, such as operating costs, management and research costs should be taken into account when assessing total income (Chesson and Clayton 1998). Other economic benefits that accrue from the provision of services such as fuel, maintenance, engineering, accommodation, meals for crew and any other peripheral services should also be considered.

As there are no local individuals working in this commercial sector, data for the following items are required:

- Annual gross value gained by the local companies from the trawling sector. A positive trend is required and a reference point of the total landing value by trawling will be used when necessary as the objective here is to Omanize the fishing vessels.

- Taxes for MAF, Ministry of Manpower (MM) and Port Services Corporation (SAOG) - the governing body of Port Sultan Qaboos
- Costs[6] associated with fuel, catering and mooring, which include: electricity, water, containers and other operation services[7].

Positive trend is required for the income component and the maximum values of total landings and operation costs will be used as a reference point for the income indicator.

6.3.4 Lifestyle

Fishing can be regarded as a lifestyle profession. One of the four objectives of the MAF view and development plans listed in Chapters 2 and 5 is to improve and steady the living standards and services of the fishing community, which give a direct indication of the lifestyle. Lifestyle component of this framework is divided into: community and fishers, where fishers' component is further sub-divided into traditional and foreign. However, the analysis at this stage will include only community represented by local fishing companies as there are no Omanis working in the foreign sector. Fishing vessels working for the foreign fishing companies will be used to calculate the required reference point in accordance to the Omanizing objective.

Number of fishing vessels is a good candidate indicator (Chesson and Clayton 1998; Chesson et al. 1999) to evaluate the lifestyle effect of commercial trawling. Indeed, it is the only applicable indicator that could be used in this fishery. Lifestyle of the individuals in the community outside the fishing companies could be evaluated using the variety of luxury goods produced by the local fishing companies. However, this will over estimate the effect as most of these goods come through the traditional sector and there is no way to identify the source of products. Therefore, the number of fishing vessels owned by local companies will be used as lifestyle indicator. The number of vessels owned by foreign companies will be used to calculate the minimum reference point to be achieved as the objective here is to Omanize the fishing vessels.

[6] These costs considered to be regional incomes gained by the operating trawlers.
[7] Maintenance is not included, as it is done outside the country.

Positive trend is required for this component, at least up to the total number of fishing vessels, assuming that all vessels are owned by local companies or individuals.

6.3.5 Conflict with Traditional Sector

Although Fletcher, Chesson et al. (2002a) included Indigenous access as an indicator in the ESD framework, this conflict issue is a new direct component in the ESD framework. It highlights the conflict between commercial trawling and traditional fishermen. It involves two issues: the resource access and the legal implication. This component is discussed in Chapter 5 and a negative correlation was found between the demersal fish landings from the trawling sector and those from the traditional fishermen in Al-Wusta, indicating some degree of resource access conflict.

It is important that MAF should pay attention to the management of such conflict between the traditional and the commercial sectors. Article 7.6.6 of the FAO Code of Conduct for Responsible Fisheries (FAO 1995; P. 14) states: *"When deciding on the use, conservation and management of fisheries resources, due recognition should be given, as appropriate, in accordance with national laws and regulations, to the traditional practices, needs and interests of indigenous people and local fishing communities which are highly dependent on fishery resources for their livelihood."* One of the MAF objectives and policies of the fisheries sector stated in the 7th five year plan (2006 – 2010) is to reinforce the contribution of fishermen in the management and development of the fisheries sector. This indicates the preference of traditional fishermen over commercial when conflict takes place. This is because 80% of the fisheries' contribution comes from the traditional sector. It should be noted that small-scale fisheries are the main source of both protein and income for large parts of the coastal population and that the large-scale trawlers are operating close to coastal waters and not in open water (Hempel and Pauly 2002).

As stated by Staples et al. (2004), policies that have promoted increased economic growth at the national level have tended to favor the development of large-scale approaches over small-scale ones. A consequence is that the resources tend to become concentrated in fewer and fewer hands, as exemplified by Omani fisheries.

Although the conflict component is a new addition to the ESD framework, literature review suggests some social indicators that could be used to asses this component. FAO Code of Conduct suggests a community's empowerment and/or co-management (participation) as a social indicator. A good example of such social involvement worthy of investigation is the case of the Maoris, New Zealand's indigenous people (Bess 2001). This could be an excellent indicator for measuring sustainability especially as the local communities in Oman are involved in an indirect way in the management of the fisheries (Senat Al-Bahar, see Chapter 2). However, events show significant limitations of these committees suggesting a failure in their uniting with management.

The candidate indicator that will be used to evaluate this conflict component is the number of cases of conflict and breaches, which are brought to court. Therefore the data required to initiate this indicator will be the number of cases, with a negative trend and a reference point of zero.

6.4 Effects on Environment

The effect of the commercial trawling sector on environment is divided into three components: effects on the primary commercial species, effects on non-target species and effects on other aspects of the environment. In general, as in the case of most developing countries, this part and especially the third component, suffers a shortage of available data required to initiate indicators for the evaluation process. This limitation was intended to be addressed by the detailed information gathered by Vessel Monitoring System (VMS) introduced in 2001. However, some of the VMS data was found to be erroneous.

As with any classification scheme, ambiguity is expected to occur in this part of the framework due to the intensive components of marine ecosystems and related issues (Chesson and Clayton 1998). Although such ambiguity is expected to happen with rich fishery data but not with a poor fishery such as this, it will be reduced to its lowest level by systemizing the components and their associates to prevent duplication of any species or effect. One good example of this ambiguity is the classification of the catch to either primary commercial species or non-target species, which will be discussed in the following sections.

As stated above, commercial trawling is the targeting of fish species for commercial gain. Although it targets specific commercial species, trawling affects the ecosystem as a whole. By affecting fish biomass directly through removal of the target species, fishing gear also affects population structure, causes genetic shifts, alters predator prey relationships and results in behavioral changes (Chesson and Clayton 1998). Thus the classification of effects on the environment relates to primary commercial species, non-target species and other aspects of the environment as shown in Figure 5.10 in Chapter 5.

6.4.1 Primary Commercial Species

This component covers the effects of the Omani commercial trawling sector on the distribution and abundance of the targeted species. The trawling sector mostly targeted the high value demersal species although it produces a lot of discards as discussed in Chapter 5.

The statistics book issued by MAF each year shows a standard and fixed form of data sheet used to display the catch and value of the fisheries sector. This sheet is organized according to the common Arabic names and their relevant English names as shown in Table 6. 1. Appendix 3 shows the detail of a typical sheet.

Although a demersal trawling, it also catches large and small pelagic species in addition to cuttlefish and some elasmobranches (Table 6. 1). There are a total of 26 categories, three of them are groups of fishes and one is a group of unidentified fishes. As this fishery targets demersal species, fishes listed in Table 6. 1 as demersal - except for the category 'other' - in addition to cuttlefish, will be classified as primary commercial species. All other fishes will be classified as non-target species.

As stated by Chesson et al. (1999), UNDESA (2001) and Potts (2003), annual catch by major species is the most used data for establishing indicators for this component. It is worthy to note that this kind of data is the only available data for the commercial trawl fishery. This data is used to build a true picture of the status of species stocks based normally on biological population parameters such as Maximum Sustainable Yield (MSY) as reference points (FAO 1999a; Garcia 1996; Simon 2003). Fisheries with poor data and multi species rely on semi-qualitative indicators to build efficient management decisions. Chesson and Clayton (1998) used annual catch by major species to develop a semi-qualitative indicator to account for a variability of assessment of different species, which is almost identical to the fishery in this study. They classified the status of each species for each year as acceptable, not acceptable or unknown based on the available information. Then, and to reduce the risk of developing an indicator which would respond to improvements in information rather than to changes in stock status, cases classified as unknown were re-classified to either acceptable or unacceptable based on classifications in later years. Chesson and Clayton (1998) classified the status of the species in their study based on some available information, missing in this study. Therefore, a biological reference point is required to classify the catch of each fish group to either Accepted (A) or Unaccepted (U) depending on the reference point. The preferred trend here is a positive proportion of accepted catch status over the unaccepted. The reference point required for such classification is discussed in Chapter 7.

Table 6. 1 Fish common names as described in the Omani fisheries statistical book

Large Pelagic	Small Pelagic	Demersal	Sharks & Rays
Yellowfin tuna	Sardine[4]	Emperor	Sharks
Longtail tuna[8]	Indian Oil Sardine[4]	Seabream	Rays
Kawakawa[4]	Indian Mackerel	Groupper	
Striped bonitto	Anchovy[4]	Crocker	**Crustaceans**
Frigate tuna[4]	Small Jacks	Sweetlips	Lobster[4]
Skipjack[4]	Mullets	Snapper	Shrimp[4]
Other tuna[4]	Needlefish[4]	Jobfish	Cuttlefish
Kingfish	Other	Rabbitfish	Abalone[4]
Queenfish		Catfish	
Barracuda		Ribbonfish	**Unidentified Fish's**
Cobia[4]		Other	
Sailfish[4]			
Large Jacks			
Other			

6.4.2 Non-Target Species

This component includes many environmental effects ranging from direct effects on fish, mammals, reptiles and invertebrates to indirect effects such as community interaction and modification or disruption of natural behavior. However,

[8] Not caught by trawlers during the past 10 years

there is a shortage of data covering such complexity of environmental and biological interaction. The available data covering this part is only for the amount of discarded catch and the number of turtles killed during fishing operations as direct effects, and the relation between the discards and structure of marine communities and changes in biodiversity as indirect effects.

6.4.2.1 Direct effects

Following Chesson and Clayton (1998), the amount of catch that is either retained or discarded is used as an indicator of the direct effects of the trawling sector on the non-target species. For this fishery, total amount of discarded catch and number of turtles killed should be used as data sources to build indicators for this component. A negative trend is preferred for both indicators. There is no other data available for more direct effects on non-target species.

6.4.2.2 Indirect effects

Catch of non-target species effects the environment in two different ways as identified in the ESD frameworks. It could have a short term positive effect such as a affecting a food source (energy subsidy) for different marine organisms for example a scavenger including charismatic types including dolphins and birds. However the main effects are of a negative nature and impose on marine communities and the interaction of their relationships. It includes modification or disruption of the natural behavior of any related species. Reduction of discards, if consistent with ESD, will in the end, have negative effects on species which are dependent on discard as a source of food.

Although this component is complex and shows multipart connection, the availability of data makes the choice of indicator much easier. Therefore, the total catch (retained and discarded) of all species (target and non-target) will be used as an indicator to evaluate this component with a negative preferred trend (further details are shown in Chapter 7).

6.4.3 Other Aspects

The field observation carried out by the researcher indicates extensive marine pollution and environmental damage caused by the trawlers. Trawl gear, as identified by Jones (1992), affects the environment in both direct and indirect ways. Direct effects include scraping and ploughing of the substrata, sediment resuspension, destruction of benthos and dumping of processing waste. Indirect effects include post-fishing mortality and long-term trawl-induced changes to the benthos (Jennings and Kaiser 1998). Recovery rates can vary greatly between different habitats, gear used and areas that experiences different levels of natural disturbance (FSBI 2004). The trawled area of this study is characterized by strong water currents such as the Somalia current and the upwelling phenomena driven by monsoon winds, (Varghese and Somvanshi 2001), which means that the recovery from fishing effects can be as short as several days or up to several weeks (FSBI 2004). However, defined areas that are fished in excess of three times per year are likely to be maintained in a permanently altered state (Collie et al. 2000).

6.4.3.1 Marine landscape and productivity

Although there are many negative practices imposed on the marine environment, the area trawled (Chesson and Clayton 1998; Chesson et al. 1999; Ward et al. 1998) and trawling intensity (Hiddink et al. 2006) are the only two possible criteria that can be used to measure the effects on the marine landscape and its components. On the other hand, the level of CPUE will be used as an indicator of marine productivity, considered as a function of stock productivity and fishing effort.

As discussed in Chapter 5, significant fluctuations in effort and a trend to concentrate fishing in specific fishing grounds occurred in the fishery, which increased the time required for the ecosystem to recover. This fluctuation and fishing behavior will reduce the effectiveness of the use of 'area trawled' as an indicator to assess the effects of trawling on the marine landscape. In addition, VMS data was found to contain some errors as well as missing information thus weakening the indicator. Also, only six years of data was available not date covering for the entire ten year study period. Therefore, and to cope with the inefficiency of the trawling geographic spread option (Ward et al. 1998), fishing effort (fishing days) will be used as an indicator for trawling intensity.

Negative trend is required for trawling intensity (fishing days) and positive trend for the stock productivity (CPUE) with minimum and maximum reference points respectively.

All identified components of the Omani commercial trawling sector ESD and their indicators, required data, preferred trend and reference point are summarized in Table 6. 2 and Table 6. 3.

6.5 Conclusion

As discussed in Chapter 4, one of the key steps involved in the development of the SDRS is the selection of appropriate indicators which are capable of measuring characteristics of the human-environmental system over time. The measurement of such characteristics is important to ensure the functionality of the human-environmental system far into the future.

Thus, following the necessary steps in the development of SDRS, the main objectives of this chapter were to develop appropriate sustainability indicators to measure the achievement of operational objectives corresponding to the main sub-components of the proposed ESD framework as discussed in Chapter 5. According to the existing literature, the effectiveness of indicators depends on factors including accuracy in their measurement, capacity to reflect fairness by incorporating values and beliefs of key stakeholders and their policy relevance to decision makers (UNDESA 2001; INDECO 2004; FAO 1999a).

It should be emphasized that developing indicators is a challenging task. However, the developers should keep in mind that indicators are symbolic representatives and are designed to communicate effectively and help in making sound decision. Keeping this simplistic view in mind and following discussion and consultation reviews with relevant stakeholders, suitable indicators were identified following the SDRS and the ESD framework. These indicators will be used as inputs into the assessment process regarding the progress of each component with respect to its objective. This quantitative assessment process will be conducted using the Multi-Criteria Analysis (MCA) in the next chapter.

It should be noted that some of the identified indicators are not used in the analysis as they suffered from measurement error. However, they are listed as potential indicators for future consideration.

Table 6. 2 Indicators used for each component of the effects of Omani Commercial Trawling Sector on Humans.

Component	Indicator	Required data	Preferred trend	Reference point
Food				
Nutrition	Fish per capita	▪ Amount of catch retained by local fishing companies that is sold in the local markets ▪ Total population	Positive	-
Food Variety	Catch diversity of the local fishing companies	▪ Number of fish species local fishing companies share ▪ Number of fish species foreign fishing companies share	Positive	1
Domestic Market	Amount of catch retained by local fishing companies that is sold in the local markets	Amount of catch retained by local fishing companies that is sold in the local markets	Positive	20% of total landed catch
Export	Share of foreign fishing companies	Amount of landing exported by foreign fishing companies	Negative	-
Employment				
Omani	Number of Omanis employed in the fishery	Number of Omani employees	Positive	Total number of personnel working in the sector
Foreign	Number of foreigners employed in the fishery	Number of foreign employees	Negative	0
Income	Annual gross value of the fishery	▪ Annual catch value gained by local fishing companies ▪ Taxes ▪ Operation costs	Positive	-
Lifestyle	Number of vessels	Number of fishing vessels owned by local fishing companies	Positive	Total number of vessels
Conflict with traditional	Number of conflict cases	Number of court cases between the commercial trawling sector and traditional fishermen	Negative	0

Table 6. 3 Indicators used for each component of the effects of Omani Commercial Trawling Sector on Environment.

Component	Indicator	Required data	Preferred trend	Reference point
Primary commercial species	Proportion of accepted CPUE status	▪ Annual catch by major species ▪ Fishing days	Positive	1
Non-target species				
Direct				
Discards	Amount of discarded catch	Amount of discarded catch each year	Negative	-
Turtle	Number of killed turtle	Number of killed turtle each year	Negative	0
Indirect	Total catch (retained and discarded) of all species	Annual catch by commercial trawling	Negative	-
Other aspect				
Marine landscape				
Area	Stock productivity	CPUE	Positive	-
Intensity	Trawling intensity	Fishing days	Negative	-

CHAPTER 7: PROGRESS OF THE TRAWL FISHERY'S ESD COMPONENTS: MULTI-CRITERIA ANALYSIS RESULTS AND DISCUSSION

7.1 Introduction

The main objective of this chapter is to assess progress over time with respect to the specified objective(s) under each component of the ESD framework described in Chapter 5, using the selected list of indicators described in Chapter 6. This assessment is carried out with respect to each component's objective(s) toward sustainability using the Multi-Criteria Decision Analysis. Furthermore, this chapter provides the justification for preferred trends of selected indicators and describes the standardization process and a method of calculating a score for each component. It should be noted that in the absence of any reference point for a particular indicator, an attempt was been made to estimate it based on data available.

The results of this chapter will be considered a base case scenario as no priority was given to one component over another.

7.2 Data Source and Software

The data used in this chapter was obtained from books of statistics from the Omani Ministry of Agriculture and Fisheries (MAF) from 1992 to 2006; Port Services Corporation (SAOG) - the governing body of Port Sultan Qaboos; and seven local fishing companies working in the trawling industry. Official letters were provided by the concerned authorities to facilitate the process of gaining access to the statistical data of the fishing companies. Appendix 4 shows two examples of such letters.

Following Communities (2000), ESD components were standardized for the entire period. The best indicator value was given the highest score of 100 and the remaining values were scored relative to it. According to the standardization process, the selected best value for each indicator was given the highest score of 100 on a preference scale of 0-100 used by Communities (2000). It should be noted that the desired choice of best value for each indicator was based on the corresponding objective(s) identified in Chapter 6 that is(are) regarded as being consistent with ESD. For example, the highest score (100) is assigned for the best (maximum) value of the nutrition indicator as it is the highest amount of fish per capita that is desired, whereas in the case of export indicator, the highest score of 100 will be assigned for the best (minimum) as it is the lowest foreign fishing companies share that is desired.

The score for a given ESD component was calculated as the weighted sum of its sub-components' standardized scores using the formula provided by Chesson and Clayton (1998) and Communities (2000):

$$\sum_{j=1}^{n} w_j u_{ij} \qquad \textbf{(7.1)}$$

Where:

j: represents ESD component

i: represents time

w_j: the weight for component j

u_{ij}: the score for component j in year i

As mentioned earlier as a base case scenario, all criteria and components were weighted equally. Therefore, the weighted summation method for a component or a sub-component is simply the average of their criteria. For example, the weighted summation of food component for a particular year will be the average of its sub-components: nutrition, food variety, domestic market and export standardized score for the same year.

Hiview software ® version 3.1.0.5 (a Multi-Criteria Decision Analysis - MCDA) is used in the appraisal and evaluation of the progress along with Microsoft Excel software ® for some calculations and statistical testing. The Hiview package is a tool used to support the appraisal and evaluation of this study's options. It has the capacity to solve large and complex MCDA problems and it allows the value tree to be both visually created and edited (Communities 2000). A variety of graphical input displays is available for data input, comparisons of options and efficiency presentation (see Figure 7. 3 and Figure 7. 4). It also provides a mechanism for sensitivity analysis and therefore can incorporate uncertainty by constructing scenarios for various possible values of uncertain parameters.

Hiview software is built on a value tree of criteria, equivalent to the ESD hierarchal structure of this study. The top of the value tree is called the Root Node, which acts as the focus for the final decision, where all the data in the model is collated (Catalyze 2003). The Root Node (main node) branches out to nodes representing objectives, grouping the criteria. Since this study assesses the progress of a trawl fishery over time, the Root Node will focus on the 'year' for making final decisions. Criteria are then structured under the nodes: effect on human and effect on environment, which, as shown in Figure 7.1, occasionally has other nodes.

Two types of weights appear in the graphical displays of the Hiview. The first is the original weight given for the criteria to represent the priority of one over another. This will be adjusted for sensitivity analysis purposes. This weight could be any figure, but has to preserve consistence in scaling. The second is the cumulative weight, which is constructed by the Hiview based on the original weight. The sum of cumulative weights for a criterion under a node will give the cumulative weight of that node and so on until, for example, it will finish with an equal weighting of 50 for the effect on humans and 50 for effect on the environment, giving a total of 100, the highest score used in weighting method.

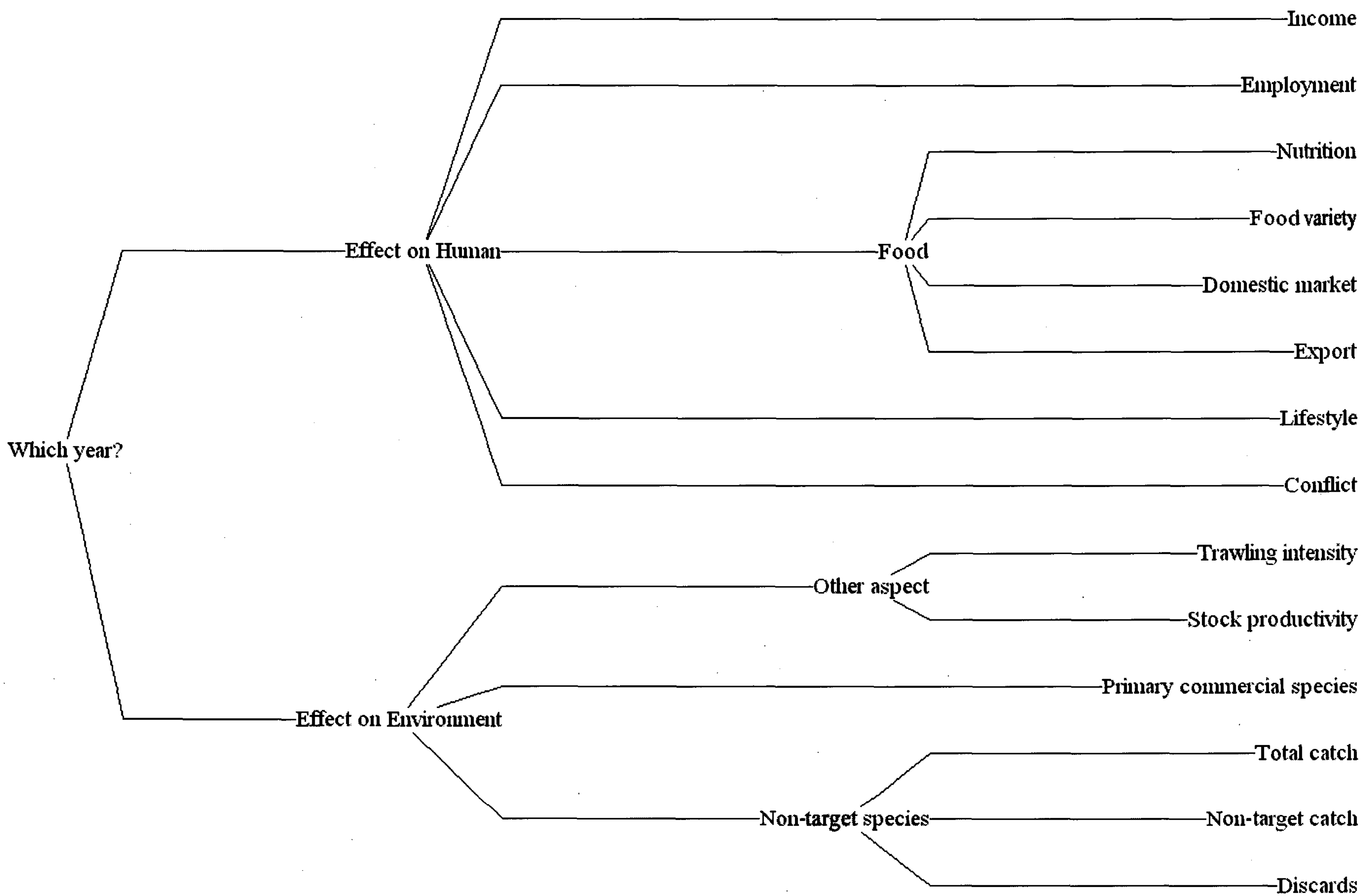


Figure 7. 1 Criteria value tree

7.3 Effect on Humans

7.3.1 Food

In Chapter 6, food was classified into four sub-components: nutrition, food variety, domestic market and export. Retained landed catch and the population size were identified to be used to determine the indicator for nutrition (quantity) and food variety (quality) sub-components. Per capita fish consumption (calculated using consumed catch and population size) is used as an indicator for quantity of seafood, where diversity of landed catch is used as an indicator of the quality of seafood.

In this study, per capita fish consumption is calculated from the trawl catch, retained at the local market that is available for local consumption. It should be noted that using retained catch for the calculation assumes that there is no loss of fish due to poor handling during harvesting and processing. Following Al-Oufi (1999), a generic flesh yield coefficient of 70 % was employed to calculate available fish quantity for human consumption. The following formula was used to calculate per capita fish consumption:

$$\text{Per capita fish consumption} = \frac{\text{Fish Quantity}}{\text{Total Population}} \qquad \textbf{(7.2)}$$

Where: fish quantity (flesh available for consumption after processing) is the amount of catch retained in the local market multiplied by 70% generic flesh yield coefficient.

As discussed in Chapter 6, the trend for the per capita fish consumption indicator for the nutrition sub-component covering the period 1997-2006 is preferred to be positive. Figure 7. 2, Figure 7. 3 and Figure 7. 4 generated by the Hiview software show standardized data and scoring process relative to the preferred value of the nutrition sub-component. It can be seen that the highest score (100) (Figure 7. 3) is assigned the value (0.157 kg) (Figure 7. 2) corresponds to the year 2000. The other preference values are relative to the year 2000. Similarly, it should be noted that the lowest value (0.017 kg) corresponds to the lowest preference value (10.828) in 2001[1]. This reflects the fact that there was a sharp reduction in the amount of catch retained by the local market in 2001. See Table 7.1 for details on data and preferred score for the nutrition component.

The vertical scale in Figure 7. 2 and Figure 7. 3 represents the rank location of years (arranged as options) for score presented in Table 7. 1. The third column in Figure 7. 2 represents the data value associated with the corresponding year while the third column in Figure 7. 3 represents the linear transformation of those data values to a 0 t0 100 preference scale (see Table 7. 1). Another way of presenting values or scores of option is through a bar chart as shown in Figure 7. 4, where the y-axis and x-axis represent preference values and years respectively.

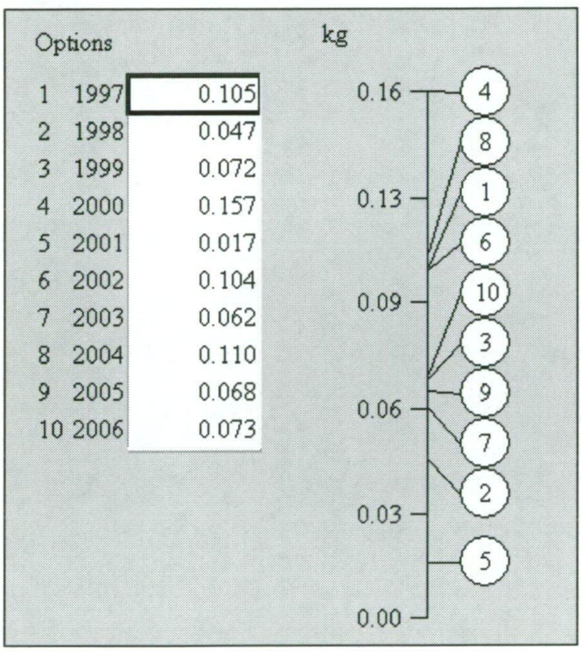


Figure 7. 2 Nutrition criterion data for food component

[1]A score of zero on a relative scale does not necessarily mean that the criterion has no value. This indicates that it is least preferred.

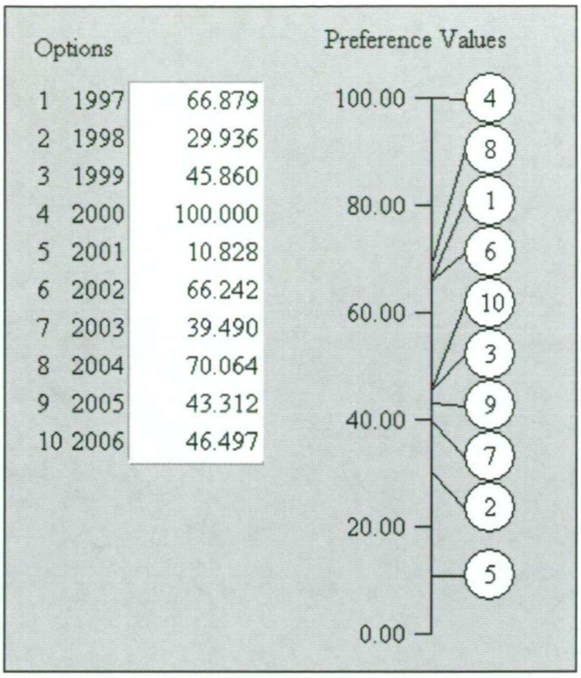


Figure 7. 3 Nutrition criterion score for food component

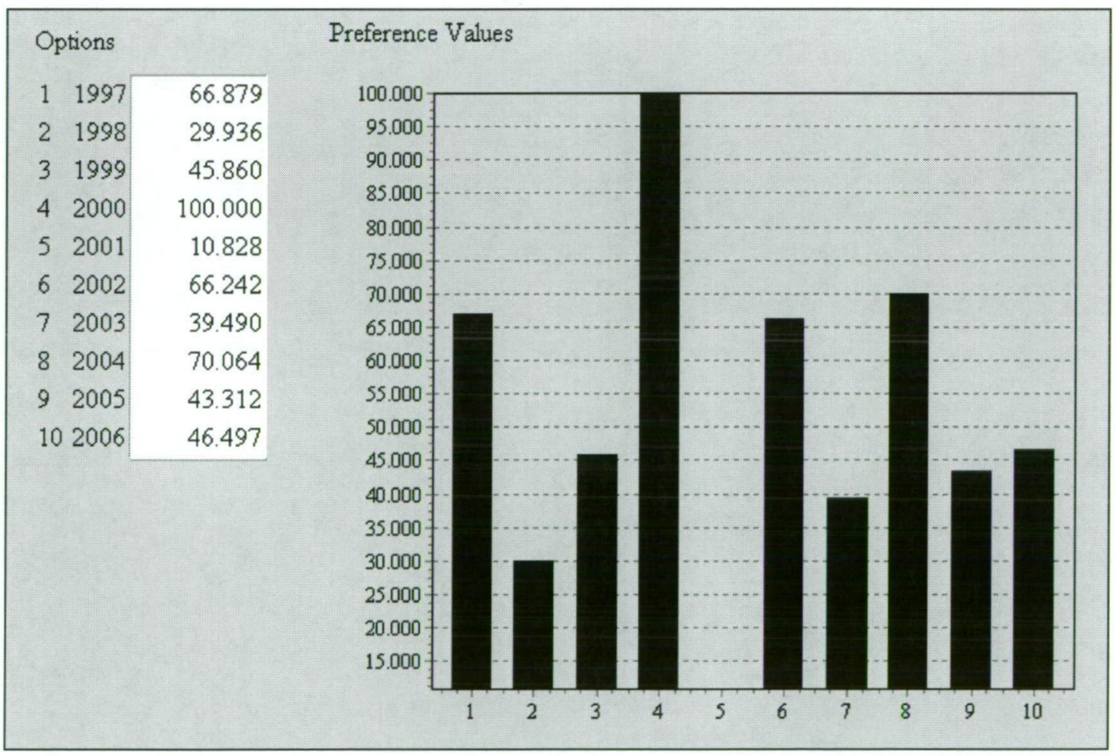


Figure 7. 4 Preference values (scores) of nutrition criterion of food component

As an indicator of food variety, the diversity of landed catch is calculated using the most common tool called Shannon diversity index (Shannon and Weaver 1949), which is sometimes mislabelled the Shannon-Weaver function (Krebs 1989; Spellerberg and Fedor 2003). Shannon diversity index is frequently used to calculate the diversity of a community, however in this study; it is used to calculate the diversity of the landed catch. Chesson and Clayton (1998) have used the same index for the same purpose. The following formula was used to calculate the index (H):

$$H = -\sum_{i=1}^{n} P_i Ln(P_i) \qquad \textbf{(7.3)}$$

Where:

n: Number of species

P_i: The proportion of ith species in the total biomass

A numbers of species, ranging from 16 recorded in 1999 up to 26 in 2006, contribute to the diversity of the food in the study. The calculated numbers for the Shannon diversity index figures for the period 1997-2006 are presented in Table 7.1. As mentioned in Chapter 6, the preferred trend of the food variety indicator (Shannon diversity index) is positive as it is the higher figure that is required. Figure 7. 5 shows the preferred values of the food variety criterion of the food component. It should be noted from Figure 7. 5 and Table 7.1 that the year 2004 scored the best value (100) with the highest Shannon diversity index number (2.368) compared to the year 2001, which scored the lowest (66.6) with the lowest index (1.577). This was due to the sharp reduction in the number of landed fish species. See Table 7.1 for details on figures and preferred score of food variety criterion.

The catch that is retained by the local companies and is sold in the local markets is used as an indicator to measure the commercial effect of trawling on the domestic market and the amount it contributes toward meeting the market demand. The preferred trend of this indicator is positive as the local companies require a higher amount of the share that is sold in the local market be retained to maintain nutritional requirements, a good supply and reasonable prices. Figure 7. 6 shows the preferred values of the domestic market criterion of the food component. It can be seen that the year 2000 scored the best value (100) with the maximum amount of catch retained by local market (538.370 mt) compared to 2001, which scored the lowest (11.13) with the lowest amount of catch (59.922 mt). This was also due to the sharp reduction in the total catch. See Table 7.1 for details on figures and preferred score of domestic market criterion.

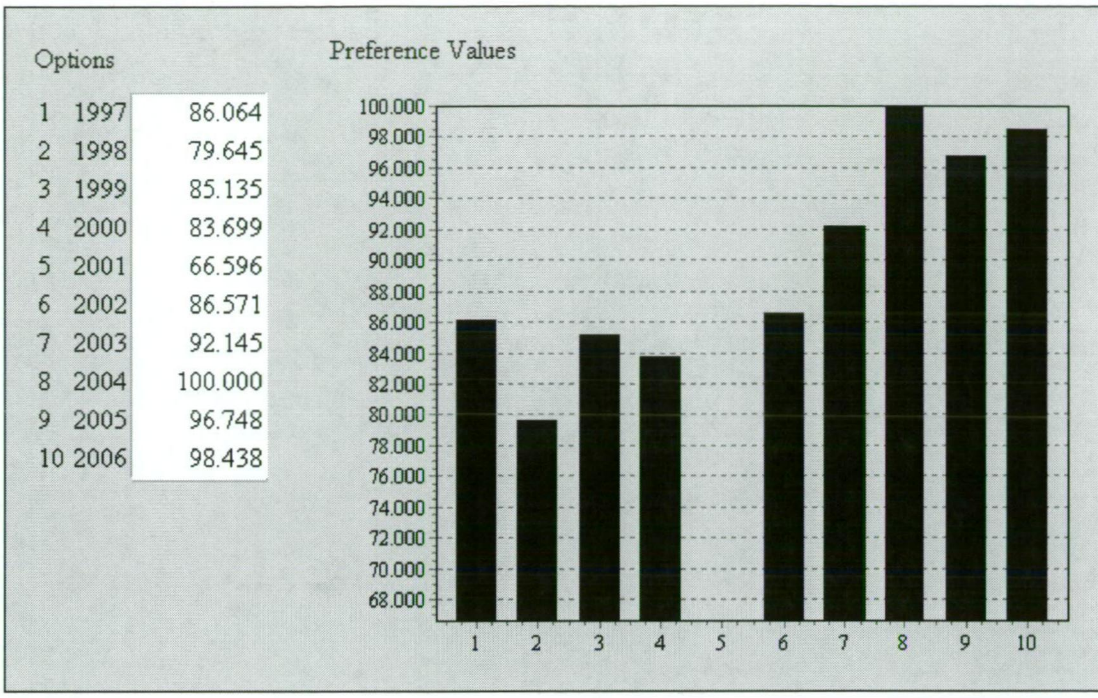


Figure 7. 5 Preference values (scores) of food variety criterion of food component

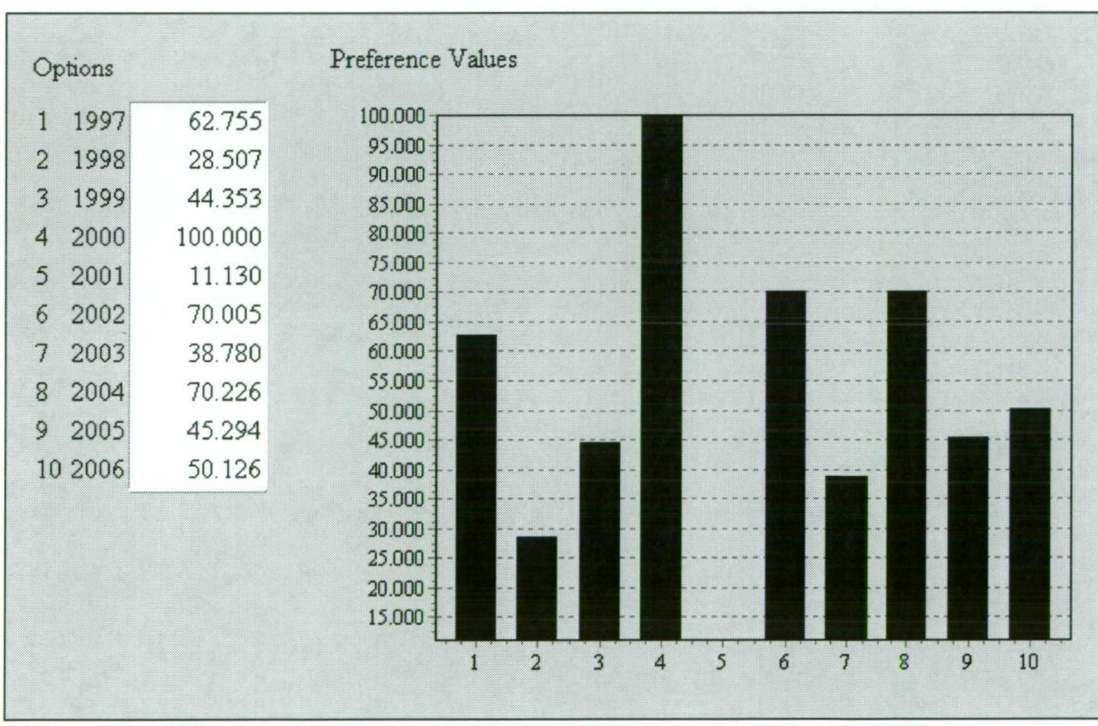


Figure 7. 6 Preference values (scores) of domestic market criterion of food component

The foreign fishing companies' share of around 80 %, which is not landed and therefore has no direct benefit to the community, is used as an indicator for the export component. The only benefit from this component is the port tax, which is included in the income component. The share needs to be reduced to gain more direct community benefit and to satisfy local market demand. Its reduction will be consistent with the ESD framework as it enhances the economic and social well being of the community. Therefore, the lowest figure will represent the most preferred indicator value. Figure 7. 7 shows the preferred values of the export criterion of the food component. It can be seen that the year 2001 scored the best value (100) with the minimum amount of foreign fishing companies share (2205.446 mt) compared to 1997, which scored the lowest value (10.1) with the highest amount of share (21817.158 mt). This preferred reduction in the share was due to the sharp reduction in the total catch. See Table 7.1 for details on figures and preferred score of domestic market criterion.

The weighted summation method mentioned in Section 7.2 was used for all criteria of the food component. Score 100 always represented the most preferred criterion and in this base case scenario, as mentioned above, all criteria have the same weight as there is no preference of one criterion over another. Figure 7. 8 shows the data, weight scores of food component and contribution of each criterion for every year for the 10 year study period.

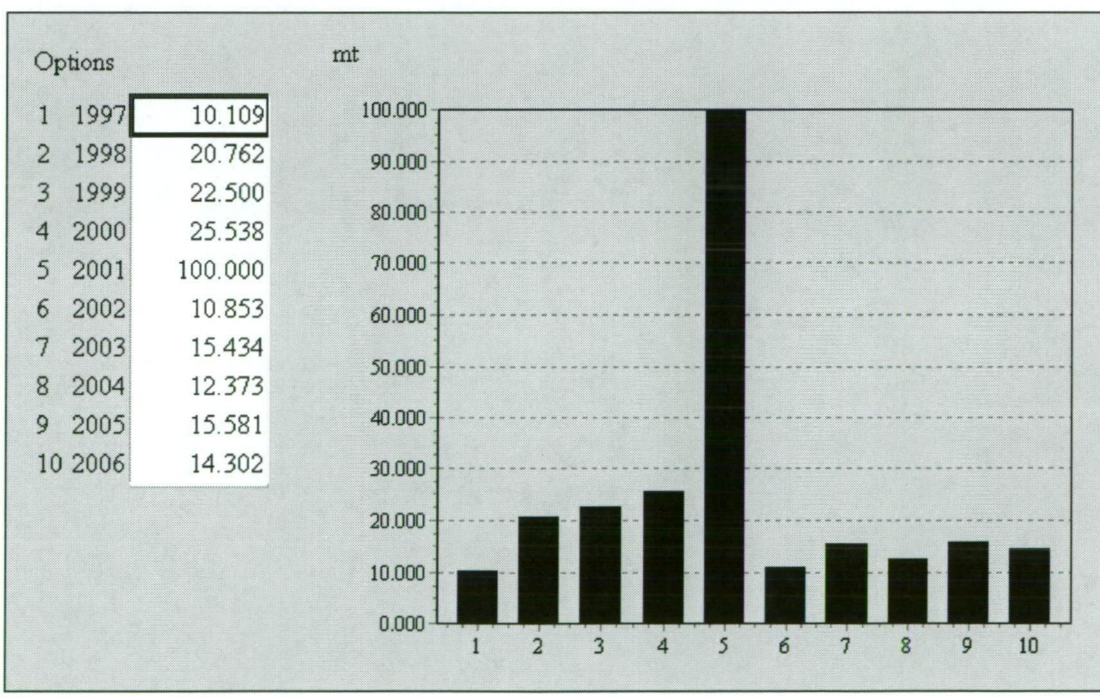


Figure 7. 7 Preference values (scores) of export criterion of food component

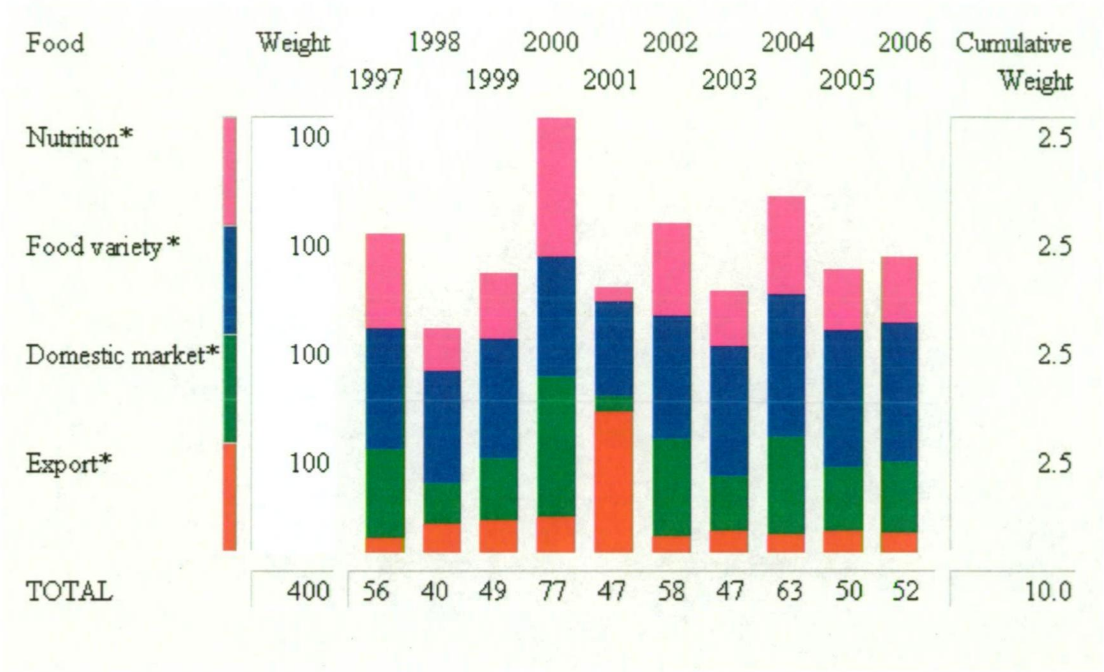


Figure 7. 8 Weight scores and criteria contributions of food component

Note: It should be noted that the sum of the criterion weights is 400 as depicted in the last row of the above figure. This is because all criteria under the food sub-component were given equal weight (i.e. 2.5% each) under the base case scenario, which is listed in the last column of the figure. The Hiview Software calculates the weighted average figure for each year for the food sub-component according to the criteria value tree presented in Figure 7. 1.
For example, the total figure (56) for the year 1997 is calculated as follows:
[66.879 (Figure 7. 3) * 0.25] + [86.064 (Figure 7. 5) * 0.25] + [62.755 (Figure 7. 6) * 0.25] + [10.109 (Figure 7. 7) * 0.25] = 56.45.

As can be seen from Figure 7. 8, being a base case; nutrition, food variety, domestic market and export criteria have identical weight (see left-hand column) and cumulative weight (see right-hand column). The weight score could be any figure, but has to be equal for all criteria representing equal preference. However, the cumulative weight is built by Hiview software based on the above components (or Nodes in Hiview term). It can be seen that the country has achieved a good food trend in 2000 followed by 2004. This means that the management measures employed in those years have favored food component compared to that of 1998. It should be noted that different management regulations were introduced in 1998 as discussed in Chapter 2.

7.3.2 Employment

As indicated in Chapter 6, the number of Omani and foreign employees will be used as indicators for Omani and foreign employment respectively to measure human benefits and well-being. According to MAF policy, foreign labor should be replaced by Omanis. Therefore, to be consistent with the policy, the foreign employment figures should decline to zero. For standardization purposes, this makes the highest number for Omani employees and the lowest figure for the foreign employees as the preferred figures. Therefore, the percentage of Omani employees as part of the total is the standardized index for this component (see Table 7.1) with maximum Omanization level (100%) as preferred value (Figure 7. 9).

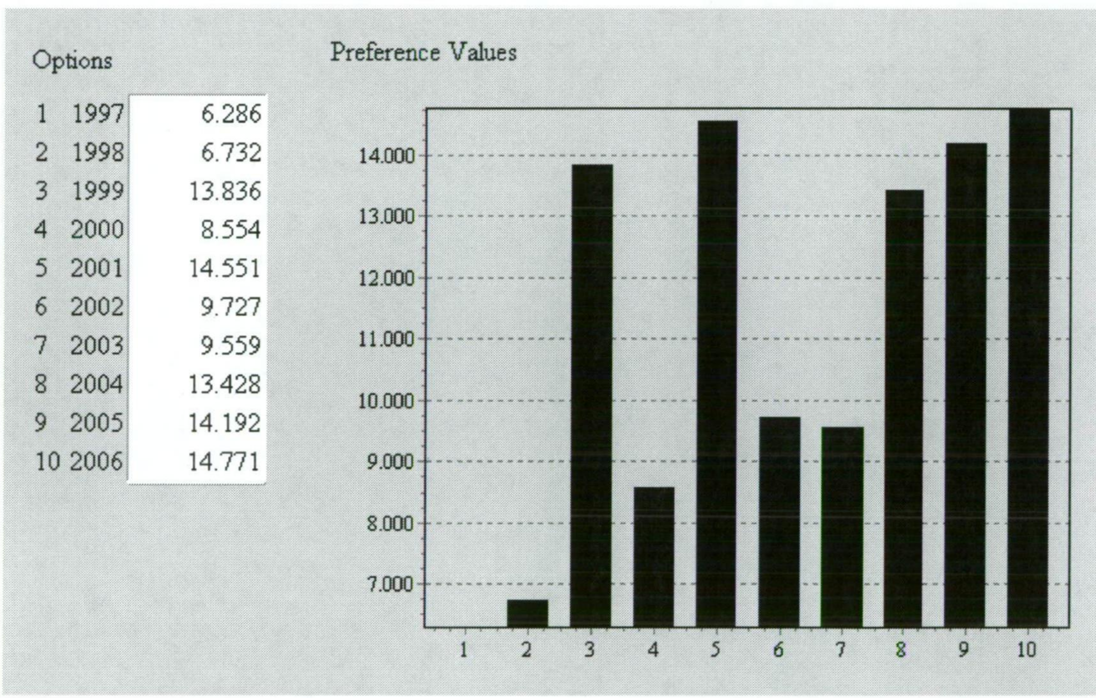


Figure 7. 9 Preference values (scores) of employment criterion

Figure 7. 9 shows the preferred values of the employment criterion. It can be seen that the year 2006 scored the best value (14.771) with the highest percentage of Omani employees in the sector compared to 1997, which scored lowest (6.286) with the lowest percentage of Omani employees. However, the Omanization plan in this sector did not progress well compared to a 90% increase in the banking sector in 2006 (MMP 2007) and 23.2% in all private sectors in 2005 (MNE 2007b). The increase in 1999 was due to a 60% increase in Omani employees and reduction in the number of foreign fishermen due to the reduction in fishing vessels. However, the increase in 2001 was mainly due to reduction in the fishing vessels, related to the

introduced fishing regulations. There was good progress in relation to the number of Omani employees working in the sector from 2004 onward (see Table 7.1 and Figure 7. 9). This improvement was only in the administrative and processing sectors of the trawl industry, while there was no record of a single Omani employee in the fishing and sailing sectors as all crew were foreign nationals.

7.3.3 Lifestyle

As identified and discussed in Chapter 6, the only available indicator for lifestyle criterion gained from the trawling sector is that of the number of fishing vessels. The majority (from 72% to 100%) of the vessels are owned by foreign companies. On the other hand, MAF has an Omanization plan to replace those foreign owned vessels with Omani owned one. Therefore, the percentage of Omani owned vessels to the total is the standardized index used for this component (Table 7.1) with maximum Omanization level (100%) as preferred value (Figure 7. 10).

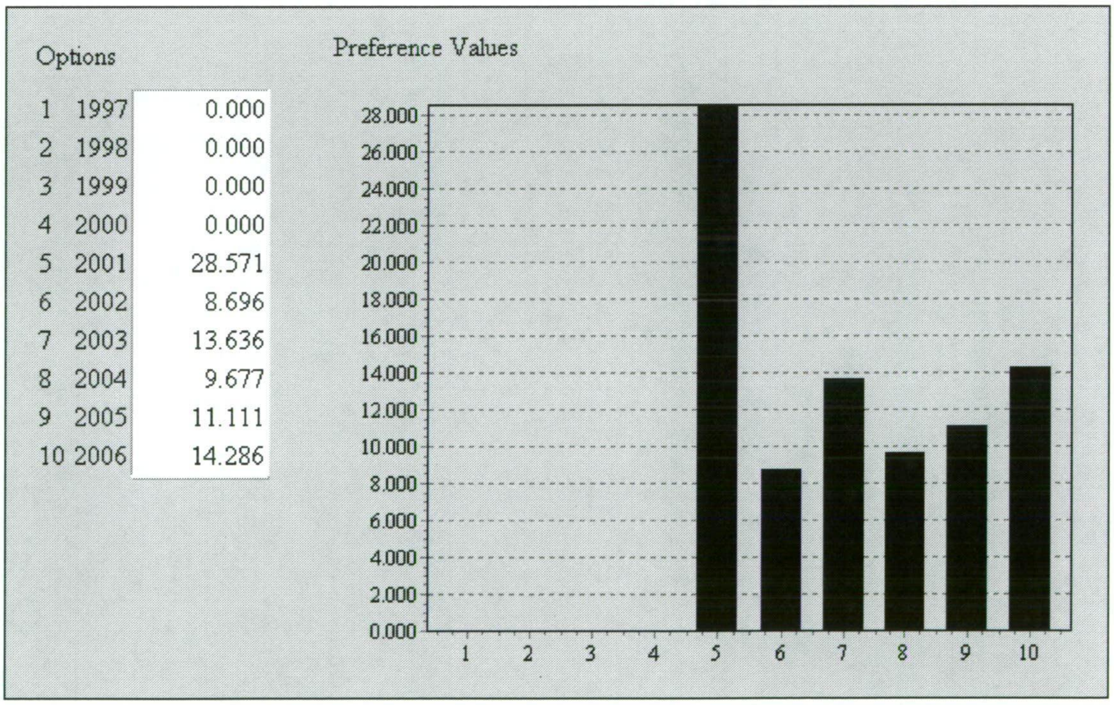


Figure 7. 10 Preference values (scores) of lifestyle criterion

Figure 7. 10 shows the preferred values of the lifestyle criterion. It can be seen that compared to other years from 1997 to 2006, the year 2001 scored the best value (28.571) with the maximum percentage of Omani fishing vessels in the sector. It should be noted that during the period 1997-2000, there was no single Omani owned fishing vessel in the sector. Two Omani fishing vessels commenced fishing in

2001 followed by another in 2003 and yet another in 2005 totalling only 4 vessels up to 2006. They are however, still operated by foreign fishing companies with completely foreign crew. The sharp increase in the percentage of Omani vessels in 2001 was due to the decline in the number of foreign vessels resulting from the new fishing regulations. The introduction of two Omani vessels contributed to the effect and 2001 scored the highest value for this criterion.

7.3.4 Income

As stated in Chapter 6, annual gross value production gained by the industrial trawling sector will be used as an indicator for the income component. This annual gross value production as used in this study is a summation of the following parts:

1. Local fishing companies share value, which counts for around 20% of the total catch value.
2. 12% and 1.5% royalty for MAF and research fund respectively from the total catch value based on the following tariff base:
   - 500 Omani Rial (OMR) per ton for Sharks, Ray and Crustacean
   - 250 OMR per ton for demersal fishes
   - 200 OMR per ton for large pelagic fishes
   - 100 OMR per ton for small pelagic fishes
3. MAF vessel license based on:
   - Horse power at rate of 0.1 OMR per horse power.
   - Crew at rate of 21 OMR per individual
4. Port entry license at rate of 1000 or 2000 OMR per vessel dependant on where the vessel obtains fuel.
5. Port tax at rate of 1 OMR per released metric ton.
6. Berthing and harbor tax at rate of 297 and 11 OMR per vessel per day respectively[2].

[2] There was no data available for numbers of days vessels spent in port. It was assumed that a vessel will spend an average of 3 days landing, provisioning and on other services each fishing trip. This assumption was based on personal communication with officers in SAOG and MAF.

Data on fuel, catering, water, electricity and containers costs was not available and therefore not included as having flow on economic benefits to the community in this indicator. This was considered as a limitation to the construction of this indicator. However, risk is minimized as the figures were standardized based on the preferred reference point (the highest figure gained within the study period) so the trend with respect to the reference point is the main focus. As mentioned in Chapter 6, neither vessel maintenance nor repairs were included as an economic benefit because they are undertaken outside the country. Table 7.1 and Figure 7. 11 show data and preferred score for the income criterion. Calculation method of all economic benefits and their standardized score for the income criterion are discussed in detail in Appendix 5.

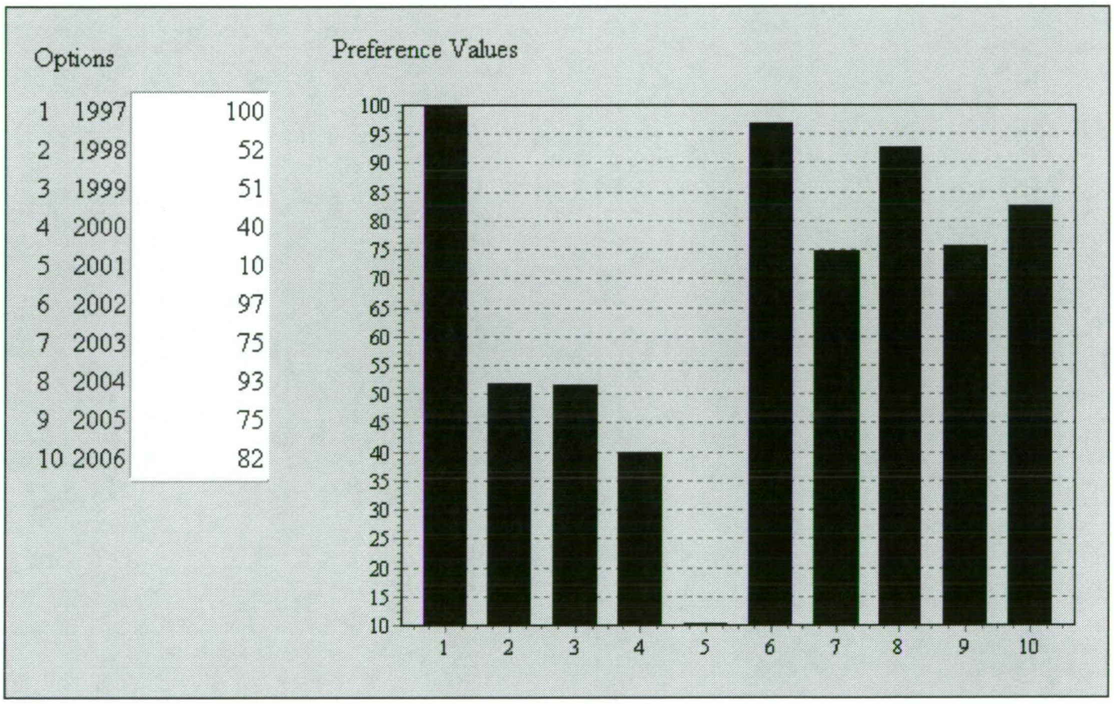


Figure 7. 11 Preference values (scores) of income criterion

Figure 7. 11 shows the preferred values of the income criterion. It can be seen that the year 1997 scored the best value (100) with the maximum economic benefit of (3.62 million OMR) compared to 2001, which scored lowest (10) with the lowest value (0.375 million OMR). This massive reduction in the economic benefit was due to reduction in the total catch as a result of the sharp decrease in the number of fishing vessels working in that year caused by the introduced fishing regulations. Once the regulations were waived year 2002, the economic benefit peaked again and scored 97. However, as is concluded in Chapter 2, there was significant increase in

the catch of the traditional sector working close to the trawling area, also accompanied by an increase in their income. This indicates a distribution of wealth from the trawling sector to the traditional sector. This fact reduces the weight of the income criterion in the whole framework, considered in the sensitivity analysis carried out in Chapter 8.

7.3.5 Conflict with Traditional Sector

The indicator that is identified in Chapter 6 to be used to evaluate this conflict component is the number of cases of conflict between the sectors, and which have been brought to court. Mostly such conflicts appear as a reaction from the traditional fishermen when trawlers breach regulations especially relating to the fishing zone. Section 5.4.2.1 of Chapter 5 investigated this conflict and found that the breaches can be classified into four types: gear, zone, discards and other kind of breaches. Therefore, total number of cases, with a negative trend and zero reference point for the preferred value (100) are used in the identification and standardization of the conflict component (Table 7.1). Figure 7. 12 shows the preferred values of the conflict criterion.

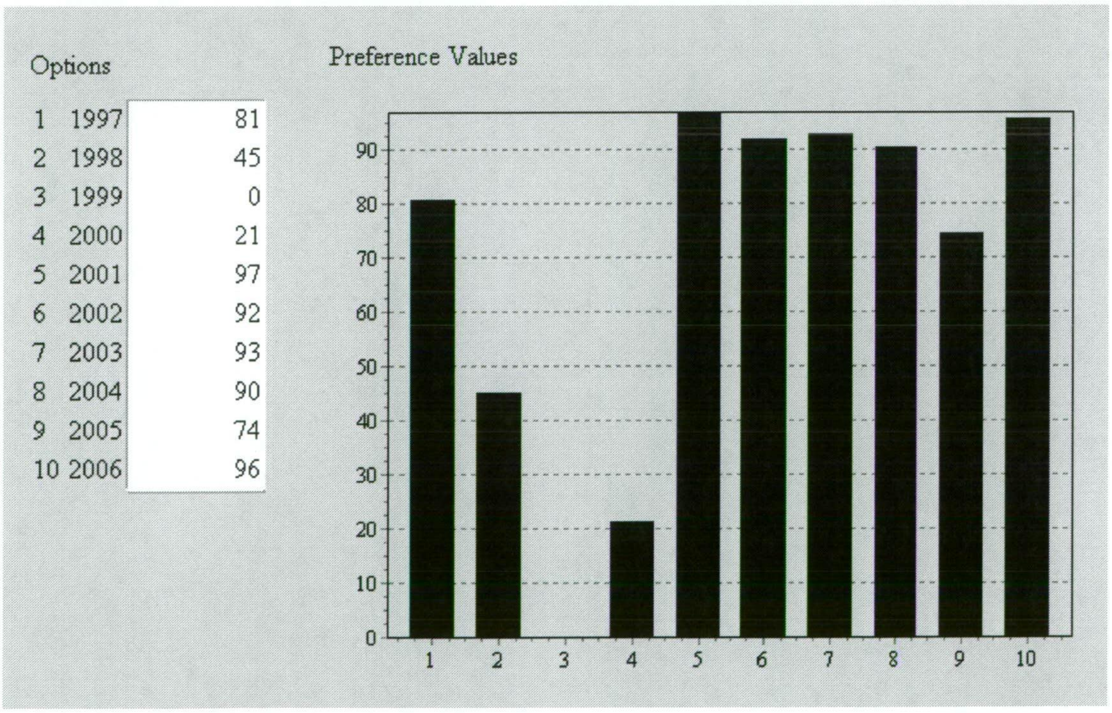


Figure 7. 12 Preference values (scores) of conflict criterion

It can be seen from Figure 7. 12 and Table 7.1 that the year 2001 scored the best value (97) with the minimum number of conflict cases (7 cases) compared to

1999, which scored the lowest (0) with the highest number of cases (227). This apparent reduction in cases in 2001 could be attributed to the reduction in the number of working fishing vessels. However, this preferred score and low number of breaches remained constant up to 2006, even when in 2002 the number of fishing vessels again increased.

As identified in Chapters 2 and 5, there was no evidence, nor official reports, explaining the sudden reduction in the breaching of fishing regulations. This could be either due to the deterrent approach taken by the authorities when new fishing regulations were introduced or due to under-reporting of the breaches. On the other hand, in order to satisfy a high-level administrative decision, not one single case was raised in the courts in the period 2001-2004. The overall situation highlights the ineffectiveness of the enforcement regime in the Omani fisheries. This issue will be further analyzed in Chapter 8 using sensitivity analysis.

Table 7.1 Data and preferred score of effect on human component indicators

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Preferred score
Nutrition (kg)											
per capita fish consumption	0.105	0.047	0.072	0.157	0.017	0.104	0.062	0.110	0.068	0.073	0.157
Food Variety (H)											
Shannon Diversity Index	2.038	1.886	2.016	1.982	1.577	2.050	2.182	2.368	2.291	2.331	2.368
Domestic Market (mt)											
Catch retained to local market	337.855	153.475	238.785	538.370	59.922	376.885	208.780	378.078	243.850	269.864	538.370
Export (mt)											
Foreign fishing companies share	21817.158	10622.751	9802.115	8635.941	2205.446	20321.992	14289.959	17824.066	14154.377	15420.627	2205.446
Employment (%)											
Percentage of Omani employees	6.286	6.732	13.836	8.554	14.551	9.727	9.559	13.428	14.192	14.771	100
Lifestyle (%)											
Percentage of Omani owned vessels	0.000	0.000	0.000	0.000	28.571	8.696	13.636	9.677	11.111	17.391	100
Income (Million OMR)											
Gross value of the fishery	3.620	1.880	1.862	1.445	0.375	3.507	2.703	3.358	2.733	2.981	3.620
Conflict											
Total number of breaches	44	125	227	179	7	18	16	22	58	10	0

7.4 Effect on Environment

7.4.1 Primary Commercial Species

As explained in Chapter 6, eleven species were identified as primary commercial species. Their catch will be used as an indicator to assess the status of individual species relative to a biological reference point. Therefore, a biological population parameter is required to assess the catch of each commercial species as acceptable or unacceptable level of harvesting. There is no single parameter available that could be used for this judgment, which is considered a major challenge to this study. The best parameters for such data poor fishery would be the Maximum Sustainable Yield (MSY) (Garcia 1996; FAO 1999a; Simon 2003). Therefore, to serve the main purpose of this study, an attempt is made to produce crude estimates of Maximum Sustainable Yield (MSY) for those commercial species. It should be emphasized that this exercise should not serve the purpose of stock assessment.

7.4.1.1 Justification of the Use of MSY

Although, MSY has the longest history in fisheries management it has been subject to wide-ranging criticisms during 1970s by many distinguished practitioners in the field. Their arguments against MSY can be grouped into three broad categories namely, simplicity, suitability and technicality. For example: 1) it is pointed out in literature that the use of the word 'maximum' in the concept of MSY is too optimistic and the likelihood of achieving its status is very low (Kesteven 1997), 2) it is also argued that the concept is not suitable as this output-based concept fails to recognize some important goals of fisheries management such as, maximization of economic and social benefits and values from the use of common property resources (Parsons 1993; FAO 1995), and 3) the concept is criticized based on technical grounds as the likelihood of obtaining an accurate estimate of MSY under uncertain environmental conditions is recognized to be low (Kesteven 1997).

However, in spite of these above-mentioned limitations, MSY still remains in use as an operational objective of fisheries management in both developed and developing countries (Barber 1988; Mkenda and Folmer 2001). The existing studies have singled out some basic reasons why MSY continues to be gaining ground in fisheries management. The common points in favor of MSY are as follows: 1) it can act as yardstick against management performance and facilitates communication among key stakeholders as the theoretical construct and the logic behind the concept are simple enough to be followed by non-technical members such as fisheries managers and fishers, involved in the industry (Barber 1988; Parsons 1993): 2) the apparent simplicity in determining MSY from catch and effort time series data using basic surplus production models as compared to other complex, data intensive operational models that lack ability to produce reliable short-term yields (Barber 1988): 3) MSY embraces the notion of future food security, at least from a theoretical standpoint, to the economies that rely to a great extent on the sea for maximum food production (Parsons 1993); and 4) MSY-based management regulation provides more employment opportunities in the sense that it encourages more fishing effort be put into the fishery compared to the concept of Maximum Economic Yield (MEY) under the basic surplus production framework (Parsons 1993). Even Larkin's (1977) farewell comment to MSY acknowledged the contribution of MSY to the conservation of world fisheries resources. Furthermore in providing a signal of production potential to managers, MSY can still play a valuable role in management decision making (Larkin 1977; Barber 1988).

Effective fisheries management relies heavily on, among other things, accurate information on stock status. In its simplest terms, stock assessment can be defined as the process of assembling, analyzing and interpreting biological information on fish stocks which serves as an important input to the fisheries management decision making process (Schnute and Richards 1994). Also, determination of stock status through stock assessment procedures is one of the important components of the process of setting accurate and reliable total allowable catch limits. Current scientific information in regard to the stock status of most of the commercial species in Oman is neither adequate nor reliable enough to formulate sound management strategies. Lack of continuity in collecting essential biological and ecological information of commercial species and the absence of any systematic procedure of collecting information cast reasonable doubt on the estimates resource status and the corresponding potential yield of the commercial species (Morgan 2004). Hilborn (2002) pointed out that good fisheries management requires simple decision rules that are not based on complex stock-assessment models. It should be emphasized that one of the purposes of the MSY estimates for these commercial species is to facilitate effective discussion among managers, fishers and government officials in relation to the status of individual species and remove scepticism and disagreement regarding the state of the fishery.

7.4.1.2 Data Validation

The data on annual landings of the eleven commercial species by vessels that are operating in the trawl sector along with the information on the number of fishers and number of fishing days covering the period 1986-2006 have been provided by the MFW. Statistical description for the individual primary commercial species catch is provided in Table 7. 2. For this study, the so-called 'composite input', fishing effort is measured by the number of fishing days. It is recognized that this type of 'composite input' measurement may not fully represent the fishing power of the vessels but the lack of necessary vessel level information hinders the construction of a better composite index for the fishery. It is also important to note that both traditional and industrial sectors are involved in harvesting of those species. However, no consistent, reliable and comparable data for fishing effort is available for either sector. Lack of relevant and consistent vessel level information for the two sectors required the researcher to produce a common index of fishing effort by following standardization procedure described in the literature (Sparre and Venema 1998; Maunder and Punt 2004; Bordalo-Machado 2006).

Although there are some significant differences in the size of trawlers, anecdotal evidence suggests that the difference in the fishing gear parameters is insignificant and the main difference among vessels lies in the storage capacity of catch and not in the harvesting capacity. In this regard, it is perhaps not unreasonable to assume that there is a positive correlation between the vessel size and the time spent fishing. This argument gives 'fishing days' priority over 'the number of vessels' as an effort variable. It is important to note that this argument is validated by a number of fishers and observers on board during field survey. Furthermore, an experimentation of running three separate simple bivariate regression models where catch is the dependent variable and number of fishing vessels, number of fishers or fishing days is the independent variable, reveals that the model with 'fishing days' as the independent variable has the lowest Mean Square Error (MSE), Standard Error

(SE) and the highest R^2 value (see Table 7. 3 and Figure 7. 13). Based on this information it was decided that the variable 'fishing days' be used as fishing effort in this study. This is not uncommon as other studies used the variable 'fishing days' as a measure of fishing effort (Winters and Wheeler 1985; Hare 1990; Stocker and Butler 1990; Mkenda and Folmer 2001).

Table 7. 2 Descriptive statistics for the catch (mt) of primary commercial species (1986-2006)

Species	Minimum	Mean	Standard Deviation	Maximum
Emperor	23.139	891.150	468.712	1837.480
Seabream	600.212	2861.666	1588.307	6816.707
Grouper	9.654	531.599	299.999	1187.396
Crocker	17.843	1226.642	907.248	3293.200
Sweetlips	1.560	335.210	251.788	1033.465
Snapper	1.504	32.410	35.816	126.075
Jobfish	0.075	552.487	548.499	1708.398
Rabbitfish	0.016	61.071	73.283	283.044
Catfish	6.851	97.071	99.117	399.457
Ribbonfish	1191.503	4116.112	2325.796	10069.499
Cuttlefish	71.487	1906.560	1338.676	4423.895

Scrutiny of the annual catch data for species revealed for three species, a number of zero catch observations. There are no official explanations available for those zero catch records. Estimation of a regression model where the catch, the regressand, is zero for a particular species creates the so-called limited dependent variable problem in estimation (Maddala 1992). Furthermore, zero value for a dependent variable would create a computation problem for a standard logarithmic model represented by equation 7.8 (Maunder and Punt 2004). To overcome this estimation problem in the case of multi-species fishery studies by Campbell and Nicholl (1994; 1995) and Bose (2001), a procedure in which zero catch observations are replaced by the arbitrary small value 0.1 kg was adopted. However, given the short span of annual catch data, the replacement of zero catch by a small value may cause an undesirable variability in the data which in turn may influence the results of the structural change test applied in this study. Thus to minimize the variability and to replace zero catch observations for those species, a five year moving average method is used. In the case of catfish the data set were not long enough to allow application of the moving average method to replace zero catch observations in the earlier part of the set. As a result, data sets for the period 1992-2006 were used for catfish species.

Table 7. 3 Regression relation between effort units and total catch (mt)

Effort variable	MSE	SE	R2
Number of fishermen	24907789	4991	0.2980
Number of vessel	23468968	4844	0.3385
Fishing days	11458963	3385	0.6770

7.4.1.2.1 Tests of Structural Change

In 1998, a shift in management regime occurred in the trawl fishery due to the fact that MFW (MAF at that time) imposed new regulations to manage the fishing season and the bycatch in the fishery. It is also noted that four years later, in 2002, the management authority then decided to withdraw the imposed regulations (see Chapters 2 and 5). Therefore, it is reasonable to expect that such a regulatory change could have had a substantial impact on the behaviour of the catch per unit of effort series. Visual inspection of the data reveals that for some species these two regulatory changes in the fishery have generated notable fluctuations in CPUE series in 1998 and 2002. In 1998 the trawl sector experienced a fall in the overall CPUE figure due to the fact that the foreign fishing vessels that are contracted to Omani local fishing companies cut down their fishing effort in response to the imposed regulations. On the other hand, in 2002 the sector experienced a rise in CPUE figure as a result of the withdrawal of those regulations. Thus, these regulatory changes in the fishery have raised an empirical question whether these structural changes have significantly influenced the catch and effort relationship and hence MSY estimates for each species.

In the time series literature, the most widely used procedure to investigate this possibility is by using the so-called 'crash and changing growth' model suggested by Perron (1989). Unfortunately, the application of this test procedure is not possible because of too small a sample size. Therefore, it was decided to use alternative test procedures, the Chow test and the dummy variable, involving the steps described below.

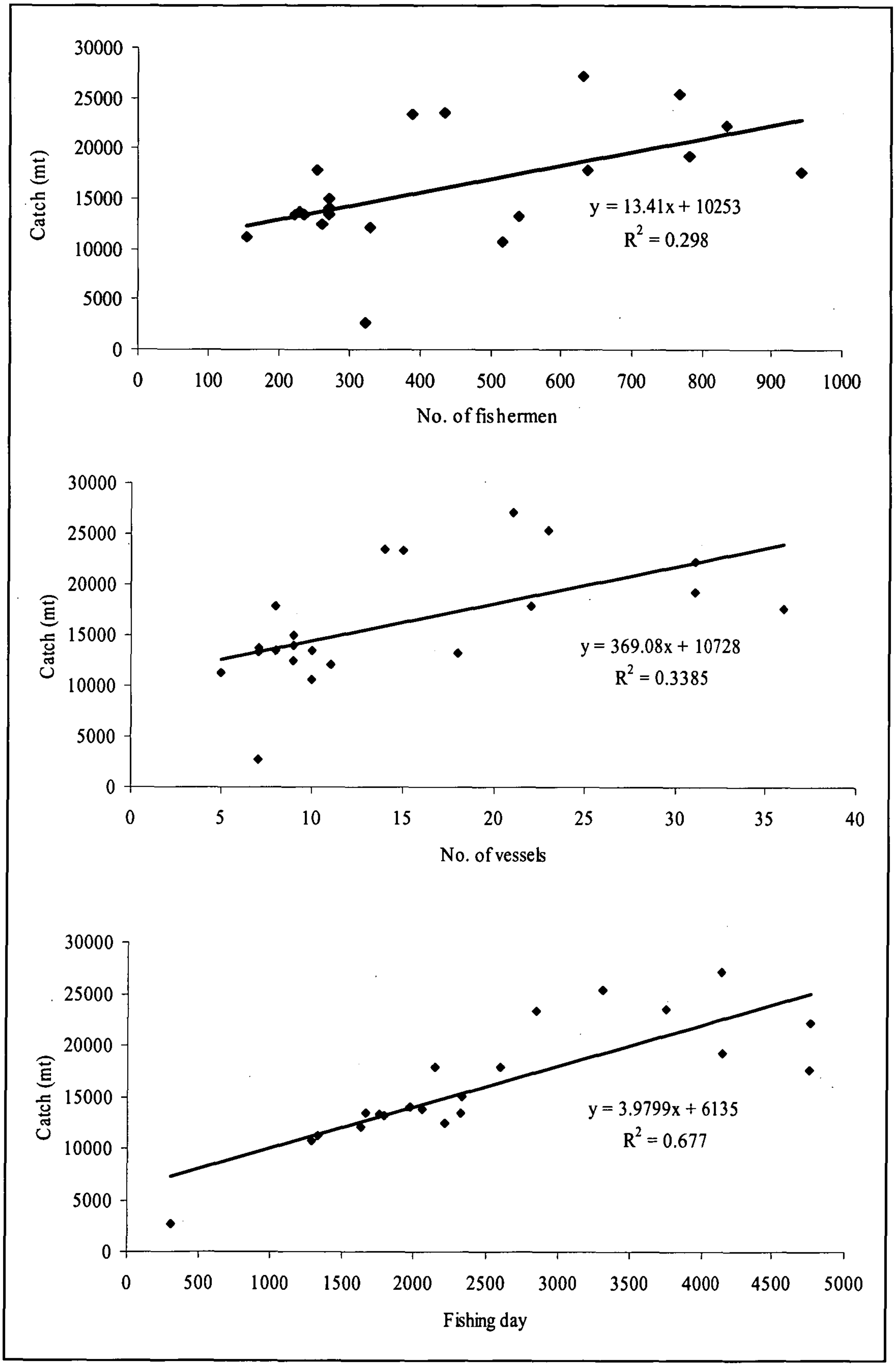


Figure 7. 13 Trend of catch (mt) verse different fishing effort units

Step 1: Tests of the equality of error variances:

In testing for the significance of structural changes for each species the Chow test procedure is followed in this study. However, application of the Chow test assumes that the error variances in the data for the pre- and post-structural periods are equal. Thus, as a pretest, an F test is used to test the *null hypothesis* (H_0): that there is no significant difference in error variances in the two subsets of data. The F statistic is defined as:

$$F = \frac{\sigma^2_1}{\sigma^2_2}, \tag{7.4}$$

Where:

σ^2_i (i = 1, 2): represent estimates error variance for each period and calculated as follows:

$$\sigma^2_i = \frac{RSS_i}{n_i - k} \tag{7.5}$$

Where:

RSS_i (i = 1, 2): denotes the residual sum squares for the corresponding subsets of data

n_i (i = 1, 2): correspond to sample size for the two subsets

k: represents number of estimated parameters

To calculate the F statistic, a simple bivariate regression model using 'catch-per-unit of effort (CPUE)' as dependent variable and 'fishing effort' as independent variable is run for each species.

The corresponding decision rule is that if the calculated F value in equation 7.4 is lower than the tabulated F value at the chosen level of significance ($\alpha = 0.05$) then the null hypothesis is accepted. The results of this pre-test for the two regulatory changes occurred in the trawl sectors in 1998 and 2002 and are presented in Table 7. 4 and Table 7. 5.

Step 2: The Chow test

The results from Table 7. 5 suggest that the pretest condition is satisfied for four species for both 1998 and 2002 and six and eight species for 1998 and 2002 respectively. Thus, as a next step, the most widely used Chow test procedure was followed for those species by estimating three regressions (for sub-period 1, sub-period 2 and for the whole period) using the same bivariate regression model - treating 'catch-per-unit of effort (CPUE)' as dependent variable and 'fishing effort' as independent variable - as described above. An F test is used to test the *null hypothesis* (H_0): that there is no significant impact of structural change on regression parameters at the 5% level of significance. The following equation was used to calculate F value:

$$F = \frac{(RSS_R - RSS_{UR})/k}{(RSS_{UR})/(n_1 + n_2 - 2k)} \sim F_{[k,(n_1+n_2-2k)]} \quad \textbf{(7.6)}$$

Where:

$RSS_{UR} = RSS_1 + RSS_2$ With $df_{UR} = (n_1 + n_2 - 2k)$

RSS_R: represents the restricted residual sum of squares (for the two selected sub-periods)

RSS_{UR}: represents the unrestricted residual sum of square (for the whole sample period)

df: denotes degrees of freedom

k: denotes the number of estimated parameters

The decision rule is that the null hypothesis of parameter stability cannot be rejected if the calculated F value is lower than the tabulated F value at the chosen level of significance. The test results are presented in Table 7. 4 and Table 7. 5.

Step 3: Dummy variable method

In situations where the Chow test cannot be applied to check the significance of structural changes a simple way to carry out the empirical analysis is by estimating the selected model including dummy explanatory variable(s). As the main purpose of the inclusion of a dummy variable is to indicate the presence or absence of the potential impact of a regulatory change, the variable can take on values of 1 or 0 indicating the presence or absence of such a change in the series under consideration. The appropriate number of dummy variables in the model is dependant upon whether the *null hypothesis* of equal error variance is rejected for both periods or not. It should also be noted that the dummy variable is used to allow for differences in intercept terms only as visual inspections of the catch and effort data did show a shift for both periods. In this regard, the coefficient of dummy variables measures the difference in intercept terms for the two sub-periods. Further useful discussions on the dummy variable method can be found in Tomek (1963) and Maddala (1992), among others.

Table 7. 4 Results for equal variance and Chow tests

Description	Year 1998	Year 2002
k	2	2
n_1	12	16
n_2	9	5
df_R	19	19
df_1	10	14
df_2	7	3
RSS_R	21.87	21.87
RSS_1	15.225	15.522
RSS_2	5.173	3.638
RSS_{UR}	20.398	19.594
σ^2_1	1.522	1.14
σ^2_2	0.739	1.231
Test of equal variance:		
F value (calculated)	2.06	1.06
F value (tabulated)	3.64	3.34
Chow test:		
F value (calculated)	0.61	0.987
F value (tabulated)	3.59	3.59

Table 7. 5 Results for equal variance and Chow tests at species level

	Year 1998				Year 2002			
	Test of equal variance		Chow test		Test of equal variance		Chow test	
	F	$F_{0.95}$	F	$F_{0.95}$	F	$F_{0.95}$	F	$F_{0.95}$
Emperor	1.09	3.64	8.56	3.59	4.75	8.71	1.71	3.59
Seabream	1.51	3.64	0.80	3.59	3.79	8.71	1.12	3.59
Grouper	3.81	3.14	N/A[3]		6.79	8.71	0.65	3.59
Crocker	1.53	3.64	11.61	3.59	5.02	8.71	13.89	3.59
Sweetlips	4.68	3.64	N/A		3.73	8.71	0.27	3.59
Snapper	9.91	3.14	N/A		2.47	8.71	0.78	3.59
Jobfish	1.39	3.64	0.11	3.59	1.38	8.71	0.53	3.59
Rabbitfish	2.83	3.64	0.30	3.59	12.90	8.71	N/A	
Catfish	36.86	4.12	N/A		4004.8	8.71	N/A	
Ribbonfish	1.70	3.64	2.19	3.59	13.50	8.71	N/A	
Cuttlefish	3.35	3.14	N/A		2.09	3.34	3.02	3.59

7.4.1.3 Estimation of MSY

Applied researchers are generally faced with the daunting task of choosing a functional form that would be able to represent the unknown nature of the true catch-effort relationship in the best possible way. A number of empirical models are available and have been employed by the researchers for estimating MSY. Further details on these available models can be found in Hilborn and Walters (1992), Walters and Martell (2002) and Haddon (2001), to name just a few. It should be emphasized, however, that the use of sophisticated models to evaluate population status is not beyond criticisms as they rely on various individual judgments and assumptions that lead not only to instability but also bias in parameter estimates (Stephenson and Lane 1995; Gay 1998; Hilborn 2002). It should also be recognized that practitioners' preferences for the use of sophisticated models are very often constrained by a lack of relevant data and information. As noted earlier, this is particularly true for the case in hand. Consequently, this study has employed two basic surplus production models, namely, Schaefer and Fox models described by the following equations 7.7 and 7.8 respectively (see King (1995) and Mkenda and Folmer (2001) for the derivation of the models):

[3] N/A represents not applicable as the null hypothesis (H_0) of test of equal variance is rejected.

Schaefer model:

$$\frac{C_t}{E_t} = \alpha_0 + \alpha_1 E_t + \alpha_2 D_{98} + \alpha_3 D_{02} + \alpha_4 T + \varepsilon_t \quad (7.7)$$

Fox model:

$$\ln\left(\frac{C_t}{E_t}\right) = \beta_0 + \beta_1 E_t + \beta_2 D_{98} + \beta_3 D_{02} + \beta_4 T + \eta_t \quad (7.8)$$

Where:

C_t: represents catch (mt)

E_t: represents effort (fishing day)

D_{98} (the dummy variables): assumes value equals 1 from 1998 onward and 0 otherwise

D_{02}: assumes value equals 1 from 2002 onward and 0 otherwise

T: denotes time trend

ε_t and η_t: represent error terms

It should be noted that a trend variable is also added to the models to investigate whether an attempt at detrending the catch-per-unit of effort series makes any differences in parameter estimates in equations 7.7 and 7.8.

MSY values for each selected commercial species were calculated for each model using appropriate parameter estimates from equations 7.7 and 7.8 as $MSY = -\left(\frac{\alpha_0^2}{4\alpha_1}\right)$ and $MSY = \left(\frac{-1}{\beta_1}\right)\exp(\beta_0 - 1)$ respectively.

To check the reliability of the preferred MSY estimates derived from equations 7.7 and 7.8, an additional empirical analysis described by Grainger and Garcia (1996) under the Generalized Fishery Development Model (GFDM) was followed in this study. The model is used to predict potential yield estimate using only catch time series data and it assumes that a fishery changes its developmental stages (i.e., developing, maturing and ageing) as the fishery experiences increase in fishing effort with respect to time. In determining the maximum production the approach monitors the value of the 'relative rate of increase in catch' -denoted by 'r'- with respect to time. The maximum production is reached when the value of 'r' drops to zero. Figure 7. 14 presents an example of this process. The time period at which the maximum production is reached can be determined from the parameter estimates of a linear regression model treating the relative catch rate 'r' as a dependent variable and the 'time' as an independent variable. As a next step, the parameter estimates from the linear regression and the first data value of actual catch from the catch data was used to predict the catch value of the next period. The same procedure was followed to predict catch values for the remaining periods. Finally, the maximum potential yield was determined from the predicted catch series. For a brief description of the procedure see Hoggarth et al. (2006).

From the point of view of statistical appraisal of the two sets of estimates, it is important to investigate whether they differ significantly from each other. To answer this question a non-parametric statistical test (Wilcoxon's Signed-Rank test) was used to test the following *null hypothesis* (H_o):- there is no significant difference between the two maximum yield estimates. A brief description of the test procedure is as follows: 1) the differences between the two estimates for each species were calculated, 2) calculated differences were ranked according to their absolute values, 3) the rank values were then assigned corresponding difference signs, 4) the positive and negative rank sums were calculated and denoted as T^+ and T^- respectively. For a two-tailed test, the rank sum that is smaller in absolute value (T_s) is then compared with corresponding critical values. The null hypothesis will be rejected if the value of the statistic T_s is less than, or equal to, the critical value (T_c) at a conventional level (5%) of significance. For a detailed discussion on the test procedures, see Mendenhall et al. (1989) and Sokal and Rohlf (1995).

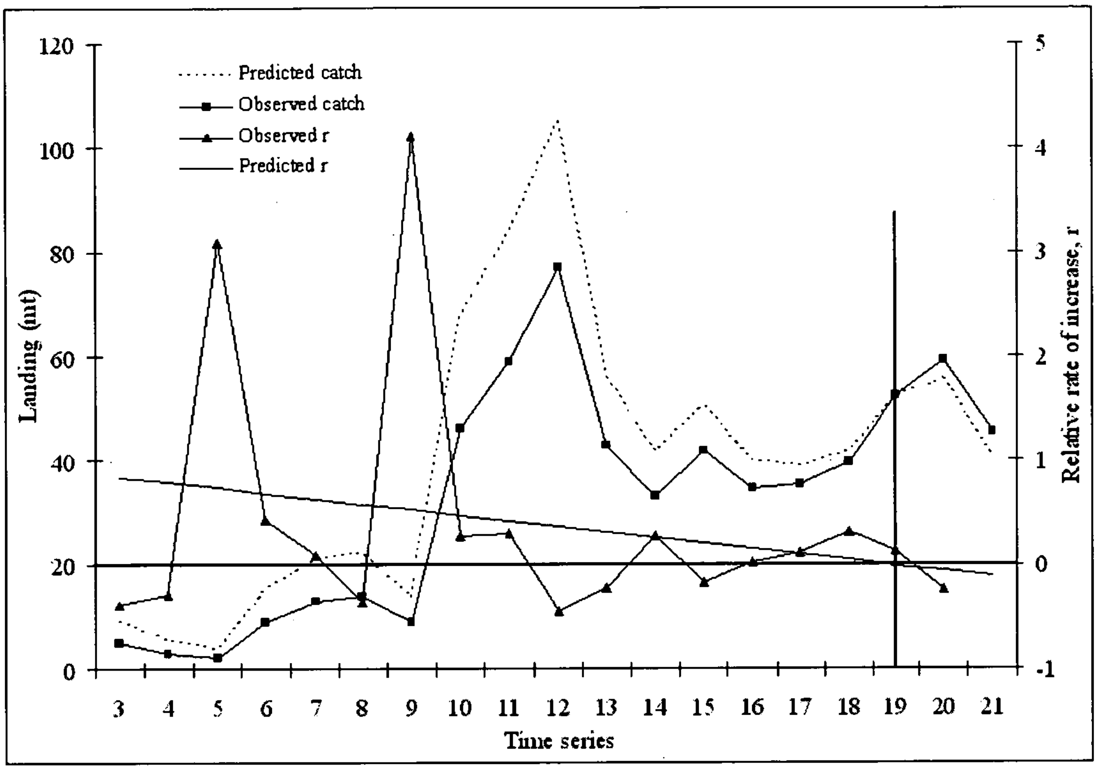


Figure 7. 14 Generalized Fishery Development Model (GFDM) for Snapper

7.4.1.4 Results and Discussion

Based on the test results of equality of error variances presented in Table 7. 5, it can be concluded that the *null hypothesis* is rejected for four species in 1998, for two species in 2002 and for one species in both periods. As the precondition is not met for those species the Chow test results are not applicable for those species corresponding to those years.

It can be noted from Table 7. 5, that for Crocker, the Chow test results are significant for both the1998 and 2002 periods thereby indicating a significant impact of those regulatory changes on the species concerned. For Emperor. the test result suggests that the structural change is significant for the year 1998. Following the steps described earlier in the section on 'tests of structural change', for those cases where the *null hypothesis* is rejected for either the 'equal variance' test or the Chow test, the dummy variable method was used as expressed in equations 7.7 and 7.8. This is either as an alternative method to examine the significance of structural change (as the Chow test cannot be applied) or to accommodate the change in the model as indicated by the Chow test results. Figure 7. 15 Summarized the followed strategy. Based on the t-test score, the statistical significance of the estimated coefficients of the dummy and the trend variables was investigated at the 5% level of significance and finally dropped from the 7.7 and 7.8. It is interesting to note that only in three cases was the dummy variable D_{98} found to be significant and therefore kept in the models to obtain the final estimates of MSY. It should also be mentioned that in the case of Snapper, the dummy variable D_{98} was not significant. However, it was found that the incorporation of the variable D_{98} helped generate a reasonable estimate of MSY from the Schaefer model represented by equation 7.7.

Table 7. 6 presents the estimated values of MSY for nine species only. It should be noted that in only two cases did both models fail to generate positive values of MSY. This, perhaps, indicates that the fishery is in the developmental stage for those two species. In the case of Snapper, the Fox model failed to generate a positive value for MSY. This is not surprising as this failure has been experienced by others (Mahon and Oxenford 1999).

In an effort to select the preferred MSY estimates form the two models for each species, three interrelated model selection criteria were used in this study, namely the mean square error (MSE), standard error of the residuals (SE) and the R^2 value. It is worth mentioning that the forecast performance of the model is measured by the values of mean square error (MSE). The lower the value of MSE the better the forecast accuracy of the model. In addition, the lower value of the standard error (SE) estimates of the residuals and the higher R^2 value, indicate the 'goodness of fit' of the model. Based on these criteria, it was decided to accept seven MSY estimates generated by the Schaefer model and two generated by the Fox model, as presented in the last column in Table 7. 6.

Finally, the results from the Wilcoxon's Signed-Rank test are presented in Table 7. 7. It was found that the test result is insignificant at the 5% level as the value of T_s (16) is higher than the value of T_c (6). It suggests, therefore, that the null hypothesis cannot be rejected. This implies that there is no significant difference between the maximum yield estimates from the surplus production models and the Generalized Fishery Development Model (GFDM). This, perhaps, indicates the reliability of the MSY estimates presented in this study.

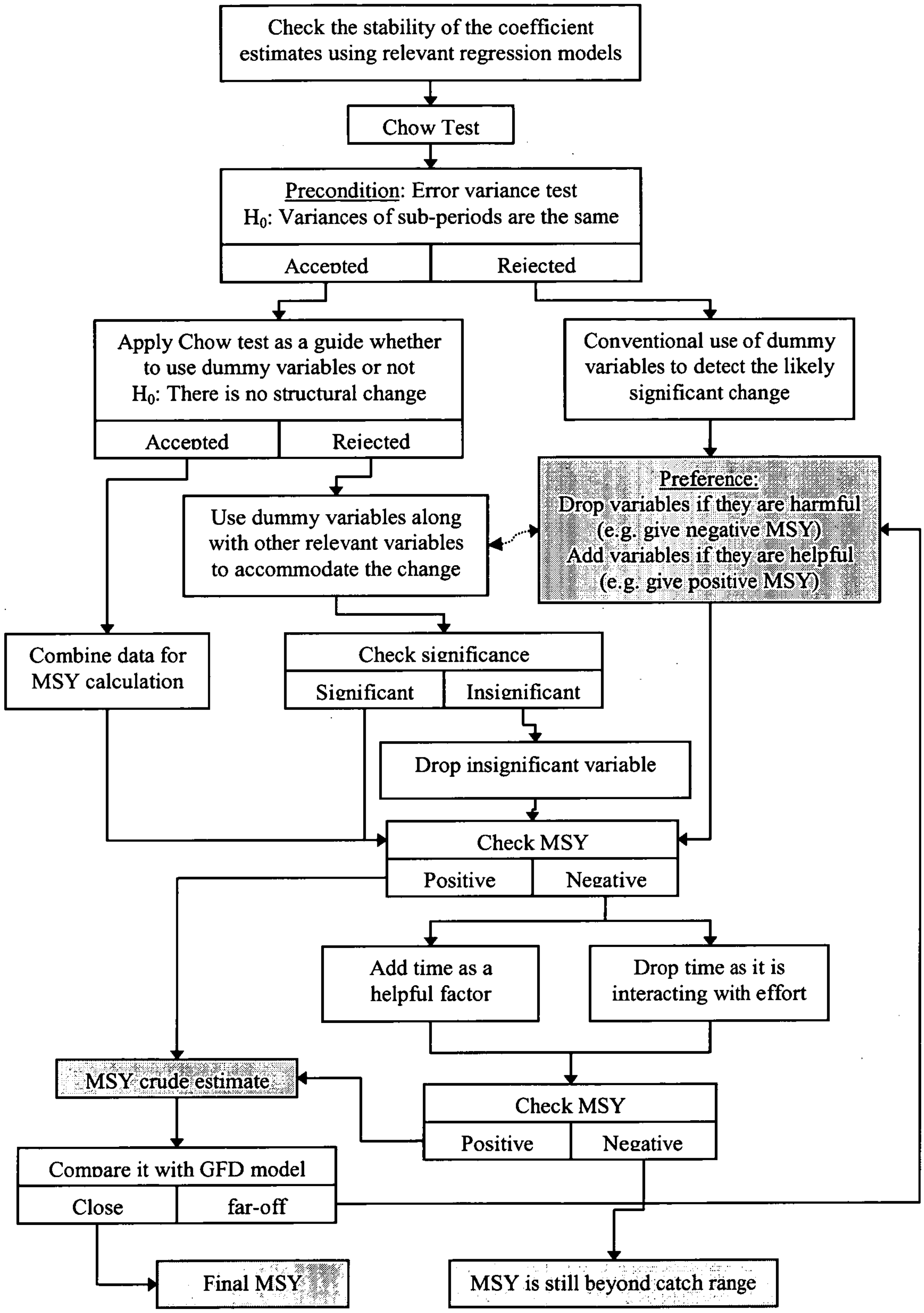


Figure 7. 15 Steps involved in estimating Maximum Sustainable Yield (MSY)

Table 7. 6 Result of Schaefer and Fox yield models based on effort and dummy and/or time variables

Species	Independent Variable	Schaefer Model				Fox Model				Preferred MSY
		MSY	Summary of Statistics[4]			MSY	Summary of Statistics			
			MSE	SE	R^2		MSE	SE	R^2	
Emperor	Effort	1526.374	0.0390	0.1976	0.0439	2872.660	0.4364	0.6606	0.0070	1526.374
Seabream	Effort	3640.683	0.5040	0.7099	0.4924	2885.202	0.3262	0.5711	0.5671	2885.202
Grouper	Effort	711.201	0.0261	0.1615	0.0723	1005.264	0.5999	0.7745	0.0162	711.201
Crocker	Effort	15514.335	0.0831	0.2883	0.0003	3422.840	0.6863	0.8285	0.0047	2132.071
	Effort, Time & D98	2132.071	0.0424	0.2060	0.5433	3284.181	0.4458	0.6677	0.4215	
Sweetlips	Effort	N/A[5]	0.0099	0.0996	0.0038	N/A	0.7055	0.8400	0.0993	N/A
Snapper	Effort	921.327	0.0003	0.0165	0.0000	N/A	1.3979	1.1823	0.0401	34.510
	Effort & D98	34.510	0.0003	0.0159	0.1146	N/A	1.2108	1.1004	0.2124	
Jobfish	Effort	691.239	0.0441	0.2099	0.0806	265.582	8.8803	2.9800	0.1467	691.239
Rabbitfish	Effort	75.375	0.0013	0.0360	0.1071	31.016	6.1253	2.4749	0.0052	75.375
Catfish	Effort	123.740	0.0027	0.0518	0.1518	80.019	0.5459	0.7388	0.3688	241.947
	Effort & D98	241.947	0.0019	0.0431	0.4586	156.397	0.2198	0.4688	0.7654	
Ribbonfish	Effort	5018.147	0.7704	0.8777	0.3035	4224.594	0.2987	0.5466	0.2904	4224.594
Cuttlefish	Effort	N/A	0.1073	0.3275	0.0992	N/A	0.2347	0.4844	0.1564	N/A

[4] The symbols MSE and SE denote Mean Square Error and Standard Error respectively.
[5] N/A represent not applicable as the model is given negative MSY for that species.

Table 7. 7 Result of Wilcoxon's Signed-Rank test

Species	Preferred MSY (mt)	GFDM maximum predicted yield	Difference	Rank
Emperor	1526.374	1439.004	87.37	4
Seabream	2885.202	3234.064	-438.862	-8
Grouper	711.201	850.837	-139.636	-6
Crocker	2132.071	2456.267	-324.196	-7
Sweetlips	N/A	N/A	N/A	N/A
Snapper	34.510	52.001	-17.491	-1
Jobfish	691.239	651.976	39.263	2
Rabbitfish	75.375	31.079	44.296	3
Catfish	241.947	152.002	89.945	5
Ribbonfish	4224.594	5386.739	-1162.145	-9
Cuttlefish	N/A	N/A	N/A	N/A
			Sum of negative values (T-)	31
			Sum of positive values T+	14
			Critical value (5% level)	6

Finally compare to MSY level (Table 7. 6), the annual catch for each species is classified as either Accepted (A) if the actual catch is less than or equal to MSY, or Unaccepted (U) if the actual catch is higher than MSY, as discussed in Chapter 6. Following Chesson and Clayton (1998), catches of all years were then standardized and scored (Table 7. 8). The weighted summation of this indicator is the percentage of (A) catch to the total (sum of A and U).

Figure 7. 16 and Table 7. 8 show that the year 2001 scored the highest preference value (100) with the maximum percentage of accepted catch compared to the unaccepted. This was due to the reduction in the effort and hence in the amount of landed catch. On the other hand, the year 1997 scored the lowest preference value (55) with the lowest percentage of accepted catch.

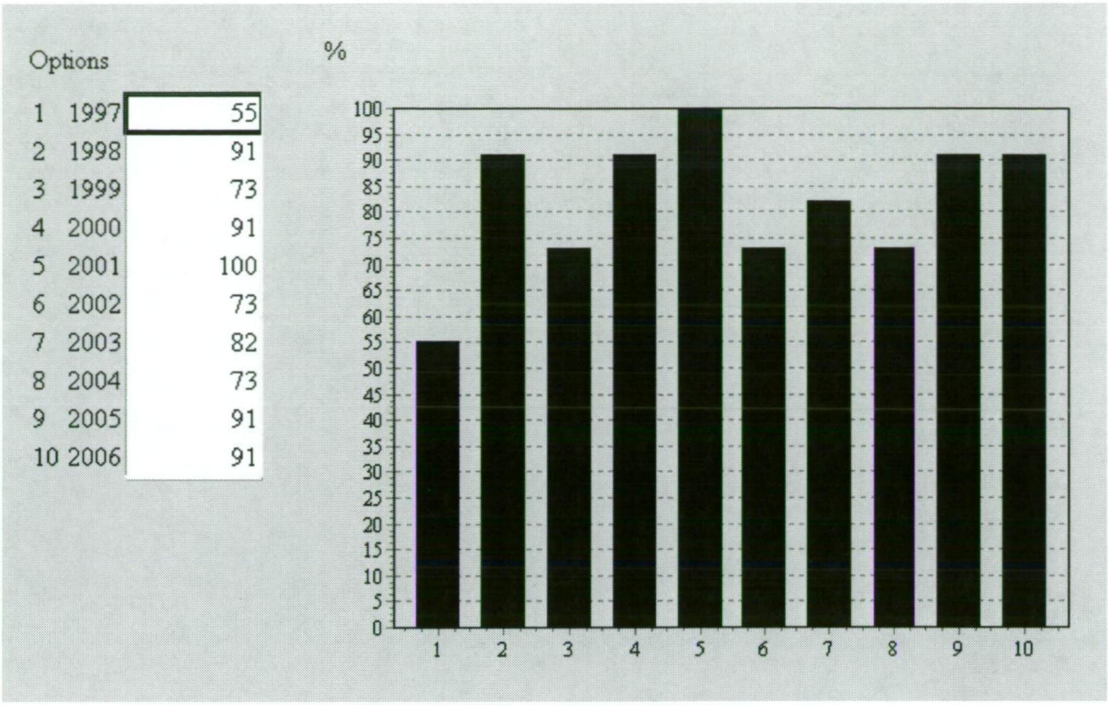


Figure 7. 16 Preference values (scores) primary commercial species criterion

Table 7. 8 Figures and score of standardized primary commercial species indicator

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Emperor	A	A	A	A	A	A	A	U	A	A
Seabream	A	A	U	A	A	U	A	A	A	A
Groupper	A	A	U	A	A	A	A	A	A	A
Crocker	U	A	A	A	A	A	A	A	A	A
Sweetlips	A	A	A	A	A	A	A	A	A	A
Snapper	U	A	A	U	A	A	U	U	U	U
Jobfish	U	A	U	A	A	U	A	A	A	A
Rabbitfish	U	A	A	A	A	A	U	U	A	A
Catfish	A	A	A	A	A	A	A	A	A	A
Ribbonfish	U	U	A	A	A	U	A	A	A	A
Cuttlefish	A	A	A	A	A	A	A	A	A	A
Sum of (A)	6	10	8	10	11	8	9	8	10	10
Sum of (U)	5	1	3	1	0	3	2	3	1	1
Preferred Score	100									
Weighted Summation (Percentage of Accepted)	55	91	73	91	100	73	82	73	91	91

Note: The symbols 'A' and 'U' stand for Accepted and Unaccepted respectively

7.4.2 Non-Target Species

As discussed in Chapter 6, total catch and total amount of discarded catch were used to assess the effect of trawling for the non-target species component. Although some data was found on turtle deaths, records show many zero figures for most years, and this appears to be unreliable. Therefore, it is been decided not to include this information in constructing an indicator, as it could mislead MCA judgment on this component.

Total catch of all fish species (target and non-target), total catch of non-target species and amount of discarded catch are the three available indicators for this component. The first two indicators were standardized following a negative trend based on the minimum figures as the preferred score, which is aiming to minimize the impacts of removals (Fletcher et al. 2002b). The discards indicator was standardized based on zero figures as the preferred score. Table 7. 9 shows figures for the three indicators and their preferred score for the non-target species component.

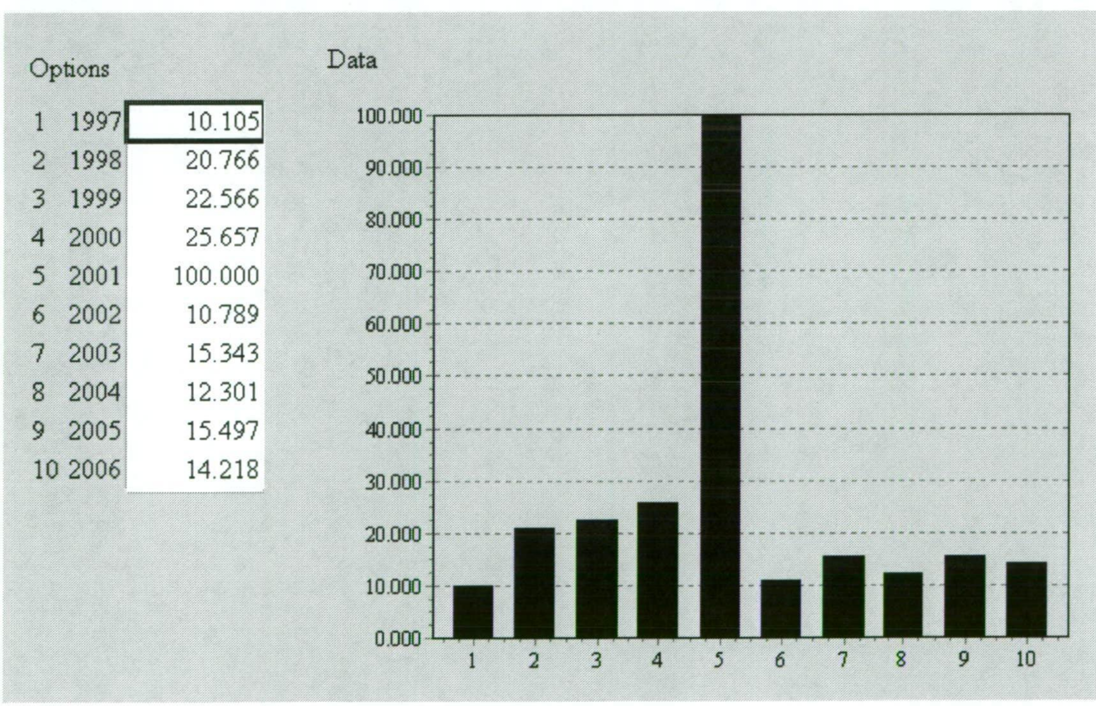


Figure 7. 17 Preference values (scores) of total catch criterion

Table 7. 9 and Figure 7. 17 show that the year 2001 scored the best value (100) for the total catch indicator of the non-target species component with the

lowest amount of catch (2740.7 mt). On the other hand, year 1999 scored the lowest value (10.105) with the highest amount of catch (27123 mt).

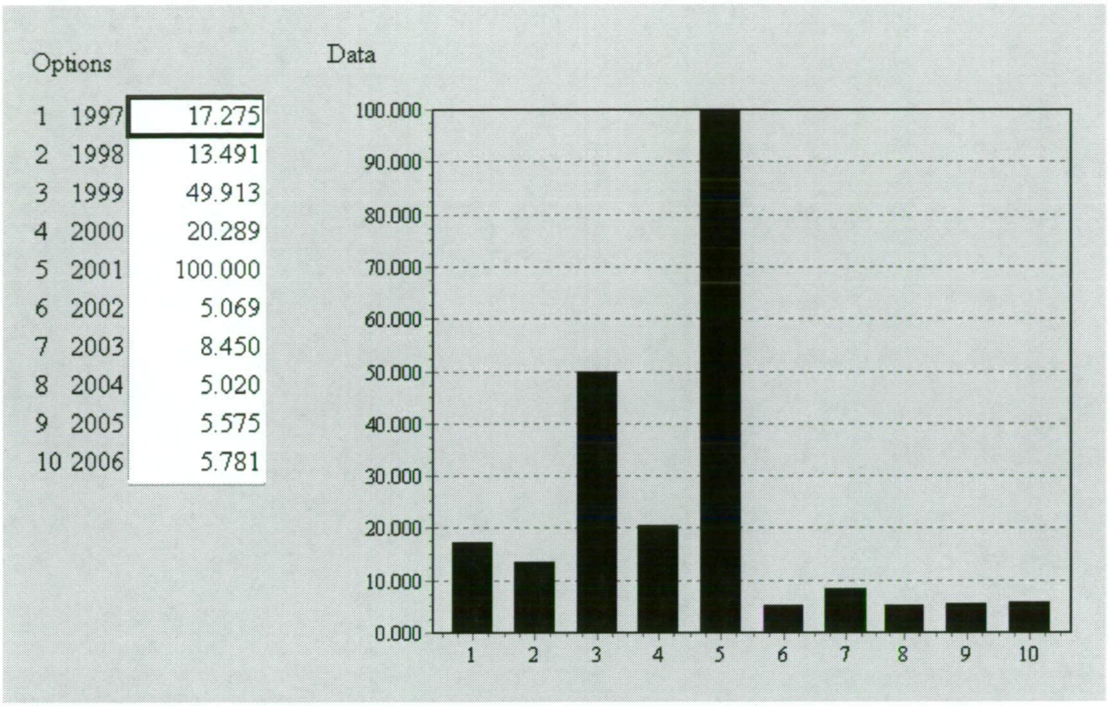


Figure 7. 18 Preference values (scores) for non-target catch criterion

Figure 7. 18 shows the preference values of the non-target catch indicator. It is clear that the year 2001 also scored the best value (100) with the lowest non-target catch (496.822 mt), while 2004 scored the lowest value (5.020) with the highest amount of non-target catch (9896.912 mt).

Table 7. 9 and Figure 7. 19 show that the year 2006 scored the best preference value (91) with the lowest amount of discards (135.771 mt) followed by 2001 with a score of (90.4) and a total discard of (143.551 mt). On the other hand, 2002 scored the minimum preference value (0) with the highest amount of discards (1506.668 mt). There is no 100 score within this indicator as the preferred score was set at zero and not to a minimum amount as in the case of total catch and non-target catch. As discussed in Chapter 2, no by-catch reduction devices are used in this fishery, which is the reason there is no improvement in the discards as well as the non-target species indicators.

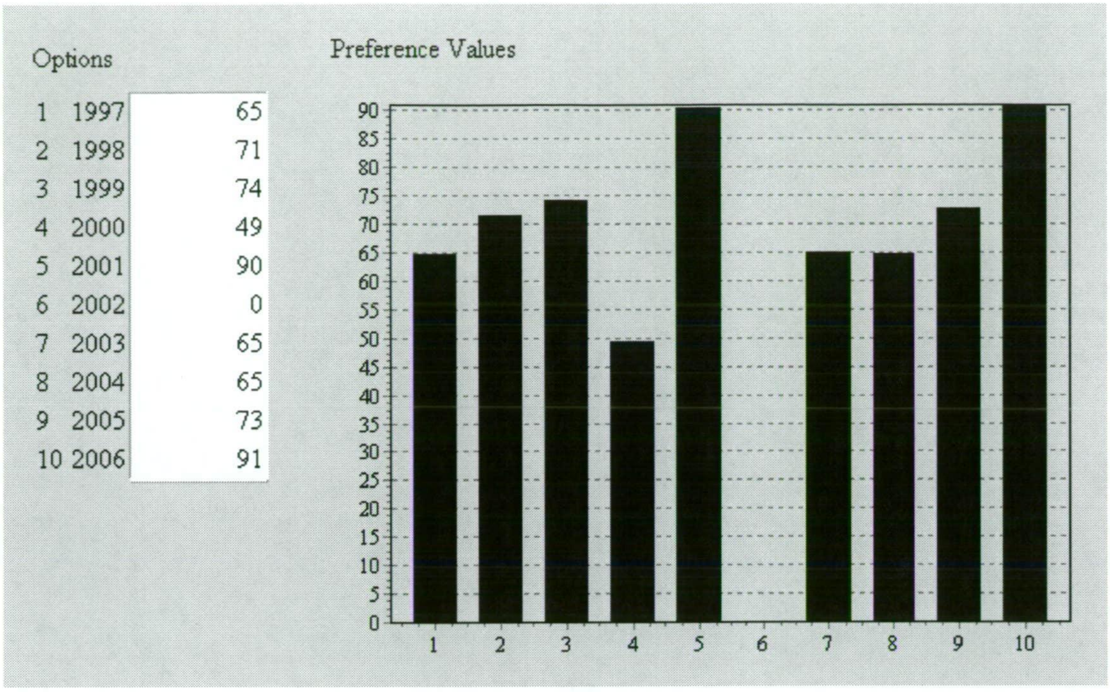


Figure 7. 19 Preference values (scores) of discards criterion

Figure 7. 20 shows the contribution of the three indicators of the non-target species. As a base case scenario, all of them were assigned weighted equally (left-hand column of Figure 7. 20) and consequently resulted in equal cumulative weighting (right-hand column of Figure 7. 20). It can be seen that the year 2001 had the highest score (97) compared to 2002, which scored the lowest value (5). It should be noted that the y-axis in Figure 7. 20 represents the criteria weight, while the x-axis represents the total score for years.

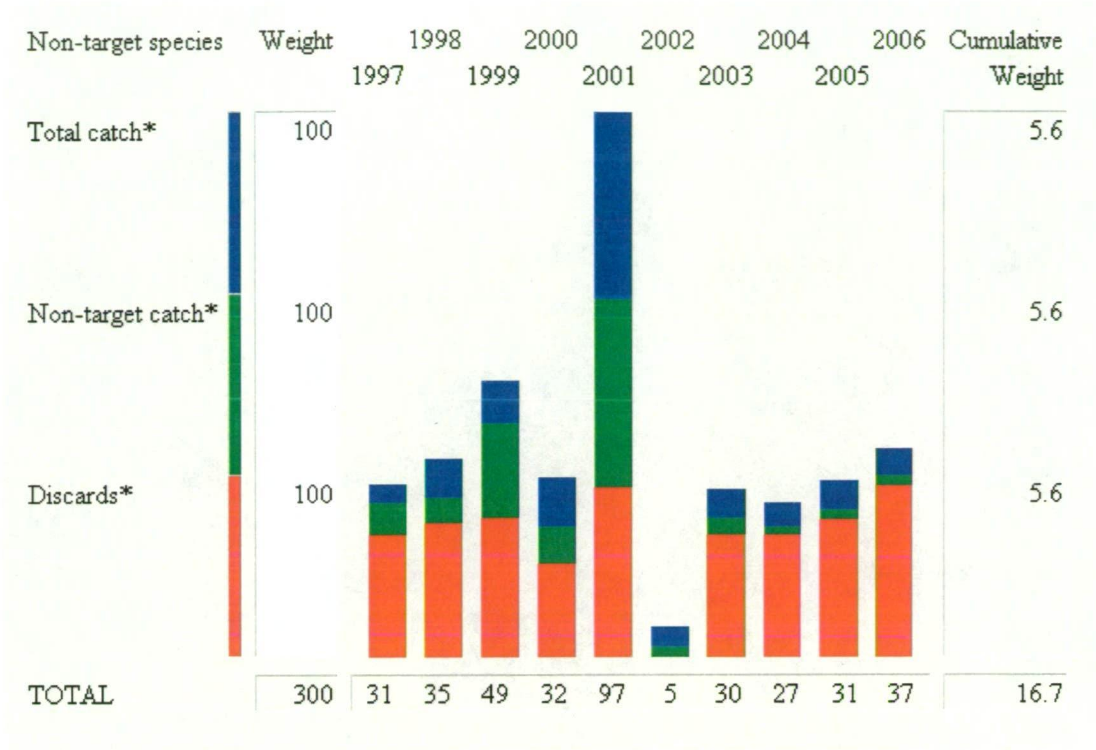


Figure 7. 20 Weight scores and criteria contributions of non-target species component

Note: the total weight for each year was calculated by following the similar steps described in footnote of Figure 7. 8.

7.4.3 Other Aspects

As discussed in Chapter 6, total catch is a function of stock productivity and fishing effort. Therefore, CPUE (using total catch including discards) is used as an indicator to give some idea of stock status and productivity. This indicator is standardized (following positive trend) based on the maximum annual CPUE figure as a preferred score assuming good status of the stock at that time. Table 7. 10 shows CPUE figures and their preferred score for the stock productivity component.

Figure 7. 21 shows the scores of the stock productivity criterion. It is clear that the year 2001 topped all other years and scored the highest value (100) with the highest CPUE of 9.015 mt per fishing day. In contrast, 2005 scored the lowest value (41.287) with the lowest CPUE of 3.722 mt per fishing day. As the reduction in the fishing effort during the period 1998-2001 outweighs the reduction in catch, the CPUE increased overall during that period. The reverse trend was observed in CPUE after 2001 and provided further support of the new regulation introduced in 1998 in regard to the conservation of stock and protection of the environment and the long-term economic benefits.

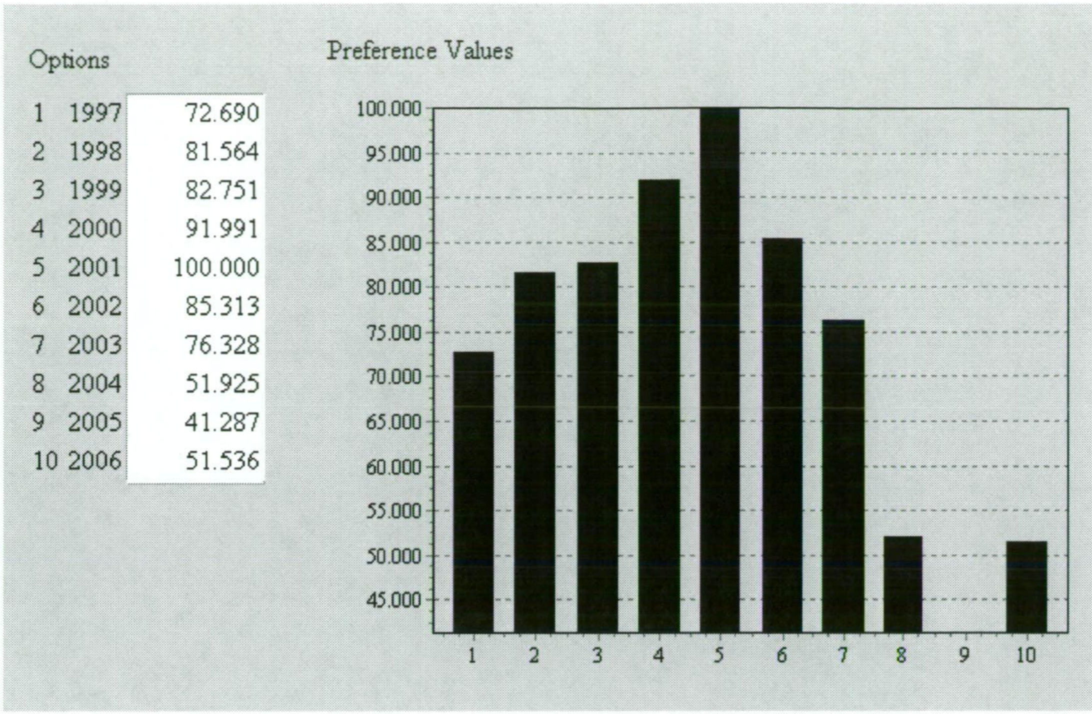


Figure 7. 21 Preference values (scores) of stock productivity criterion

As indicated in Chapter 6, it was decided to use 'fishing days' as an indicator of trawling intensity. This indicator is standardized (following negative trend) based on the minimum fishing days figure as a preferred score assuming less disturbances (low intensity) to the environment at that time. Table 7. 10 shows fishing days figures and their preferred score for the trawling intensity component.

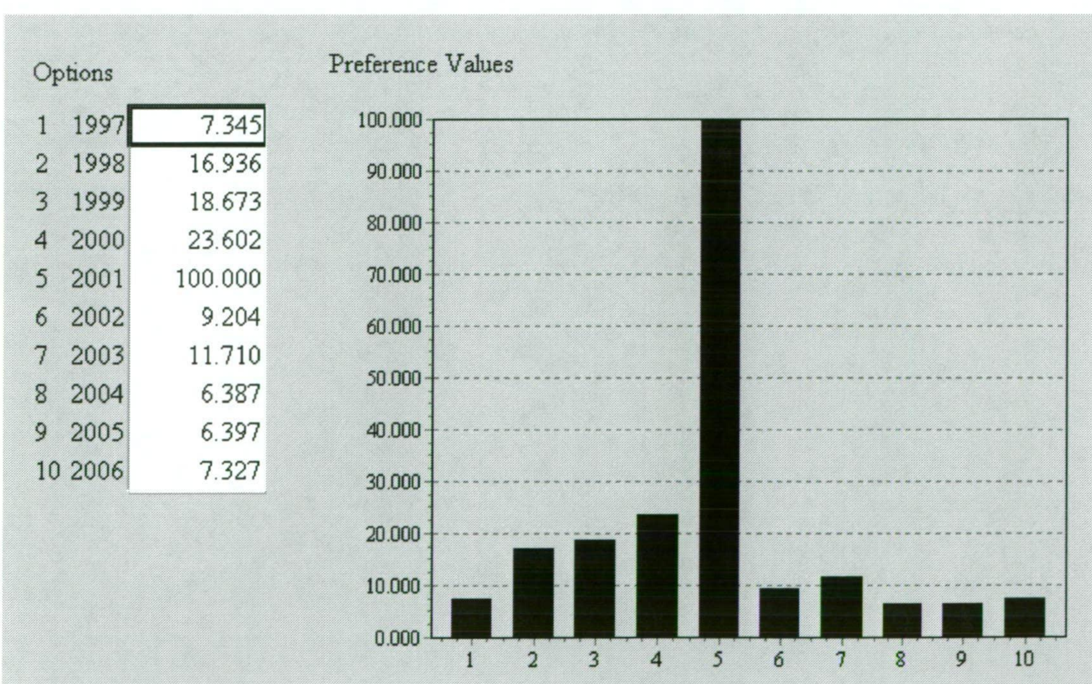


Figure 7. 22 Preference values (scores) of trawling intensity criterion

Table 7. 10 and Figure 7. 22 show the scores of the trawling intensity criterion. It is clear that the year 2001 topped all other years and scored the highest value (100) with the lowest number of fishing days (304). In contrast, 2004 scored the lowest value (6.387) with the highest number of fishing days (4760) followed by 2005 with a difference of eight fishing days. Although there is a reduction in the number of vessels in 1999, CPUE (7.353) was relatively lower compared to the reduction in 2001. More importantly, it means that any increase in the number of fishing vessels is not justified as the CPUE will tend to face a decline. Therefore, more environmental disturbances will occur with no overall economic benefit nor improvement in the catch per fishing day.

As a result, both stock productivity and trawling intensity criteria contributed positively toward year 2001, which scored the highest (100) (Figure 7. 23). This trend clearly signified that the management regime practiced during the period 1997-2001 was in favor of 'other aspect' component.

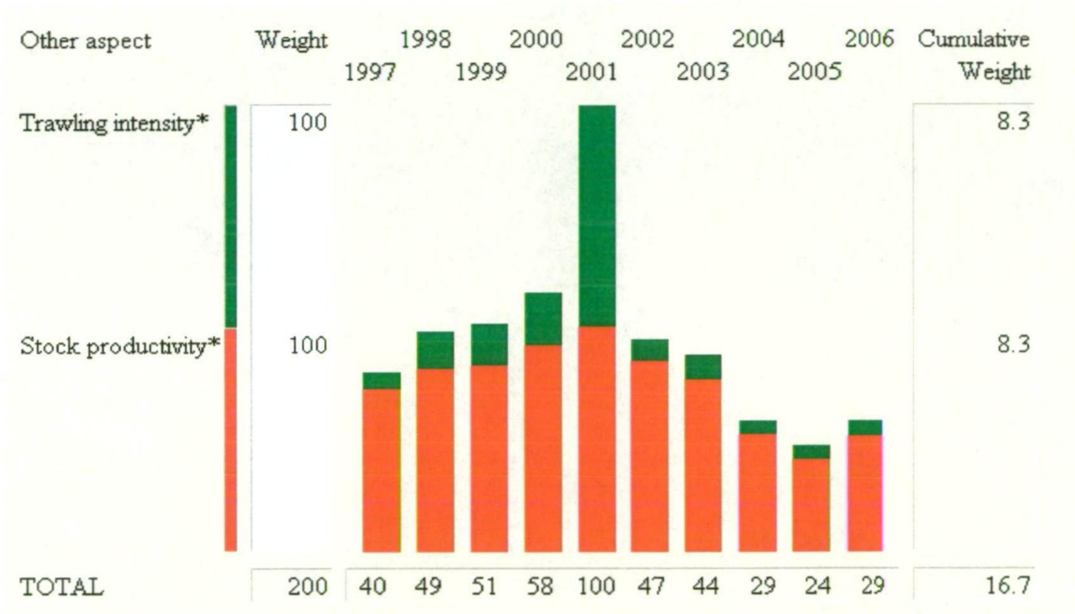


Figure 7. 23 Weight scores and criteria contributions of other aspect component

Table 7. 9 Data and preferred score of non-target species indicators

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Preferred score
Non-target Catch (mt)											
Total catch of non-target species	2876.009	3682.640	995.385	2448.754	496.822	9801.223	5879.470	9896.912	8911.931	8594.781	496.822
Total Catch (mt)											
Total catch (retained and discarded)	27123	13198.244	12145.3	10681.918	2740.7	25402.392	17862.359	22279.866	17685.257	19275.827	2740.7
Discards (mt)											
Total discarded	531.145	430.686	387.411	761.6825	143.551	1506.668	525.373	534.011	410.199	135.771	0

Table 7. 10 Data and preferred score of other aspect component indicators

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Preferred score
Stock Productivity											
CPUE (mt per fishing day)	6.553	7.353	7.460	8.293	9.015	7.691	6.881	4.681	3.722	4.646	9.015
Trawling Intensity											
Fishing Days	4139	1795	1628	1288	304	3303	2596	4760	4752	4149	304

7.5 Overall Result for the Base Case

According to the results depicted in Figure 7. 24, the year 2004 scored the highest preferred value (54) for the effect on humans, whereas the year 1999 scored the lowest (23). On the other hand, the year 2001 scored the highest preferred value (99) for the effect on environment, as shown in Figure 7.25, whereas years 1997 and 2002 scored the lowest (42). In comparing Figure 7. 24 and Figure 7. 25, it can be seen that there is a big difference between the highest preferred scores for environment and for human components respectively. Figure 7. 26 presents an overall comparative assessment between human and environmental components by combining Figure 7. 24 and Figure 7. 25. It is clear from Figure 7. 26 that the year 2001 scored the highest value (69), where the major contribution was from the environmental components. This suggests the fact that relatively higher priority was given by the management authority towards the environment in that year.

In the analysis of the 'base case' scenario, the aggregated results presented by combining the human and environmental components indicate that the management measures adapted in 2001 favored environmental protection. The policy relevance of this key finding is that it is consistent with the conservation policy objectives and the national conservation system as stated in the development plans set out in Chapter 2. The results also provide further support to Oman's commitment towards environmental sustainability.

Considering the period 1998-2001, it was found that the human component of the ESD framework was weakened mainly due to the poor performances of income and conflict criteria. This situation is reflected in Table 7.1. It can be seen from Table 7.1 that the income scores were lower during 1998-2001 whereas total number of breaches were higher for that period. As discussed in section 7.6, the difference in landings, and therefore in income, shifted to the traditional sector during 1998-2001.

It is important to note that the apparent shift in landings during 1998-2001 was purely by chance. In this context, it creates economic inefficiency in the harvesting sector as it indicates that the trawl sector was unable to harvest their share of production quota and thus the quota system become non-binding in nature. The important policy implication of this evidence is that it undermines one of the core objectives of the sustainable development principles. It should also be noted that the magnitude of conflicts, as measured by the number of breaches, was high during this period. This, perhaps, was influenced by the existing tension between the traditional and commercial sectors in relation to resource access.

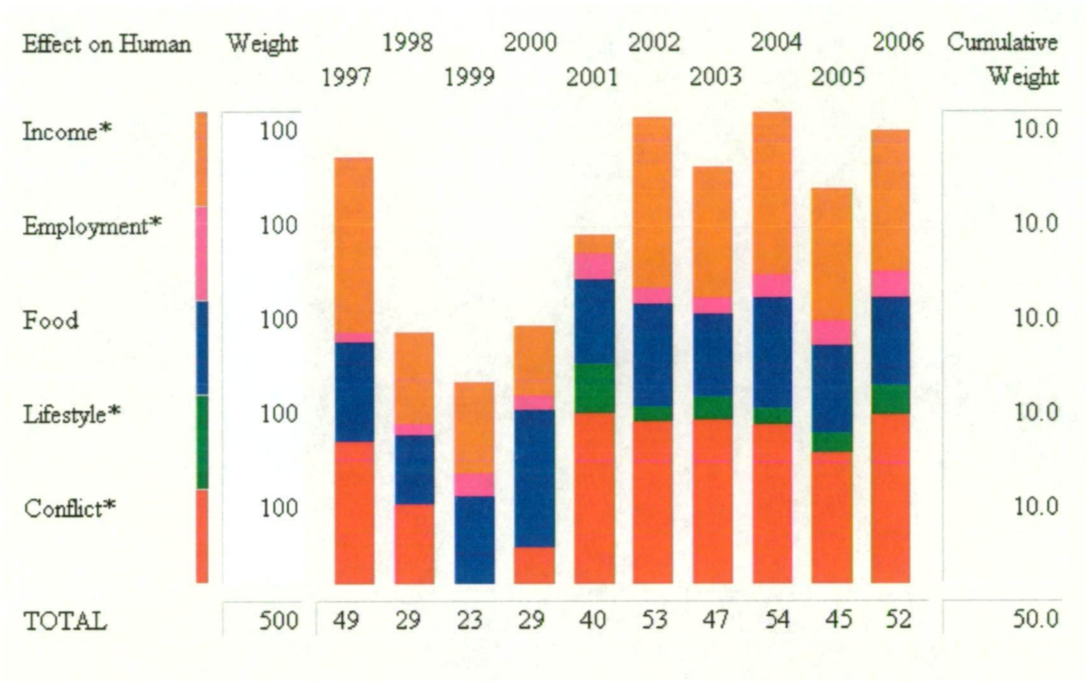


Figure 7. 24 Weight scores and criteria contributions of effect on human component

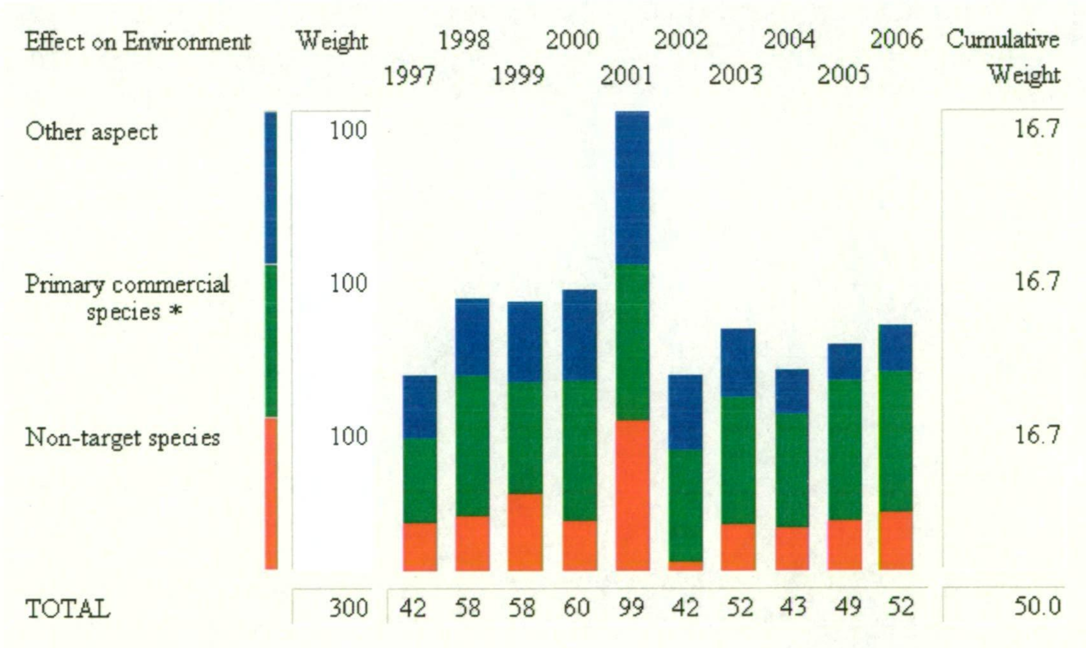


Figure 7. 25 Weight scores and criteria contributions of effect on environment component

The policy implication of this finding is that, to make regulations effective and thereby progress toward sustainability, the management authority must control fishers' behavior and introduce an appropriate and transparent resource sharing framework in the fishery.

Figure 7. 26 Weight scores and criteria contributions from both human and environment components

7.6 Conclusion

Following the steps involved in MCDA as discussed in Chapter 4, the present chapter has presented and discussed the methods of standardization and weighted summation followed by all relevant indicators and their components at each level in the hierarchy of the ESD structure. As a next step in the assessment process, an MCA approach was used to carry out a structured assessment on the trawl fishery's progression toward sustainability. The important policy implication of this analytical approach is that it provides support in relaxing the context barrier[6] to successful implementation of fishery management system as discussed in Chapter 3.

The MSY estimates presented in section 7.4.1 were used to assess the status of individual species under the sustainability framework, which is considered to be a major challenge to commercial fisheries that suffer from data limitations and structural uncertainty. It is intended that those set of estimates would not only be useful as general guidelines for proactive management actions by the management authority but also as a starting point for effective communication and negotiation

[6] Context barrier as stated by Lane and Stephenson (1999) happen when "*fisheries-management problems present a difficult valuation problem that denies presentation of a singular contextual objective and at the same time represents multiple and conflicting objectives*'.

between industry and the management authority. In the present climate where fisheries science is admitting its limitations through recognition of uncertainty, these estimates offer an opportunity for the management authority to engage in conversation with fishers so that their first-hand fishing knowledge and experience could be used to check whether the estimates accurately reflect reality. This type of communication has the potential to further develop mutual trust and thereby better management outcomes in the future.

It should be noted from the discussion in this chapter that a major shift in management regime occurred in the trawl fishery with the introduction of fishing effort regulations in 1998. This regulatory regime lasted three years, up to 2001. The main intent of this measure was to reduce both by-catch and environmental degradation.

After deciding on the most preferred year (i.e. 2001), it is important to investigate the strength and weaknesses of the year with respect to the listed sub-components in the hierarchical structure. It should be noted that due to the imposition of regulations to control fishing effort of the trawl sector during 1998-2001, there was evidence of an increase in landings in the traditional sector during that period. This was considered as a transfer of income towards the traditional sector. It is important to investigate the influence of such income transfer on the most preferred year.

Considering the apparent tension at policy level between economic development and environmental conservation, as discussed in Chapter 5, it is also important to investigate the following question: How does the decision makers' preference towards economic development over environmental conservation influence the selection of the preferred year and vice versa?

The sensitivity analyses of the above mentioned cases will be carried out in the next chapter.

CHAPTER 8: SENSITIVITY ANALYSIS RESULTS AND DISCUSSION

8.1 Introduction

Chapter 7 considered the base case scenario which gives equal weight to environmental and human components and has assessed the extent of progress made towards sustainability. Some potential scenarios that need to be examined to enable the decision makers to choose the best options were also identified in Chapter 7. In this context the main objectives of this chapter are to èxamine the following: 1) the strengths and weaknesses of the preferred option (i.e. year) under the base case; 2) the sensitivity of the preferred option after making adjustment to the income component as discussed in Chapter 7; 3) the decision makers' preference for short-term financial gain as opposed to conservation and protection of the environment; 4) the decision makers' preference for conservation and protection of the environment as opposed to economic development; and 5) the decision makers' preference for short-term financial gain as opposed to conservation and protection of the environment under the income-adjusted case as mentioned above.

This type of scenario analysis points to both risks and opportunities associated with the 'best alternatives'. It also gives a signal to the decision makers on the causes of potential imbalance in human-environment relations if a sustainable path is pursued. Furthermore, sensitivity analysis (broadly speaking)[1] helps improve the credibility of the present analytical model (based on subjective judgments) as it incorporates stakeholders' preferences and attempts to provide appropriate answers to 'what if' questions (Erkut and Tarimcilar 1991). It is important to note that as the

[1] As stated by Saltelli (2000), "*sensitivity analysis is the study of how the variation in the output of a model (numerical or otherwise) can be apportioned, qualitatively or quantitatively, to different sources of variation, and of how the given model depends upon the information fed into it*". Sensitivity analysis is used to judge the sensitivity of model behavior to uncertain assumptions about model formulations and parameter values (Moxnes (2002). Erkut and Tarimcilar (1991) have developed a mathematical method to facilitate sensitivity analysis involved in AHP, which might be a tedious and time consuming exercise. In this study, Hiview software (see Section 7.2) is used to carry out the sensitivity analysis.

theoretical foundation of MCDA is in decision theory, it is possible to accommodate uncertainty in a systematic way. For example, sensitivity analysis can be carried out on the weights given to the key components under a particular scenario to examine the effects of the scenario on the overall ordering of the options (years). Two types of variations or uncertainties will be investigated in this chapter through the above-mentioned cases. Firstly the variation in the values of the input (indicators) and secondly the variation in the amount of weight given to each indicator and their effect on the final conclusion on the most preferred year.

8.2 Study Cases

Four different cases will be analyzed for their sensitivity to the two above mentioned variations. The first case (case 1) will investigate and observe primarily the weight of the components that have significant effects on the most and least preferred years. This investigation aims to study the behavioral change of those components on preferred years to weight alteration. Case 1 will also highlight weaknesses and strength of the most and least preferred years. There will be no changes in components' weight assuming no preference is prioritized and all sides of the framework (model) is weighed equally. Therefore, case 1 will represent the sensitivity analysis of the results presented in Chapter 7 (base case).

Chapters 2, 5 and 7 showed there was clear management change in the period 1998-2001 and presented some evidence of landing and income transfer toward the traditional sector. Therefore, the second case (case 2) will reflect an adjustment in the values of each affected component as investigated in Chapter 7. It will therefore follow the same procedures and target the same objectives as in case 1 after changing the values. This case will represent the hidden truth of the industrial sector status in that period.

The third and fourth cases (cases 3 and 4) will reflect a short-term financial return trend and a conservation preference respectively, following specific weight distribution applied to the base case as discussed in the following section. Following the same method, apart from the adjusted case (case 2), the fifth case (case 5) was aimed at testing short-term financial returns and conservation preference trends and to see how a change in values of some indicators might affect the results and the decision on the preferred year. Sensitivity analysis for the adjusted case concluded that amendment in the weight will reinforce the most preferred year when favoring a conservative trend. Therefore, case 5 will investigate the sensitivity analysis of the adjusted case only when short-term financial return is preferred.

8.2.1 Weights Allocation

Discussion in Chapter 2 reveals that Oman has a positive attitude toward environmental protection as there is clear legislation, strong management regulations and efficient monitoring programmes. However, present events show that fisheries resources are under stress particularly in the trawling sector and probably some stocks are facing overfishing. As identified in Chapter 5, this was mainly due to the weakness of the enforcement program, ineffective regulations and political intervention. All these factors encouraged short-term financial gains for the fishing companies. On the other hand, the environmental movement, represented by non-governmental or social bodies, was not effective in the country. This evidence suggests that economic objectives took preference over environmental protection. As shown in Figure 8.2, sensitivity analysis of the base case has revealed that for some criteria at least 15 extra points were required to change the most preferred year. This means that overall there is a difference of 30 points in components' actual weight distribution. It is important that the differences in weight distribution should reflect actual progress in relation to environmental and economic sustainability in the country. In this context, according to the 2005 ESI benchmarking, it should be noted that Oman ranked 83 with an Environmental Sustainability Index (ESI) score of 47.9 (Daniel et al. 2005). On the other hand, Australia ranked 13 with an ESI score of 61 (Daniel et al. 2005). Based on this information, it was decided to use 40 points difference when preferring conservation or financial returns in the sensitivity analysis for the trawl fishery compared to the 20 points used by Chesson et al. (1999) when analyzing Australian cases.

For the financial preference case, extra weight was given to the components with economic benefits and less to the environmental ones assuming that a short-term financial returns policy is desired by the management authority. On the other hand, extra weight is given to environmental components and less to the economic component for the conservation case. The allocation of weights to the components was done following the same scenario used by Chesson et al. (1999).

In the base case scenario, both ESD main components - effect on human, which included the social and economic characteristics of sustainable development; and effect on environment, were assigned equal weight. This equivalent weighting process was also applied to all sub-components. As mentioned above, 40 points weight difference was used in the sensitivity analysis following a similar scheme used by Chesson et al. (1999) as presented in Figure 8. 1.

Figure 8. 1 represents five cases namely: case 1 (Cl), case 2 (C2), case 3 (C3), case 4 (C4) and case 5 (C5). C3 will be given as an example to explain the allocation of weight. C3 gives 70% weights to the 'effects on human' component and 30% to the 'effects on environment' component. At the next step, the 70% of the total weight allocated to the 'effects on human' component is subdivided into the subcomponents of income (50%): lifestyle (10%), employment (20%), food (10%) and conflict (10%). As a final step, the 10% weight (of the overall 70% weight) which corresponds to the food component is further subdivided into nutrition (0%), food variety (0%), domestic market (50%) and export market (50%) according to the justification provided for the case in examination.

This weight arrangement does not represent the actual set of values practiced by the authority, but is aimed only at investigating sensitivity of options toward the choice of weights, which represent different trends from different decision makers.

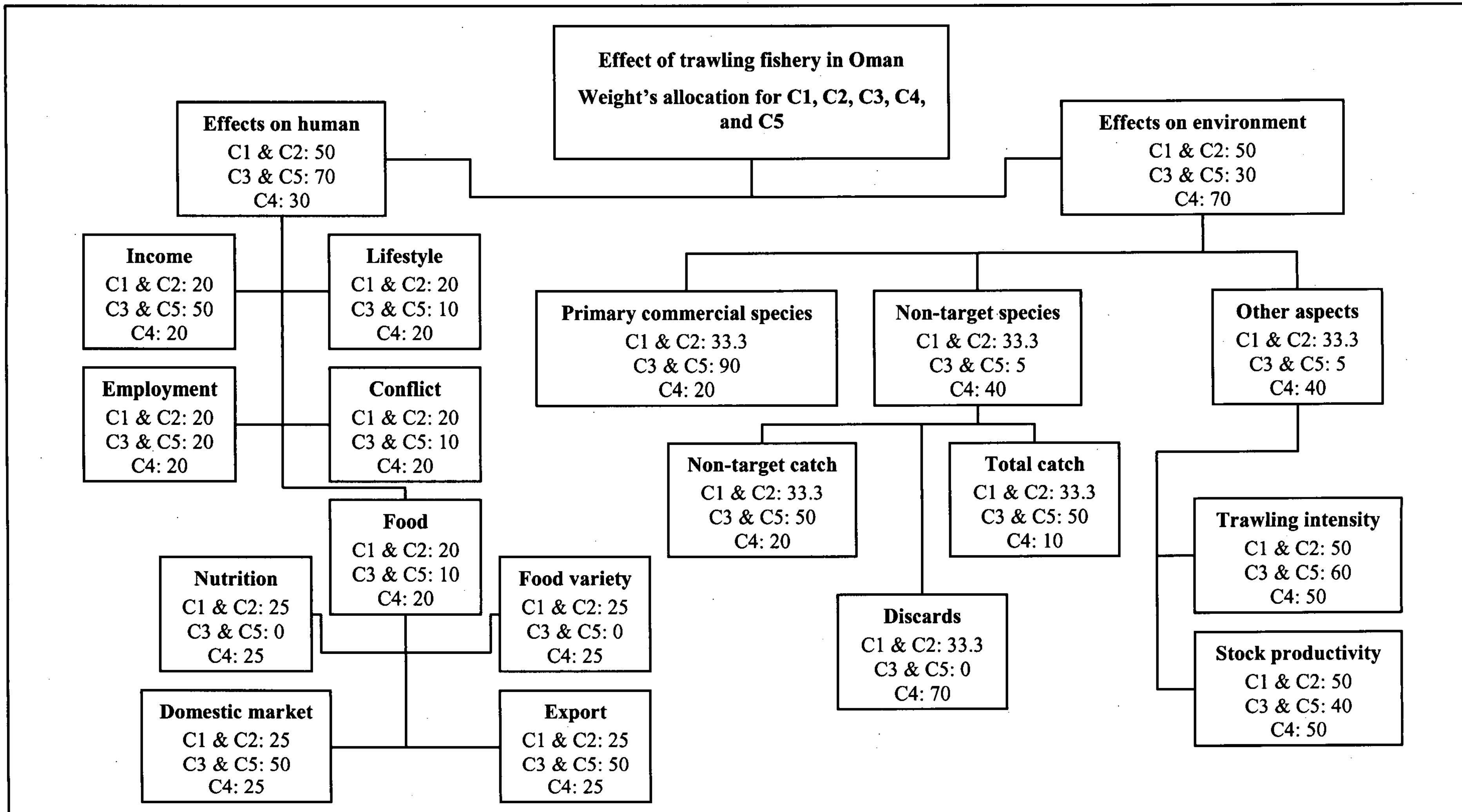


Figure 8. 1 Relative weights for the base (C1), adjusted (C2) short-term financial preference (C3), conservation preference (C4) and adjusted case with short-tern financial preference (C5) cases

8.2.2 Case 1: Sensitivity Analysis for the Base Case

Based on the overall comparison as depicted in Figure 7. 26 in Chapter 7, it can be seen that the year 2001 was the most preferred year followed by year 2006. Figure 8. 2 confirms this and shows that year 2006 could override year 2001 if the weights of income, employment, food variety and discards components are increased by more than 15 points, which is referred to as sensitivity down[2] (see Box 1 for sensitivity down graph interpretation). The same figure also shows also that the year 2000 can override the most preferred year if nutrition and domestic market components weights are increased by more than 15 points. The sensitivity down graph is used to direct further analysis of the model. Where, for example, criteria have a red bar, further analysis is a high priority. In this case, year 2001 has a strong position as the most preferred year, where it is low sensitive (green bar) to any change in weight. It should be noted that an important feature of the MCDA Hiview Software is the color coding display. This feature reflects the impact on the most preferred option by independently increasing or decreasing the weight on each of the criterion eliminating the need for specific sensitivity analysis for each criterion. The absence of the color bar against any criterion means that no change in the weight of that criterion will change the most preferred year.

[2] The sensitivity down graph in the Hiview software displays a summary of weight sensitivity for all criteria below the selected node. It is mostly used for the root node to give a summary of sensitivity throughout the whole model.

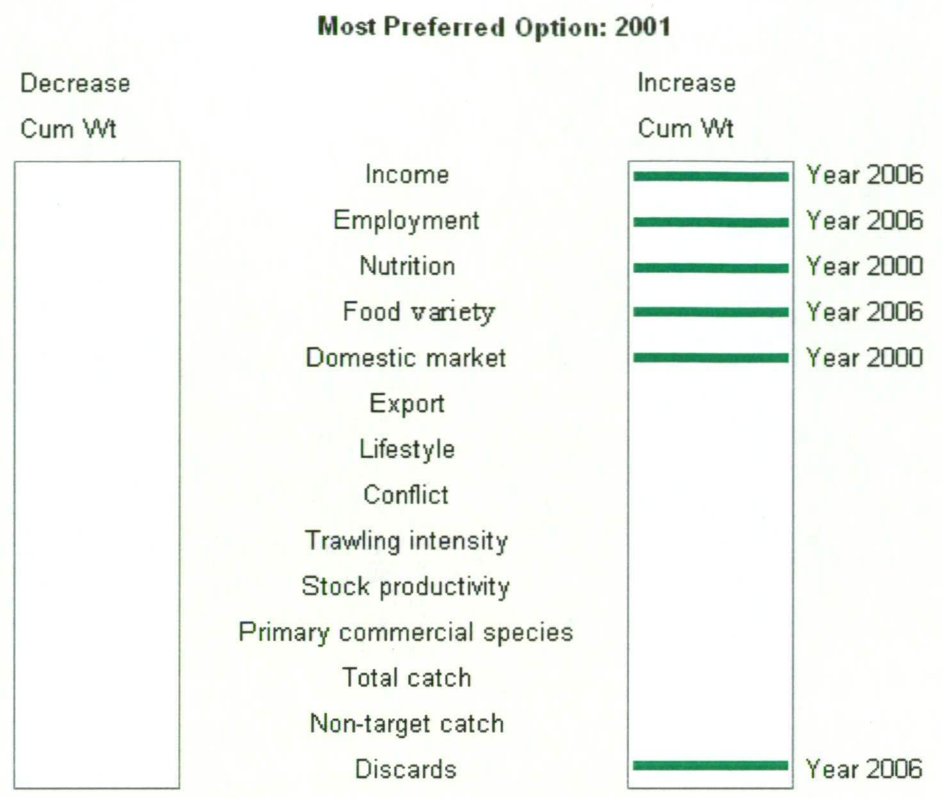


Figure 8. 2 Most preferred year (sensitivity down) during the study period

Note: Change in preference option conditioned to the increase in cumulative weights of criteria (listed in the middle column of the figure) shown by color coding horizontal bars in the right box.

Another way to compare the performances of two options against each of the criteria and to examine the strengths and weaknesses of any option is to use the so-called sorts graph, which is based on weighted differences (see Box 2 for sorts graph interpretation). Figure 8. 3 shows the weakness of the most preferred year (2001). Most of the weak components of year 2001 are in the human sector. They are dominated by income, as investigated in Chapter 7, employment, lifestyle and food components. On the other hand, the year gained its strength from the environmental side in primary commercial species, other aspects and non-target species components along with the conflict component of the human sector (Figure 8. 4). In other words, it can be concluded that the year 2001 was stronger in conservation than in financial returns, which implies that it was favoring long-term rather than short-term benefits.

Box 1: Sensitivity Down Graph Interpretation

Source: (Catalyze 2003)

Rather than manually change weights to test for sensitivity, the sensitivity down graph calculates which criteria weights are sensitive. The criteria are listed down the middle of the screen. Where a change to the cumulative weight of a criterion can result in a new most preferred option, a bar is drawn on the graph.

The bars are color coded. A red bar is very sensitive, a yellow bar less sensitive and a green bar would require a large weight change to alter the most preferred option.

The thresholds for color coding are as follows:

Red: Cumulative weight would have to change by less than 5 points in order to change the most preferred option.

Yellow: Cumulative weight would have to change by between >5 to 15 points in order to change the most preferred option.

Green: Cumulative weight would have to change by more than 15 points in order to change the most preferred option.

The bars drawn to the left of the criteria list represent a decrease in cumulative weight, whilst the bars drawn to the right represent an increase. For each instance of a bar being drawn, the new most preferred option is displayed at the end of the bar. Where there is no bar, no amount of weight change will change the most preferred option.

On the other hand, 1999 was the least preferred year during the study period. Figure 8. 5 shows the weakness of that year. Most of the weak components of the year 2001 are in the human sector. They are dominated by lifestyle, conflict, employment and income components along with the trawling intensity of the effects on environment component. Figure 8. 5 also shows that the differences in lifestyle and conflict are 100 points. This is because there was no single Omani owned vessel that year and the number of breaches were at their maximum level representing the lowest preferred score for lifestyle and conflict components respectively. As mentioned in Chapter 7, conflicts, as measured by the number of breeches, was high in 2001 as detected by the management authority through the monitoring enforcement of regulation in the period 1998-2001. This fact makes 2001 much stronger in reality, as it can be concluded that the number of breaches was underestimated in the other years (see Chapters 5 and 7).

Compare All at 100 minus 2001

	Model Order	Cum Wt	Diff	Wtd Diff	Sum
Effect on Human	Income	10.0	90	9.0	9.0
Effect on Human	Employment	10.0	85	8.5	17.5
Effect on Human	Lifestyle	10.0	71	7.1	24.7
Food	Nutrition	2.5	89	2.2	26.9
Food	Domestic market	2.5	89	2.2	29.1
Food	Food variety	2.5	33	0.8	29.9
Non-target species	Discards	5.6	10	0.5	30.5
Effect on Human	Conflict	10.0	3	0.3	30.8
Effect on Environment	Primary commercial species	16.7	0	0.0	30.8
Other aspect	Stock productivity	8.3	0	0.0	30.8
Other aspect	Trawling intensity	8.3	0	0.0	30.8
Non-target species	Non-target catch	5.6	0	0.0	30.8
Non-target species	Total catch	5.6	0	0.0	30.8
Food	Export	2.5	0	0.0	30.8
		100.0		30.8	

Figure 8. 3 Weaknesses of most preferred year (2001)

Note: The weakness is calculated as 100 minus year x score as explained in Box2. Columns 1 and 2 of the figure exhibit the selected node and the corresponding components under the node respectively. Column 3 lists the cumulative weight of each criterion (see Figure 8. 1 for cumulative weight distribution for each criterion). Following the information presented in Box 1, the difference column (column 4) is calculated as follows. For example, the score 90 = (100 - 10), where 10 is the preference score for income criterion in 2001 as shown in Figure 7. 11. The score 85 = (100 – 14.55), where 14.55 is the preference score for employment criterion in 2001 as shown in Figure 7. 9. The remaining values are calculated following a similar procedure. The corresponding weighted difference (Wtd Diff) values listed in column 5 are calculated by multiplying the 'Diff' figure by the corresponding cumulative weight (in %). For example, the score 9 = 90 * 0.10 and the score 8.5 = 85 * 0.10. The sum of the weighted scores gives the overall weight (i.e. 30.8 in this case). The 'Sum' column presents the cumulative sum of the weighted scores. The horizontal colored bars in the final box of the figure show the relative size of the weighted score. It is noted that the three key disadvantages of the year 2001 are related to its human components namely: income, employment and lifestyle.

Box 2: Sorts Graph Interpretation

Source: (Catalyze 2003)

The sorts graph displays four main types of data:

Cumulative Weight (Cum Wt): Displays the cumulative weight of the criteria. This is the proportion of the weight of the entire model that each criterion takes.

Unweighted Difference (Diff): Displays the difference between the unweighted preference values of the two options. It is the difference in score (on a 0 to 100 scale) of the two compared options as indicated below:

- Comparing two years: year *x* score minus year *y* score
- Strength: year *x* score
- Weakness: 100 minus year *x* score

Weighted Difference (Wtd Diff): Displays the unweighted difference (Diff) multiplied by the cumulative weight after cumulative weight is normalized on a 0 to 1 scale. These weighted numbers show the contribution of each of the criteria to the overall difference between the options as following:

Wtd Diff = Diff * (Cum Wt / 100)

The summation of weighted differences gives the difference in weight between the two compared years or by how weak much the year is (below 100) or strong (above 0) when using sorts graph to show weakness or strength.

Difference Graph: Displays the values in the sorted column graphically, using horizontal bars. The colors presented in sorts graphs have nothing to do with the level of sensitivity as explained in Box 1. They only indicate the direction of comparison i.e. year *x* minus year *y* or year *y* minus year *x*.

Compare 2001 minus All at 0

	Model Order	Cum Wt	Diff	Wtd Diff	Sum
Effect on Environment	Primary commercial species	16.7	100	16.7	16.7
Effect on Human	Conflict	10.0	97	9.7	26.4
Other aspect	Trawling intensity	8.3	100	8.3	34.7
Other aspect	Stock productivity	8.3	100	8.3	43.0
Non-target species	Total catch	5.6	100	5.6	48.6
Non-target species	Non-target catch	5.6	100	5.6	54.1
Non-target species	Discards	5.6	90	5.0	59.2
Effect on Human	Lifestyle	10.0	29	2.9	62.0
Food	Export	2.5	100	2.5	64.5
Food	Food variety	2.5	67	1.7	66.2
Effect on Human	Employment	10.0	15	1.5	67.6
Effect on Human	Income	10.0	10	1.0	68.7
Food	Domestic market	2.5	11	0.3	69.0
Food	Nutrition	2.5	11	0.3	69.2
		100.0		69.2	

Figure 8. 4 Strengths of most preferred year (2001)

Note: Strength is calculated as year x score minus zero according to the instructions presented in Box 2.

Compare All at 100 minus 1999

	Model Order	Cum Wt	Diff	Wtd Diff	Sum
Effect on Human	Lifestyle	10.0	100	10.0	10.0
Effect on Human	Conflict	10.0	100	10.0	20.0
Effect on Human	Employment	10.0	86	8.6	28.6
Other aspect	Trawling intensity	8.3	81	6.8	35.4
Effect on Human	Income	10.0	49	4.9	40.3
Effect on Environment	Primary commercial species	16.7	27	4.5	44.8
Non-target species	Total catch	5.6	77	4.3	49.1
Non-target species	Non-target catch	5.6	50	2.8	51.8
Food	Export	2.5	78	1.9	53.8
Other aspect	Stock productivity	8.3	17	1.4	55.2
Non-target species	Discards	5.6	26	1.4	56.6
Food	Domestic market	2.5	56	1.4	58.0
Food	Nutrition	2.5	54	1.4	59.4
Food	Food	2.5	15	0.4	59.8
		100.0		59.8	

Figure 8. 5 Weaknesses of least preferred year (1999)

In comparing the most preferred year (2001) to the least preferred year (1999), the results in Figure 8. 6 show that the year 2001 has the four largest advantages in conflict, trawling intensity, primary commercial species and total catch components. The results also show five smaller advantages in s lifestyle, non-target catch, export, stock productivity and discards. On the other hand, the year 1999 shows one largest advantage in regard to income component and three smaller advantages in its food sub-components (indicated by negative differences). This reflects the shift in the total landing from the commercial sector to the traditional sector as discussed in Chapter 7. This shift in turn affected the food components also. This particular case is further investigated as a case 2 (adjusted case) scenario in this chapter to reflect the true situation.

Compare 2001 minus 1999

	Model Order	Cum Wt	Diff	Wtd Diff	Sum
Effect on Human	Conflict	10.0	97	9.7	9.7
Other aspect	Trawling intensity	8.3	81	6.8	16.5
Effect on Environment	Primary commercial species	16.7	27	4.5	21.0
Non-target species	Total catch	5.6	77	4.3	25.3
Effect on Human	Lifestyle	10.0	29	2.9	28.1
Non-target species	Non-target catch	5.6	50	2.8	30.9
Food	Export	2.5	78	1.9	32.8
Other aspect	Stock productivity	8.3	17	1.4	34.3
Non-target species	Discards	5.6	16	0.9	35.2
Effect on Human	Employment	10.0	1	0.1	35.3
Food	Food variety	2.5	-19	-0.5	34.8
Food	Domestic market	2.5	-33	-0.8	34.0
Food	Nutrition	2.5	-35	-0.9	33.1
Effect on Human	Income	10.0	-41	-4.1	29.0
		100.0		29.0	

Figure 8. 6 The overall comparative results of years 2001 and 1999

Note: In this so-called sort graph, criteria are sorted according to the weighted difference between 2001 and 1999.

As mentioned above and shown in Figure 8. 3, income has contributed a lot to the weakness of the most preferred year. The so-called sensitivity up graph[3] was used to have a closer look at, and further investigation of, the income component. The sensitivity up graph shows how most options (year) at the top of the tree may change over the 0-100 weight range. It shows more detail than the sensitivity down graph (see Box 3 for sensitivity up graph interpretation). Figure 8. 7 shows sensitivity up graph for the income component, which has a current cumulative weight of 10 points shown on the x-axis. The vertical red line shows the current

[3] The sensitivity up graph displays the sensitivity of the overall results to a change in the weight of a selected criterion or node over the entire range of 0 to 100.

cumulative weight of the income criterion (10%) as shown on the x-axis. The total scores of the other options are read where the current cumulative weight intersects with the total weighted scores, which are represented by the slanting lines (see Box 3). Figure 8. 7 shows also that the year 2001 (as indicated by option 5) has the highest score at 10 points cumulative weight, thereby indicating the fact that year 2001 is the most preferred year. However, if income cumulative weight, for example, is increased either slightly by more that 17 or 22 points (as shown by the shaded areas), year 2006 (as option 10) or 2002 (as option 6) stand out as the most preferred years respectively. Furthermore, if income cumulative weight for example increased to over 50 points, year 2001 would be fully dominated by all the other years and 1997 would be the dominant year.

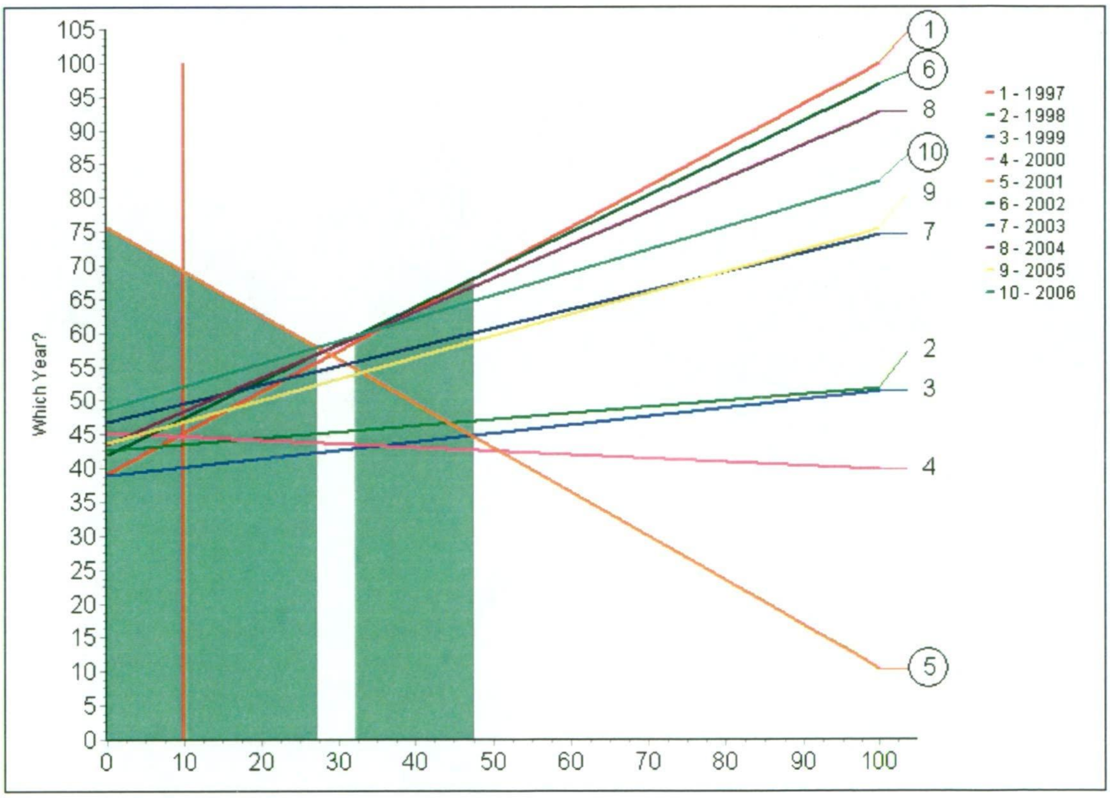


Figure 8. 7 Sensitivity up analysis on income component

Note: The current cumulative weight on income of 10% is shown by the vertical red line.

Box 3: Sensitivity Up Graph Interpretation

Source: (Catalyze 2003)

Sensitivity up graph demonstrates how the overall weighted preference values for all the options vary with the cumulative weight on a component. The x-axis represents the cumulative weight of the component. The y-axis shows the total weighted values, at the root node, of each of the options.

The vertical red line shows the current cumulative weight of the component. The y-values for each option at the intersection with the vertical red line are the same as the total weighted scores in the node data window for the root node. The sloping lines for the options show how the total weighted scores change as the cumulative weight of the component changes.

The most preferred option at any cumulative weight has the highest y-value. The upper surface of the graph always shows the most preferred option for a given cumulative weight. At the vertical red line, the most preferred year should have the highest y-value. The green shaded area shows the amount of cumulative weight required by any option to take over as the most preferred.

8.2.2.1 Effect on Humans

As investigated in Chapter 7, and shown in Figure 8. 3, the weaknesses of the most preferred year (2001) were mainly caused by the criteria of the effect on humans component. Sensitivity up graph for effect on humans component (Figure 8. 8) shows that there is an approximate difference of 30 more points to the next preferred year. The assigned weight for this component required adjustment to around 80 points for years 2006 and 2004 to become the most preferred year. It also shows that years 1998, 1999 and 2000 are totally dominated and will never be preferred at this level of analysis.

There is a connection between the most preferred year (2001) and the dominated years of 1998, 1999 (the least preferred year) and 2000. The relationship is that during this period, the fisheries sector had witnessed different management phases and suffered structural changes. For a short period (1998-2002), it was unexpected to embrace both most and least preferred year with two years difference. This extraordinary event raises many interrogative issues evoking more investigation. The main examination, as mentioned previously, is to adjust some of the possible modifiable components, which will be carried out in case 2. One possible explanation worth mentioning is that once the new regulations were introduced (see Chapters 2, 5 and 7), those fishing companies concerned, opposed and protested and as a result, a reduction in the fishing effort occurred. This protestation did not last for long and the number of vessels again increased. This may give an indication that the trawling fishing sector could be restored back to normal size even if the new fishing regulations were not cancelled.

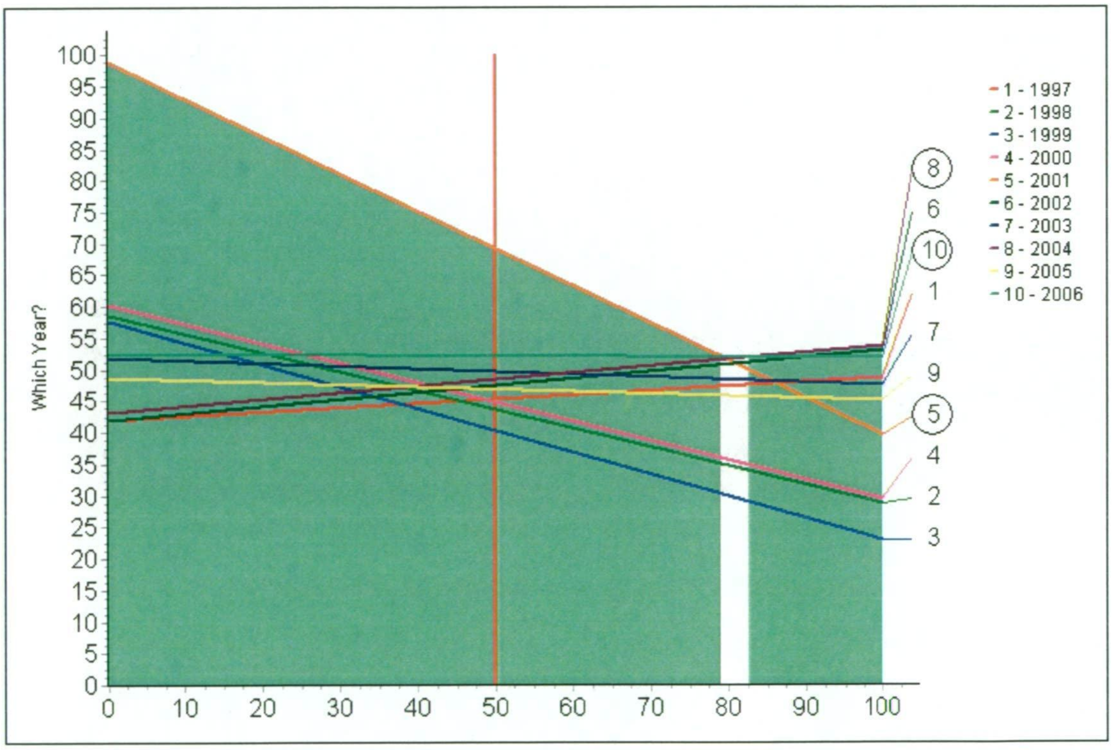


Figure 8. 8 Sensitivity up of effect on human component

Figure 8. 9 shows that the most preferred year for effect on human component is 2004. It also shows that if the cumulative weight of income is decreased by more than 15 points[4], the overall most preferred year (2001) will take over and also become the most preferred year for the effect on human component. The same will happen if the weight of export is increased by between 5 to 15 points. In other words the year 2001 would overtake 2002 if income figures were adjusted for the period 1998-2002, the period during which a sharp reduction in landings and

[4] Such results support the decision to use 40 points weight difference in Sections 8.4 and 8.5.

therefore in income occurred. This is true as there is some evidence of income shift from commercial trawling to the traditional sector. A close look at food component (Figure 8. 10) shows that the most preferred year is 2000. However an increase of more than 15 points in the weight of food variety or export will change it to year 2004 (the most preferred year for effect on human component) or 2001 (the overall most preferred year) respectively (Figure 8. 10). On the other hand, sensitivity up graph of food component (Figure 8. 11) shows that for the year 2000 to overtake 2001 as the most preferred year, food weight is required to change to 50 points instead of the present 10 points.

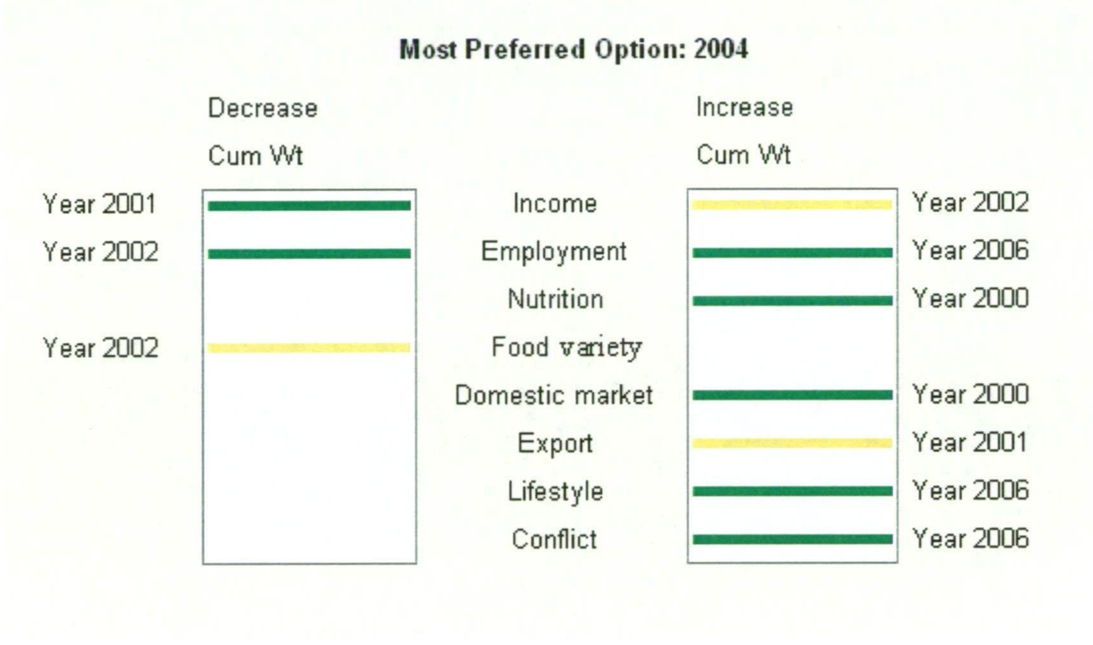


Figure 8. 9 Most preferred year (sensitivity down) of the effect on human component

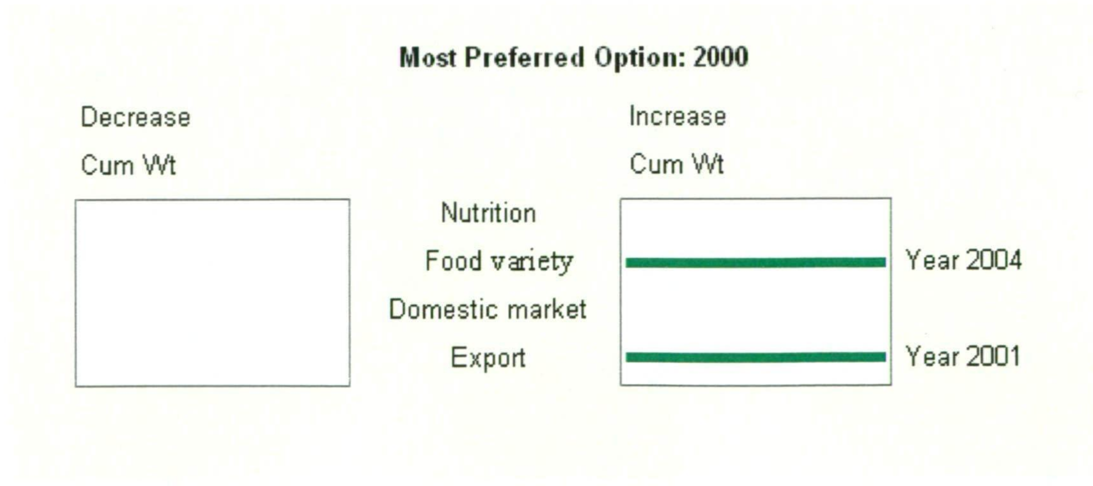


Figure 8. 10 Most preferred year (sensitivity down) of food component

8.2.2.2 Effect on the Environment

Sensitivity analysis of effect on environment component shows that the most preferred year is 2001. The sensitivity down graph (Figure 8. 12) shows that only a change in the cumulative weight of discards component by more than 15 points will change the preferred year to 2006. No other amount of weight change will ever change the most preferred year. This indicates a strong management trend toward environment and a long-term benefit in the year 2001. Sensitivity up graph (Figure 8. 13) supports this argument and indicates that only a reduction in the weigh, by not less than 29 points given to this component will change the most preferred year to the years 2006 or 2004.

A close look at the non-target species component (the node for discards criterion) shows that no amount of weight change can alter the most preferred year (Figure 8. 14). This indicates that 2001 is the fully dominant year and no other year will ever be preferred at this level of analysis. Sensitivity up graph of discards component (Figure 8. 15) shows that a change of discard weight from its recent level of 5.6 points to around 97 points will allow 2006 only to take over as preferred year.

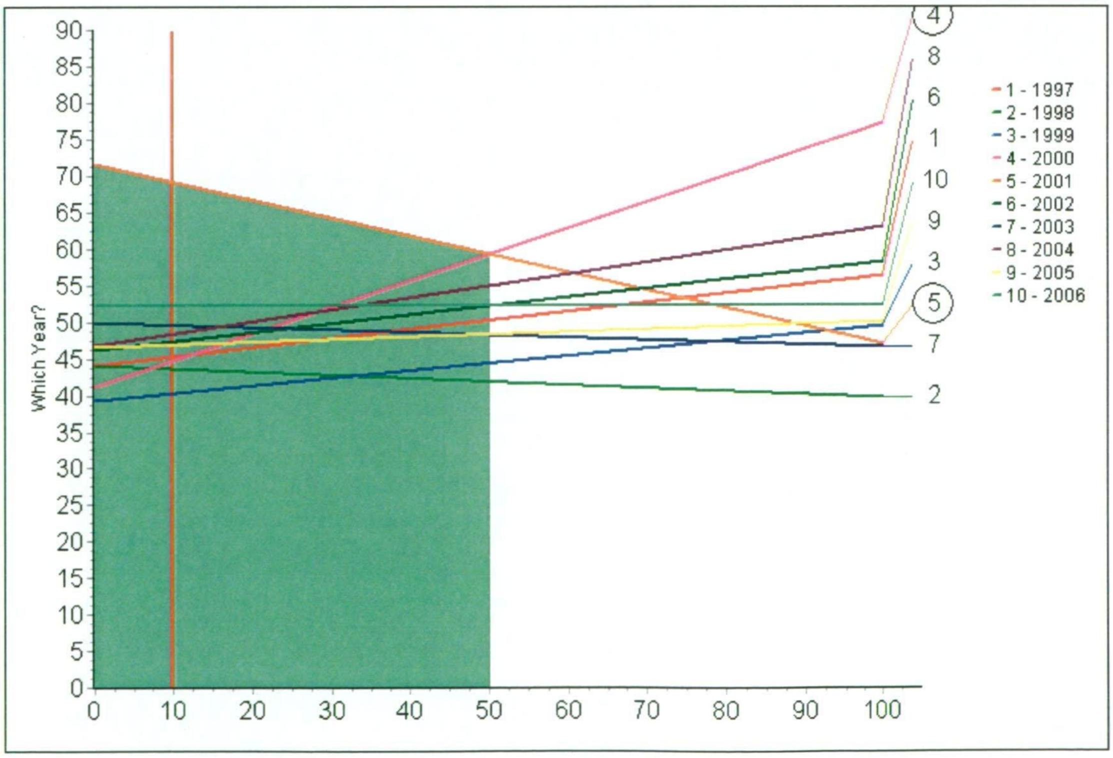


Figure 8. 11 Sensitivity up of Food component

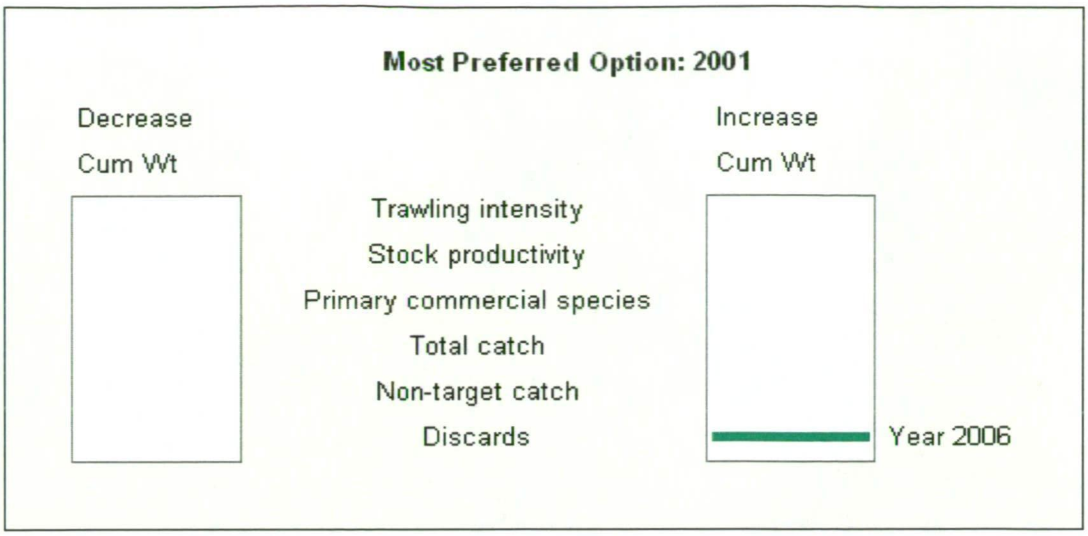


Figure 8. 12 Most preferred year (sensitivity down) of the effect on environment component

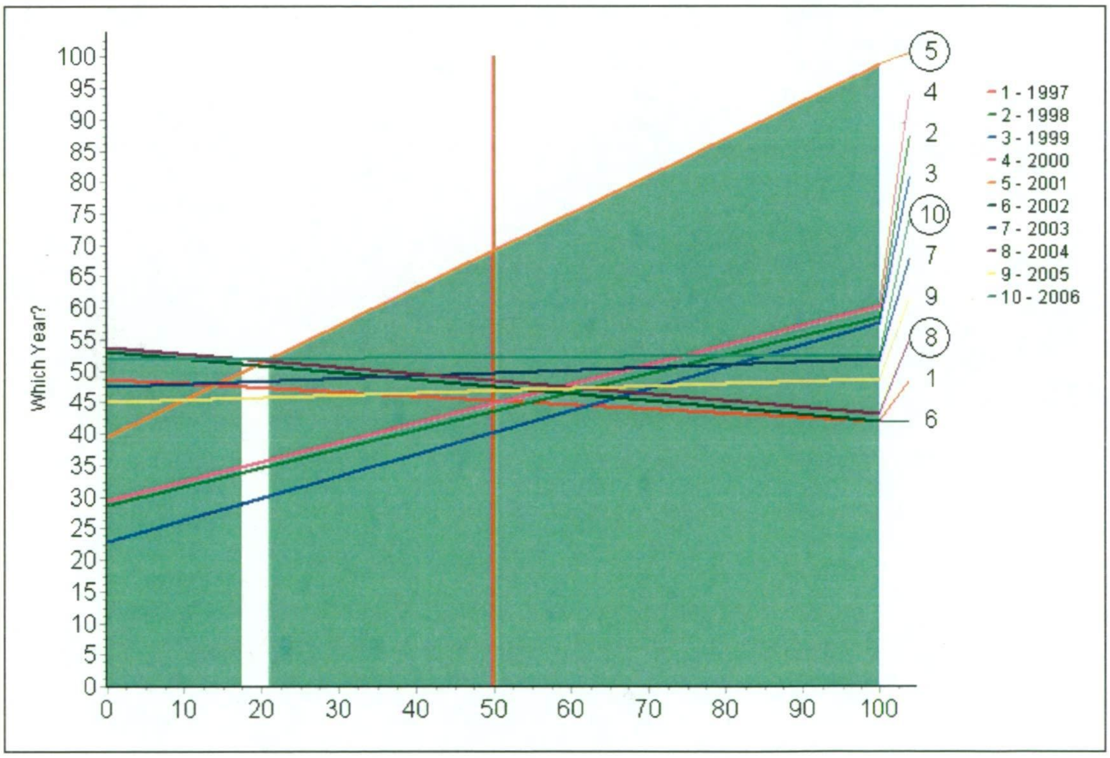


Figure 8. 13 Sensitivity up of effect on environment component

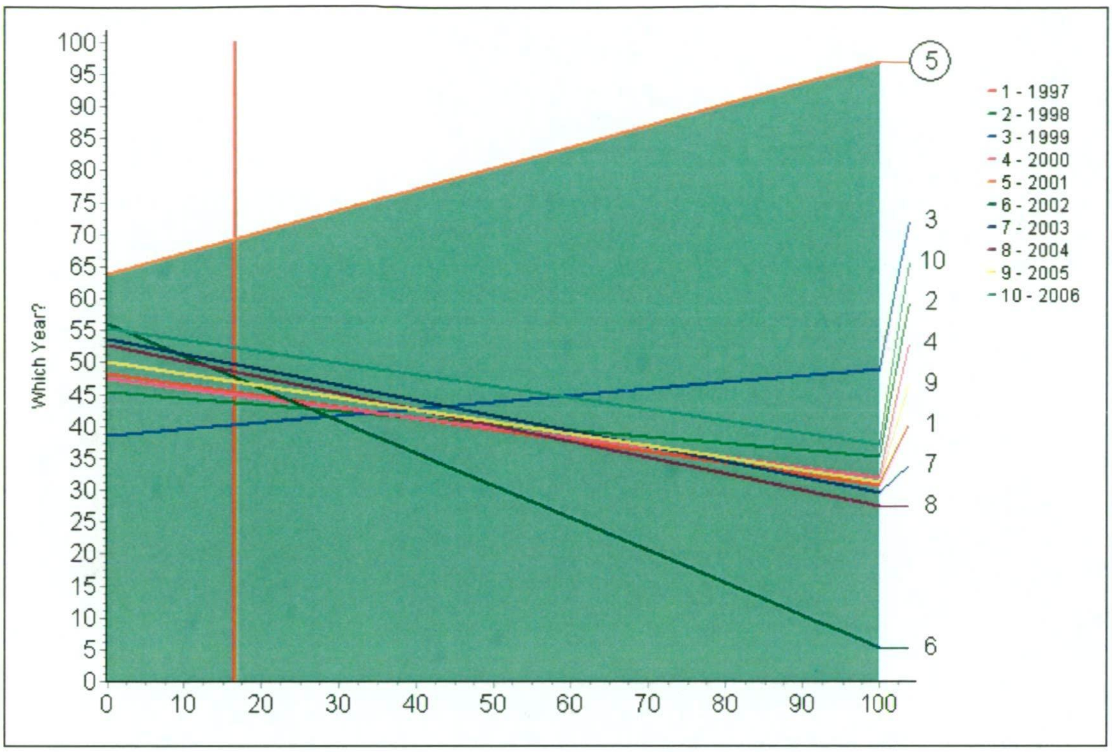


Figure 8. 14 Sensitivity up of non-target species component

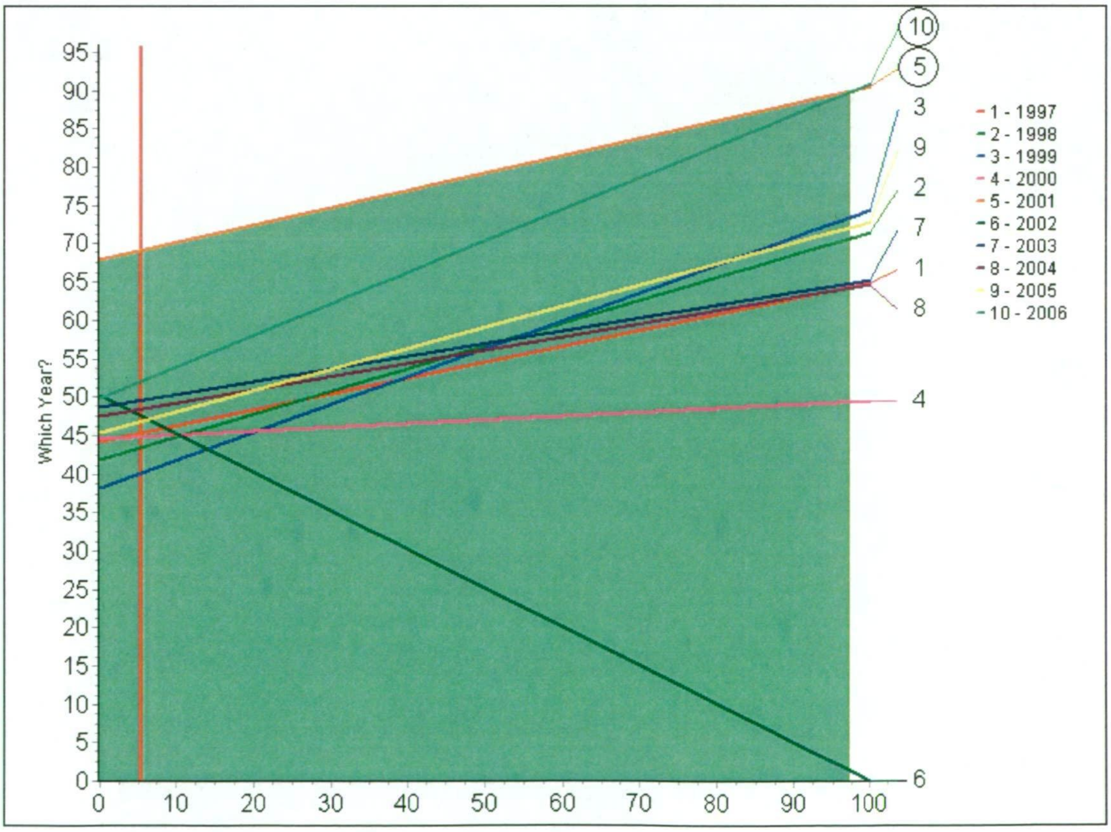


Figure 8. 15 Sensitivity up of discards component

8.2.3 Case 2: Sensitivity Analysis for the Adjusted Case

Sensitivity analysis worked out for the base case (Section 8.3) highlighted the need for further examination on the effect of human component. The evidence of income shift toward the traditional sector reinforces this argument and therefore concentrates the investigation primarily on income. Although sensitivity results also highlighted employment, lifestyle and food components as heavily contributing to the tendency of the MCA result and its decision, availability of data and indicators only minimized the adjustment to the income component and the nutrition and domestic markets sub-components of the food component.

Mathews et al. (2001) were the first to investigate the increase in traditional landing driven by the reduction in the amount of exerted effort by commercial trawling. They stated that the gross revenue of traditional fishermen is impacted heavily by the industrial fishery. It increases by 600 OMR per year from 1,245 OMR to 1845 OMR as the closed season increases from zero to 12 months per year. Those figures will be used to roughly estimate the amount of income transferred to the traditional fishermen to be recalculated with the income gained by commercial trawling for the required adjustment.

The landing of the commercial trawling sector was not only affected by the closed season but also by the number of working vessels. Therefore, actual number of closed months were calculated based on the total fishing days exerted by the total number of trawlers for each year in the period 1998-2001. To be more precise and accurate, the calculations of the total number of fishermen were taken from fishing grounds around the permitted trawling area, these being Al-Wusta region, Masirah Island and Wilayat Shalaim & Hallaniyat. Table 8. 1 shows the calculation process followed to allow adjustment of the income component data.

As revealed previously by Figure 8. 9, income weight has to be reduced by more than 15 points in order to change the most preferred year from 2004 to 2001 (the overall most preferred year). However, this sensitivity level increases as the point is reduced to less than 5 points after income is adjusted (Figure 8. 16).

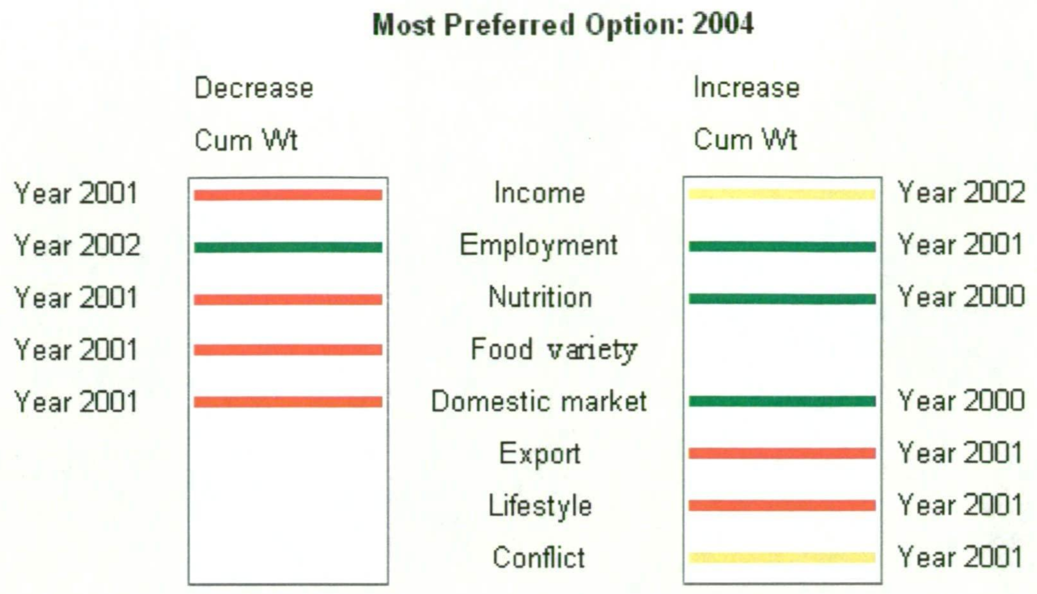


Figure 8. 16 Most preferred year (sensitivity down) of the effect on human component after income adjustment

The income shift described above was a result of proportional transfer of catch from trawlers to traditional fishermen and hence more catch was available for the domestic market and consequently for nutrition. Proportionally, the percentage of income increment was then used to compute a crude estimate of the amount of catch gained by the traditional fishermen around the permitted trawling area. This amount of reallocated catch is certainly not entirely consumed by local market. Therefore, average annual export percentage was employed to subtract the amount of catch anticipated to be exported. The remaining figure was then added to the total catch retained for the local market in the period 1998-2001 (Table 8. 2). This adjusted catch retained for the local market was used to adjust nutrition and domestic market sub-components data for the period 1998-2001. It should be noted that a normally low percentage of catch coming from traditional fishermen will be exported (38 % average in the period 1998-2001), whereas most of the catch from trawlers is exported (87 % average in the period 1998-2001). This means more catch will be retained by the local market in the period 1998-2001 if it comes from traditional sources compared to that coming from trawlers. Therefore, per capita fish consumption will definitely increase.

Table 8. 1 Adjusted annual income of commercial trawling sector

Year	1998	1999	2000	2001
Actual income (OMR)	1879717	1861870	1444632	374724
No. of fishermen in the region				
Masirah	1027	1114	1170	1211
Al-Wusta	2701	2761	2864	2958
Shalaim & Hallaniyat	371	420	451	466
Total	4099	4295	4485	4635
No. of Vessels	18	11	10	7
Fishing Days	1795	1628	1288	304
Actual season duration	3.3	4.9	4.3	1.4
Actual closed months	8.7	7.1	7.7	10.6
As per Mathews et al. (2001):				
income gain/fisher/month:	50 OMR			
Total gain by each fisherman	433.796	353.333	385.333	527.619
Gain by all fishermen in the region	1778131	1517567	1728220	2445514
Adjusted income (OMR)	3657848	3379437	3172852	2820239

Table 8. 2 shows per capita fish consumption for the period 1998-2001. It is clear that the per capita maximum figure has increased from 0.157 kg in 2000 to 1.007 kg in 2001 due to the increase in the amount of catch retained by the local market in the same year.

The preferred change in nutrition and domestic markets significantly distinguished the period 1998-2001 for the food component (Figure 8. 17) compared to the base case status (Figure 7. 8). The most preferred year has changed from the year 2000 to 2001, with the score raised from 77 to 92 points. After this adjustment, sensitivity up graph (Figure 8. 18) proves that 2001 is the dominant year and no change in the food component weight will alter 2001 from being the most preferred year. Before adjustment, a change by more than 40 points was required to change the most preferred year to 2000. With regard to other components, sensitivity down graph (Figure 8. 19) shows that only a change in the food variety weight by more than 15 points will change the most preferred year to 2000; still within the period

1998-2001. However, along with landing, food variety[5] is also assumed to improve, which overall will strengthen the position of year 2001 as the most preferred year.

Table 8. 2 Adjusted catch retained by local market from commercial trawling sector

Year	1998	1999	2000	2001
Actual catch retained by local market (mt)	153.475	238.785	538.370	59.922
Total traditional landing (mt)	88557	96663	108019	125275
Total traditional value (OMR)	46658000	49144000	46566000	51573000
Unit price (OMR/mt)	526.870	508.405	431.091	411.678
Income gain (OMR)	1778131	1517567	1728220	2445514
Catch gain (mt)	3374.897	2984.953	4008.946	5940.353
Percentage of export	33	42	39	40
Percentage of retained	67	58	61	60
Adjusted catch retained by local market (mt)	2261.181	1731.273	2445.457	3564.212
Per capita fish consumption (kg)	0.692	0.521	0.713	1.007

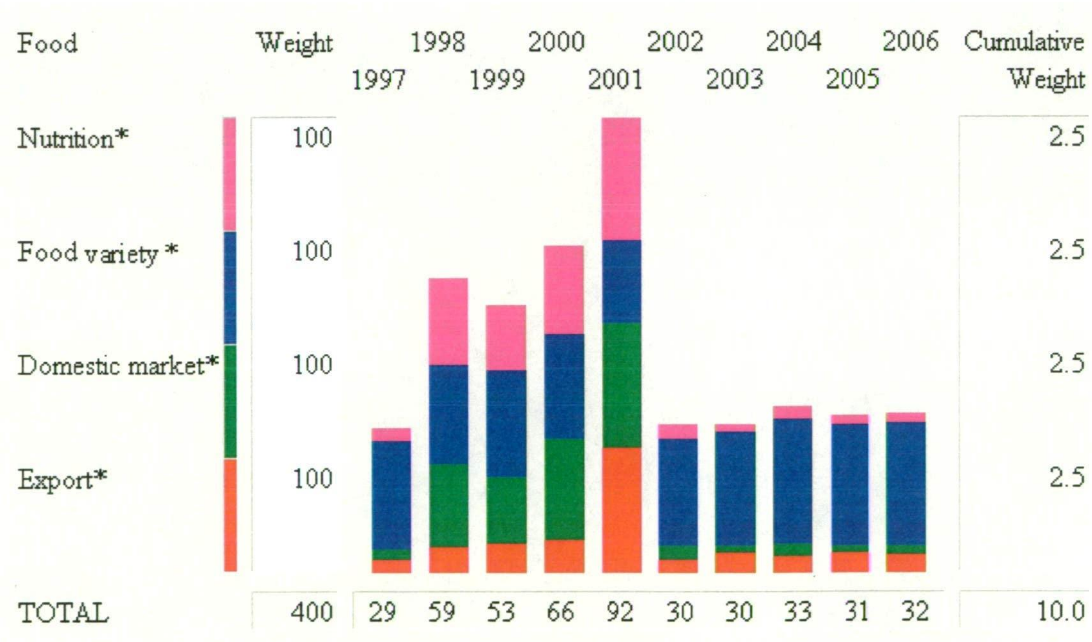


Figure 8. 17 Weight scores and criteria contributions of food component after adjustment

[5] This indicator could not been adjusted along with income due to unavailability of data.

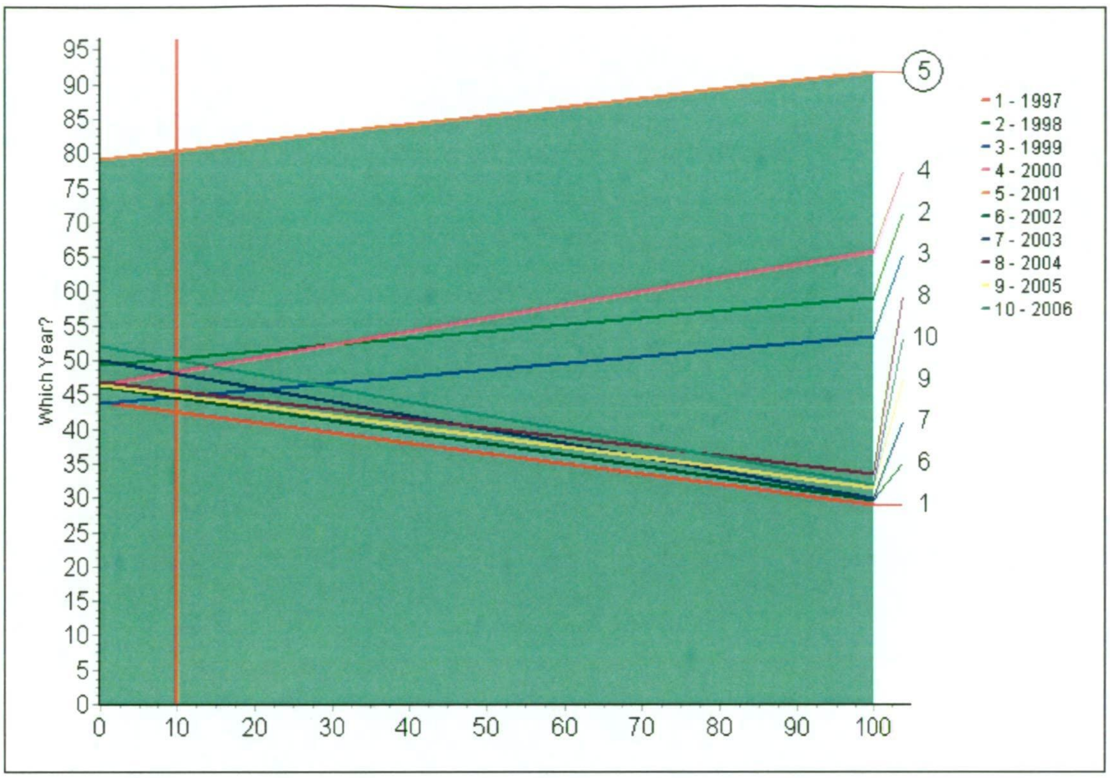


Figure 8. 18 Sensitivity up of food component after adjustment

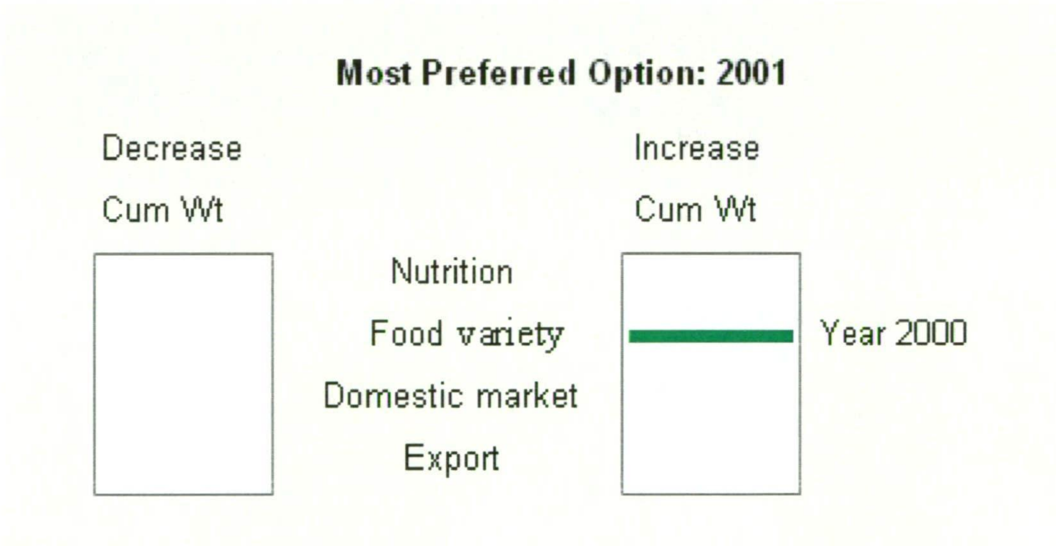


Figure 8. 19 Most preferred year (sensitivity down) of food component after adjustment

Since the adjustment was only calculated for nutrition and domestic market of the food and income components, effect on human component was greatly affected. The most preferred year for this component has changed from the year 2004 (Figure 7. 26) to the year 2001 (Figure 8. 20) with a change in score from 54 to 62 points. It should be noted that year 2001 was the seventh preferred option with a score of 14 points less than the most preferred year, where it now has a score of 14 points higher than the second preferred year (2004).

The most preferred year (2001) of this adjusted case was compared with the most preferred year (2004) of the human component of the base case (Figure 8. 21). The result of this comparison revealed that year 2004 performed better only in income and food variety with weighted difference of 1.5 and 0.8 points respectively. On the other hand, year 2001 performed better in all other criteria, significantly in trawling intensity with 94 points score difference and 7.8 points in weighted difference. Overall as with the case of food component, no further change (increase or decrease) in the weight of effect on human component will alter the most preferred year 2001 as confirmed by the sensitivity up graph (Figure 8. 22). The same result was revealed for the effect on environment component (Figure 8. 23).

All the above results and sensitivity analyses clearly conclude that any level of preference weight given to effect on human component or effect on environment component, by the management scheme imposed in year 2001 will still favour sustainable economic growth, sustainable society and ecological sustainability.

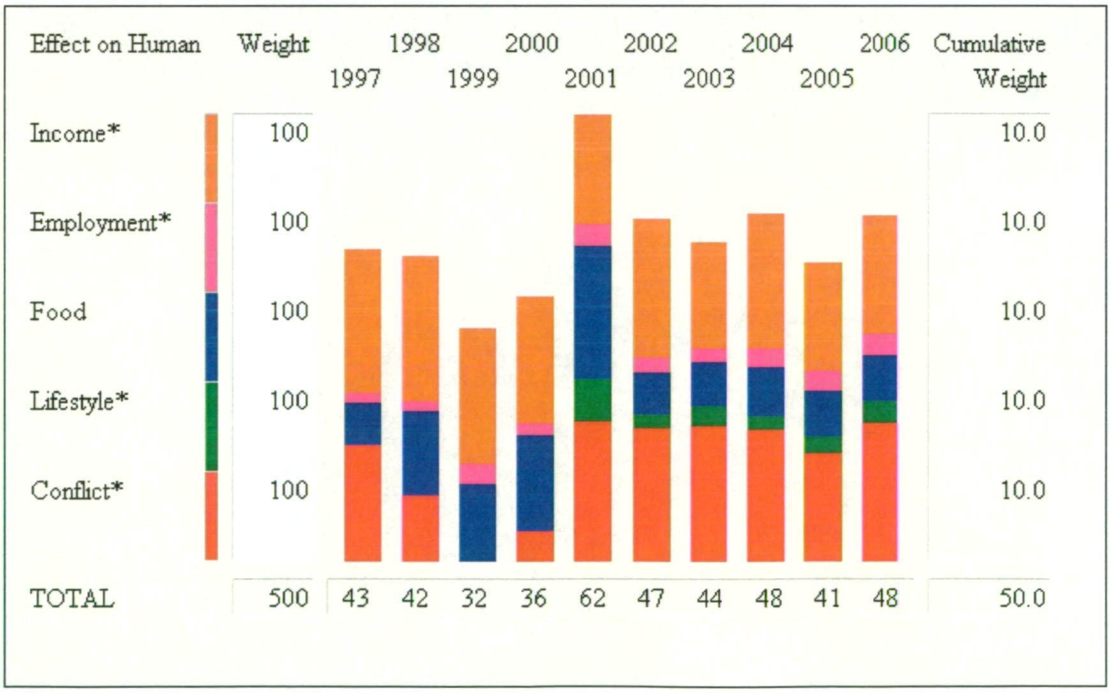


Figure 8. 20 Weight scores and criteria contributions of effect on human component after adjustment

Compare 2001 minus 2004

	Model Order	Cum Wt	Diff	Wtd Diff	Sum
Other aspect	Trawling intensity	8.3	94	7.8	7.8
Non-target species	Non-target catch	5.6	95	5.3	13.1
Non-target species	Total catch	5.6	88	4.9	17.9
Effect on Environment	Primary commercial species	16.7	27	4.5	22.4
Other aspect	Stock productivity	8.3	48	4.0	26.5
Food	Domestic market	2.5	90	2.2	28.7
Food	Nutrition	2.5	89	2.2	30.9
Food	Export	2.5	88	2.2	33.1
Effect on Human	Lifestyle	10.0	19	1.9	35.0
Non-target species	Discards	5.6	26	1.4	36.4
Effect on Human	Conflict	10.0	7	0.7	37.1
Effect on Human	Employment	10.0	1	0.1	37.2
Food	Food variety	2.5	-33	-0.8	36.4
Effect on Human	Income	10.0	-15	-1.5	34.9
		100.0		34.9	

Figure 8. 21 Sorts comparing most preferred year for adjusted case (2001) with most preferred year of the human component base case (2004)

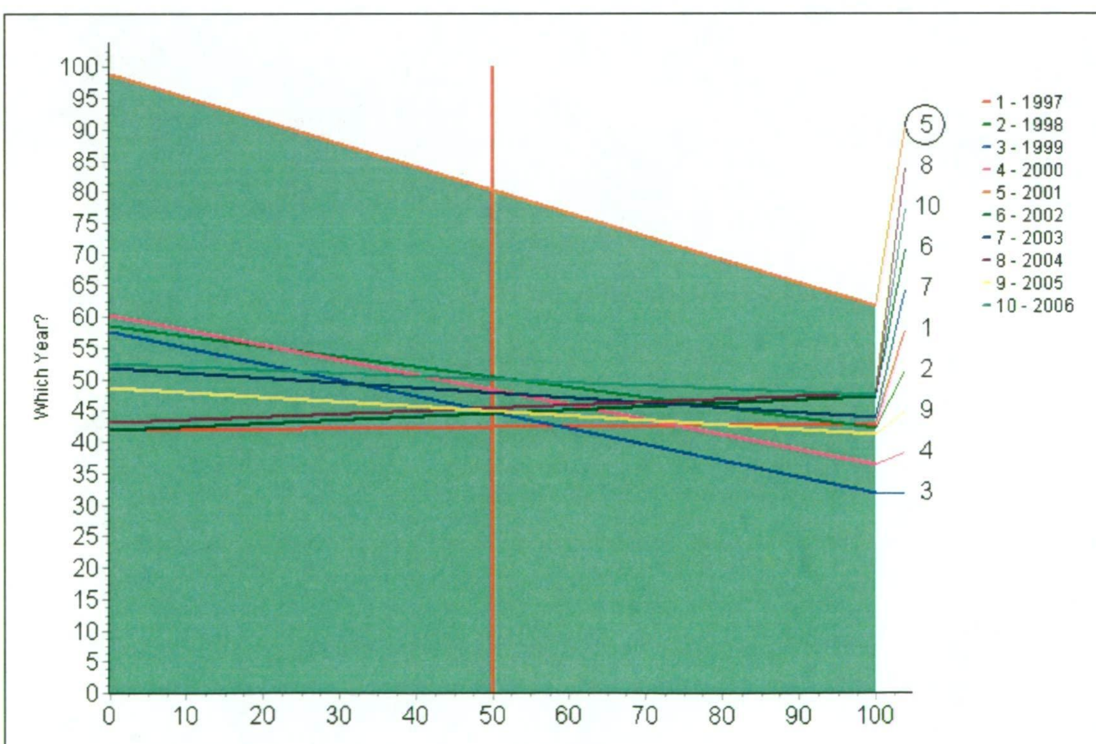


Figure 8. 22 Sensitivity up of effect on human component after adjustment

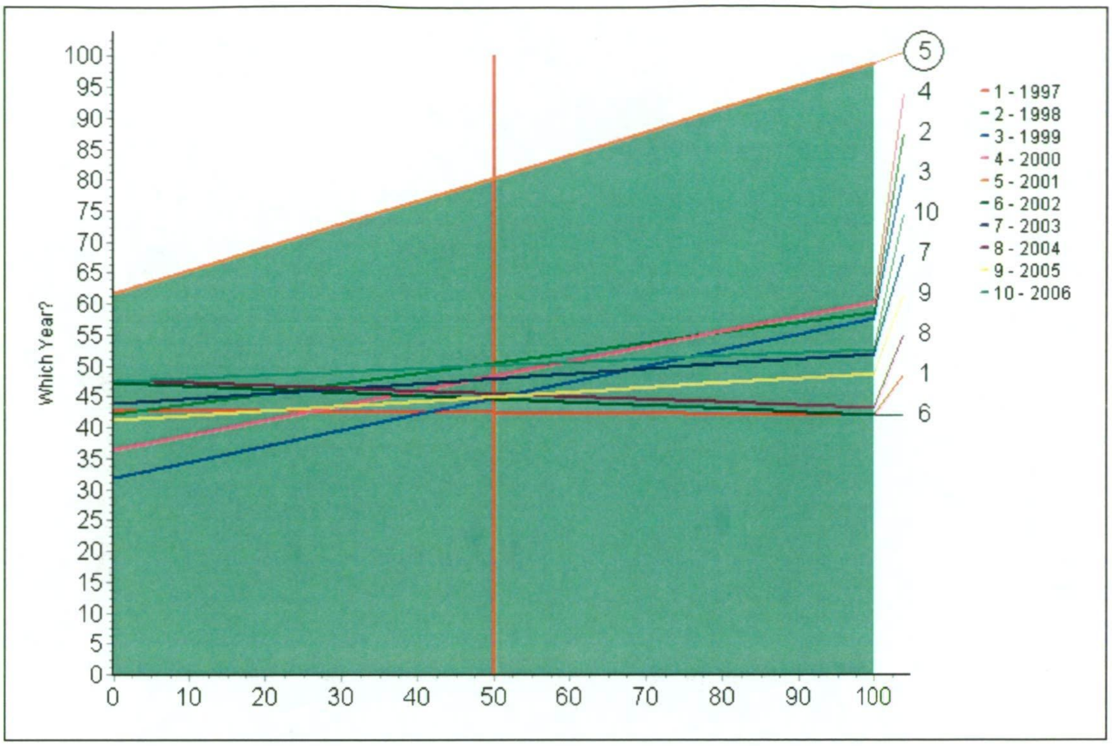


Figure 8. 23 Sensitivity up of effect on environment component after adjustment

8.2.4 Case 3: Short-term Financial Returns Case

In this case extra weight is given to the economic components assuming a short-term financial returns policy is that aimed for by the responsible authority. In contrast, less weight is assigned to the environmental components following the weights plan showed in Figure 8. 1. Sensitivity analysis results of this case show that the period 1998-2001 demonstrated the lowest contribution toward short-term financial objectives (Figure 8. 24). This period, as mentioned earlier, had witnessed different management phases, was distinguished as a conservation stage and encompassed the most preferred year (2001) in both base and adjusted cases. The weakness of this period was mainly represented in effect on human component (Figure 8. 25). However it still performed well in the effect on environment component although conservation components were assigned low weights (Figure 8. 26).

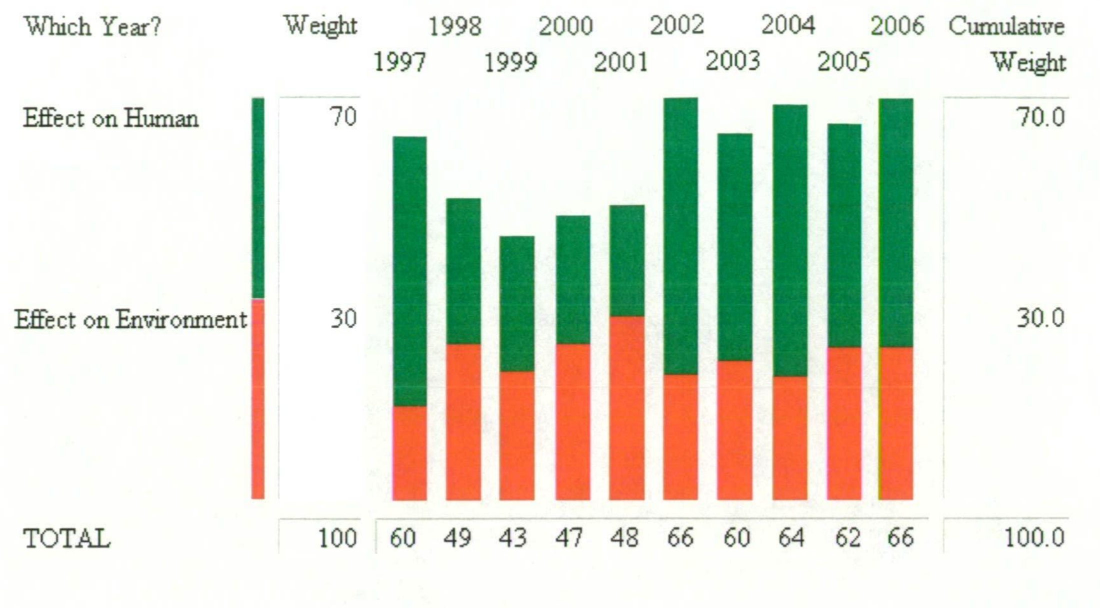


Figure 8. 24 Weight scores and criteria contributions from both human and environment components for short-term financial returns case

As revealed in the base case sensitivity analysis (Section 8. 2), favoring some criteria such as income and employment by more than 15 points will change the most preferred year from 2001 to 2006. This prospect was supported by this case when favoring financial returns over conservation. As shown by Figure 8. 27, the most preferred year for this case is 2006. The same figure shows that year 2002 is a strong rival to year 2006 and holds most of the criteria with high sensitivity to any change in their weight. This means that any change by less than 5 points in weights will change the most preferred year to 2002.

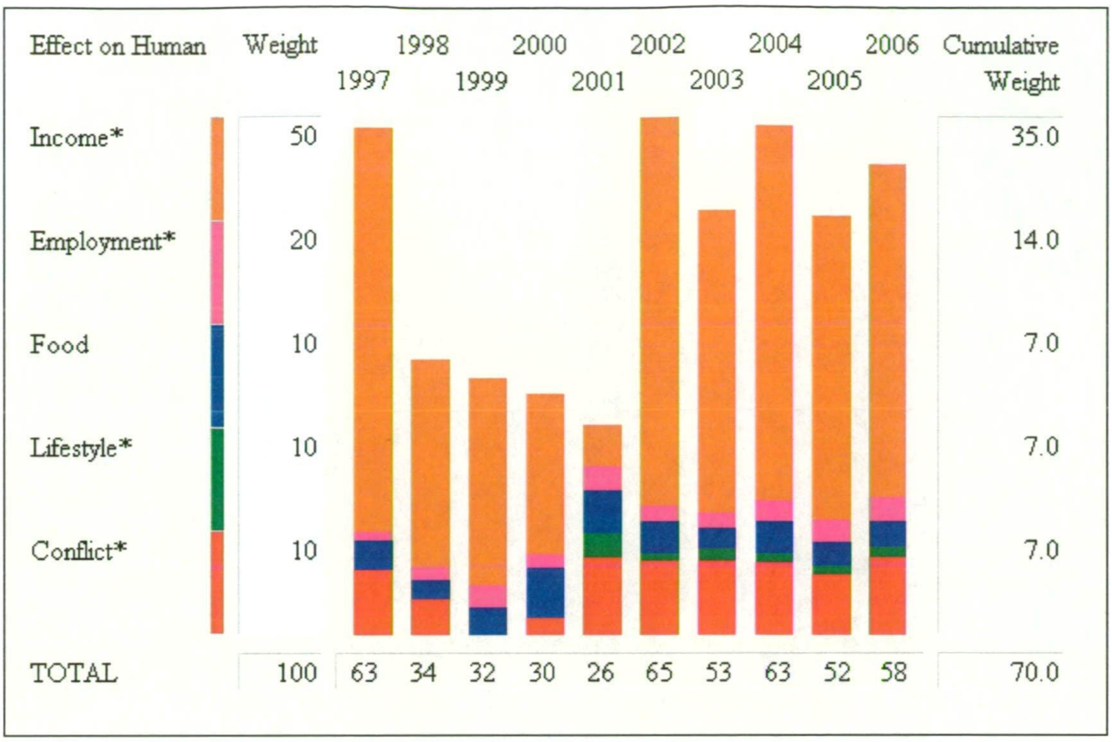


Figure 8. 25 Weight scores and criteria contributions of effect on human component for short-term financial returns case

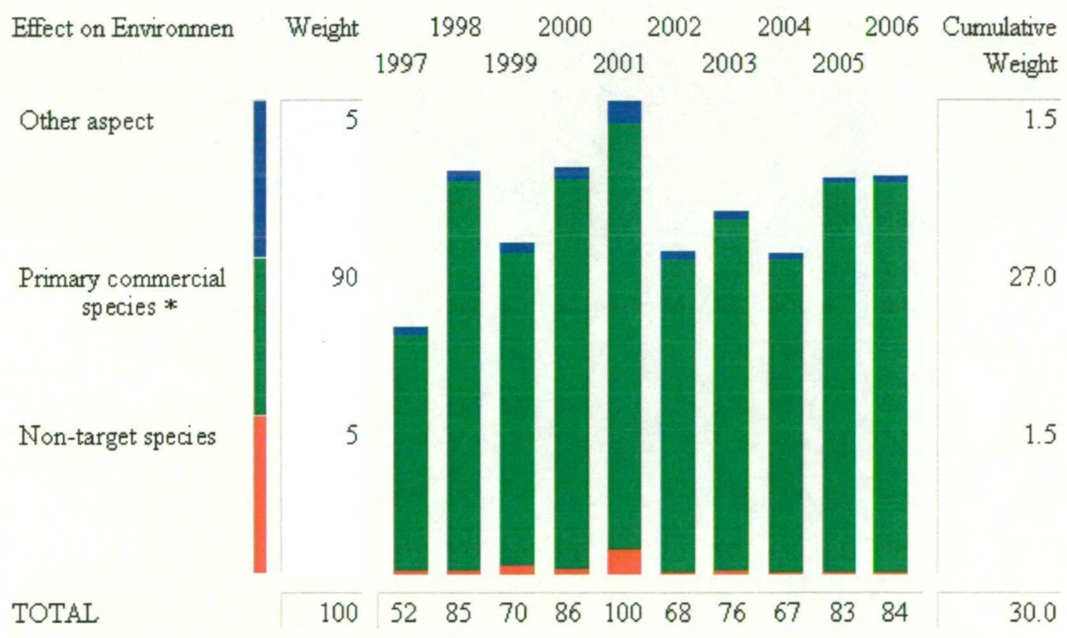


Figure 8. 26 Weight scores and criteria contributions of effect on environment component for short-term financial returns case

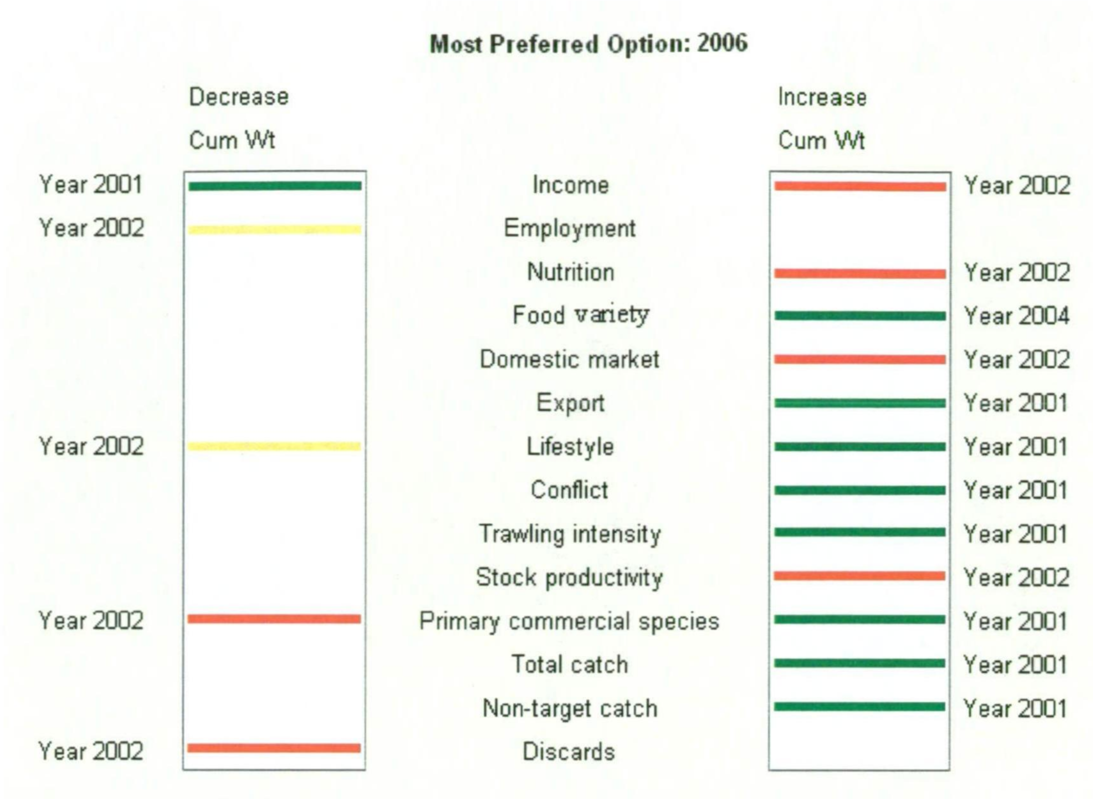


Figure 8. 27 Most preferred year (sensitivity down) during the study period for short-term financial returns case

Figure 8. 28 shows strengths of the most preferred year (2006). It is clear that year 2006 gained its strength from the human component (financial returns) and the primary commercial species. The primary commercial species component has been assigned high weight compared to other environmental components because a higher financial return was expected when more catch was landed. On the other hand, year 2006 suffered weakness in the employment component (Figure 8. 29) due to the low number of local employees, as was the case for all other case studies.

Figure 8. 30 and Figure 8. 31 show sensitivity up graphs for effect on human and effect on environment components respectively. Both graphs support the decision to use 40 points weight difference as the weight of the human component. For year 2002 to overtake year 2006, the figure was required to be raised to around 72 points (compared to the recent 70 points). On the other hand, for year 2002 to take over 2006 effect on environment component required weight to be reduced to around 28 points (compared to the recent 30 points). It is also clear that no other option can overtake year 2006 in the 30-70 points weight scale.

Compare 2006 minus All at 0

	Model Order	Cum Wt	Diff	Wtd Diff	Sum
Effect on Human	Income	35.0	82	28.9	28.9
Effect on Environmen	Primary commercial species	27.0	91	24.6	53.4
Effect on Human	Conflict	7.0	96	6.7	60.1
Effect on Human	Employment	14.0	15	2.1	62.2
Food	Domestic market	3.5	50	1.8	64.0
Effect on Human	Lifestyle	7.0	14	1.0	65.0
Food	Export	3.5	14	0.5	65.5
Other aspect	Stock productivity	0.6	52	0.3	65.8
Non-target species	Total catch	0.8	14	0.1	65.9
Other aspect	Trawling intensity	0.9	7	0.1	65.9
Non-target species	Non-target catch	0.8	6	0.0	66.0
Food	Nutrition	0.0	46	0.0	66.0
Food	Food variety	0.0	98	0.0	66.0
Non-target species	Discards	0.0	91	0.0	66.0
		100.0		66.0	

Figure 8. 28 Strengths of most preferred year for short-term financial returns case

Compare All at 100 minus 2006

	Model Order	Cum Wt	Diff	Wtd Diff	Sum
Effect on Human	Employment	14.0	85	11.9	11.9
Effect on Human	Income	35.0	18	6.1	18.1
Effect on Human	Lifestyle	7.0	86	6.0	24.1
Food	Export	3.5	86	3.0	27.1
Effect on Environment	Primary commercial species	27.0	9	2.4	29.5
Food	Domestic market	3.5	50	1.7	31.2
Other aspect	Trawling intensity	0.9	93	0.8	32.1
Non-target species	Non-target catch	0.8	94	0.7	32.8
Non-target species	Total catch	0.8	86	0.6	33.4
Effect on Human	Conflict	7.0	4	0.3	33.7
Other aspect	Stock productivity	0.6	48	0.3	34.0
Food	Nutrition	0.0	54	0.0	34.0
Food	Food variety	0.0	2	0.0	34.0
Non-target species	Discards	0.0	9	0.0	34.0
		100.0		34.0	

Figure 8. 29 Weakness of most preferred year for short-term financial returns case

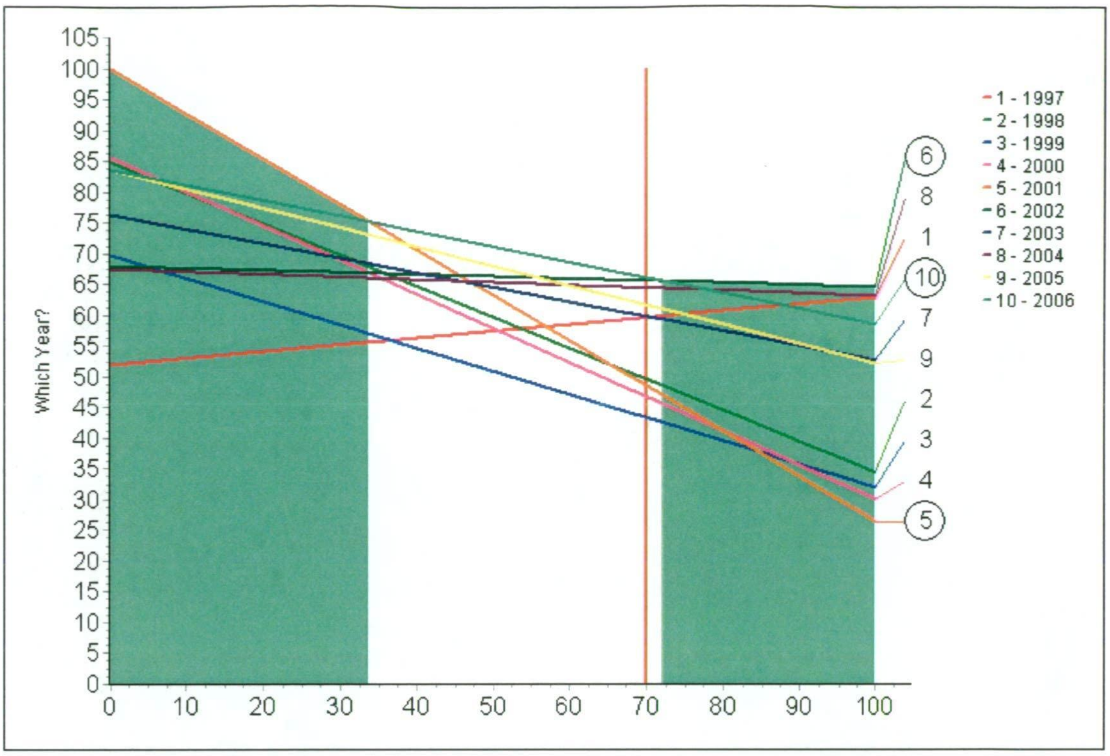


Figure 8. 30 Sensitivity up of effect on human component for short-term financial returns case

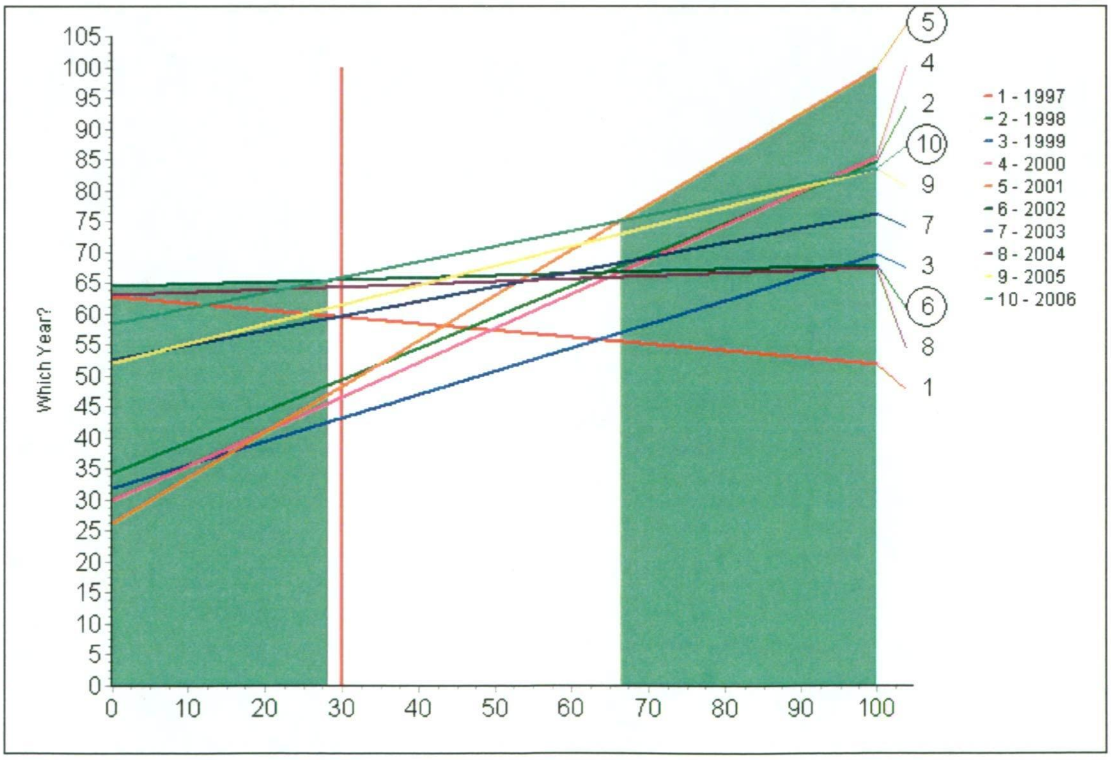


Figure 8. 31 Sensitivity up of effect on environment component for short-term financial returns case

8.2.5 Case 4: Conservation Preference Case

In this case extra weight is given to the environmental components assuming conservation policy for long-term benefit is aimed for by the responsible authority. In contrast, less weight is assigned for the economic components following the weights plan showed in Figure 8. 1. Sensitivity analyses graphs of this case show that all years have similar trends (scores of 40 to 55) except 2001 (80), the most preferred year for both base and adjusted cases as mentioned earlier (Figure 8. 32). The results also support the fact that the period 1998-2001 showed the lowest contribution toward the short-term financial objectives (case 1) (Figure 8. 33). However, the same period performed very well in the effect on environment component where financial components were assigned low weights (Figure 8. 34).

Figure 8. 32 Weight scores and criteria contributions from both human and environment components for conservation preference case

As revealed in the base case sensitivity analysis (Section 8. 2), the year 2001 will still be the most preferred year favoring environment and dominating all other years. It would only be dominated by year 2006 (Figure 8. 35) if the weight of the financial components such as income and employment were increased by more than 15 extra points, as discussed in the financial short-term return case. Figure 8. 35 demonstrates also that year 2001 will be taken over by year 2000 if the weight of nutrition and domestic market is increased by more than 15 points. Compared to the most preferred year for the financial short-term return case, year 2001, the most preferred year for this case (2001) is less sensitive to any change in any ESD component. This means that year 2001 is much stronger in conservation than year 2006 in financial short-term return. In other words, if, up to 78 weight points, effect on human component is favored over effect on environment without any changing to sub-components, year 2001 will still be the most preferred year.

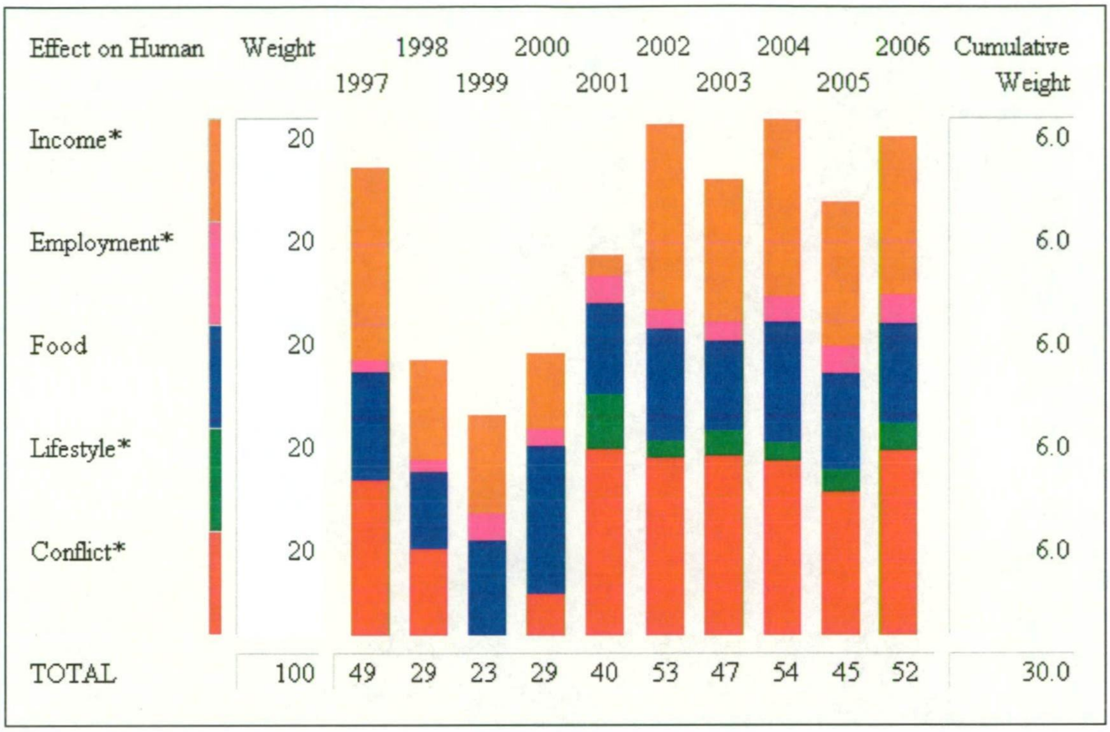


Figure 8. 33 Weight scores and criteria contributions of effect on human component for conservation preference case

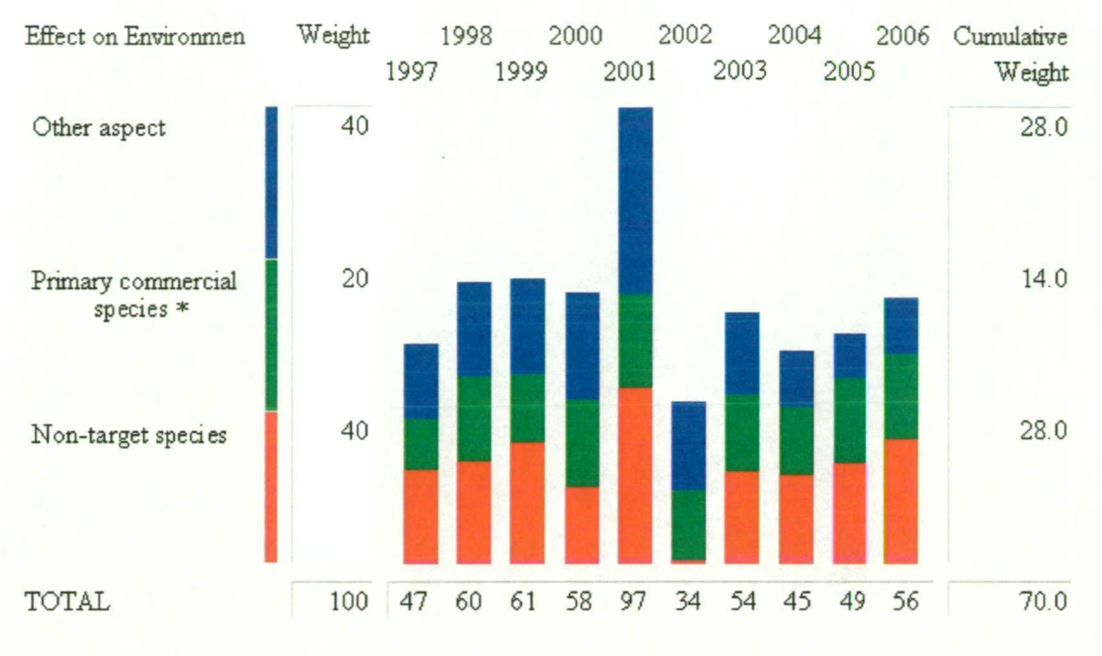


Figure 8. 34 Weight scores and criteria contributions of effect on environment component for conservation preference case

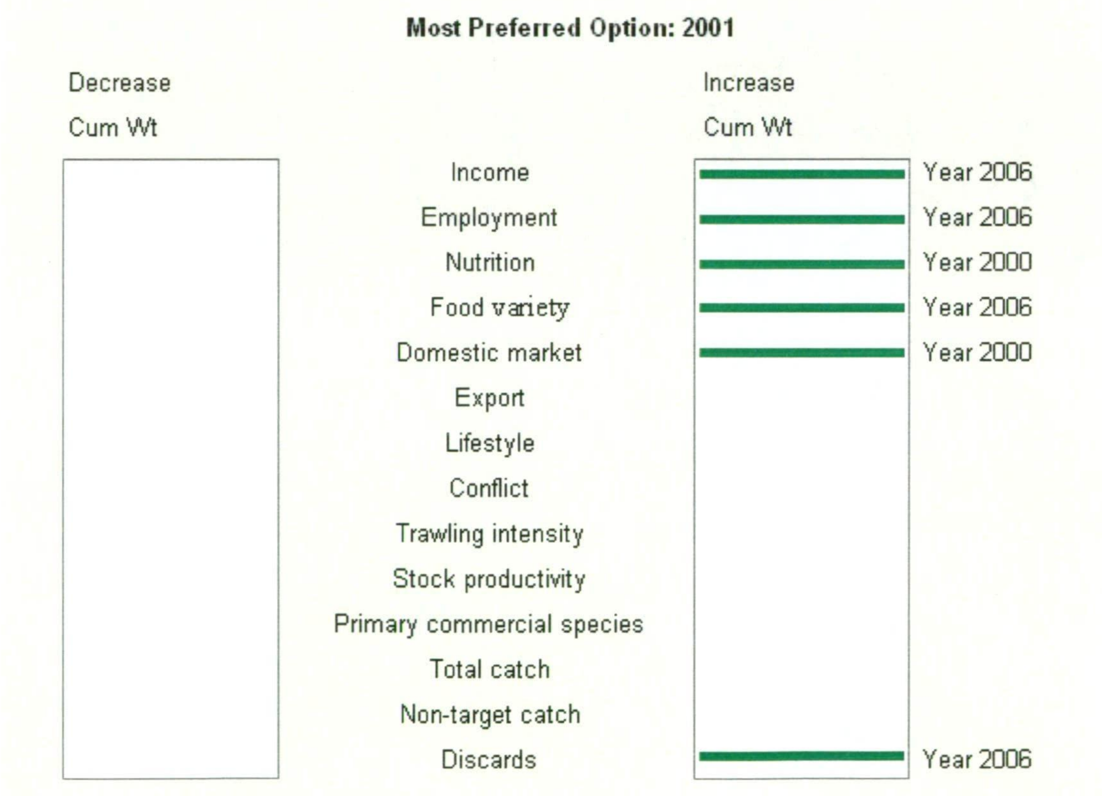
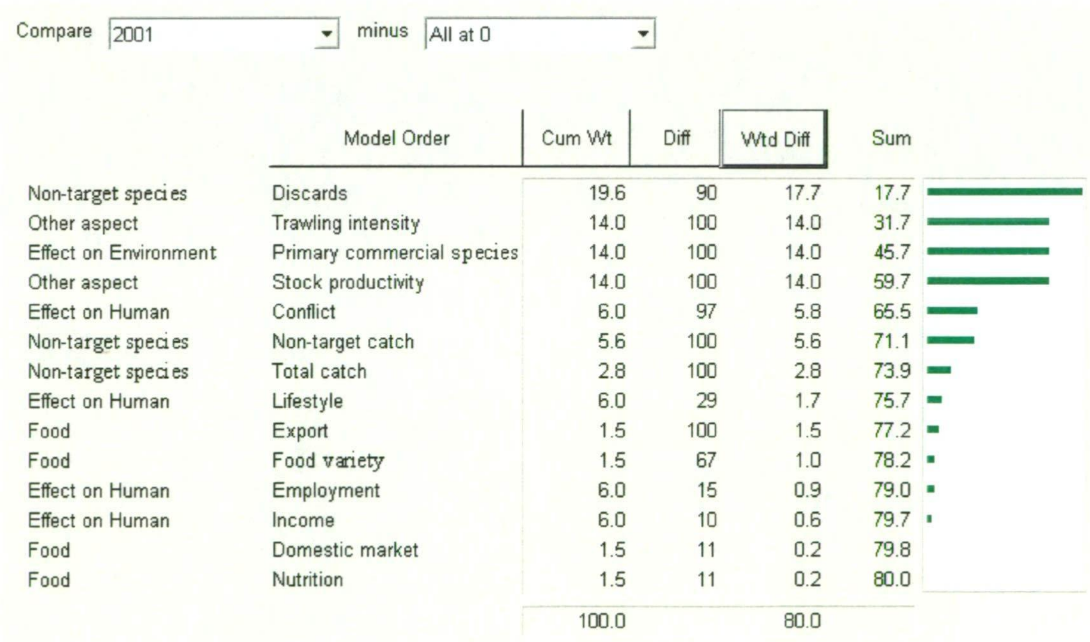


Figure 8. 35 Most preferred year (sensitivity down) during the study period for conservation preference case

Figure 8. 36 shows strengths of the most preferred year (2001). It is clear that year 2001 gained its strength from the environmental components and the conflict and lifestyle components of the effect on humans. There are many components that give this case more strength compared to the financial short-term return case. On the other hand, year 2001 suffered weakness mainly in the effect of human component and discards component (Figure 8. 37). Its weakness is also less compared to the weakness of the financial short-term return case.

Figure 8. 38 and Figure 8. 39 show sensitivity up graphs for effect on humans and effect on environment components respectively. Compared to the financial short-term return case, no further reduction in the weight of the effect on human and nor increase in effect on environment, will change 2001 from the most preferred year. It is also clear that year 2006 is the year closest year to the possibility of overtaking 2001, but only if the weight scale is reversed as occurred with the financial short-term return case.


Compare 2001 minus All at 0

	Model Order	Cum Wt	Diff	Wtd Diff	Sum
Non-target species	Discards	19.6	90	17.7	17.7
Other aspect	Trawling intensity	14.0	100	14.0	31.7
Effect on Environment	Primary commercial species	14.0	100	14.0	45.7
Other aspect	Stock productivity	14.0	100	14.0	59.7
Effect on Human	Conflict	6.0	97	5.8	65.5
Non-target species	Non-target catch	5.6	100	5.6	71.1
Non-target species	Total catch	2.8	100	2.8	73.9
Effect on Human	Lifestyle	6.0	29	1.7	75.7
Food	Export	1.5	100	1.5	77.2
Food	Food variety	1.5	67	1.0	78.2
Effect on Human	Employment	6.0	15	0.9	79.0
Effect on Human	Income	6.0	10	0.6	79.7
Food	Domestic market	1.5	11	0.2	79.8
Food	Nutrition	1.5	11	0.2	80.0
		100.0		80.0	

Figure 8. 36 Strengths of most preferred year for conservation preference case

Compare All at 100 minus 2001

	Model Order	Cum Wt	Diff	Wtd Diff	Sum
Effect on Human	Income	6.0	90	5.4	5.4
Effect on Human	Employment	6.0	85	5.1	10.5
Effect on Human	Lifestyle	6.0	71	4.3	14.8
Non-target species	Discards	19.6	10	1.9	16.7
Food	Nutrition	1.5	89	1.3	18.0
Food	Domestic market	1.5	89	1.3	19.3
Food	Food variety	1.5	33	0.5	19.8
Effect on Human	Conflict	6.0	3	0.2	20.0
Food	Export	1.5	0	0.0	20.0
Other aspect	Trawling intensity	14.0	0	0.0	20.0
Other aspect	Stock productivity	14.0	0	0.0	20.0
Effect on Environment	Primary commercial species	14.0	0	0.0	20.0
Non-target species	Total catch	2.8	0	0.0	20.0
Non-target species	Non-target catch	5.6	0	0.0	20.0
		100.0		20.0	

Figure 8. 37 Weakness of most preferred year for conservation preference case

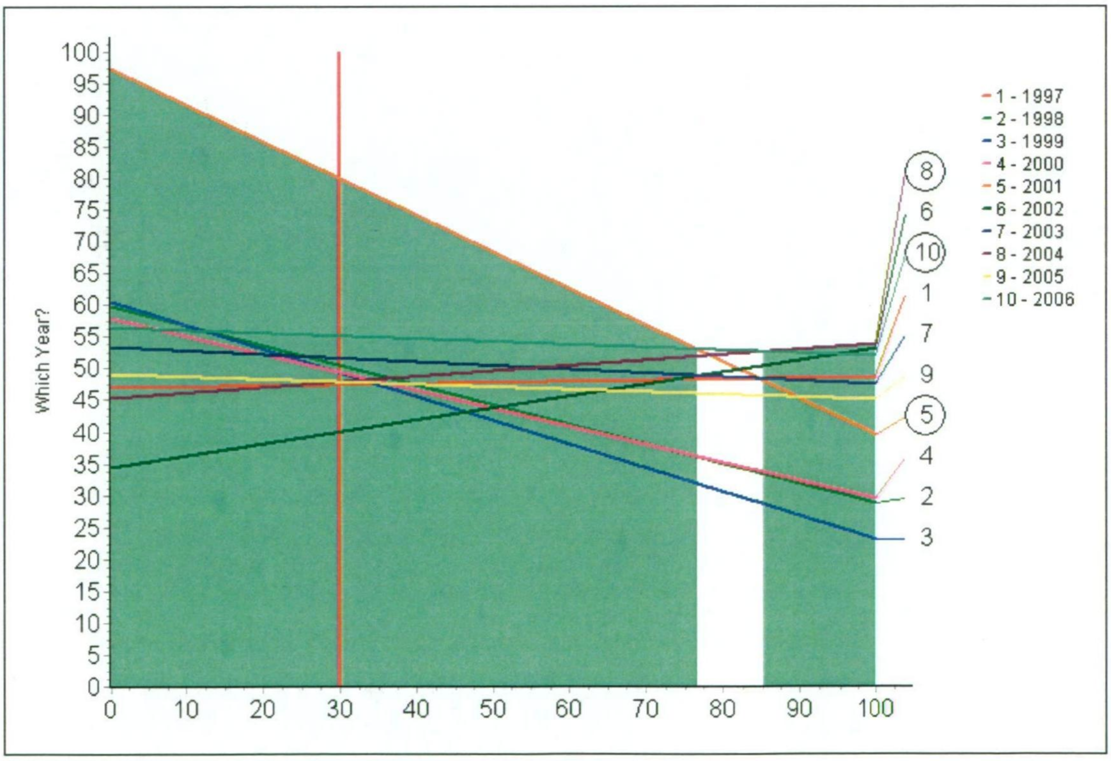


Figure 8. 38 Sensitivity up of effect on human component for conservation preference case

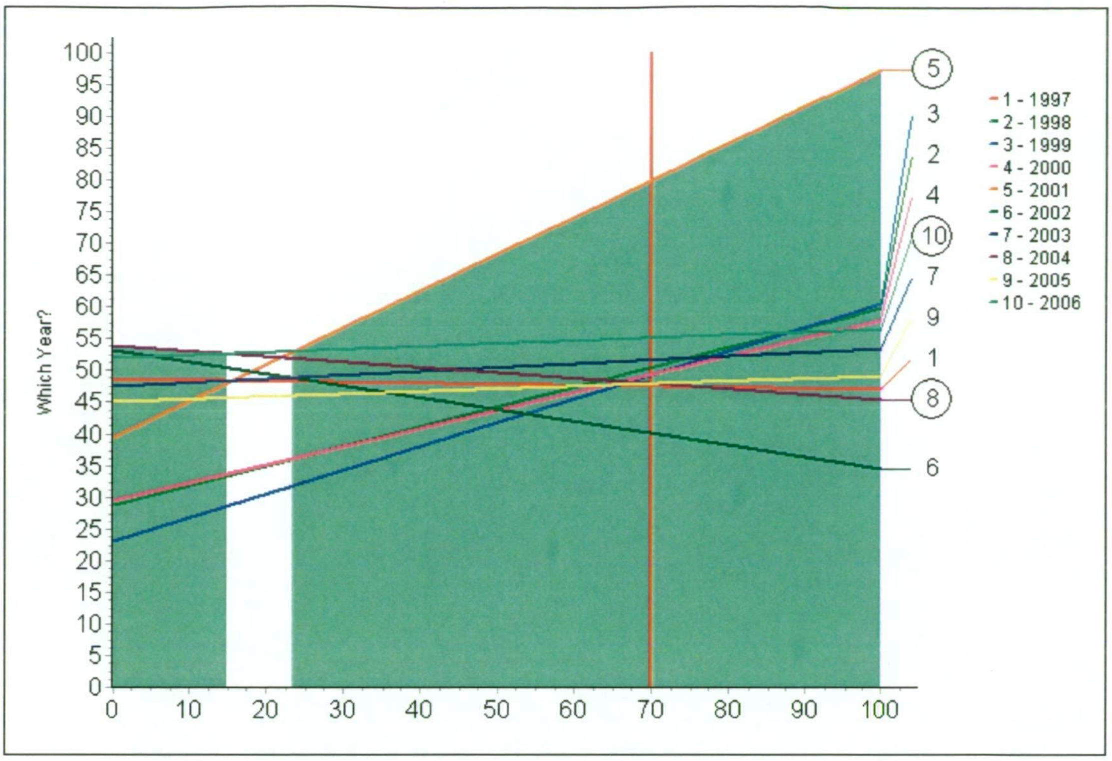


Figure 8. 39 Sensitivity up of effect on environment component for conservation preference case

8.2.6 Case 5: Adjusted Case with Short-term Financial Returns Weight Plan

As mentioned in Section 8.4, some evidence of income shift occurred in the fishery sector during the period 1998-2001. Therefore, it can be concluded that the adjusted case can be counted as the case closest to reality. As mentioned above, the financial short-term return and conservation cases weight plan were applied to the base case. However, when applying the same financial short-term return case plan to the adjusted case, year 2001 was found to be the most preferred year (Figure 8. 40).

Figure 8. 41 shows that year 2006 could overtake year 2001 if the weight of employment, food variety and discards components increased by only 15 points or more. Year 1998 can also overtake year 2001 if the weight of income component is also increased by more than 15 points. However, sensitivity up graphs for both effect on human and effect on environment show that year 2001 will still dominate all other year as the most preferred year no matter how much weight is given to human or the environment component (Figure 8. 42 and Figure 8. 43).

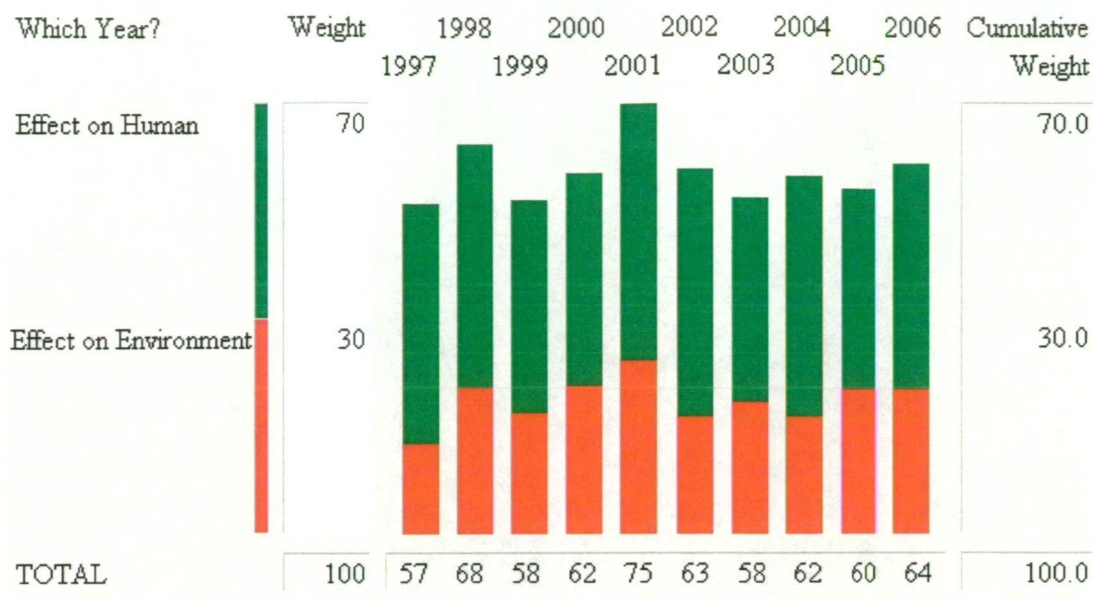


Figure 8. 40 Weight scores and criteria contributions from both human and environment components for the adjusted case when applying the short-term financial returns weight plan

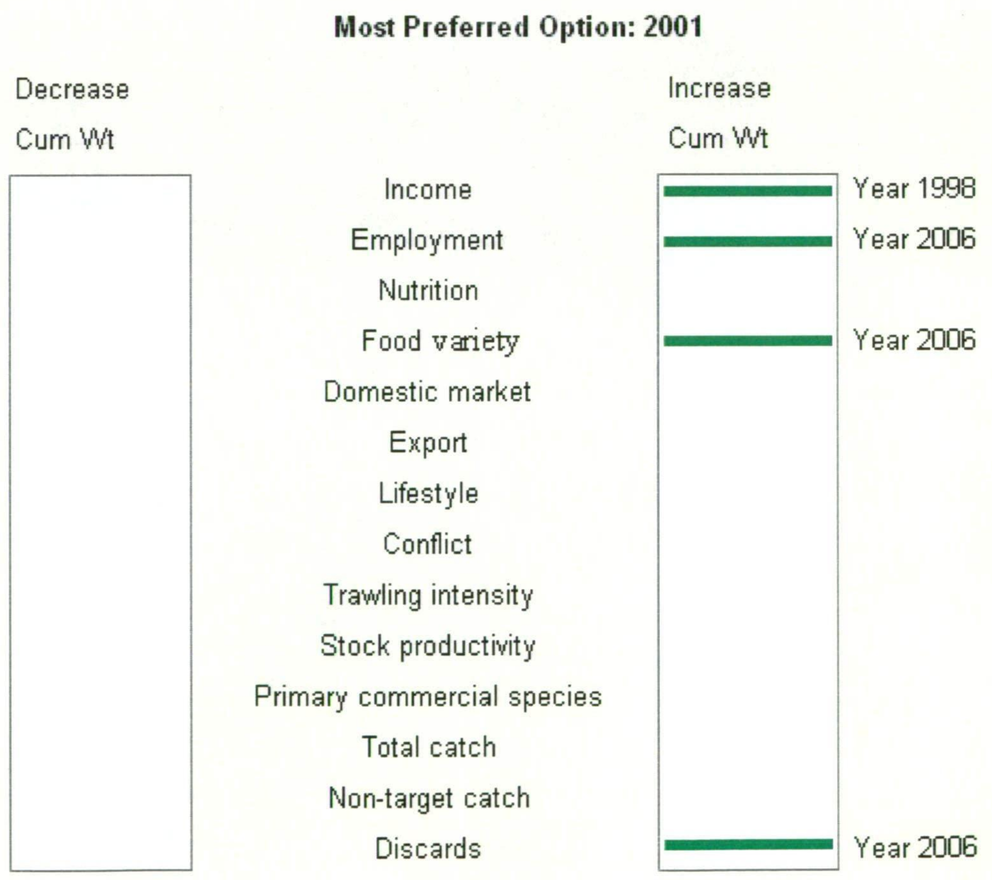


Figure 8. 41 Most preferred year (sensitivity down) during the study period for the adjusted case when applying the short-term financial returns weight plan

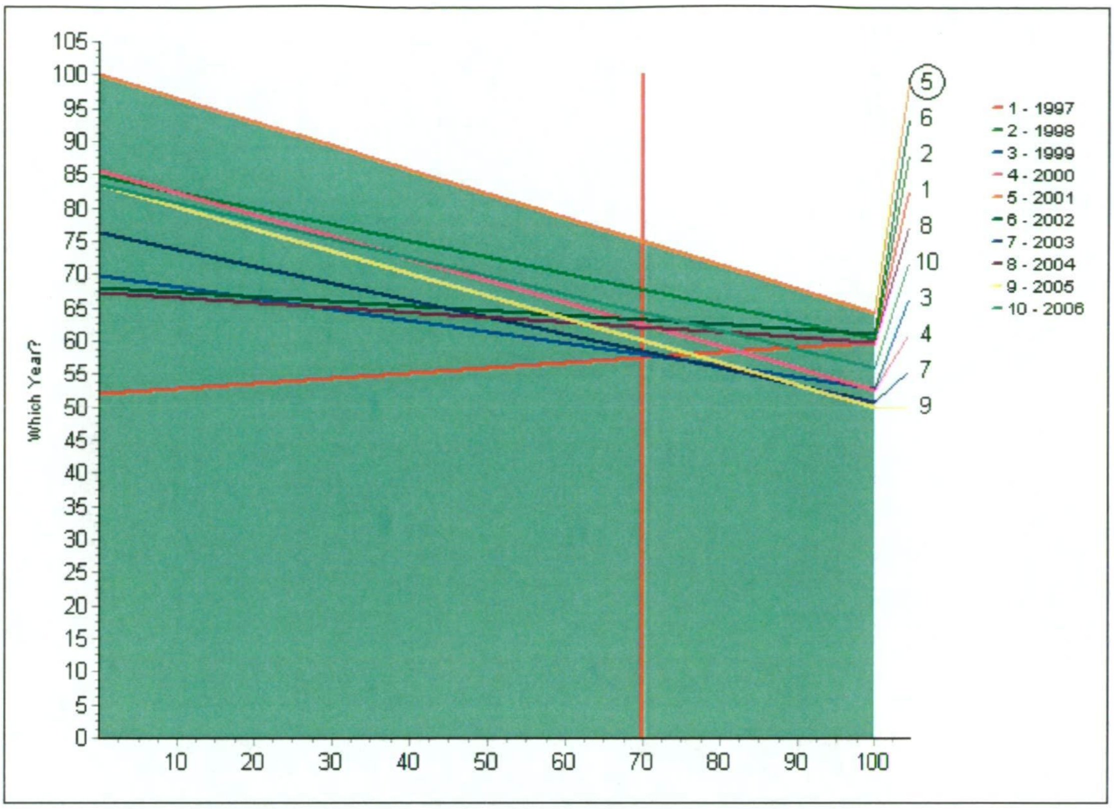


Figure 8. 42 Sensitivity up of effect on human component for the adjusted case when applying the short-term financial returns weight plan

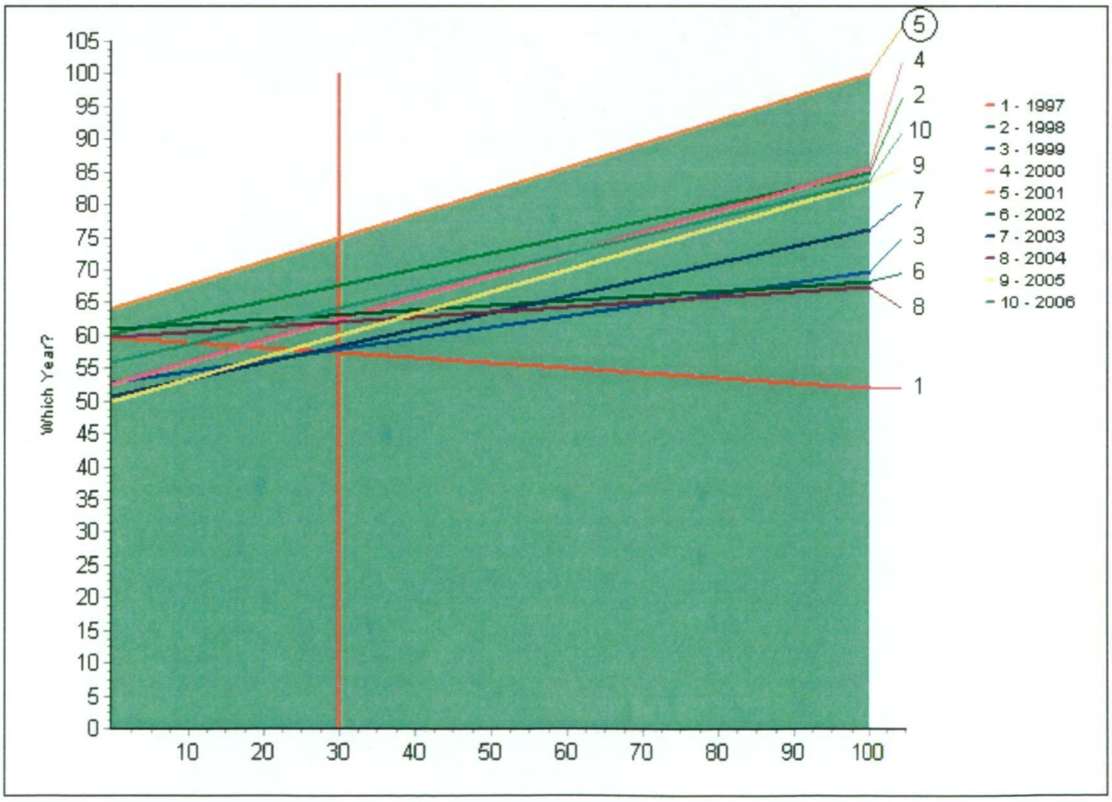


Figure 8. 43 Sensitivity up of effect on environment component for the adjusted case when applying the short-term financial returns weight plan

This fifth case proves that the management scheme practiced in year 2001 was the best of all years. As there were two distinguished management schemes practiced in the study period, the one practiced in the period 1998-2001 is considered to be the best for both financial and conservation preferences.

8.2.7 Overall Results

Table 8. 3 presents scores for all cases for effect on human, effect on environment and for overall performance for the whole study period. The results revealed that year 2001 was the most preferred option for all cases except for the short-term financial preference case, where year 2006 was the most preferred year. Figure 8. 44 shows scores of all options (years) for all weight cases for overall performance. It can be seen that the overall scores aggregated over all components maintained similar trends with exception of the year 2001, which showed the best overall performance. A close look at scores of all options for effect on humans revealed that the period 1998-2001 performed weakly (Figure 8. 45) with obvious strength and significant performance in the effect on environment (Figure 8. 46). It is clear also that the management schemes in 1997 and in the period 2002-2006 were mostly targeting short-term financial returns more than any other cases. Contrary to this, the period 1998-2001 was more balanced and favoring conservation (long-term preferences) more than short-term financial returns. The main weakness, mainly due to the reduction of catch and therefore income and other related components in reality would have been overcome (as explained earlier) and the trawling fishing sector could be restored back to its normal size without terminating the new fishing regulation.

So far, all analysis done was to assess the progress of management schemes over time for the period 1997 - 2006. The overall conclusion was that the policy makers were mainly favoring the economic indicators through supporting the short-term financial returns. Therefore, further MCDA will be carried out to investigate this behavior at indicator and criteria level in order to gain a wider view and draw a conclusion on the status of the fisheries governance.

Table 8. 3 Scores of all options (years) under different weight cases

	Year	Case 1	Case 2	Case 3	Case 4	Case 5
Effect on Human	1997	49	43	63	49	60
	1998	29	42	34	29	60
	1999	23	32	32	23	53
	2000	29	36	30	29	53
	2001	40	62	26	40	64
	2002	53	47	65	53	61
	2003	47	44	53	47	51
	2004	54	48	63	54	60
	2005	45	41	52	45	50
	2006	52	48	58	52	56
	Best Year	2004	2001	2002	2004	2001
Effect on Environment	1997	42	42	52	47	52
	1998	58	58	85	60	85
	1999	58	58	70	61	70
	2000	60	60	86	58	86
	2001	99	99	100	97	100
	2002	42	42	68	34	68
	2003	52	52	76	54	76
	2004	43	43	67	45	67
	2005	49	49	83	49	83
	2006	52	52	84	56	84
	Best Year	2001	2001	2001	2001	2001
Overall	1997	45	42	60	47	57
	1998	44	50	49	50	68
	1999	40	45	43	49	58
	2000	45	48	47	49	62
	2001	69	80	48	80	75
	2002	48	45	66	40	63
	2003	50	48	60	52	58
	2004	49	45	64	48	62
	2005	47	45	62	48	60
	2006	52	50	66	55	40
	Best Year	2001	2001	2006	2001	2001

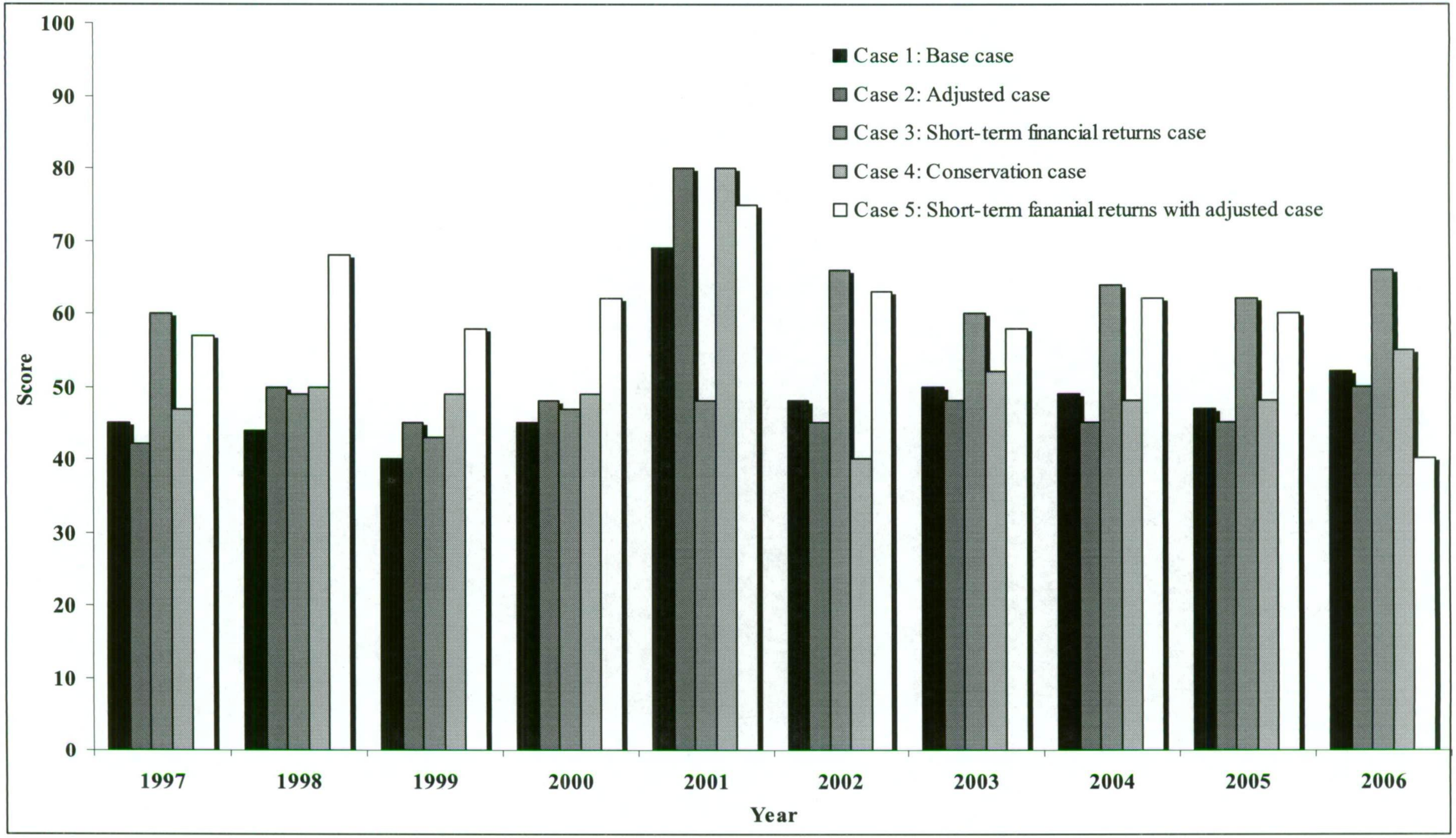


Figure 8. 44 Scores of all options (years) under different weight cases for overall

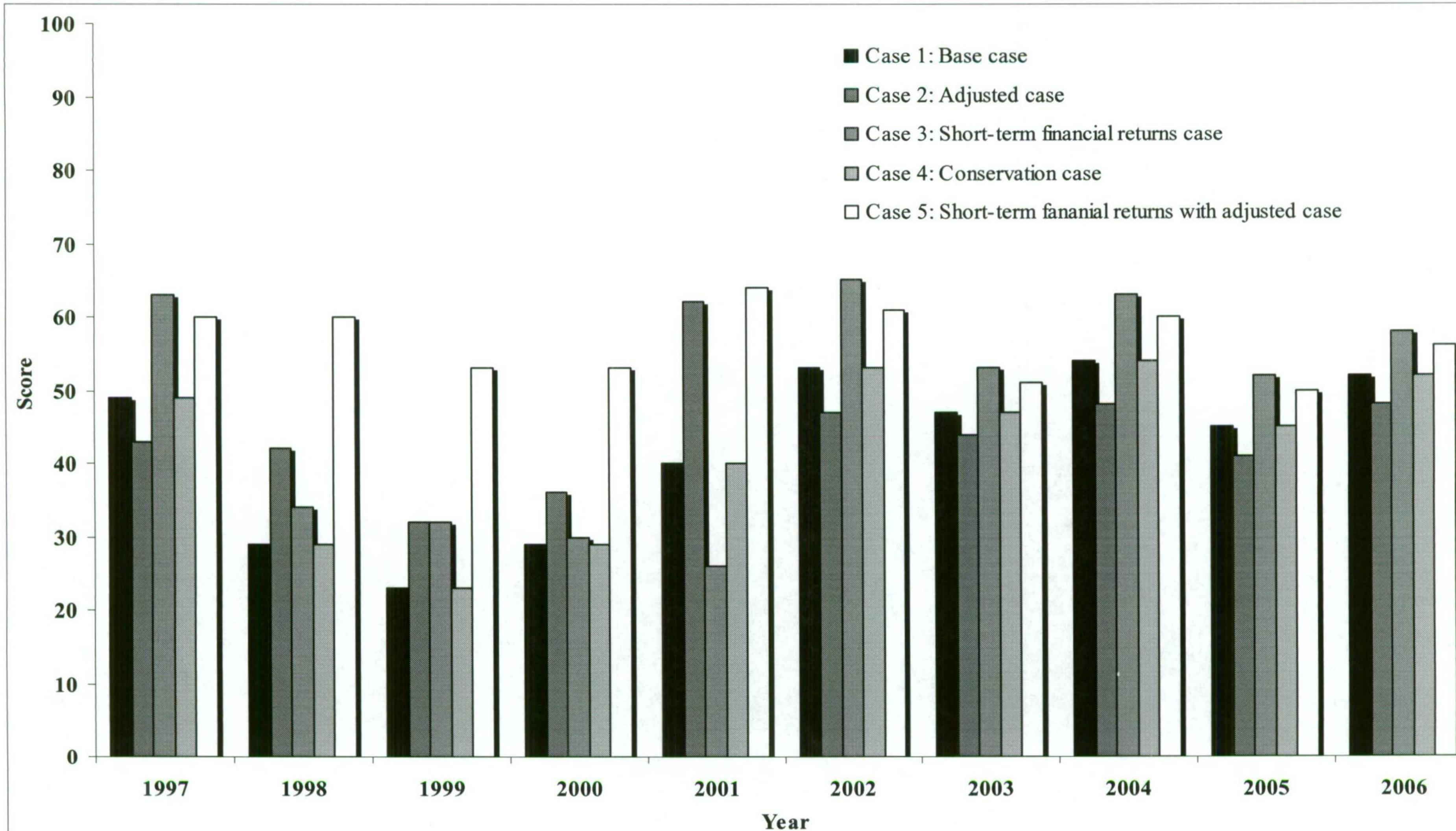


Figure 8. 45 Scores of all options (years) under different weight cases for effect on human

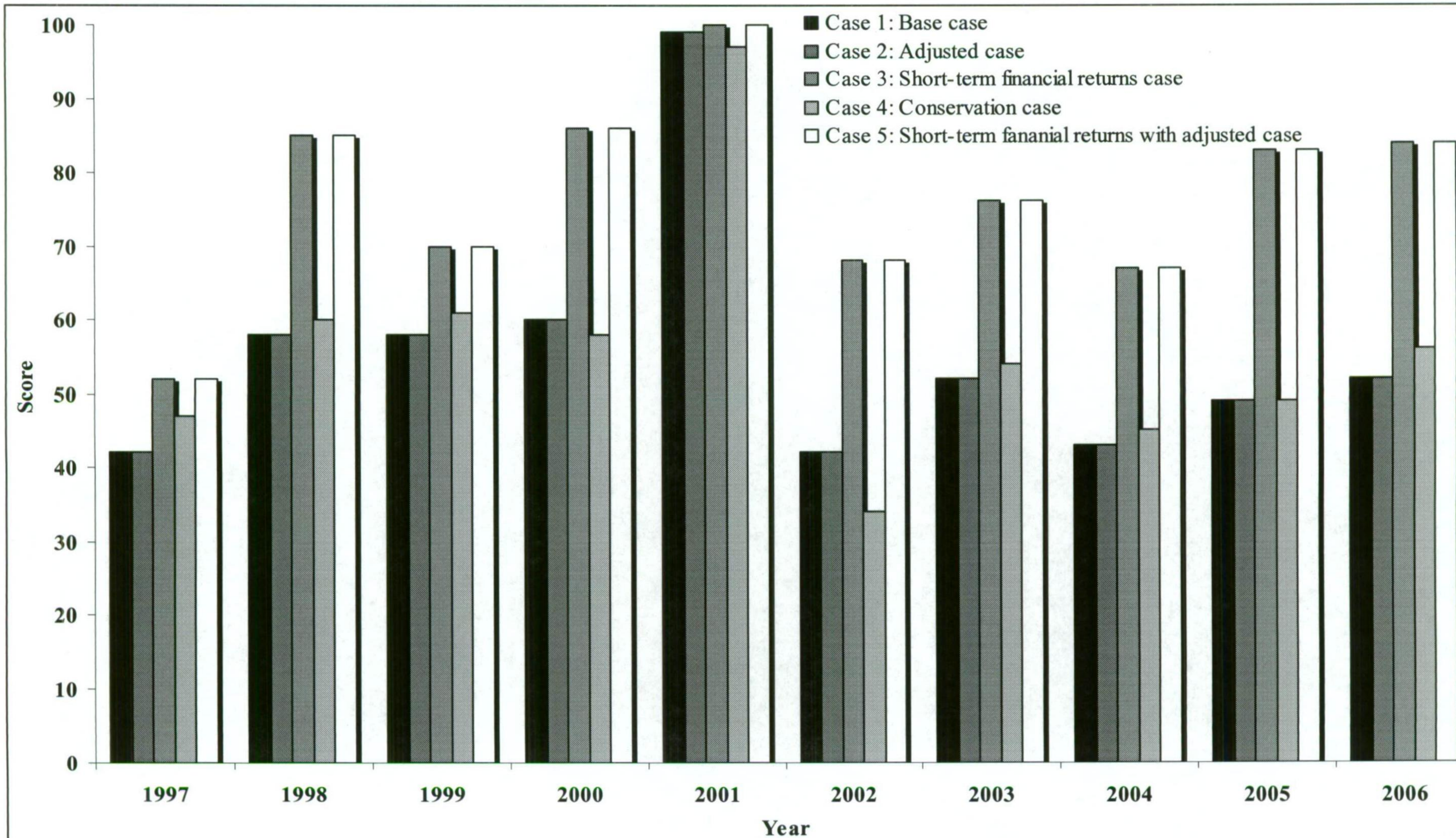


Figure 8. 46 Scores of all options (years) under different weight cases for effect on environment

8.3 Importance and the Present Status of Sustainability Indicators

The strengths and weaknesses of the management system practiced during the past ten years have been analyzed in Section 8.2. Overall, this study has so far investigated the progress toward sustainability over time, but has not made any attempt to assess the indicators themselves to see how they were preferred by managers and decision makers. This section will examine the importance and present status of the sustainability indicators used in this study. The results from this investigation will help in assessing the overall fisheries governance during the study period.

It is argued that indicators are often linked together and consequently may impact sustainability directly or indirectly (Adrianto et al. 2005). More specifically, a single indicator may eventually be compromised because of its linkage to other indicators (Mendoza and Prabhu 2003). However, this type of linkage among indicators is not examined in this study due to data and information constraints. It should be noted that in identification and assessment of indicators by involving various stakeholders may create bias in indicators rankings. This type of complexity in sustainability assessment is discussed by Ducey and Larson (1999).

Due to the above mentioned constraints, the assessment of the importance of sustainability indicators in this study will be carried out based on the average scores gained by each indicator for the whole study period. This will specifically represent the degree of satisfaction of those indicators targeted by decision makers and will indicate their level of importance. In a holistic overview, this process will represent the average reality of the two distinguished management schemes practiced in the period 1997 - 2006. As concluded in Section 8.2.7 above, the adjusted case (Section 8.2.3) represents the actual reality of the components situation because of the correction to the score of some components. Therefore, scores from this case will be used to reflect the degree of importance of indicators given by the decision makers for each year. In this case, each year will present a participant to assign a degree of importance for each component. Scores were presented on a 0-100 scale and the indicators were aggregated and arranged following the classification of the ESD reporting framework (Whitworth et al. 2002). Table 8. 4 shows the list of indicators and the way they were aggregated under specific criteria. The 0-100 score scale was then translated proportionally to a 5-point scale representing degree of importance as explained in Figure 8. 47. Table 8. 5 and Table 8. 6 show criteria scores, averages and standard deviations for both scales. Based on these scores, average score and Sustainability Index of Criteria (SIC) are calculated for each criterion.

Table 8. 4 Trawling fishery criteria and their indicators for reporting framework

Criteria	Sub-criteria	Indicator
Ecological Well-being	Retained Species	Primary commercial species
		Total catch
	Non Retained Species	Non-target species
		Discard
	General Ecosystem	Stock productivity
		Trawling intensity
Human Well-being	Local Community Issues	Conflict
	Community Issues	Nutrition
		Food variety
		Domestic market
		Lifestyle
	National Social and Economic Issues	Income
		Employment
		Export

As SIC is a function of score and weight, a relative weight must be identified for each indicator. There are different approaches used to estimate the relative weight associated with each indicator. A simple procedure will involve standardized weight as explained by Mendoza and Prabhu (2003) as follows:

$$W_j = \frac{a_j}{\sum a_j} \qquad \textbf{(9.1)}$$

Where:

a_j: represent the average weight of indicator j

W_j: represent the relative weight of indicator j

However, as all indicators and criteria in this study were assigned equal weight, relative weight will be similar for all and hence an SIC will be equal to the average score of the criteria as verified by the following equation (Mendoza and Prabhu 2003; Adrianto et al. 2005):

$$SIC = \sum S_j \, W_j \qquad \textbf{(9.2)}$$

Where:

SIC: represent Sustainability Index of Criteria i (ecological well-being or human well-being)[6]

S_j: represent the score of indicator j

W_j: represent the relative weight of indicator j

Therefore, the average score of any criterion will also represent the sustainability index of that criterion.

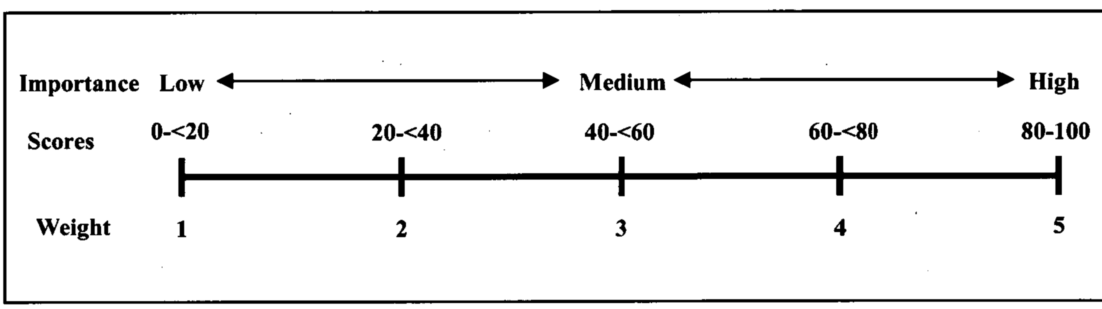


Figure 8. 47 Semantic scale (weight) used to identify indicators' degree of importance

The final scores and sustainability indices for the ecological well-being and the human well-being criteria are shown in Table 8. 6 and Figure 8. 48. It can be seen that on average, the ecological indicators scored higher (2.9) than the human (social and economic) indicators (2.37). This means that the ecological indicators were preferred more than the human indicators. Closer investigation indicates that the retained species criteria under ecological well-being gained the maximum score (higher importance) (3.1) followed by the general ecosystem and non retained species criteria with scores of 2.9 and 2.7 respectively. On the other hand, local community issues criteria under human well-being gained the minimum score (lower importance) (2.1), while both general community issues and national social and economic issues criteria each scored 2.5.

[6] SIC and relative weights were carried out in Chapters 7 and 8 by the application of Hiview3 software.

In other words, the sustainability index for the ecological well-being criteria (SIC = 2.9) is higher than the human well-being criteria (SIC = 2.37). This means that based on their perceived value of satisfaction, which reflect their importance to the decision makers, the ecological indicators relatively have a better standing than the human indicators.

Table 8. 5 List of criteria and their scores, average and standard deviation details

Component	Criteria	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average	SD
Ecological Well-being	Retained species	32.3	55.8	47.6	58.3	100.0	41.8	48.6	42.5	53.2	52.6	53.3	18.1
	Non retained species	41.0	42.5	62.1	34.9	95.2	2.5	36.8	34.8	39.2	48.4	43.7	23.4
	General ecosystem	40.0	49.2	50.7	57.8	100.0	47.3	44.0	29.2	23.8	29.4	47.1	21.5
Human Well-being	Local community issues	15.9	5.6	3.1	3.9	100.0	38.9	43.8	31.8	12.1	70.0	32.5	32.0
	Community issues	26.5	53.8	47.8	59.2	73.8	29.0	29.4	32.7	30.3	31.9	41.4	16.2
	National social and economic issues	38.5	42.5	42.9	40.3	63.9	38.8	33.0	39.2	34.8	36.9	41.1	8.6

Table 8. 6 Degree of importance, standard deviation and relative weights

Component	Criteria	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average	SD
Ecological Well-being	Retained Species	2	3	3	3	5	3	3	3	3	3	3.1	0.7
	Non Retained Species	3	3	4	2	5	1	2	2	2	3	2.7	1.2
	General Ecosystem	3	3	3	3	5	3	3	2	2	2	2.9	0.9
											Average	2.90	0.92
Human Well-being	Local Community Issues	1	1	1	1	5	2	3	2	1	4	2.1	1.4
	Community Issues	2	3	3	3	4	2	2	2	2	2	2.5	0.7
	National Social and Economic Issues	2	3	3	3	4	2	2	2	2	2	2.5	0.7
											Average	2.37	0.95

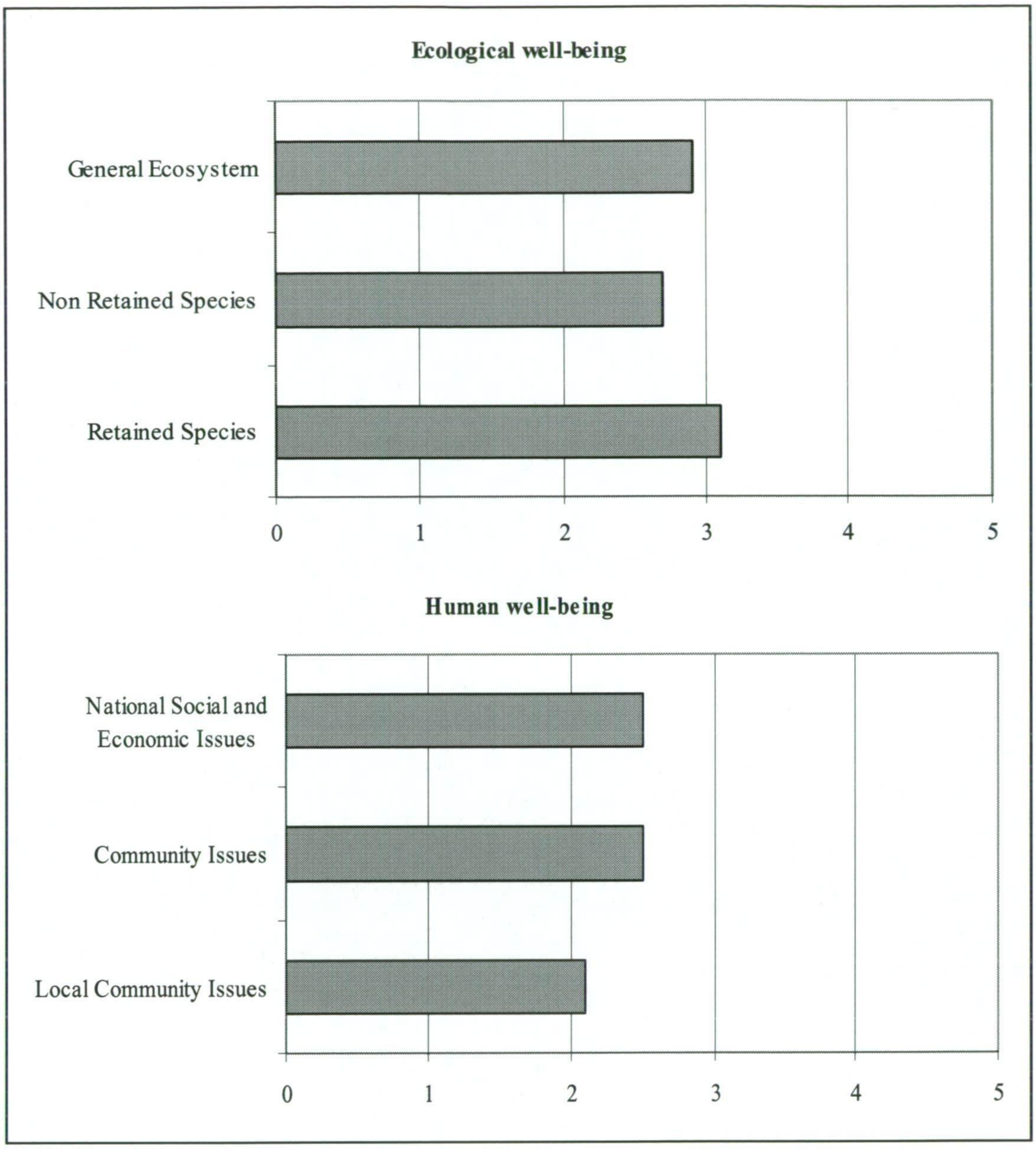


Figure 8. 48 Overall sustainability index of criteria (SIC)

When compared to the social and economic indicators, the ecological indicators performed better. This was considered a good indication of long-term environmental sustainability however, the SICs scores for all indicators are low thereby indicating a below average level of attainment of overall sustainability. Further investigation was carried out to determine the differences in the policies of the decision makers of both management schemes practiced in the study period.

Scores for the entire period were divided into two periods namely the period of fishing effort regulations (1998-2001), termed the '1998 management scheme' and the period 1997 and 2002-2006, indicating the absence of effort regulations and termed '1997 management scheme'. Table 8. 7 shows scores, average scores and standard deviation for the original management scheme practiced in the year 1997 and then 2002 - 2006 (1997 management scheme). Table 8. 8 shows comparative figures for the management scheme practiced in the period 1998-2001 (1998 management scheme). It is clear that the 1998 management scheme has improved the sustainability of both criteria. SIC for the ecological indicators was 3.5 for the 1998 management scheme, while it was only 2.5 for the 1997 management scheme. On the other hand, SIC for the human indicators was 2.83 for the 1998 management scheme, while it was only 2.06 for the 1997 management scheme. These results confirm the better performances of the 1998 management scheme in relation to environmental conservation human well-being (see Figure 8. 49).

It can also be seen that all scores for all criteria of the 1998 management scheme were more than 3.3 except for the local community issues criteria, which scored only 2 (Figure 8. 49). It can be seen from Table 8. 4 that local community issues under the human well-being criteria have conflict indicators. It was concluded in Chapters 5 and 7 and Section 8.2.7 that the conflict cases were higher in the period 1998-2001 due to the strong enforcement practiced at that time, which produced the actual figures for the conflict cases. This concludes there is a major problem with the conflict indicator and also indicates over-estimation of its score (under-estimation of the number of cases) for the 1997 management scheme (see Chapter 7).

Close investigation of the average scores at indicators level (Figure 8. 50) shows that six actual indicators scored lower than the conflict indicators. The lowest was the employment indicator (1) followed upward by lifestyle (1.1), trawling intensity (1.5) and then export, non-target species and total catch indicators with scores of 1.7 for each of them (Figure 8. 50). All nine indicators including nutrition and domestic market scored less than the middle point of sustainability (2.5) according to the 5-points scale used.

On the other hand, five indicators showed good sustainability index, where they all gained scores in the last quarter of the sustainability index (>3.75). The maximum SIC was gained by food variety (4.8) followed downward by income (4.7) then primary commercial species, stock productivity and discards with scores of 4.5, 4.2 and 3.8 respectively. It is worth noting that food variety indicator was measured as diversity of landed catch using the Shannon diversity index (Shannon and Weaver

1949) and so it represents the food variety provided by the trawling sector. However, this kind of community advantage was minimized as a high proportion of the landings is actually exported as discussed in Chapters 2, 5 and 7.

Although, landings of different species influence the score of food variety, their low availability for consumers in the domestic markets should be of concern to the authorities. It should be noted in this context that although the income component scored high (4.7 out of 5), a major share of this income goes to the foreign fishing companies and the indirect benefits to the community are in the form of a 20% share in the local fishing companies, Government royalties and benefits from fuel, catering and water services as discussed in Chapter 7.

The important policy implication in relation to the low average scores of employment and lifestyle indicators is that it undermines the good intent of Omanization strategies and the national development plan. It is also important to note that the highest score (3.8 out of 5) of the discards indicator may mislead the policy decisions as the actual amount of discards was underestimated as discussed in Chapter 5.

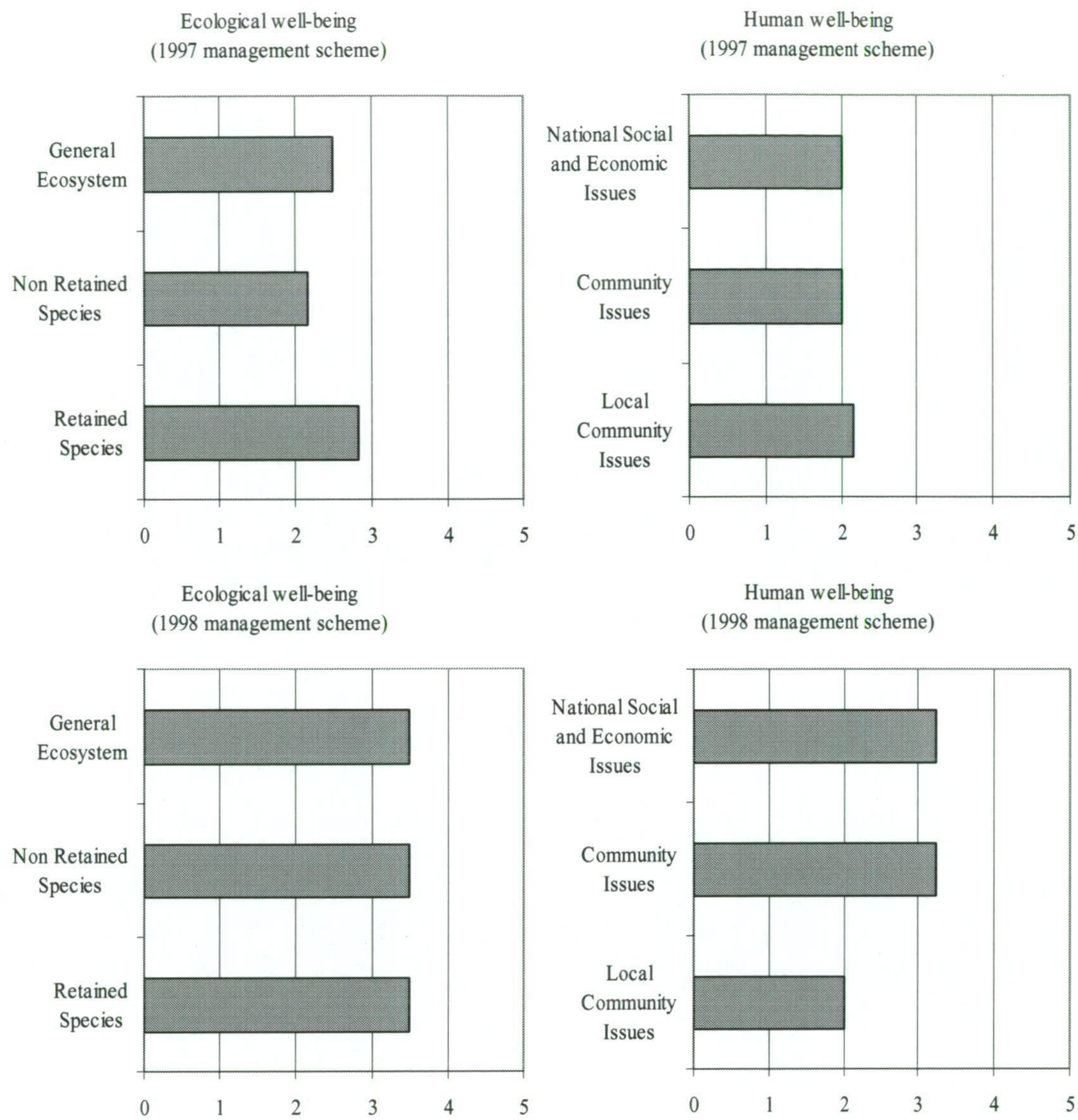


Figure 8. 49 Sustainability index of criteria (SIC) for 1997 and 1998 management schemes

The discussion and conclusion above show that indicators have significant linkages and relationships between each other. These interactions consequently impacted on sustainability directly and indirectly at indicator and/or criteria levels. In other words, although some indicators appear to be good, overall sustainability is compromised due to the cross-criterion or cross-indicator interaction. This is not an exceptional attribute to the Omani commercial trawling fishery sector, but it is a natural and healthy feature of sustainability indicators (UNDESA 2001; Mendoza and Prabhu 2003; Adrianto et al. 2005). However, it should be agreed that the commercial trawling fishery has achieved a below average level of attainment of overall sustainability. From Table 8. 7 and Table 8. 8, it can be seen that there is less variation in the rankings as measured by the Standard Deviation (SD) within the ecological well-being criteria as compared to human well-being criteria. This indicates inconsistency in the preferences of the decision makers over time. In a comparison of the two management schemes, it can be seen that the variation for both ecological and human well-being criteria of the 1997 management scheme is lower than that of the 1998 management scheme. This may reflect the reaction from the primary stakeholders to the fishing effort control introduced in 1998.

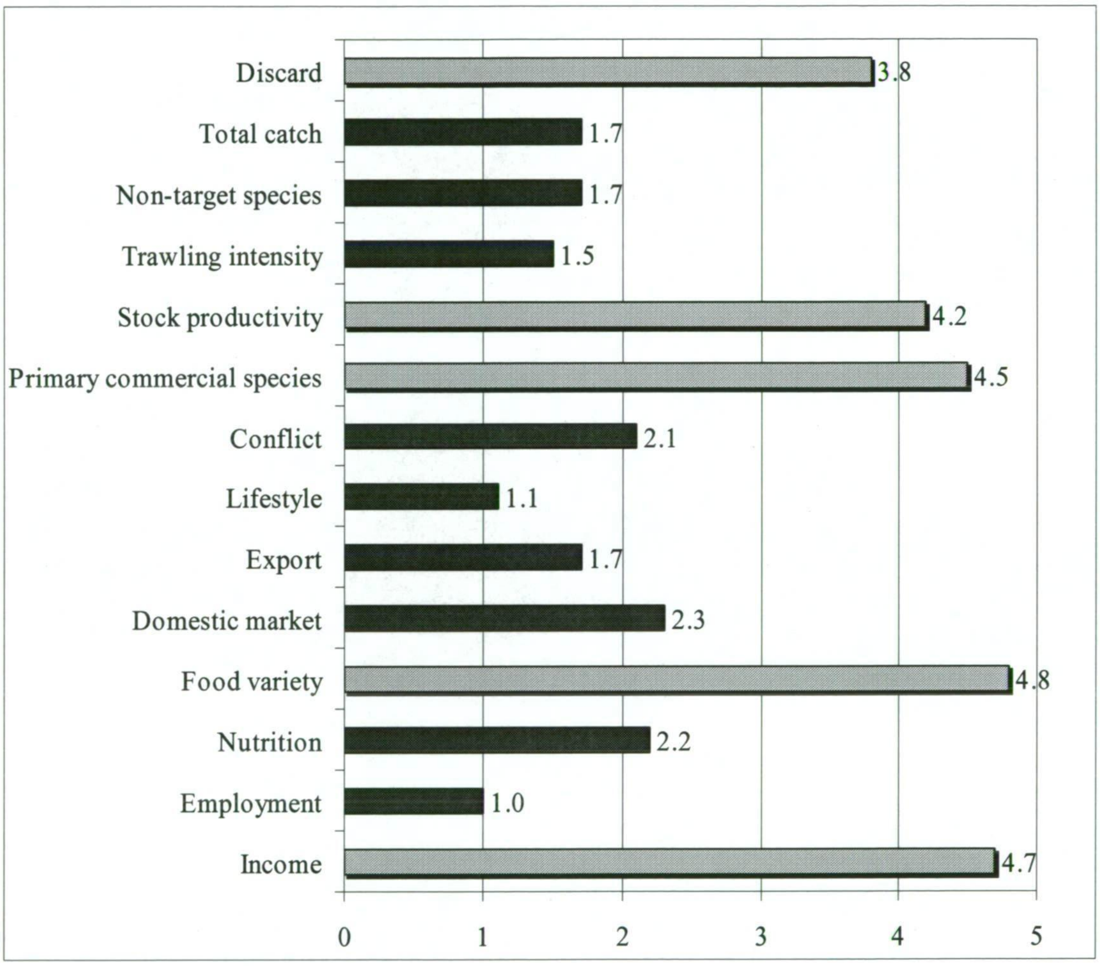


Figure 8. 50 Average scores at indicators level

Table 8. 7 Degree of importance, standard deviation and relative weights for 1997 management scheme

Component	Criteria	1997	2002	2003	2004	2005	2006	Average	SD
Ecological Well-being	Retained Species	2	3	3	3	3	3	2.8	0.4
	Non Retained Species	3	1	2	2	2	3	2.2	0.8
	General Ecosystem	3	3	3	2	2	2	2.5	0.5
							Average	2.50	0.57
Human Well-being	Local Community Issues	1	2	3	2	1	4	2.2	1.2
	Community Issues	2	2	2	2	2	2	2.0	0.0
	National Social and Economic Issues	2	2	2	2	2	2	2.0	0.0
							Average	2.06	0.39

Table 8. 8 Degree of importance, standard deviation and relative weights for 1998 management scheme

Component	Criteria	1998	1999	2000	2001	Average	SD
Ecological Well-being	Retained Species	3	3	3	5	3.5	1.0
	Non Retained Species	3	4	2	5	3.5	1.3
	General Ecosystem	3	3	3	5	3.5	1.0
					Average	3.50	1.10
Human Well-being	Local Community Issues	1	1	1	5	2.0	2.0
	Community Issues	3	3	3	4	3.3	0.5
	National Social and Economic Issues	3	3	3	4	3.3	0.5
					Average	2.83	1.00

8.4 Conclusion

This chapter presented results from the sensitivity analysis of five different cases for the commercial trawling sector in Oman: 1) base case; 2) adjusted case; 3) short-term financial returns case; 4) conservation preference case and 5) adjusted case with short-term financial returns weight plan.

Sensitivity analysis results revealed that year 2001 was the most preferred option for all cases except for the short-term financial preference case, where year 2006 was the most preferred year. It was observed that the overall scores aggregated over all components maintained similar trend with exception of year 2001, which shows the best overall performance. Close evaluation of the scores for the period 1998-2001 indicated that weak performance was detected for effects on humans, while strong performance was detected for the effect on environment. It is clear that the management scheme for the year 1997 and in the period 2002-2006 were primarily targeting short-term financial returns more than any other of the cases. Conversely, the period 1998-2001 was more balanced and favored conservation (long-term preferences) more than short-term financial returns. The main weakness during the period was the reduction of catch, consequently affecting income and related components. Gradual improvement in the number of the fishing vessels suggests that the trawling fishing sector's effort could be restored back into its normal size without terminating the fishing regulations that were introduced.

It can be concluded that the results indicate superior performance priority to year 2001, and hence to the management measures practiced in the period 1998-2001, as opposed to the practices in the periods before 1998 and after 2001. Therefore, the management schemes practiced in the period 1998-2001 were considered to be the best choice for both long-term financial and conservation preferences and hence the best option toward Ecologically Sustainable Development.

In order to give a wider perspective and to determine the status of the fisheries governance in this fishery of Oman, further MCDA's were carried out to investigate the effect of the management schemes at indicator and criteria level. This exercise identified the sustainability index of criteria and indicators and distinguished the 1998-2001 management scheme over others in higher sustainability indices.

Based on the all analyses, it can be concluded that overall, the year 2001 is the most preferred year, falling within the 1998 management scheme period (see Table 8. 3). Therefore, the management measures practiced in the period 1998-2001, are considered to be the most suitable for advancement towards the Ecologically Sustainable Development principles. However, it is also important to note that the overall attainment of sustainability in regard to its key dimensions is below par. This low attainment was mainly a result of undermining the importance of employment, lifestyle, discards, conflict with the traditional sector and export components of the fishery by the fisheries management authority (see Figure 8. 50).

CHAPTER 9: CONCLUDING REMARKS AND POLICY RECOMMENDATIONS

9.1 Background

Problems, such as biological and economic overfishing, stock depletion and user-group conflicts which generally occur in the case of open access fisheries, are well documented in fisheries literature. As a result, fisheries managers and experts are concerned about the sustainability of open-access resources. In pursuing the legislative objectives of the Fisheries Act (see Chapter 2), fisheries managers generally impose regulations to protect and conserve resources. There are a variety of regulatory measures and management approaches available for fisheries managers to use, mainly to conserve fish stocks and their habitat in order to help meet intra-generational and inter-generational equity obligations under the sustainable development principles. Depending on the characteristics of the fishery, the commonly used measures are broadly classified as input controls, technical measures (for example, area and seasonal closures), output controls (for example, TAC, ITQs) and monetary measures (such as taxes and subsidies). The most commonly followed approaches to fisheries management can be classified as adaptive management, ecosystem based management, precautionary principle, and co-management.

As mentioned in Chapter 1, following global initiatives and policy agenda in relation to fisheries sustainability, the Sultanate of Oman has devoted particular attention to the development of the fisheries sector as a mechanism to increase fisheries' share in the Gross Domestic Product (GDP), foreign exchange, food security and socio-economic well-being of fishers. These initiatives and agenda are reflected in country's economic vision 2020. However, as a signatory to Agenda 21 Oman has not yet attempted to assess the overall performance of her fisheries sector with respect to the core principles of sustainable development. This study carried out an assessment of the performance of the commercial trawl fishery of Oman over the period 1997-2006 using the Ecologically Sustainable Development (ESD) framework with particular emphasis on human impact and the environment.

9.2 Chapter Summaries

Chapter 1 outlines the intended research objectives along with scopes and limitations of the study. The chapter also highlights the requirements of this type of study.

Chapter 2 briefly discusses the socio-economic and administrative structures of the country and examines the nature, status and characterization of the overall fisheries sector under a fisheries system approach. The chapter also highlights the implications of renewed attention to the fisheries sector due to the implementation of the 'Vision 2020' charter influenced by the Omanization plan and economic diversification strategies. These initiatives along with the fisheries development plan, perhaps, indicate Oman's political commitments to sustainable development in general, and ecologically sustainable development in particular, to the fisheries sector. In the context of fisheries, given its socio-economic contributions to the national economy and given the obvious dichotomy between the commercial and traditional sectors, a balanced approach to fisheries management is suggested for progress towards a sustainable development path.

Chapter 3 reviews the concept of sustainable development, its inherent complexity from the socio-economic, environmental and institutional contexts. The importance of the concept, as highlighted in the national and international policy agendas, and the challenges involved in making the concept operational, are also discussed in the chapter. Given the necessity of measuring progress towards sustainability in response to the global initiatives and global calls, it is important to proceed in a systematic fashion.

In pursuing a systematic approach, Chapter 4 describes the sustainable development reference system and the key elements involved in the development of that system, which shaped the main objectives of the present study as described in Chapters 5, 6 and 7. The chapter also discusses the different type of sustainability frameworks and their pros and cons in relation to their suitability in analyzing the case study in hand. It nominated the framework (i.e. the ESD framework) to be used under the existing constraints in relation to data, information and other issues relevant to the fishery

Chapter 5 identifies the relevant key components and various sub-components of the ESD hierarchal structure to ensure its applicability to current and future fisheries conditions. The intention was also to ensure flexibility in the framework to enable necessary extension for future use for the assessment of other important sectors in the economy. This intention seems to be consistent with the current mood of the global community in the context of sustainability assessment of the various sectors in the economy. The chapter also identifies the objectives of each key component and sub-component that are not only in line with the national plans and international policy initiatives but also coherent with the overall principles of sustainable development. Some important policy issues in relation to fisheries non-compliance and environmental degradation are also highlighted in the chapter.

As the next step in the development of Sustainable Development Reference System (SDRS), Chapter 6 developed appropriate sustainability indicators along with preferential trends and reference points to measure the achievement of objectives associated with key components and sub-components of the ESD framework as developed in Chapter 5. The preferred trend in performance indicators associated with the objectives of each sub-component is also justified under ESD principles. It is noted in the chapter that the effective evaluation of the objectives identified under the key components and sub-components would depend on the appropriateness of the performance indicators and the quality and accuracy of data and information. As outlined in Chapter 1, this is one of the limitations of this study.

Chapter 7 assesses the progress of the specified objectives of each sub-component of a key component over time using the Multi-Criteria Decision Analysis (MCDA) techniques. Furthermore, this chapter provides the justification of preferred trends of selected indicators and describes the standardization process and a method of calculating a score for each component. It should be noted that in the absence of any reference point for a particular indicator, an attempt was made to estimate it based on the available data. This chapter also highlights some important policy issues in the context of human-wellbeing under the base case scenario (where equality in weight distribution to the main components and then subsequently to the sub-components is maintained). In analyzing the base case scenario, it was found that the human component of the ESD framework was mainly weakened due to income and conflict criteria during the period 1998-2001 which resulted in economic inefficiency in fisheries management.

In recognition of uncertainties in the fisheries management decision-making process, Chapter 8 presents a critical analysis of the base case scenario by identifying the strengths and weaknesses of the most preferred option (year) using a sensitivity analysis. Sensitivity analysis was also performed for four other potential cases depending on the policy preferences of various stakeholders involved and on some adjustment in the inputs values. Some key policy implications are also included, mainly under the human well-being component of the ESD framework, based on the analytical findings.

As discussed in Chapter 8, the study period was divided into two periods; namely the '1998 management scheme' and the '1997 management scheme'. Based on analysis, it is was found overall that the year 2001, which fell within the 1998 management scheme period, was the most preferred year. Therefore, the management measures practiced in the period 1998-2001, are considered to be the most suitable for the advancement towards the ESD principles. However, it is concluded that overall attainment toward sustainability is below par.

9.3 Overall Findings

Despite the presence of clear legislation, strong management regulations and efficient monitoring programmes, the findings in previous chapters revealed that the Omani fishery, primarily the commercial trawling sector, suffer the following difficulties:

1. The fisheries sector is suffering from data errors and data limitations for reporting and management statistics and for the development of appropriate indicators.
2. Deficiencies exist in the indicators and their reference points.
3. Some specific aspects of the fishery have weak regulations or currently do not have regulation.
4. Fisheries resources are under stress, with some stock probably facing overfishing.

5. The sector's contribution to the national economy has dropped instead of growing, as planned by Vision 2020.
6. There has been a failure in 'Omanizing' the commercial trawling sector as planned by the sixth five-year plan (2001-2005), given that the sector is still 100% foreign.
7. There is weak domestic food security and the per capita fish consumption has declined by more than 30.8% in 8 years from 1997 to 2005.
8. There is a clear indication of political interference in the management of the fisheries sector.
9. There is a weakness in the enforcement, compliance and sustainability of management regulations.
10. There is a critical problem with fish discards in the commercial trawling sector.
11. There is a resource access conflict between the local traditional fishermen and the commercial trawlers, resulting in the undermining of local community welfare by the privatization strategy.
12. The overall management schemes practiced in the study period (1997-2006) seem to favor short-term financial returns over long-term conservation strategy.
13. The overall attainment of sustainability in regard to key dimensions is below par.

The above listed main findings are further discussed below and policy recommendations were highlighted.

9.4 Policy Recommendations

It is important to note that to create effective governance of marine resources, it is essential, amongst other factors that are constraining the sector's progress towards sustainability, to consider environmental, socio-economic and institutional issues in a multi-disciplinary context. The ESD framework used in this study, in assessing the extent of progress towards sustainability of the commercial trawl sector, encompasses those key dimensional (environmental, economic, social and institutional) issues and points out the issues affecting the effective governance of fisheries resources in Oman. Grafton et al. (2007) have used various factors including accountabilities for management decisions, transparency in the decision-making process, incentive generating mechanisms, management approaches to dealing with risk and uncertainty and adaptability to changed conditions by both managers and primary stakeholders, in a benchmarking exercise for fisheries governance.

Based on the governance criteria listed above and some key findings from this study (observational as well as analytical), a few central policy recommendations have emerged as follows:

9.4.1 Legislative Framework

A legislative mandate is a crucial element for effective enforcement of regulations. However, it is noted that current legislative framework is not effective in its present form in the sense that it has failed to produce a cost-effective and efficient enforcement regime for the fisheries sector in Oman. Broadly speaking, the main concern for regulatory authorities in Oman, with regard to non-compliance in fisheries, is that it undermines the attainment of, amongst others, the following key management objectives: a) conservation of resources, b) economic efficiency and cost-effectiveness of regulations, and c) legitimacy of regulations, stipulated in the fisheries development plan. It should be emphasized that these key management objectives are coherent with ESD principles. Regardless of the sources, non-compliant behavior in the trawl fishery sector undermines the effectiveness of management regimes, and thereby the achievement of management objectives. In enforcing fisheries regulations, an important question regulators should ask is, what is the cost of enforcement? Put another way, what determines the optimum level of enforcement of regulations? The management authority should identify whether there are constraints to the enforcement of fisheries regulations, otherwise, they could fail to achieve the legislative objectives. The apparent reluctance of the authority to achieve total compliance is in the fact that fisheries enforcement is a costly exercise. Considering these enforcement and regulatory issues the authority should:

1. Develop a fisheries management plan that explicitly states the management objectives that are consistent with the ESD principles, defining strategies to achieve those objectives and with attached performance indicator(s) to each objectives allowing the level of achievement of those objectives to be measured;

2. Amend the existing fisheries regulations to control all potential internal and external influences that are harmful to the conservation of living marine resources available in the Omani EEZ and thereby ensuring sustainable utilization of living marine resources. This would enhance Oman's ability to give effect to rights and obligations under the UNCLOS III in relation to the conservation and management of living marine resources;

3. Redesign the compliance system and processes to support the management plan. In recent years, concerns about fisheries compliance have been well documented in various international policy documents such as, the FAO Code of Conduct for Responsible Fisheries, United Nations Convention on the Law of the Sea (1982) and United Nations Fish Stock Agreement, to name a few;

4. Realize the importance of management as well as operational issues. Management authorities, experts, researchers and policy makers at national and international levels are putting their efforts into designing cost-effective strategies to achieve targeted levels of compliance in the fisheries sector. In this context, the authority has to decide on either voluntary compliance or creation of effective deterrents or, a combination of the two to achieve optimal levels of compliance in fisheries and;

5. Create sea safety initiatives including vessel maintenance through the effective enforcement of health and safety regulations. In addition, an awareness campaign through conducting sea safety workshops involving fishers and fisheries officers would definitely mitigate the occupational health and Safety issues observed during the field observation.

9.4.2 Livelihood Approach

It appears that the fishing activities of the commercial sector aimed at maximizing economic benefits by the use of fisheries resources are threatening to harm the community interests including those of the traditional sector. In the absence of effective governance, the recent renewed growth of interest in the fisheries sector influenced by economic diversification strategies (as discussed in Chapter 2) has the potential to generate more resource conflicts between resource users. Under present conditions it seems inevitable that the commercial interests will clash regularly with the traditional interests and if this is true, it will undermine the overall program objectives. The appropriate authority should institutionalize the conflicts and consider adopting a cost-effective procedure from those alternatives available. To reconcile the conflicting interests over the use of fisheries resources, procedures should include, reinforcing social norms through community institutions, (for example Senat Al-Bahar as mentioned in Chapter 2), legal regulations, consultations and negotiation and a co-management approach.

Although, privatization under the 'Vision 2020' plan (as discussed in Chapter 2) was expected to accomplish a number of objectives, namely, economic efficiency, productivity growth and environmental conservation, it could disadvantage the traditional sector as local community welfare may be undermined in protecting private interests. The authority must find ways to provide protection to traditional fishing communities so that the privatization strategy does not distort local community livelihoods. This is consistent with one of the plan's objectives.

Furthermore the vision of developing fisheries resources through the use of modern technology may prove incompatible with the aim of preserving the traditional fishing communities in Oman. However, despite this concern of incompatibility, international evidence suggests that two such radically different socio-economic visions can co-exist and contribute positively towards the achievement of sustainability in the fisheries sector in Oman. In this context, the case of Japan provides an example of how traditional systems have continuously been adapted to fulfill modern functions within the fisheries sector (Kalland 1995).

It should also be noted that the fundamental threat to the survival of traditional fishing communities in Oman may not necessarily arise solely from existing government policies. It may also arise from the depletion of the resource base, change in world environment due to globalization or other societal dynamics such as urbanization. Therefore, the government must search for effective solutions by formulating appropriate rural development policy based on the 'livelihood approach' which attempts to identify the different capabilities of traditional communities (or rural households) to deal with such crises (Allison and Ellis 2001). It is important to note that fishing in the traditional sector is carried out by family labor and in some instances casual labor is hired. In addition, there is also a reasonable proportion of part-time fishers in the traditional sector. Therefore, policy and management support of 'occupational pluralism' could be an effective strategy for fisheries development in Oman. This is consistent with international policy in regard to traditional fisheries that aims to: provide food security, create employment opportunities and increase income for the traditional fishing communities (Bailey and Jentoft 1990; Lawson 1980).

It is further noted that the current modes of distribution of fish and associated revenue generated from the trawl sector is contrary to food security as well as foreign exchange earnings as the catch by the foreign fishing companies is directly exported to international markets and a major share of the revenue generated from the catch is also transferred to owners of the foreign fishing companies (as discussed in Chapters 2 and 8). This situation clearly undermines the objectives of the "Vision 2020' plan. The Government should adopt appropriate policy measures through the distributional operation of exports and imports of fish to expand the supply of fish at an affordable price within the domestic market. It should be mentioned that market relationships are also important to the coastal communities as it is one of the ways of incorporating the traditional fishers in the export market. It is observed that, in many instances, the traditional fishers rely on the market to dispose of the greater part of their landings. The fish dealers tend to buy fresh fish at the landing site and supply it directly to the export market. In this regard, a centralized marketing approach could achieve the desired outcome. A preferable policy, from the socio-economic point of view, is to focus on the balanced development strategies within the sector.

9.4.3 Discards

The high level of discard experienced by the trawl industry needs particular attention because of the ecological and economic consequences that undermine national commitment to the sustainability of marine resources. A number of important causes of discards were identified during field observation namely, lack of management strategies, fishers' attitudes and neglect towards discarding and ineffective enforcement of regulations. The management authority should consider the following potential measures to reduce discards in the trawl industry:

1. Adopt an awareness campaign to educate fishers about the consequences of discards and introduce appropriate objectives into the management plan;
2. Adopt a partnership approach to implement technical fishing gear modification measures such as, Bycatch Reduction Devices (BRDs) to meet management targets. International evidence suggests that such measures are more effective than other input control, and technical measures such as time restriction, closed area and season or making discards illegal (Catchpole et al. 2005) and;
3. As some level of bycatch is inevitable, the authority should also look for a market based solution to economically utilize discards. However, in doing so, the authority has to ensure that this strategy does not create pressure on the discarded species thus posing a threat to sustainability.

9.4.4 Partnership Approach

Given the socio-economic, cultural and political significance of the fisheries sector in Oman, it is important to explore the human dimension of the industry. A study of the human factors including individual expectations, motives and interests, amongst others, is of obvious importance as these factors influence individual perception (Pringle 1985). Furthermore, resource managers have recognized that decisions, to comply or not comply with the existing or proposed management regulations, mainly depend on perception and attitudes of user groups of fisheries resources. It is worth mentioning that the effective implementation and cost-effectiveness of management regulations depend upon the acceptability of the regulations by the affected party. It is perceived that the lower the degree of acceptability of proposed regulations by the affected parties the higher the transaction costs (Abdullah et al. 1998; Van der Burg 2000). International experience also suggests the centralized approach is associated with high transaction costs.

Therefore, to promote efficiency in managing fisheries resources, various forms of partnership approach to fisheries management have been proposed by scholars and practitioners amongst them Jentof (1989); Jentoft et al. (1998); Neis et al. (1999) and Nielsen and Vedsmand (1997). This partnership approach to fisheries management attempts to incorporate fishers' knowledge, behavior and attitudes to the fisheries management process. Thus, it is important for fisheries managers to gain better understanding of commercial, as well as traditional, fishers' perceptions of existing regulations to enable them to formulate effective and efficient policies and programs. The user group consultations and their participation in the decision-making process have been encouraged in many fisheries around the world (Makino and Matsuda 2005; Symes 1997; Satria and Matsuda 2004; Nielsen et al. 2004).

9.4.5 Co-Management

Given the tension between the commercial and traditional sectors, considering the significant landing share of the traditional sector and the inherent objectives of the national development plans, the authority should create a legal and operational framework by drawing experiences from other areas such as Japan, South-East Asia and Africa to promote partnership between the authority, traditional sector and commercial industries. Co-existence of dual sectors and their positive contribution toward the goal of sustainable development is not uncommon as other countries have experienced the positive impact of this approach in attaining economic efficiency and regulatory effectiveness (Satria et al. 2006).

In developing such a framework, the management authority should consider the following key issues in line with the sustainable development principles:

1. Clear definition of the word 'community' to remove any confusion;
2. Legal recognition and establishment of community rights. Establishment of procedural and distributive justice in allocating fishing rights among resource users;

3. Reinforcement of the nationalization strategy in the commercial sector;
4. Revitalization of the contractual agreements between national and foreign fishing companies to maximize community benefits and clearly establishing the operational accountability of national fishing companies in supporting national development strategies;
5. Recognition of the diverse nature of livelihood strategies adopted by the traditional fishers to enhance community resilience in case of external impacts (precautionary approach);
6. Ensuring policy consistency at each level of governments (local, regional and national) relevant to fisheries management;
7. Identification of institutional (local) incapacity in the decentralization process and;
8. Developing a co-management plan that must contain objectives, strategies to achieve objectives, management measures to support strategies, performance indicators to evaluate the level of achievement, budgetary constraints and a review process.

The goals of 'Vision 2020' and the promotion of economic diversification will be difficult to attain without appropriate initiatives and political commitment to accommodate the new approaches to fisheries management. It is important to emphasize the urgency of educational training; to build human capacity involving all key stakeholders to encourage mutual learning processes so that information can be shared efficiently and effectively. This would allow effective governance of the marine resources of Oman. It should be recognized that in fisheries management, government is severely constrained by the access to information and by the requirement of 'fairness and equity'. These two constraints are interconnected because to establish 'distributive justice' the Government requires accurate information which in itself is difficult to obtain where rivalry exist between the suppliers (traditional and commercial) of fish resources. Therefore, a partnership approach needs to be developed to overcome this obstacle. It is important to recognize the positive step taken by the Government in establishing the Ministry of Fisheries Wealth – a statutory authority – which is responsible for the enforcement of fisheries regulations within the Omani EEZ. However, to provide effective management services to conserve resources, to achieve sustainability of fish stocks and to maximize socio-economic benefits to the Omani community, long-term investments and national commitment is required.

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Appendix 1

Consultation Review

On
Ecologically Sustainable Development Framework for the Commercial Trawl Sector of the Sultanate of Oman

Dear Respondent,

My name is Hussein Samh Al-Masroori, lecturer at Sultan Qaboos University, and I am currently pursuing my studies at the Australian Maritime College, under the supervision of Professor Paul McShane, Vice-President International and Development, and Mr. Steve Eayrs, lecturer in fisheries technology.

I am carrying out a consultation review to design an Ecologically Sustainable Development (ESD) Framework to study the effects of the commercial trawl sector on human and on environment for my PhD study. This review aims to identify all possible relevant components of the attached hierarchical framework structure of the trawling sector in the Sultanate of Oman. I will be grateful if you can participate in this review.

The contents of this consultation or any further discussion or survey (after your acceptance) are absolutely confidential and only be used for the purpose of this research. Information identifying you will not be disclosed under any circumstances. Your co-operation in this review is very important for the success of this study. Under no circumstances will your name or position be linked to the data of this work or any related work.

Thank you very much for your time and co-operation.

Hussein Samh Harib Al-Masroori	
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PREFACE

Effective management of any living resource requires the maintenance of a dynamic balance between obtaining the benefits of exploitation and minimizing the impacts of exploitation (Brown et al. 1998). It should encourage participation from various stakeholders to achieve meaningful progress in marine resource management to ensure the future well-being of the stock (Krouse 1989) as well as skills, science and knowledge. For this reason as well as to cope with the human demand, the concepts of conservation, development and access need to be reconciled before serious progress can be achieved in marine resource environment. All those approaches are manipulated with what is identified as Sustainable Development (SD). SD is the practical link, which resolves the conflict between environment and development. It is been defined by the World Commission on Environment and Development report as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

Ecologically Sustainable Development (ESD) is the Australian notion for the SD. It is defined as "using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained and the total quality of life now and in the future can be increased". ESD framework (Figure 1) is a comprehensive structure, which include environmental, economic and social components used to evaluate the progress of SD over time. This evaluation is done by examining the effect of fishing in terms of impacts on ecological processes and on total quality of life. The structure is designed to organize information about the fishery, avoiding omission and duplication.

This review aims to identify all possible components of the hierarchical structure that are relevant to the fishery. It aims also to maximize the consistency and minimize the chance of missing issues or impacts (positive or negative) related to the trawling sector in the Sultanate in a comprehensive and structured manner. This step will never involve any discussion of importance, rather evaluating or scaling of any issue. Any issue raised by a participant will be added to the relevant place for subsequent assessment.

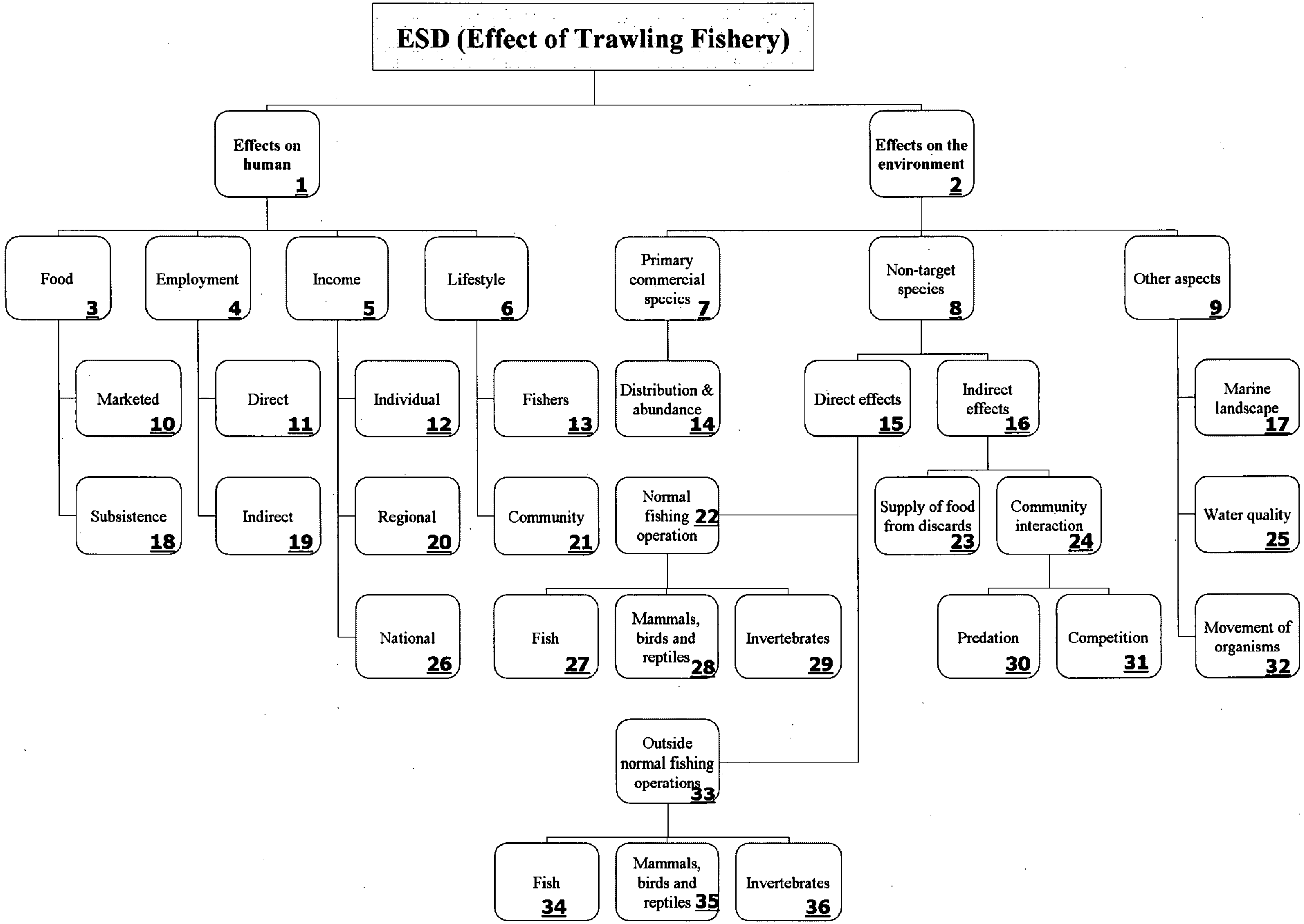


Figure 1: ESD Framework of Industrial Trawling Sector in Sultanate of Oman
Source: Chesson and Clayton, 1998

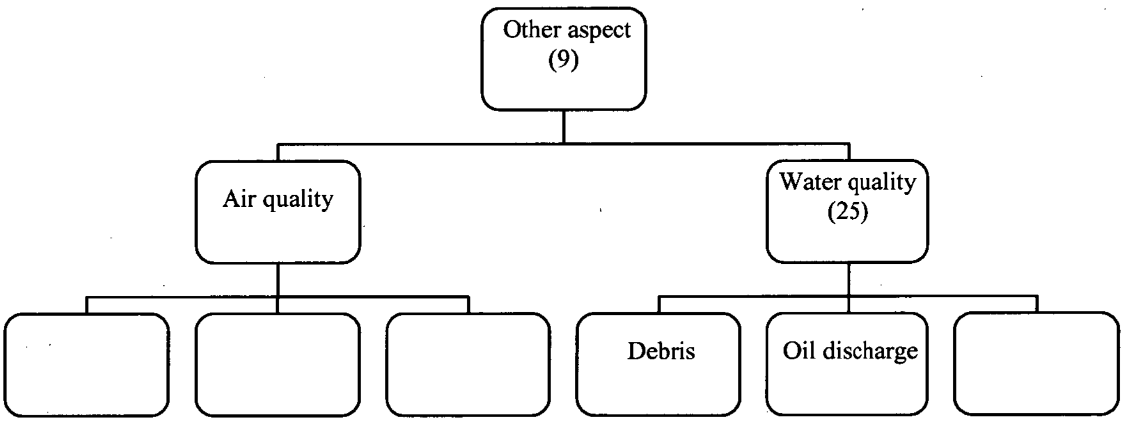
INSTRUCTION FOR MODIFYING THE HIERARCHICAL STRUCTURE

Where appropriate and based on your experience and knowledge please:

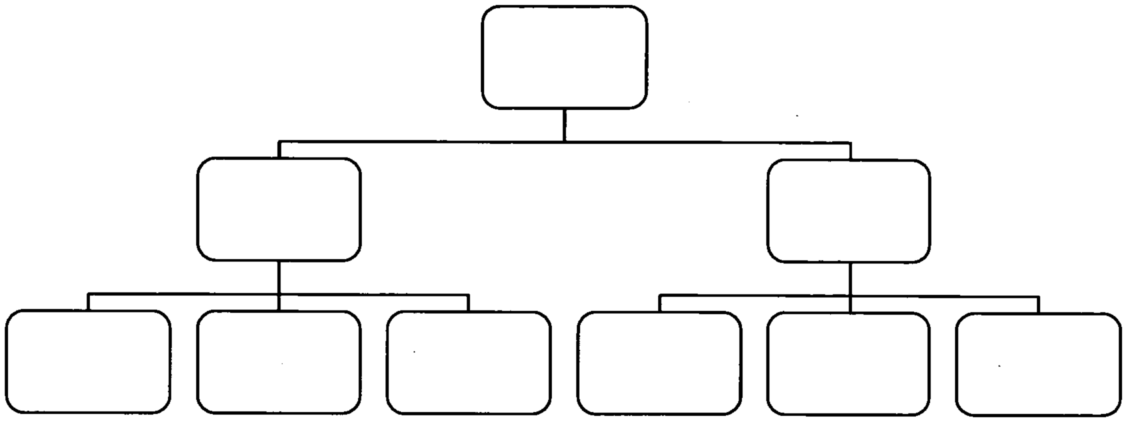
1. Add any missing issue
2. Expand (splitting) and/or contract (removing/lumping) the number of sub-components as required
3. Delete any available non-related issue (please provide a justification for this action)

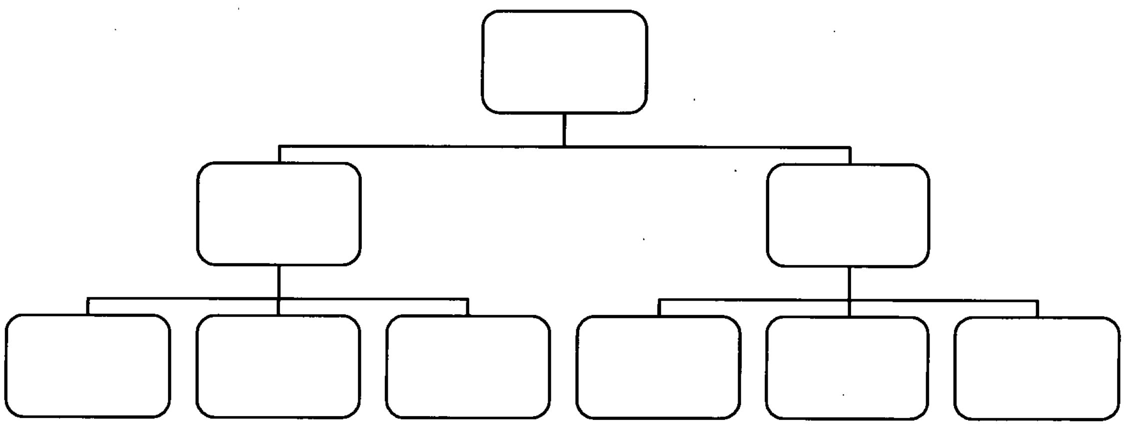
Please use the provided blank organization charts to add, modify or expand the component in figure 1 and just provide the name or number of sub-component in case of deleting accompanied with reasons.

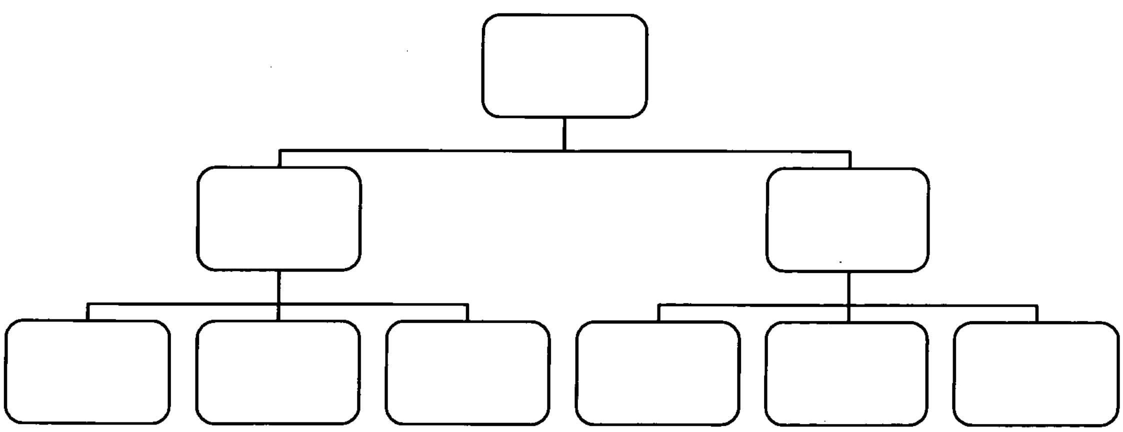
Example:
If you want to add air quality under other aspects (sub-component number 9) and expand the water quality (sub-component number 25) into debris and oil discharge, then your sketch will look like:



PLEASE KEEP IN MIND	**This stage is about issue identification and not for evaluating, scaling or discussing the importance of any issue**







Please give here any further remarks, comments or reasons for deleting of any issues:

Use the back for extra space →

Many thanks for your contribution.
As consultation and group discussion are of important element in this study, I will appreciate if you agree to receive more reviews in future. If you do so, please fill-in the following information, which will facilitate the way of communication:

1. Name: ....
2. Position: ....
3. Qualification: PhD① Master② Degree③
   Other③, Specify: ....
4. Field of Work: Academic① Research②
   Management③ Industry (Company)④ Other⑤,
   Specify: ....
5. E-mail(s): ....
6. Signature (required for human ethics purpose):
   ....

Appendix 2

Voyage Fishing Vessel License

تصريح إبحار سفينة صيد لرحلة واحدة

ONE VOYAGE FISHING VESSEL LICENSE

Voyage No: / 200
From: / / 200 To: / / 200
Vessel Name:
Company Name:
Call Sign :
License No : / Muscat
Observer Name :
Captain Name :
Captain License No: / Muscat

رقم الرحلة : / ٢٠٠
من : / / ٢٠٠م إلى: / / ٢٠٠م
اسم السفينة:
اسم الشركة:
النـــــــداء :
رقم الترخيص: /مسقط
اسم المراقب:
اسم القبطان :
رقم الرخصة: / مسقط

Fishing is permitted in areas between Latitude (21 00)N And Longitude (55 45)E , Along the Southern coast of

منطقة الصيد المصرح بها هي تلك التي تنحصر بين خطوط العرض (٠٠ ٢١) شـمالا و خطوط الطول (٤٥ ٥٥) شرقا على طول الساحل الجنوبي لسلطنة عمان مع التقيد بالآتي:

1. Fishing should be practiced in depths not less than (50m) And at distance not less than (10 Nm.).

١. تتم عمليات الصيد في أعماق لا تقل عن (٥٠)مترا، و على مسافة لا تقل عن (١٠) أميال بحرية عن الشاطئ.

2. Fishing is prohibited in all areas located at the eastern said of masirah island & the area around ras hasik between longitude (55 and 55° 45′)E

٢. غير مصرح بالصيد في كل من المنطقة الواقعة على الجانب الشرقي لجزيرة مصيره وفي المنطقة حول رأس حاسك بين خطوط الطول (٥٥ و ٤٥ ٥٥) شرقا.

3. The fishing methods: Trawling (the eye mesh size for the net should not be less than (110mlm.) (to be measured from inside) demarsal fish only.

٣. يصرح للسفينة باستخدام الشباك التي لا يقل قياس عين الشبكة عن (١١٠) ملم ويكون القياس من داخل العين . لصيد الأسماك القاعية فقط.

4. Number of CROW ( )Person.
The Captain shell maintain this license onboard the vessel throughout the voyage & present it to whomever it

٤. عـــدد الطاقـــم:( ) فـــــردا.
يحتفظ قبطان السفينة بهذا التصريح أثناء الرحلة و يجب تقديمه للمختصين عند الطلب.

Mr. NASIR Bin SAIF Bin SHAMIS AL KEYOMI
.DIRECTOR OF FISHERIES SURVEILLANCE & LICENSES DEPARTMENT

ناصر بن سيف بن شامس الكيومي
مدير دائرة الرقابة والتراخيص السمكية

CC.
Office of A.COSSAF.
R.O.A.F.
R.O.N.
COASTAL GUARD.
.Vessel file.

نسخة إلى:
- رئاسة مكتب مساعد أركان قوات السلطان المسلحة.
- سلاح الجو السلطاني العماني.
- البحرية السلطانية العمانية.
- وحدة شرطة خفر السواحل.
- ملف السفينة.

Appendix 3

Standard Form of Statistical Data Sheet

Example of landings and value from the commercial trawl fishery

Industerial Fishery: Total catch by Trawlers in (ton) during 2006.														الصيد التجاري: إنتاج سفن الجرف بالطن خلال عام 2006م.
Month Species	الإجمالي Total	ديسمبر Dec	نوفمبر Nov	اكتوبر Oct	سبتمبر Sep	اغسطس Aug	يوليو Jul	يونيو Jun	مايو May	ابريل Apr	مارس Mar	فبراير Feb	يناير Jan	الشهر النوع
Large Pelagics														الأسماك السطحية
Yellowfin t	23	0	0	0	0	0	0	0	0	4	12	6	0	جيذر
Longtail tu	0	0	0	0	0	0	0	0	0	0	0	0	0	سهوة
Kawakawa	0	0	0	0	0	0	0	0	0	0	0	0	0	صدة
Striped bo	29	3	2	4	0	0	1	1	4	6	4	3	1	سقلانة
Frigate tun	0	0	0	0	0	0	0	0	0	0	0	0	0	نبانة
Skipjack	0	0	0	0	0	0	0	0	0	0	0	0	0	حقبة
Other tuna	0	0	0	0	0	0	0	0	0	0	0	0	0	تونات اخرى
Kingfish	4	2	0	0	0	0	0	0	0	0	1	1	0	كنعد
Queenfish	1	0	0	0	0	0	0	0	0	0	0	0	0	حبس
Baracuda	322	54	32	10	13	22	11	10	11	10	29	37	84	عقام
Cobia	0	0	0	0	0	0	0	0	0	0	0	0	0	سكل
Sailfish	0	0	0	0	0	0	0	0	0	0	0	0	0	مبخ
Large Jack	894	172	75	65	51	22	31	45	73	66	102	82	111	صال كبير
Other	12	1	2	3	1	0	0	0	0	0	0	1	2	اخرى
Subtotal	1284	232	113	82	64	44	43	56	89	86	147	129	199	الإجمالي
Small Pelagics														اسماك سطحية صغيرة
Sardine	0	0	0	0	0	0	0	0	0	0	0	0	0	عومة مختلفة
Indian Oil S	0	0	0	0	0	0	0	0	0	0	0	0	0	عومة
Indian Mac	1074	41	39	21	7	17	14	94	123	235	174	107	200	ضلعة
Anchovy	0	0	0	0	0	0	0	0	0	0	0	0	0	بربة
Small Jacks	1361	96	57	53	57	55	26	97	114	115	205	275	211	صال صغير
Mullets	0	0	0	0	0	0	0	0	0	0	0	0	0	بياح
Needlefish	0	0	0	0	0	0	0	0	0	0	0	0	0	خرخور
Other	25	11	1	1	0	0	0	0	0	1	1	3	6	اخرى
Subtotal	2461	148	97	76	65	72	40	191	237	351	381	386	417	الإجمالي
Demersal														الاسماك القاعيه
Emperor	924	146	134	75	49	104	109	44	79	29	20	41	93	شعري
Seabream	1132	102	158	90	207	51	74	92	109	81	63	35	69	كوفر
Groupper	545	31	29	86	74	141	13	30	25	12	15	34	55	هامور
Crocker	707	17	11	17	38	33	128	150	109	38	97	44	24	صارف
Sweetlips	442	48	53	70	86	35	39	18	22	16	18	15	21	نجرور
Snapper	59	9	13	17	6	1	0	1	1	1	2	5	3	حمراء
Jobfish	0	0	0	0	0	0	0	0	0	0	0	0	0	عندق
Rabbitfish	70	3	13	25	13	1	2	4	0	1	1	2	4	صافي
Catfish	46	11	3	2	0	0	0	0	1	3	10	10	7	جلم
Ribbonfish	2910	443	129	31	33	36	19	34	134	488	542	491	530	صفق
Other	4283	498	541	307	280	463	495	183	227	173	321	465	330	اخرى
Subtotal	11118	1307	1085	721	786	865	879	556	707	842	1090	1142	1137	الإجمالي
Sharks & Rays														قرشيات
Sharks	240	57	17	4	6	5	5	9	6	9	19	43	59	جرجور
Rays	2	1	0	0	0	0	0	0	0	0	0	0	0	طباق
Subtotal	242	58	17	4	6	5	5	9	6	10	19	43	59	الإجمالي
Crustaceans														قشريات و رخويات
Lobster	0	0	0	0	0	0	0	0	0	0	0	0	0	شارخة
Shrimp	0	0	0	0	0	0	0	0	0	0	0	0	0	ربيان
Cuttlefish	3846	158	288	475	832	280	311	442	444	257	214	92	53	حبار
Abalone	0	0	0	0	0	0	0	0	0	0	0	0	0	صفيلح
Subtotal	3846	158	288	475	832	280	311	442	444	257	214	92	53	الإجمالي
Unidentified Fish's														اسماك غير معروفة
Other	325	55	45	37	17	2	16	3	18	17	59	27	30	اخرى
Grand Tota	19276	1958	1645	1396	1770	1267	1294	1258	1501	1562	1910	1818	1896	المجموع الكلي

Appendix 3

(Continued)

Traditional Fishery: Total Value by Trawlers in (Thousand R.O) during 2006.													الصيد الحرفي: قيمة الإنتاج لسفن الجرف بالألف ريال خلال عام 2006م.
Month Species	الإجمالي Total	ديسمبر Dec	نوفمبر Nov	أكتوبر Oct	سبتمبر Sep	أغسطس Aug	يوليو Jul	يونيو Jun	مايو May	أبريل Apr	مارس Mar	فبراير Feb	يناير Jan	الشهر النوع
Large Pelagics														الأسماك السطحية
Yellowfin t	15	0	0	0	0	0	0	0	0	3	8	4	0	جيذر
Longtail tu	0	0	0	0	0	0	0	0	0	0	0	0	0	سهوة
Kawakawa	0	0	0	0	0	0	0	0	0	0	0	0	0	صدة
Striped bo	13	1	1	2	0	0	0	1	2	3	2	1	1	سقلانة
Frigate tun	0	0	0	0	0	0	0	0	0	0	0	0	0	تبانة
Skipjack	0	0	0	0	0	0	0	0	0	0	0	0	0	حقيبة
Other tuna	0	0	0	0	0	0	0	0	0	0	0	0	0	تونات اخرى
Kingfish	4	2	0	0	0	0	0	0	0	0	1	1	0	كنعد
Queenfish	0	0	0	0	0	0	0	0	0	0	0	0	0	حبس
Baracuda	126	21	13	4	5	8	4	4	4	4	11	14	33	عقام
Cobia	0	0	0	0	0	0	0	0	0	0	0	0	0	سكل
Sailfish	0	0	0	0	0	0	0	0	0	0	0	0	0	مبخ
Large Jack	626	121	53	46	35	15	22	31	51	46	71	57	78	صال كبير
Other	5	1	1	1	0	0	0	0	0	0	0	0	1	اخرى
Subtotal	789	145	68	53	41	24	26	36	58	56	93	78	113	اجمالي
Small Pelagics														اسماك سطحية صغيرة
Sardine	0	0	0	0	0	0	0	0	0	0	0	0	0	عومة مختلفة
Indian Oil S	0	0	0	0	0	0	0	0	0	0	0	0	0	عومة
Indian Mac	467	18	17	9	3	7	6	41	54	102	76	47	87	ضلعة
Anchovy	0	0	0	0	0	0	0	0	0	0	0	0	0	بربة
Small Jacks	1021	72	43	40	43	41	19	73	85	86	154	206	158	صال صغير
Mullets	0	0	0	0	0	0	0	0	0	0	0	0	0	بياح
Needlefish	0	0	0	0	0	0	0	0	0	0	0	0	0	خرخور
Other	8	3	0	0	0	0	0	0	0	0	0	1	2	اخرى
Subtotal	1495	93	60	50	46	49	25	114	139	189	230	254	247	الإجمالي
Demersal														الاسماك القاعيه
Emperor	503	80	73	41	27	57	59	24	43	16	11	22	51	شعري
Seabream	604	54	84	48	110	27	40	49	58	43	34	19	37	كوفر
Groupper	349	20	19	55	47	90	8	19	16	8	10	22	35	هامور
Crocker	226	6	4	5	12	11	41	48	35	12	31	14	8	صارف
Sweetlips	188	20	23	30	37	15	17	8	9	7	8	6	9	نجرور
Snapper	38	6	8	11	4	1	0	0	1	0	1	3	2	حمراء
Jobfish	0	0	0	0	0	0	0	0	0	0	0	0	0	عندق
Rabbitfish	46	2	9	16	9	1	1	3	0	1	1	1	2	صافي
Catfish	8	2	0	0	0	0	0	0	0	1	2	2	1	جلم
Ribbonfish	1228	187	54	13	14	15	8	14	57	206	229	207	224	صفق
Other	1631	190	206	117	107	176	188	70	87	66	122	177	126	اخرى
Subtotal	4821	566	480	337	366	392	363	235	305	359	448	474	495	الإجمالي
Sharks & Rays														قرشيات
Sharks	176	42	13	3	4	4	4	7	5	7	14	32	43	جرجور
Rays	0	0	0	0	0	0	0	0	0	0	0	0	0	طباق
Subtotal	177	42	13	3	4	4	4	7	5	7	14	32	43	الإجمالي
Crustaceans														قشريات و رخويات
Lobster	0	0	0	0	0	0	0	0	0	0	0	0	0	شارخة
Shrimp	0	0	0	0	0	0	0	0	0	0	0	0	0	ربيان
Cuttlefish	3094	127	232	382	669	225	250	356	357	206	172	74	43	حبار
Abalone	0	0	0	0	0	0	0	0	0	0	0	0	0	صفيلح
Subtotal	3094	127	232	382	669	225	250	356	357	206	172	74	43	الإجمالي
Unidentified Fish's														اسماك غير معروفة
Other	135	23	19	16	7	1	7	1	8	7	24	11	12	اخرى
Grand Tota	10511	996	871	840	1133	694	675	749	871	824	982	922	953	المجموع الكلي

Appendix 4

Official Letters to Fishing Companies

Letter from Ministry of Agriculture and Fisheries asking one of the fishing companies to provide statistical data for the researcher.

بسم الله الرحمن الرحيم

Sultanate of Oman
Ministry of Agriculture & Fisheries
D.G. of Fisheries Wealth

سلطنة عمان
وزارة الزراعة والثروة السمكية
المديرية العامة للثروة السمكية

No. :
Date : ....
Date : ....

الرقم : ١٥١٢
التاريخ : ٥/٤/١٤٢٨هـ
الموافق : ٢٣/٤/٢٠٠٧م

الفاضل/ المحترم

السلام عليكم ورحمة الله وبركاته.. وبعد ، ،

الموضوع / طلب بعض البيانات

نود إفادتكم بأن الفاضل/ حسين بن سمح بن حارب المسروري يعمل حالياً على استكمال دراساته العليا في مجال (تقييم قطاع الصيد التجاري لسفن القاع نحو تنمية مستدامة بيئياً)، وقد تقدم إلينا بطلب مساندته للحصول على بعض البيانات التي سوف يستعين بها في دراسته، وفي هذا الشأن نرجو التكرم بالتعاون نحو تزويده بالبيانات التي يتطلبها حول أنواع الأسماك المصادة بواسطة سفن القاع والتي تدخل ضمن حصتكم وكمياتها وقيمتها وكذلك الكميات المصدرة منها وعدد العاملين لديكم.

وتفضلوا بقبول فائق الاحترام ، ، ،

إبراهيم بن سعيد البوسعيدي
مدير عام تنمية الثروة السمكية

ص.ب : ٤٦٧ – الرمز البريدي : ١١٣ مسقط – تليفون : ٦٩٦٣٠٠ – تلكس : ٥٥٠٣ اجريفش او ان – فاكس : ٦٠٥٦٣٤
P.O. Box : 467 - Postal Code : 113 - Muscat - Tel : 696300 - Telex : 5503 AGRIFISH ON - Fax : 605634

Another letter from Australian Maritime College.

Australian Maritime College

Australia's National Centre for Maritime Education, Training and Research

To Whom It May Concern:

We would like to invite your participation in a research project by providing some specific statistical data. The title of the research project is ***"Evaluation of Industrial Trawling Sector in the Sultanate of Oman with respect to Ecologically Sustainable Development (ESD)".*** The purpose of this study is to investigate the social, economic and environmental effects of the trawling sector. This will be achieved through the following methods:

- Designing an ESD framework and identifying its hierarchical structure components.
- Specifying criteria, objectives, potential indicators and reference points following a Sustainable Development Reference System (SDRS).
- Assessing the progress of each component with respect to its objective.

The significance of this research is that it goes beyond the kind of present research that targets: the efficiency and selectivity of the fishing gears in the Sultanate of Oman; and stock assessment, protection and conservation without considering other aspects that are connected to the target of the research. This study therefore responds to a gap in the recent research and generates new knowledge by providing an insight into the role of sustainable development and the need to address all aspects of any fishery (biology, ecology, environment, politic, social and economic) to maintain sustainable growth and development of any fishery.

Your company has been chosen to participate in this study due to its involvement in the trawling sector. You will be asked to provide some annual statistical data about fish species, catch, value, exports and employment.

Although the required data are general statistical figures, information identifying your company name will not be disclosed under any circumstances and neither will it be linked to the data or any related work.

Should you require any additional information regarding this research, please do not hesitate to contact the Australian Maritime College.

Yours sincerely,

Brigid Freeman
Manager, Research Development (b.a.freeman@amc.edu.au)

Professor Paul McShane, Principle Supervisor (paul.mcshane@bigpond.com)
Hussein Samh Al-Masroori, PhD Research Student (h.masroori@amc.edu.au)
Department of Fisheries & Marine Environment
Australian Maritime College

Telephone: (03) 6335 4711 Fax: (03) 6326 6493 IDD prefix (3) www.amc.edu.au
PO Box 986 Launceston Tasmania 7250 Australia

Appendix 5

Economic Benefits Calculation

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total catch (mt)	27123	13198.244	12145.3	10681.918	2740.7	25402.392	17862.359	22279.866	17685.257	19275.827
Total value (1000 OMR)	11237.15	6061.5309	6371.7	4954.7421	1223.3629	12310.259	9096.0228	11621.645	9785.7566	10511.243
Local fishing companies share	5433	2650.8	2428.8	2136.2	548.2	5080.4	3572.4	4455.8	3530.88	3855.2
Local fishing companies share value (OMR)	2250910.1	1217427.6	1274203.6	990863.24	244699.36	2462013.8	1819167.9	2324238.7	1953736.5	2102267.3
Large pelagic @ 200 OMR per mt	621.63438	484.64485	569	711.81612	84.432922	6629.733	843.43105	1680.404	1329.243	1284
Small pelagic @ 100 OMR per mt	543.93008	628.64132	0	497.07937	27.770443	50.112995	1193.1236	2477.345	3711.564	2461
Demersal @ 250 OMR per mt	21255.275	10122.737	9795.8	8871.8079	2508.4412	16919.829	11178.707	13011.366	9162.631	11118
Sharks, Ray & Crustacean @ 500 RO per mt	4594.0041	1962.2206	1780.5	601.21471	120.05541	1802.7169	4529.4339	4453.035	3281.046	4087.8383
MAF @ 12% OMR	934744.89	440590.53	414360	325275.66	84816.197	775472.84	641687.08	727580.91	548182.29	639150.09
Research fund @ 1.5% OMR	116843.11	55073.816	51795	40659.457	10602.025	96934.104	80210.884	90947.614	68522.786	79893.762
Number of foreign sea workers	630	540	330	516	324	768	637	837	942	781
Tax @ 21 OMR per worker	7560	6480	3960	6192	3888	9216	7644	10044	11304	9372
Number of vessels (Iranian @ 2000 OMR)	0	0	0	0	4	9	6	7	7	4
Number of vessels (Other @ 1000 OMR)	21	18	11	10	3	14	16	24	29	24
Total vessels	21	18	11	10	7	23	22	31	36	28
Value from vessels registration to enter Port	21000	18000	11000	10000	11000	32000	28000	38000	43000	32000
Total hp	38297.369	32826.316	20060.526	18236.842	12700	47076	42723	56144	61160	50502
Tax @ 0.1 OMR per hp	3829.7369	3282.6316	2006.0526	1823.6842	1270	4707.6	4272.3	5614.4	6116	5050.2
Fishing trips	279	136	100	64	17	110	113	151	91	107
Berthing and harbor tax @ 308 OMR per vessel per day	257796	125664	92400	59136	15708	101640	104412	139524	84084	98868
Port tax @ 1 OMR per mt	27123	13198.244	12145.3	10681.918	2740.7	25402.392	17862.359	22279.866	17685.257	19275.827
Annual gross value of the fishery (OMR)	3619806.9	1879716.8	1861870	1444632	374724.28	3507386.7	2703256.6	3358229.5	2732630.8	2985877.2
Annual gross value of the fishery (M. OMR)	3.620	1.880	1.862	1.445	0.375	3.507	2.703	3.358	2.733	2.986
preferred Score (1)	**3.620**									
Standardized Index	**1.000**	**0.519**	**0.514**	**0.399**	**0.104**	**0.969**	**0.747**	**0.928**	**0.755**	**0.825**

Appendix 6

List of Abbreviations

AGCC: Arab Gulf Cooperation Council

AHP: Analytical Hierarchy Process

ALECSO: Arab League Educational Culture and Scientific Organization

AOAD: Arab Organization for Agricultural Development

BRD: By-Catch Reduction Devices

CAMS: College of Agricultural and Marine Sciences

CBA: Cost-Benefit Analysis

CBD: Convention of Biological Diversity

CBO: Central Bank of Oman

CCEPP: Council for Conservation of the Environment and Prevention of Pollution

CEA: Cost-Effectiveness Analysis

CISA: Council of the International Seabed Authority

COAG: Council of Australian Governments

COFI: Committee on Fisheries

CPUE: Catch-Per-Unit of Effort

CSD: Commission on Sustainable Development

CV: Coefficient of Variation

DGFR: Directorate General of Fisheries Resources

DPSIR: Driving-Force-Pressure-State-Impact-Response

DPSR: Driving-Force-Pressure-State-Response

DWFN: Distance-Water Fishing Nation

EAM: Ecosystem Approach to Management

EBA: Ecosystem-Based Approach

EBFM:	Ecosystem-Based Fisheries Management
EBM:	Ecosystem-Based Management
EEZ:	Exclusive Economic Zone
EIA:	Environmental Impact Assessment
EPBC:	Environment Protection and Biodiversity Conservation Act
ESD:	Ecologically Sustainable Development
ESI:	Environmental Sustainability Index
EU:	European Union
FAO:	Food and Agriculture Organization
GDP:	Gross Domestic Product
GFDM:	Generalized Fishery Development Model
GNP:	Gross National Product
GPS:	Global Positioning System
HACCP:	Hazard Analysis and Critical Control Point
ICAM:	Integrated Coastal Area Management
ICES:	International Council for the Exploration of the Sea
ICSU:	International Council of Scientific Unions
IEEP:	Institute for European Environmental Policy
IESCO:	Islamic Education, Scientific and Cultural Organization
IFAD:	International Fund for Agricultural Development
IISD:	International Institute for Sustainable Development
ILO:	International Labor Organization
IMO:	International Maritime Organization
IORARC:	Indian Ocean Rim Association for Regional Cooperation
ISD:	Indicators of Sustainable Development
ITQ:	Individual Transferable Quota

IUCN:	International Union for Conservation of Nature
IWC:	International Whaling Commission
LAS:	League of Arab States
LNG:	Liquefied Natural Gas
MA:	Millennium Ecosystem Assessment
MADM:	Multi-Attribute Decision Making
MAF:	Ministry of Agriculture and fisheries
MCDA:	Multi-Criteria Decision Analysis
MCS:	Monitoring Control and Surveillance
MD:	Ministerial Decision
MDA:	Ministry of Diwan Affairs
MECA:	Ministry for Environment and Climate Affairs
MEY:	Maximum Economic Yield
MFW:	Ministry of Fisheries Wealth
MM:	Ministry of Manpower
MNHC:	Ministry of National Heritage and Culture
MOA:	Ministry of Agriculture
MODM:	Multi-Objective Decision Making
MRME:	Ministry of Regional Municipalities and Environment
MRMEWR:	Ministry of Regional Municipalities, Environment and Water Resources
MSE:	Mean Square Error
MSF:	Marine Science and Fisheries
MSFC:	Marine Science & Fisheries Center
MSY:	Maximum Sustainable Yield
NBSAP:	National Biodiversity Strategy and Action Plan

NCS:	National Conservation Strategy
NGO:	Non-Governmental Organization
NSESD:	National Strategy for Ecologically Sustainable Development
OACE:	Office of Advisor for Conservation of the Environment
OAFB:	Oman Agriculture and Fisheries Bank
ODB:	Oman Development Bank
OECD:	Organization for Economic Co-operation and Development
OH&S:	Occupational Health and Safety
OMR:	Omani Rial
PSR:	Pressure State Response
RD:	Royal Decree
RFMO:	Regional Fisheries Management Organization
ROPME:	Regional Organization for Protection of the Maritime Environment
SCFA:	Standing Committee on Fisheries and Aquaculture
SCOPE:	Scientific Committee on Problems of the Environment
SD:	Standard Deviation
SDRS:	Sustainable Development Reference System
SE:	Standard Error
SIC:	Sustainability Index of Criteria
SQU:	Sultan Qaboos University
TAC:	Total Allowable Catch
TED:	Turtle Excluder Devices
UN:	United Nation Organization
UNCED:	United Nations Conference on Environment and Development
UNCLOS:	United Nation Convention on the Law of the Sea
UNCSD:	United Nation Commission on Sustainable Development

UNDP:	United Nations Development Program
UNEP:	United Nations Environment Program
UNESC:	United Nations Economic and Social Council
UNESCO:	United Nation Educational, Scientific and Cultural Organization
UNFSA:	United Nation Fish Stock Agreement
UNIDO:	United Nations Industrial Development Organization
UNSC:	United Nations Security Council
VHF:	Very High Frequency
VMS:	Vessel Monitoring Systems
WCED:	World Commission on Environment and Development
WCS:	World Conservation Strategy
WSSD:	World Summit on Sustainable Development
WWF:	World Wildlife Fund