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Developing indicators for the assessment of sustainability of an industrial fishery: a case study in the Sultanate of Oman

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Abstract

With the widespread concern about the state of world fisheries, sustainability in fisheries sector is now high on both national and international policy agendas. Given the priority and the resulting approach to responsible and effective decision-making, the demand for an assessment of fisheries sustainability is on the rise. To accomplish this priority task and meet the growing demand, fisheries managers and decision-makers require appropriate and relevant indicators related to the core dimensions of sustainability. Using an appropriate sustainable development framework and considering the particular conditions of a commercial fishery from the Sultanate of Oman, this study has developed some essential indicators along with their preferred trend to facilitate the assessment of sustainability as well as to determine the changes in indicator over time. As a part of the recommended process, the selection of assessment framework and a set of relevant indicators were carried out through a consultation process involving representatives from key stakeholder groups. It should be noted that for a data poor fishery the development of criteria and indicators is a challenging task. Notwithstanding, the information provided in this study would help fisheries managers and policy-makers tracking progress and indicating to what extent strategies and policies contribute to achieving sustainability for the case in hand. Furthermore, it is hoped that the methodological approach followed in the development of suitable indicators would serve as a useful guide for other commercial fisheries in the world.

Keywords: Fisheries Indicators, Sustainability, Industrial Fishery, Sultanate of Oman

1. Introduction

During the past four decades or so, sustainable development[1] has been a highly debated topic among natural and social scientists, governments and policy makers attributable to concern about the interaction of economic growth and natural environment. A great deal of confusion exists in the literature regarding precise meaning and operational content (Morita *et al.*, 1993; Drummond and Marsden, 1995; Mitchell, 1997; Murcott, 1997; Garcia, 2000; 2000) of sustainable development. Despite this ongoing debate and confusion, sustainable development has been a widely accepted guiding principle for the management of natural resources worldwide. Therefore, a genuine attempt for the measurement of sustainability in the various sectors of a national economy is of strategic importance.

In the context of capture fisheries, significant progress has been made in defining the concept of sustainable development and identifying the factors that determine the concept.[2] However, the key challenge is to determine whether a particular fishery sector is on or off the sustainability path. Keeping this challenge in mind, the main purpose of this paper is to develop a set of indicators and reference points that are relevant and practical, and could easily be used under a suitable sustainable development framework for the measurement of sustainability in a commercial fisheries sector in Oman. In addition, a special attention has been given in developing indicators to ensure that they are consistent with the objectives of the sectoral development plans. To provide further specificity to the subject matter, the demersal trawl fishery has been selected as a case study. The choice of the trawl sector as a relevant case study of sustainable development is mainly influenced by its strategic importance in the country's economic development and environmental policy agenda.

[1] Critical reviews on the concept can be found in Tisdell (1994), Lele (2002) and Pisani (2006) to name just a few.

[2] Definition provided by FAO (1995) is of particular interest to the case in hand as it encompasses the core dimensions (i.e. social, economic, environmental and institutional) of sustainability. It is important to note that to meet the goal of sustainable development, a fulfilment of economic, social, environmental and institutional sustainability in a simultaneous fashion is fundamental (Barbier, 1987; Charles, 2001).

1.1 Brief history of trawl fishery in Oman

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 two types according to their method of fishing and the species fished: Demersal Trawlers and Longliners. Trawlers are licensed to operate along the continental shelf between latitude 21^{o} 40' N, south of Masirah Island and longitude 55^{o} 45' E, North of Halaniyat Island, and at a distance of 10 nautical miles from the shore or at more than 50 meters depth.

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. 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).

1.2 Concept and approach to the development of indicators

To assess the progress of sustainability, a system of references, often called Sustainable Development Reference System (SDRS)[3] is required that develop a set of indicators and reference points covering different dimensions of sustainable development. As stated by Garcia and Staples (2000), 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, 1999).

Although there are various definitions of the concept of indicators existing in literature (Garcia, 1996; Staples, 1996; FAO, 1999; Garcia *et al.*, 2000; UNDESA, 2001), the commonality lies in its legitimate role in performance monitoring (INDECO, 2004). As stated by Dahl (1995), "*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. It should be mentioned that 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. There could be more than one reference point for each indicator and more than one indicator for each criterion.

Usually, any set of indicators are developed based on a set of criteria (Charles, 2001) to provide a bridge between objectives and actions (FAO, 1999). 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. Potts (2003) has listed the following key functions for indicators: a) linking goals and objectives to management actions; b) reporting and performance assessment; c) building consensus, participation and understanding amongst stakeholders; and d) forming linkages and integrating scientific and policy disciplines.

As stated by Garcia and Staples (2000), for indicators and reference points to be acceptable and effective, they should meet a number of technical specifications. According to FAO, criteria and standards required to be considered
in developing a set of potential indicators can be described as follows: a) policy priorities; b) practicality/feasibility; c) data availability; d) cost-effectiveness; e) understandability; f) accuracy and precision; g) robustness to uncertainty; h) scientific validity; i) acceptability to users/stakeholders (consensus among parties); j) ability to communicate information; k) timeliness; l) formal (legal) foundation; and m) adequate documentation.

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, 1999; Garcia *et al.*, 2000). This paper follows a modified version of the ESD framework developed by Chesson and Clayton (1998) to analyze the present case study (See Figure 1). To facilitate the process of modifying the framework and specifying the objectives, discussions and consultation review with key stakeholder and field workers were conducted.

[3] In the context of capture fisheries, the concept of Sustainable Development Reference System (SDRS), defined by FAO (1999) 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*".

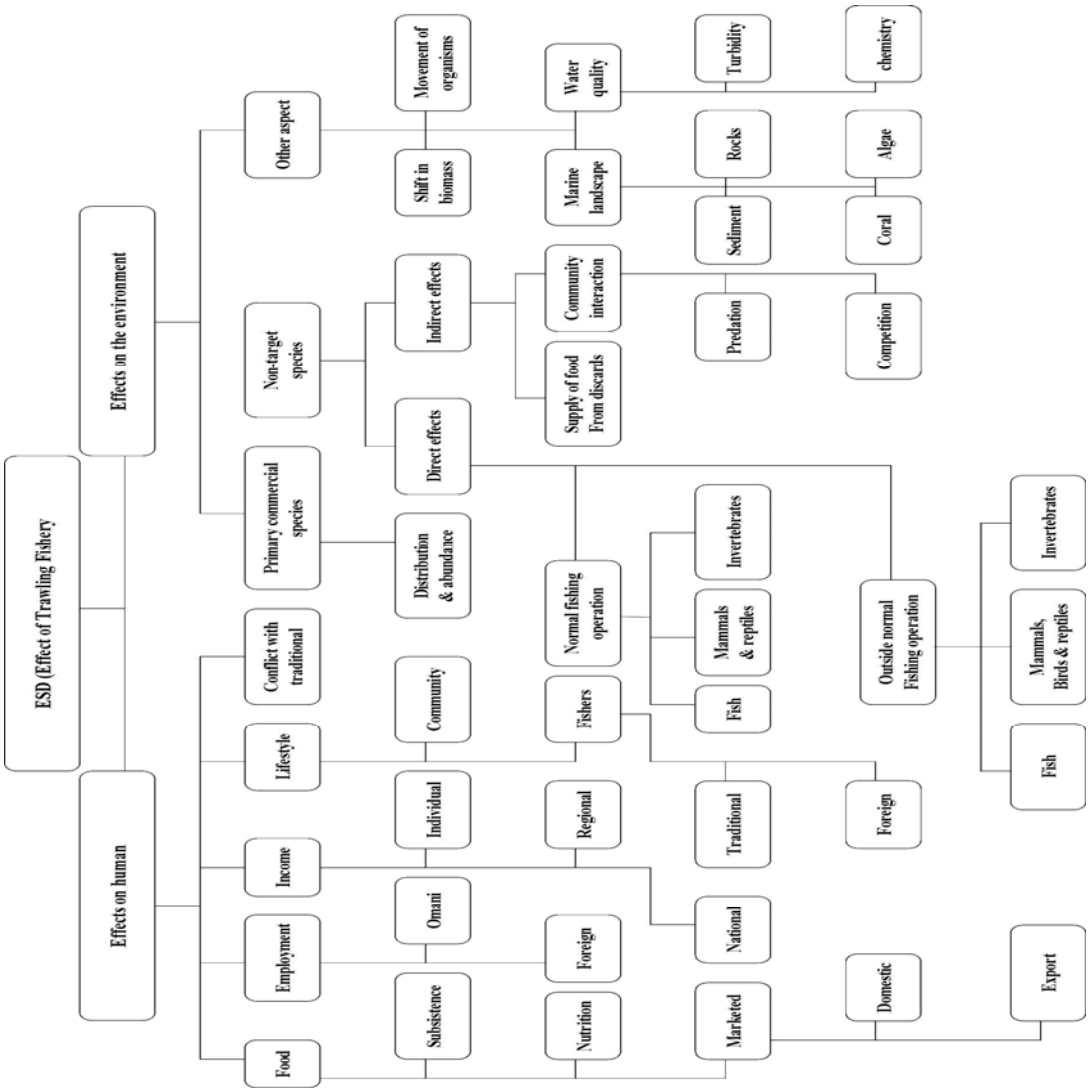

Figure 1: Modified ESD framework for Oman Industrial trawling sector.

2. Methodology

2.1 Field observation

The field observation was carried out in the third week of September 2005 onboard a fishing vessel. The initial aim was to observe more than one 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. The field task was mainly aimed at gathering and clarifying new information about the Omani commercial trawling sector to facilitate the process of identifying the relevant components of the modified ESD framework. The main areas of focus during the field trip were related to: a) regulation, enforcement and compliance, b) quality control and occupational health and safety, c) resource use conflicts, d) impacts of fishing, and e) marine pollution and environmental damage.

2.2 Stakeholder consultation

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.*, 2002). This consultation review, with a response rate of 70%, was carried out in January 2006.

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.

The modified ESD framework was shown to a panel of 30 experts (13 academics, 10 managers and 7 industry representatives) made up from amongst those concerned stakeholders. 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 after explaining its aim and considering any ambiguous issues around it. The review was then collected after few days and any outstanding issues were discussed with the respondents.

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 (1999) and Fletcher *et al.* (2004).

Figure 1 presents the modified ESD framework incorporating key issues discussed above.

3. Results and discussion

3.1 Regulations, enforcement and compliance

The trawlers and their crews who are 100% non-Omani, use the fishing rights of the Omani national companies according to contracts between them. Those trawlers get a fishing vessel license for each voyage. 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.

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 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 with 32 (27.6%) of them for breaching the fishing zone specification of less than 50 meter depth or within the 10 Nm zone.

3.2 Quality control and occupational health and 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 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.

It is also observed that the facilities available for fish processing are of low quality and not consistent with MD 121/98. Other significant issues observed include the poor living standard on board the fishing vessels. 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.

3.3 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"*. Some secondary data in the form of court cases and breaches brought to court indicate a clear resource access conflict between the traditional and the commercial trawling sector as they are both competing for same resources.

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. To highlight this conflict, an additional component has been added under the effect on human component.

3.4 Contribution to health and nutrition

Most of the trawlers' catch is exported, leading to a reduction in the variety of fish landed. 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. Exportation of the catch also influences local nutrition and the declining scenario of per capita fish consumption. 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. The marketed component on food of the human component is further subdivided into: Domestic and Export.

3.5 Impacts of fishing

3.5.1 Discards

Most of the breaches of fishing regulations were in the areas of by-catch and the discarding of catches that had market value. 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.

Captains and high rank crew of the vessels have a strong incentive to discard any catch of low economic value not on the list. This action is clearly evident to the observers with the crew undertaking this illegal activity. 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.

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. 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.

The absence of By-catch Reduction Devices (BRD) in the fishing gear and other causes mentioned above are the main causes, amongst others, 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.

Based on the above 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).

3.5.2 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 hence 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^{o} 40' N, south of Masirah Island and longitude 55^{o} 45' E, North of Halaniyat Island. 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). As an effect of trawling 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.

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. 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 to distinguish each factor responsible for each component and facilitate objective identification.

Since this ESD 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. 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.

Table 1 summarizes all issues identified, from field observations and discussion with experts, and shows their link to the ESD component (See Figure 1).
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. Table 2 summarizes all identified criteria under the ESD framework and their objectives.

Table 1: List of identified issues and their relation to ESD components

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

3.7. Indicators of the ESD components

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. 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 and following the SDRS guideline.

All identified components of the Omani commercial trawling sector ESD and their indicators, required data, preferred trend and reference point are summarized in Tables 3 and 4.

4. Concluding remarks

It should be emphasized that developing indicators is a challenging task and they should be designed to communicate effectively and help decision-makers in making sound decisions. Keeping this simplistic view in mind and based on consultations with relevant stakeholders, suitable indicators were developed in accordance with the modified ESD framework. These indicators could easily be used as inputs into the assessment of the progress of each component with respect to its intended objectives and thereby the assessment of the progress of the overall trawl sector towards the sustainable path. We do not wish to suggest that these are the only suit of indicators and reference points that could be used for measurement. However, this paper provides some insights into the challenge and offers a starting point to develop stronger and robust criteria and indicators over time.

Table 2: 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[4]
2. Employment	To provide more productive employment and careers for Omanis
b. Omanis	To increase the number of workers
c. Foreign[5]	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	To be kept as natural as possible and minimize any negative impacts
d. Movement of organisms	
e. Marine landscape	
f. Water quality	

[4] 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.
[5] Foreign segment is not targeted by MAF objectives and policies.

Table 3: 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[6]
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 4: 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[7]
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	-

[6] 1 represent a share of all landed fish species (the highest of 0-1 scale) calculated using the most common tool called Shannon diversity index (Shannon and Weaver, 1949).
[7] The preferred trend here is a positive proportion of accepted catch status over the unaccepted based on MSY.

References

Charles, A.T.: 2001, Sustainable Fishery Systems, Blackwell Science Ltd, Oxford.

Chesson, J. and Clayton, H.: 1998, A framework for assessing fisheries with respect to ecologically sustainable development, Bureau of Rural Sciences, Canberra.

Dahl, A.L.: 1995, Towards Indicators of Sustainability. SCOPE Scientific Workshop on Indicators of Sustainable development. Wppertal, Wuppertal, 15-17 November 1995.

Drummond, I. and Marsden, T.K.: 1995, Regulating sustainable development. *Global Environmental Change*, 5(1): 51-63.

FAO 1999, Indicators for sustainable development of marine capture fisheries. FAO Technical Guidelines for Responsible Fisheries, Rome, *FAO***:** 68.

Fletcher, W. and Sainsbury, K. *et al.*: 2004, Information Package: Ecological Risk Assessment Version 4. National ESD Framework Project.

Fletcher, W.J. and Chesson, J. *et al.*: 2002, National ESD Reporting Framework for Australian Fisheries: The 'How To' Guide for Wild Capture Fisheries, FRDC Project 2000/145, Canberra, Australia**:** 120.

FSBI 2004, Effects of fishing on biodiversity in the north sea. Breifing Paper 3, Fisheries Society of the British Isles, Granta Information Services, 82A High Street, Sawston, Cambridge CB2 4HJ, UK.

Garcia, S.: 1996, Indicators for Sustainable Development of Fisheries. 2nd World Fisheries Congress. Workshop on Fisheries Sustainability Indicators, from *http://www.fao.org/docrep/W4745E/w4745e0f.htm#indicators%20for%20sustainable%20development%20of%20fisheries*.

Garcia, S.: 2000, The FAO definition of sustainable development and the Code of Conduct for Responsible Fisheries: an analysis of the related principles, criteria and indicators. *Marine and Freshwater Research*, 51(5): 535-41.

Garcia, S. and Cochrane, K.L.: 2005, Ecosystem approach to fisheries: a review of implementation guidelines. *ICES Journal of Marine Science*, 62: 311-318.

Garcia, S. and Staples, D.J.: 2000, Sustainability reference systems and indicators for responsible marine capture fisheries: a review of concepts and elements for a set of guidelines. *Marine Freshwater Research*, 51: 385-426.

Garcia, S. and Staples, D.J. *et al.*: 2000, The FAO guidelines for the development and use of indicators for sustainable development of marine capture fisheries and an Australian example of their application. *Ocean and Coastal Management*, 43(7): 537-556.

Hall, M.A.: 1995, Stratigic Issue in Managing Fishery Bycatches. Solving Bycatch workshop: Consideration for Today and Tomorrow, Seattle, Wash.

INDECO 2004, Indicators: An Overview, Development of Indicators of Environmental Performance of the Common Fisheries Policy**:** 22.

Jennings, S. and Kaiser, M.J.: 1998, The Effects of Fishing on Marine Ecosystems. *Advances in Marine Biology*, 34: 201-352.

Jones, J.B.: 1992, "Environmental impact of trawling on the seabed: a review." *New Zealand Journal of Marine and Freshwater Research*, 26: 59-67.

Lele, S.: 2000, "Sustainable Development: A Critical Review." World Development, 19(6): 607-621.

MAF 2007, Annual Statistics Report for 2006, Ministry of Agriculture and Fisheries, Muscat, Oman

Mitchell, B.: 1997, Resource and environmental management, Longman Harlow, Essex, England.

Morita, T.K.Y. *et al.:* 1993, Sustainable Development: Its Definitions and Goals. *Mita Journal of Economics*, 4(85).

Murcott, S.: 1997, Appendix A: Definitions of Sustainable Development. AAAS Annual Conference. IIASA "Sustainability Indicators Symposium", Seattle WA.

Potts, T.W.: 2003, Sustainability Indicators in Marine Capture Fisheries. Thesis (PhD), University of Tasmania**:** 393.

Shannon, C. E. and Weaver, W.: 1949, The mathematical theory of communication, *The University of Illinois Press*, Urbana

Staples, D.: 1996: Indicators of Sustainable Fisheries Development. Developing and sustaining world fisheries resources: the state of science and management: 2nd World Fisheries Congress proceedings, Brisbane, Qld., Australia, CSIRO Publishing.

Suuronen, P.: 2005, Mortality of fish escaping trawl gears. *FAO Fisheries Technical Paper*. No. 478. Rome, FAO**:** 72p.

UNDESA 2001, Indicators of Sustainable Development: Guidelines and Methodologies, United Nations Economic and Social Development**:** 310.

Varghese, S. and Somvanshi, V.S.: 2001, Marine fish biodiversity and exploited fishery resources in the Northern Arabian Sea. Proceeding of First International Conference on Fisheries, Aquaculture and Environment in the Northern Indian Ocean, Sultan Qaboos University, Muscat, Sultanate of Oman