Journal of Economics and Sustainable Development
ISSN 2222-1700 (Paper) ISSN 2222-2855 (Online)
Vol.2, No.7, 2011

Fisheries Sustainability in Oman

Manaa Saif Alhabsi (Corresponding author)

Faculty of Management and Economics, University of Malaysia Terengganu (UMT)

Terengganu D.I .Malaysia

Tel: 006-0179351463 e-mail: manaasaif@yahoo.com

Nik Hashim Nik Mustapha.

Faculty of Management and Economics, University of Malaysia Terengganu (UMT)

Terengganu D.I .Malaysia

Tel: 006-0192075234 e-mail: nhm06@umt.edu.my

Revised: October 19th, 2011

Accepted: October 29th, 2011

Published: November 4, 2011

The research is financed by the Ministry of Higher Education in The Sultanate of Oman (Sponsoring information)

Abstract

Overfishing is a consequence of changes in the absolute and relative abundance of many important commercial species in Omani waters. To adjust to this change more rigorous management of this fishery is required. This paper examines the Maximum Sustainable Yield (MSY), Economic Sustainable Yield (ESY), Maximum Carrying Capacity (MCC) and the Economic Rent of all six coastal states in Oman. The Maximum Sustainable Yield (MSY) and Economic Sustainable Yield (ESY) catch and effort that were estimated for some states like Albatinah and Dhofar show higher than the actual figures (according to MOFW, 2007 statistics). The MSY and ESY in Albatinah state were (46,608.1 mt, 1883 vessels) and (34,636.6 mt, 1,428 vessels) respectively. While, the actual estimated quantities were (21,853 mt, 4,347 vessels). This point is situated beyond MSY, showing that the catch is declining and the number of vessel increasing. On the other hand, MSY and ESY in Dhofar state were (20,696.9 mt, 1566 vessels) and (11,754.2 mt, 1,176 vessels) respectively. However, the actual estimated quantities were (17,823 mt and 1,939 vessels). Also, this point is situated behind MSY point showing that the catch is declining and the number of vessel increasing. The analyses of data for all coastal states indicate over fishing, especially in Albatinah and Dhofar states. However, the other states shows normal fishing levels like Muscat, Alsharquiah, Musandam and Alwusta.

Keywords: Fisheries Management; Maximum Sustainable Yield; Economic Sustainable Yield; Overfishing

1. Introduction

It has become apparent, particularly in recent time, that sustainability concept has its weakness in fisheries management because the main concern is the static biological output of MSY. The concept of balancing of present and future catches is more important because it deals with the dynamic fisheries management. Sustainable development is an important issue, but one that is open to a variety of interpretations. Since the 1987 Brundtland report World Commission on Environment & Development (1987), researchers in educational institutions, environmental organisations, national governments and international bodies have proposal various studies for measuring sustainable development (WCED 2008). Researches on the fisheries highlighted its importance in food security for the world's food production, which provide a livelihood to about 200 million people and protein supply for a billion people (Luky *et al*. 2005). Also, it can be considered as a major income source for poor people in many coastal regions for different levels of the community members.

Deterioration in environment can affect the economic and social conditions for the well-being of an increasing human population, adding to the various stress elements that contribute to conflict **(**Homer-Dixon 1994; Scheffran 1999). Alternative expression of conflicting relationships between humanity and nature is called natural resource scarcity (Farber 2000). It has been noticed that many fishery resources are declining despite attempts to improve scientific understanding and management practices. This occurred because of unsustainable fishing practices and rapid improvements in fishery technology (Myers & Worm 2003). As a result of the above reasons, sustainability issue becomes vital and has been discussed as the central topic in fishery industries.

Most often sustainability is mentioned beside the management concept, because the management is a tool to achieve good sustainability for fisheries. In Australia, the concept that seeks to integrate short and long-term economic, social and environmental effects and values in all decision making, is called sustainable development (or ecologically sustainable development (ESD) (Fletcher, W. 2005). There are many definitions of sustainability originated from the relationship between human and natural resources system. World Commission on Environment and Development defined the sustainable development as the

“Development that meets the needs of present generation without compromising the ability of future generations to meet their own needs” (WCED 1987p 43 & Luky *et al*, 2004)

In the same context, community view the best method to achieve fishery sustainability is through a complex and systematic analysis on community-based methods. This method is capable of controlling production, making use of proper technology, with long-term elasticity and diversity (Charles 2001, 1994).

Sustainability has been brought to the centre of socio-economic and environmental argument after the well defined concept of sustainable development by World Commission on Environment and Development (WCED 1997). There are many kinds of sustainability, which most of them are formulated from the relationship between human and natural resources system. This covers ecological, economic, social and institutional aspects of the full fishery system. Lucky *et a*, (2005) cited some types of sustainability as follows:Ecological sustainability which focuses on the long standing concern for ensuring that productions are sustainable, by avoid steep declining of resources. Socio-economic sustainability concentrates on the macro level, that is, on maintaining and avoiding long run socio-economic issues. Community sustainability emphasizes the groups cooperative work, that is , focusing on the understanding of sustaining communities as a valuable comprehensive human system in their own right, more than simple collections of individuals (Charles 2001).

.Harvest that can be taken today without being detrimental to the resources available in future has been the strategy of many types of fisheries system worldwide. This concept covers the fisheries that are trying to attain the framework of the sustainability yield. This method is questioned due to biological crisis of fishery management that started during the last decade and after awareness grew about the warning status of fishery resources. For example, Ludwig (1993) called researchers and decision makers to give critical attention to depletion of fish stocks such as those of the Pacific salmon, the Californian sardine, Atlanto-Scandian and the Peruvian anchovy. In 1994, FAO reports showed, in an interpretation, of global fish production, that there had been declining in the annual growth in landings since 1980. In 1990 the reduction in the global annual catch had been 3% in comparison with the previous year (FAO 1994**).** Christy F. (1997) estimated that the gross revenues and incomes from the total global marine landing in 1989 was US$ 70 billion, showing a deficit balance since the global operating costs for the year were estimated at a level of US$ 92 billion. With an annual capital cost of US$ 32 billion per year, the total deficit in global fisheries was estimated to be US$ 54 billion per year (Cochrane KL. 2000).

In Japan a deficit gross cash flow was also reported for the operation of purse seine fisheries. In this type of fisheries, the quantities of catch were found to be less than its MSY, OSY as well as MEY level (Zulbainarni N. 2003). He added, collapses in cash flow happened, due to its high operating cost and low price of fish caught by the purse seine fishermen. In addition to the above cases, there are many causes contributed to these collapses despite unclear objective of conservative exploitation, use new of efficient technology with adverse environmental conditions and insufficient for identify threats to the fisheries sustainability.

Conflict can be associated with sustainability if it leads to over fishing in the midst of fish wars, as has occurred in the Canadian-US dispute over salmon on North America's Pacific coast during 1990s. Also, the so-called 'turbot war', that was in 1995 between Canada and Europe, off the coast of Newfoundland (Charle 2001). The author stated that in a country where full exploitation occurs, there appears to be few spaces available to increase long-term sustainable fishery benefits. As a result, fishery policy in general is limited by: (i) decreasing the efficiency of fishing and of management shortcomings and (ii) making allocation (distributive) decisions, in particular, about who has the right of access to the fish available for capture. It is in these two areas that the conflicts typically happened, with the latter (allocation of harvest shares) generally being at least as critical as optimising the total harvest itself.

There are many classifications of conflict. In order to understand the nature of resource conflict, some authors categorised it into four classes: (i) Fishery jurisdiction: this deals with conflicts over fishery aims, who owns the fishery and who controls access. Also, it covers the issues of, what should be the best method of fishery management and the role played by government. (ii) Management mechanism: this part concerns the cases of developments and implementation of management plan. Typically this conflict involves fishermen/ government over fishing activity, consultative process and fishery enforcement and inspection. (iii) Internal allocation usually occurred between the fishermen and processor. In addition to the above cases, there are some conflicts due different perceptions. They deal with the appropriate allocations of fishery access and using rights between various user groups and gears type. Also, they concern about problems among fishermen, processor and other parties. (iv) External allocation: this class deals with conflicts that occur between internal fishery parties and outsiders like commercial foreign fleets, aquaculturists and tourism (Charle 2001).

In order to achieve ecologically sustainable, effort should be focused to measuring and controlling fish populations (Whitmarsh *et al.* 2000; Davis & Gartside 2001). Hannesson R. (2008) stated that the exploitation of resources can be retained under the condition of the stocks sustainability. Extra considerations in fishery policy analysis are being paid to misperceptions and sensitivities around fishery management (Moxnes 2004, 2005). Increase cooperation of regulated fishing and compulsory among fishermen have been recognised as potential ways to overcome on the unsustainable results of competitive fishing practices (Roughgarden & Smith 1996; Pomeroy & Berkes 1997; Eisenack *et al.* 2006). In order to increase participation and strengthen compliance with regulatory constraints, suggestion for marine resources co-management implementation has been raised (Pinkerton 1989; Kearney 2002; Mahon *et al.* 2003; Jentoft 2005).

One of the hottest issues of many researches is to implement sustainability criteria for a complex fishery–human interaction involving multiple fishermen and conflicting objectives (Scheffran 2000). This interaction is sustainable if it does not deplete the natural resource stock and the fishermen capital stock. From the beginning, steady-state cases have been suggested as one set of sustainability standards, balancing several system variables in a dynamic environment (Daly 1973 & Daily 1997).

The paper is organized as follows. In Section 2, an overview on the fisheries sector in the Sultanate of Oman, followed by a concise description of the methodological issues used in this study in section 3. Then, the analysis proceeds with the presentation of empirical results and discussions regarding the analysis in section 4, and finally, conclusion and recommendations are covered in section 5.

2. Review of Fisheries Sector in the Sultanate of Oman

The Sultanate of Oman occupies the south-eastern tip of the Arabian Peninsula. Oman is bounded by sea on two sides, the Gulf of Oman to the northeast and the Indian Ocean to the southeast. The Sultanate's landward borders are with the Kingdom of Saudi Arabia to the west and the Republic of Yemen to the south, while the United Arab Emirates borders Oman to the north. Oman has 3.165 Km (including bays and islands) of coast line extending from the Musandam at the entrance to the Gulf in the north to the border with the Yemen Republic in the south (National Authority for Survey 1999). It has an area of 309,500 sq. Km (Gulf cooperation council, 2004) and total population of 2,733,391 (Ministry of National Economy 2004). Oman has shores on two gulfs (Oman Gulf and Arabian Gulf) and one sea (Oman Sea). There are six coastal states. Some of them on the Arabian Gulf (Musandam), some on the Gulf of Oman (Albatinah, Muscat and Alsharquiah) and the rest on the Arabian Sea

(Alwusta and Dhofar) Figure1.The fisheries and agriculture sectors have always been important to Oman, providing a valuable source of employment and food security. Indeed, before the detection, and subsequent exploitation of oil in the late 1960s, the two sectors dominated the Omani economy and supported around 80% of the population. Even today, approximately 50% of the populations rely upon fisheries and agriculture as a source of income and together, the two sectors retain major prominence in terms of the renewable resource economy (Aloufi H. *et al*. 2000). A 200-mile exclusive economic zone extends to seaward from the shores of Oman and has a huge variety of fish, some of which are not yet exploited. Currently the fisheries sector represents close to 1% of the total GDP (Ministry of National Economy, 2008). The fisheries sector consists of 2 types: traditional or artisinal fishery and Commercial or industrial fishing.

2.1 Artisinal Fishery

This type of fishery is represented by traditional fishermen (37,520 licensed and non licensed fishermen) (MOFW 2008). They are using limited gears and fiberglass boats (vessels) which is represent 93% (13,806 boats) of artisinal vessels with total overall length between 5 and 9 meters. Also, they use wooden ships (Daws) which are 460 ships and they are mainly used in the east of Oman (Alsharqiah) with length of between 10 – 15 meters. *Ashasha* is another kind, which is made of the palm trees branches and mostly used in north east of Oman (Albatinah), there are only 274 boats of them and are used for light activities. In addition, there is *Hori* which is small wooden boat and counting about 197 units. Table 1 illustrates number of fishermen, types and number of vessels by state for all states in Oman (MOFW 2008).

2.2 Commercial Fishery

This type of fishery is represented by modern fishing ships, using developed techniques and gears for fishing. These ships are hired by fishing Omani companies to fish in pre determined areas and specific quota set by the Ministry of Fisheries Wealth. In each of these ships, there is a government watcher to insure that the ship is fishing according of fishing regulations of Oman and in the areas that authorized to fish. In addition, they make sure that these ships are fishing the right species based on the license that have been given. Also, there is satellites surveillance system using (VMS) for surveillance for double check on the fishing trips of the ship. Commercial fishing ships can be divided regarding to fishing method and targeted fishes into two categories: demersal drawlers and long liners (Aloufi, 2000). Trawlers ships which are targeting pelagic fishes (cuttlefish, crocker, sea breams, ribbonfish and catfish) and working in areas for about 10 miles from the coasts or in depth of 50 m and more which is closer. The ships of long liners is fishing big demersal fishes (Yellow fin Tuna, Long tail Tuna, Sailfish and Sharks) and work about 20 miles from the coast. There are about 76 commercial ships, which 47 of them are long liners and 29 are trawlers (MOFW 2008).

During 2008, the total production of Oman from fish was 153,000 m tons, which is recording a small increase of 0.1% compared to the year of 2007. This production represents the value of 96 millions RO with an increase of 10% (MOFW 2008). The production of artsnal sector was 133.9 m. tons which represents percentage of about 88 of the total production, while the commercial sector production was 17,990 m. tons which gives 12% of the total production. The aquaculture also produced some quantities but in small portions which is about 121 m tons (MOFW 2008).

Fishing gears and methods in Oman differs across the country. Al-Masroori *et al.* (2009) stated that due to the seasonality of the fishery, most fishers in Oman operate several types of gear viz., bottom set and drift gill nets, traps (wire mesh and plastic types), barrier traps, hand and trawl lines and cast nets (Siddeek *et al.* 1999). By far the most significant gear employed in the fishery is drift gill net, (about 56% of total gears). Fish traps, (about 19% of the total gears) were the most common passive gears (Al-Oufi *et al.* 2000). These gears are used commonly to catch fishes and crustaceans.

Regulations and legislations of fisheries set by the Ministry of Fisheries Wealth through royal decree RD53/1981 and ministerial decision MD3/1983 (MAF ACT 1981) which known as ACT OF 1981. It include laws of licensing, definition of fishing areas and seasons, conservation and development of living wealth and all aspects related to fishery in general. There are some species set in closed areas and season spite of: shrimp (closed area in Awusta region and season during April and Augst) and abalone (closed season only opened for two months October and November. Also, some islands are protected like Aldemanyate Islands in Albatinah region (MOFW 2007).

The Government was concerned of the decline of these communities and the threat it represented to the fisheries sector, and took early action to support the livelihood of the fishermen. The concern was that the fishermen looking for less demanding, higher paid jobs outside the fisheries sector would create overstaffing in the government sector while other resources or sectors would be under utilised. Therefore, the Government introduced certain incentives to encourage fishermen to remain in their villages, to attract those who had left to get reinvolved in the fishery, and to develop the sector. These incentives included establishment of the following agencies:

(i). 1972 – The establishments of The Fisheries Department.

(ii). 1974 – The establishments of the Ministry of Agriculture and Fisheries (MAF).

(iii). 1978 The establishments of the Fishermen's Encouragement Fund (FEF).

(iv). 1986 – The establishments of the Marine Science and Fisheries Center (MSFC).

(v). 1991 – Fund for financing fisheries research which is extended to Fishermen's Encouragement Fund in 1992.

(vi). 1997- The issuance of ministerial decision No. 4/97 (Official Gazette, 1997), introducing fish quality control measures and regulations.

(vii). 1997- The issuance of Royal decree No. 18/97 (Official Gazette 1997), forming The Development Bank (DB) and merging it with the Oman Bank of Agriculture and Fisheries (OBAF).

(viii). 2007- The issuance of Royal decree No. 91/2007 (Official Gazette 2007), forming the Ministry of Fisheries Wealth.

These incentives and services motivated resource users to stay in business and attracted new, other "users" to the industry. This resulted in resource users more than doubling from 1985 to 1999 and the number of boats increased by a third (Bertram 1948 & MAF 2001).

3. Methodology

Archival data of annual fisheries statistical reports from the Ministry of Agriculture and Fisheries (MAF) and the Ministry of Fisheries Wealth (MOFW) were used. These reports were used to get the landings of fish and number of vessels for 23 years during (1985 – 2007) for all six coastal states in Oman. The data were processed using Microsoft office excels to estimate the production function or production models for states of Oman. Also, Shazam econometric package was used to estimate the values of maximum sustainable yield and the related coefficients for fishing efforts and catches for all states. Crutchfield & Pontecorva (1969) and Howe (1979) used Schaefer's model to explain the biological production relationships of the salmon fishery in their research. O'Rourke (1971) adopted the catch–effort function to estimate and analyze the economic potential of the California trawl fishery using annual landings of catch against the number of trawl vessels to derive cost and revenue curves and the related optimality condition. Similarly, Sagura (1973) employed the model to estimate the optimal effort that should be applied to the Peruvian Anchoveta. Tomkins and Butlin (1975) discussed various forms of the modified Schaefer's model in their studies for the open-access commercially exploited Manx Herring fishery, and Angello and Anderson (1977) extended the model to study the production relationships among interrelated fisheries stock of different species (Nik Hashim 2008).

In this study, Schaefer's model was used to explain the economic production relationships of catch and effort for all coastal states in Oman. The model was used to estimate MSY, ESY, MCC and economic rent (π) for all states. First of all, values of V and Q at MSY and then values of Q and V at ESY were calculated. After that, values of V, Q at MCC and the economic rent were estimated using Excel spread sheet.

In estimating fisheries production function the difficulty of obtaining the right estimate of the policy variables, is one of the obstacles that faces the practical application of the theory of marine fisheries, particularly, for economic analysis. For example, researchers in the social sciences, normally depend on the methods of estimating fisheries stock and on the fisheries production functions that has been developed by fisheries biologists. There are practical problems involved in the using of these techniques. One of the problems in question is getting an accurate secondary data for production function estimates. We may be able to get precise approximation of the biological fisheries function that has limited applications to the fisheries economists (Nik Hashim 2008).

With the same argument, another possible issue that may arise in applying the fisheries theory developed in the last sections is the oversimplification of the fisheries dynamics into a simple and manageable analysis. It would not be practical to include all variables that contributed to the dynamism of fisheries production. However, the results obtained from a simplified production function analysis may be more practical in terms of formulating fisheries management policy because a complicated production model may not necessarily yield results that are easy to interpret and useful for fisheries management.

4. Results and discussions

Archival data of annual fisheries statistical report on the amount of production (landings) and number of vessels for all six coastal states in Oman have been the used. The data were processed using Shazam Econometric Package to estimate the values of *V*, V^2, R^2, *DW (Durbin-Watson)* of the normal fisheries production function. Microsoft office excel was used to process the production function or Production models of *Schaefer* to estimate the needed values. Production function represented in equation (1) were used to estimate the values of number of vessels *V*, amount of production *Q*, MSY, ESY, MCC and Economic Rent (**π**) in Omani Rials (RO) (note: Omani Rial= 0.385 $US) (Ministry of National Economy, 2009). Table 2 shows the estimated regression coefficients for fisheries production functions using Schaefer Model in Oman by States for a period of 23 years.

Fisheries production function equation (1) is represented below.

$$Q = \alpha_0 + \alpha_1 V + \alpha_2 V^2; \qquad \text{for } \alpha_2 < 0 \tag{1}$$

where Q is the catch in (mt)
V is the number of vessels representing fishing effort
α_0 is a constant
α_i are parameters of the input variable of fishing efforts for i=1 and 2

$$dQ/dV = 0 \text{ (maximum sustainable yield)} \tag{2}$$

$$dQ/dV = c/p \text{ (economic sustainable yield) for } c = \text{cost per unit effort and } p = \text{price per unit of catch} \tag{3}$$

Table 2 illustrates the estimated regression coefficients for fisheries production functions in Oman using Schaefer Model by States. It shows the values of v, v^2, R^2 and DW. In the state of Musandam, the standard error for v is statistically significant at 0.05 *p l*, while the v^2 term was not significant. The coefficient of determination, R^2 is 0.787, which means that 79% of the variation in the number of vessels can be explained by regression model. While DW of 1.900 which is close to 2 shows that there is no autocorrelation in the estimated equation.
For the state of Albatinah, the standard error for v is statistically not significant, while for v^2 is statistically significant at 0.01 *p l*. R^2 is 0.526, which means that 53% of the variation in the number of vessels can be explained by regression model and DW was 1.906 which is close to 2 shows that there is no autocorrelation in the estimated equation. The estimated regression coefficient of Muscat state shows that the standard error for v is not statistically significant, however for v^2 is statistically significant at 0.05 *p l*. While R^2 was 0.759, which means that 76% of the variation in the number of vessels can be explained by regression model. The DW is 1.778 which is also close to 2 shows that there is no autocorrelation in the estimated equation.
On the other hand, in the state of Alsharqiah the p value for v and v^2 are not significant. The value of R^2 was 0.439, which means that 44% of the variation in the number of vessels can be explained by regression model. While, the DW value was 1.860 and it is close to 2 shows that there is no autocorrelation in the estimated equation. As for the state of Alwusta, the estimated regression coefficients show that p value for v and v^2 are not statistically significant. R^2 value was 0.39 which means that 39% of the variation in the number of vessels can be explained by regression model. However, DW is 1.601 which shows there is no autocorrelation in the estimated equation. Finally, p

value in the state of Dhofar for v and v^2 are statistically significant at 0.001 *p l*. The value of R^2 was 0.44 that means 44% of the variation in the number of vessels can be explained by regression model, While, the DW is 1.845 shows that there is no autocorrelation in the estimated equation.

Table 3 reveals that there were differences between the figures of the states, some states have high number of vessels at (MSY) and (ESY) like Albatinah state. While some of them recorded negative signs which means that MSY is not attainable and fisheries are not fully exploited like in Muscat and Alsharqiah. As for the production at (ESY), Albatinah state recorded the highest value, while Musandam state recorded the lowest quantities. The production function for Muscat and Alsharqiah do not achieve maximum fishing effort (catch/ landing) and the resources are considered under exploitation. Maximum carrying capacity (MCC) recorded the highest in Albatinah state, while Musandam had the lowest value. The economic rent (in RO) was the highest in Albatinah; however the lowest was in Musandam, which means that fishermen of this state were making more profit than fishermen from other states.

Figure 2 reveals the fisheries production function by state in Oman. Generally, from this figure it can be observed that an increase in effort (catch) there will be followed by a corresponding increase in the yield (number of vessels) from the fishery. These variations in the size of them are due to the level of catch per unit effort (CPU). The higher the pressure by the application of fishing effort the greater is the yield, however a turning point will be reached when the stock falls beyond a level where it can not regenerate itself. As expected result, the increased effort of the fishery will cause a lower yield and result in overfishing of the stock. The MSY is the point on the graph that provides the highest return for the effort without effecting the population (Van den Bergh et al., 2006).

The same Figure 2 shows that Albatinah had the biggest curve with the highest MSY as (1833, 34,983). while Dhofar shows the next big curve as (1566, 20,670) MSY level. Then is the state of Alwusta which accounted MSY of (824, 18,071). The figures of Albatinah and Dhofar are close which means that the stocks are close to the same condition. Musandam state had the smallest curve and the lowest MSY as (1429, 4959). These figures disclose that Albatinah had the biggest availability of resources and providing a lot of quantities for longer time than other states. While, the resources availability in Alwusta and Dhofar were medium, comparing with the other states and will provide production for shorter time than Albatinah. However, Musandam had the lowest availability of resources; that will cause more pressure on the resources and will lead to faster depletion and overfishing. This situation requires review of the management polices to ensure the sustainability level.

5. Conclusion

For the establishment of ecological sustainability in fish harvests, the estimated MSY and the corresponding effort level were compared with actual catch and effort figures. Obviously a fishery is not sustainable if total catch exceeds the MSY level. As noted, in general there were variations in the results from one state to another (Table 3). As a comparison between the current state values and the values of MSY, ESY, MCC and economic rent recorded in Albatinah and in Dhofar state, it is clear that the fisheries is under overfishing and economic rent is less than the optimal levels in both states. As a conclusion this finding shows that Albatinah and Dhofar states' fishery is under over fishing.

Over fishing has been observed in many parts of the world's fisheries, Oman is without exception due to this phenomenon. In general, when this happens, fisheries are a prime example of the tragedy of the commons: competitive market structures that exploit fish stocks and result in unsustainable economic supports, which cannot be compensated for by either more efforts or more efficient technology. On the contrary, limits for effort and technology application would avoid the negative side effects of uncontrolled competitive interactions between fishers and the fisheries resource. Given the difficulty of limiting technology, the challenge is to find efficient mechanisms to restrain the adverse impacts on fishery.

By testing a cooperative mechanism that serves the viability of both the ecological and the socio-economic systems, BenDor *et al.* (2009) found in their study vastly different results in terms of sustainability and market stability. Here, our competitive fishing structure requires a mechanism for setting catch targets and distributing actual catch. This mechanism needs to be implemented through institutional procedures, including negotiation frameworks, management authorities, and input from scientific institutions equivalent to a system of individual quotas (Eisenack *et al*. 2006).

This behavior implies that this cooperative allocation method may be equally or more efficient at meeting market needs for fish supply than purely competitive scenarios. The design, implementation, and enforcement of these allocation mechanisms, which diverge from the individually preferred decision rules, requires effective institutional procedures that provide either incentives to join (or penalties in case of violation) an agreed upon or imposed framework. A critical factor is the selection of distribution rules which are justifiable to the fishermen involved and are also verifiable and enforceable. Rules that attract opposition by major fishermen or that cannot be monitored and verified, are less likely to be successful.

Hence, it is clearly that cooperation and sustainability can improve and strengthen all parties of the fishery. In some competitive fisheries environment, ecological and socioeconomic sustainability can suffer, leading to major environmental conflict. On the other hand, a lack of sustainable fishing structures makes it harder to overcome competitive attitudes and selfish interests.

Future work needs to address possible alternatives of fisheries management, e.g. involve the fishermen in the management of the sector through well organized institutions. Overcoming this vicious cycle requires major policy initiatives which help organize a process that balances interests of individual fishermen and supports negotiation of quotas within sustainability limits. Involvement of key stakeholders is as important as incorporating the best available scientific information about the complex interactions and the data that feed into models. Also, developing adaptive co-management frameworks that allow for social learning is essential to overcome the tragedy of the commons in fishery (BenDor *et al*. 2009).

Acknowledgement:

Great appreciation is to the Ministry of Higher education in Oman, for funding this study Also, I share my sincere thanks to Mr. Faisal alhabsi for English revising of this paper.

References:

Al-Masroori, H.S., H. Al-Oufi & P. McShane. (2009), Causes and mitigations on trap ghost fishing in Oman: Scientific approach to local fishers perception. J. *Fish. Aquatic Sci* **4**: 129-135.

Al-Oufi, H., E. McLean & A. Palfreman. (2000), Observations upon the Al-Batinah artisinal fishery, the Sultanate of Oman. *Mar. Policy* **24**: 423-429.

BenDor T., Scheffran J. & Hannon B. (2009), Ecological and economic sustainability in fishery management: A multi-agent model for understanding competition and cooperation *Ecological Economics* **6 8**, 1 0 6 1 – 1 0 7 3.

Charles AT. (2001), *Sustainable fisheries system*. London, UK: Blackwell Sciences.

Cochrane KL. (2000), Reconciling sustainability, economic efficiency and equity in fisheries: the one that got away? *Fish and Fisheries* 3–21.

Charles AT. (1994), Toward sustainability: the fishery experience. *Ecological Economics* **11** :201–11.

Christy F. (1997), Economic waste in fisheries: impediments to change and conditions for improvement. In: Pikitch EK, Huppert DD, Sissenwine MP, editors. Global trends: fisheries management. *Proceedings of the American Fisheries Society Symposium* 14–16 June, 1994.

Constanza R. (1992), Toward an operational definition of ecosystem health. In: Constanza R, Haskell BD, Norton BG, editors. *Ecosystem health: new goals for environmental management*. Washington, DC: Island Press.

C.W. Howe. (1979), Natural Resource Economics, *John Wiley and Sons*, New York, Chapters 4, 5 & 13.

Davis, D. & Gartside, D. (2001), Challenges for economic policy in sustainable management of marine natural resources. *Ecol. econ* **36**, 223–236.

Daily, G. (1997), Nature's Services: Societal Dependence On *Natural Ecosystems*. Island Press, Washington.

D.CDaly, H. (1973), Toward a Steady State Economy. *W.H.Freeman & Co Ltd*, New York, NY.

D.O 'Rourke. (1971), Economic Potential of the California Trawl Fishery, *Am. J.A gric.E con* **55**, 583–592.

Eisenack, K., Scheffran, J. & Kropp, J. (2006), Viability analysis of management frameworks for fisheries. *Environ. model. assess* **11**, (69–79).

Edwards V M & Al-Mukhini H M. (2004), FISHERIES MANAGEMENT IN OMAN: Moving towards co-management approaches in fisheries management in Sur. http://www.marecentre.nl/people.../Edwards-modified-Amsterdam-paper. PDF, [accessed 21 March 2010].

E.L. Sagura. (1973), Optimal Fishing Effort in the Peruvian Anchoveta Fishery Management, Discussion and Research, *NOAA Technical Report*, U.S. Department of Commerce, Washington D.C. 20230.

Fletcher, W. J., Chesson, J., Sainsbury, K. J., Hundloe, T.J. & Fisher, M. (2005), A flexible and practical framework for reporting on ecologically sustainable development for wild capture fisheries. *Fisheries Research* **71**, 175–183.

Farber, S. (2000), Welfare-based ecosystem management: an investigation of trade-offs. *Environ. Sci. Policy* **3**, S491–S498.

FAO. (1994), Review of the state of World marine fishery resources. *FAO Fisheries Technical Paper* 335. 136pp.

Fishing low of Oman, 1981.

Homer-Dixon, T. (1994), Environmental scarcities and violent conflict: evidence from cases. *Int. Secur* **19** (1), 5–40.

Hannesson R. (2008), Sustainability of Fisheries. *The Electronic Journal of Sustainable Development* 1(2).

Jentoft, S. (2005), Fisheries co-management as empowerment. *Mar. Policy* **29**, 1–7.

J.M. Tomkins and J.A. Butlin. (1975), A Theoretical and Empirical Approach to Fisheries Economics, Am. J. Agric. Econ. **26**, 105–125.

J.A. Crutchfield & G. Pontecorva. (1969), The Pacific Salmon Fishery: *A Study of Irrigation Conservation*, John Hopkins Press, Baltimore, MD.

Ludwig DE, Hilborn R & Walters C. (1993), Uncertainty, resources exploitation, and conservation: lessons from history. *Science* **260**:17, 36.

Luky A, Yoshiaki M. & Yoshiaki S. (2005), Assessing local sustainability of fisheries system: a multi-criteria participatory approach with the case of Yoron Island, Kagoshima prefecture, Japan. *Marine Policy* **29**: 9–23.

Ministry of fisheries wealth. (2007), Muscat, Sultanate of Oman.

Moxnes, E. (2005), Policy sensitivity analysis: simple versus complex fishery models. *Syst. Dyn*. **21** (2), 123–145.

Moxnes, E. (2004), Misperceptions of basic dynamics: the case of renewable resource management. *Syst. Dyn*. **20** (2), 139–162.

Ministry of National Economy. (2008), Muscat, Oman. http://www.omancensus.net, [accessed 10/5/2004].

Myers, R.A. & Worm, B. (2003), Rapid worldwide depletion of predatory fish communities. *Nature* **423**, 280–283.

Mahon, R., Almerigi, S., McConney, P., Parker, C. & Brewster, L. (2003), Participatory methodology used for sea urchin.

N.M. NIK HASHIM. (2008), STEADY STATE AND INTERTEMPORAL MANAGEMENT MODELS FOR MARINE FISHERIES. *NATURAL RESOURCE MODELING* **21**, (1).

National Authority for Survey. (1999), A survey on Sultanate of Oman area, coasts, and islands. Unpublished report in Arabic. Royal Navy, Muscat, Sultanate of Oman.

Pomeroy, R.S. & Berkes, F. (1997), Two to tango: the role of government in fisheries co-management. *Mar. Policy* **21** (5), 465–480.

Pinkerton, E. (Ed.). (1989), *Co-operative Management of Local Fisheries: New Directions for Improved Management and Community Development*. University of British Columbia Press, Vancouver.

Roughgarden, J.& Smith, F. (1996), Why Fisheries Collapse and What to Do About it. *Proc. Natl. Acad. Educ. Sci.* **93**(10), pp. 5078–5083.

R.J. Angello & L.G. Anderson. (1977), Production Relationship Among InterrelatedvFisheries, in (L.G. Anderson, ed.), *Economic Impacts of Extended Fisheries Jurisdiction*, Ann Arbor Science, Ann Arbor, MI, pp.331–348.

Scheffran, J. (2000), The dynamic interaction between economy and ecology: cooperation, stability and sustainability for a dynamic-game model of resource conflicts. *Math. comput. simul* **53**, 371–380.

Scheffran, J. (1999), Environmental conflicts and sustainable development: a conflict model and its application in climate and energy policy. In: Carius, A., Lietzmann, K.M. (Eds.), *Environmental Change and Security*, pp. 195–218.

Siddeek, M.S.M., M.M. Fouda & G.V.H. Jr. (1999), Demersal fisheries of the Arabian Sea, the Gulf of Oman and the Arabian Gulf. *Estuarine Coastal Shelf Sci* **49**: 87-97.

WCED. (2008), MEASURING SUSTAINABLE DEVELOPMENT. *Report of the Joint UNECE/OECD/Eurostat Working Group on Statistics for Sustainable Development*. UNITED NATIONS New York and Geneva,

Whitmarsh, D., James, C., Pickering, H. & Neiland, A. (2000), The profitability of marine commercial fisheries: a review of economic information needs with particular reference to the UK. *Mar. Policy* **24** (3), 257–263.

WCED. (1987), *Our Common Future. World Conference on Environment and Development*. Oxford: Oxford University Press. 400pp.

Zulbainarni N, Matsuda Y. & Adrianto L. (2003), *Poverty in large catch: an evaluation of purse seine fisheries in Kagoshima Prefecture*, Japan. Working Paper, Department of Marine Social Sciences, Faculty of Fisheries, Kagoshima University.

Table 1: The Number of Fishermen, Types and Number of Vessels by State in Oman.

State	Number of fishermen	*Shasha*	*Alminum*	*Lanch* (Dows)	*Hori*	Fiberglass
Musandam	3780	0	4	65	1	1204
Albatinah	12036	272	18	37	55	3965
Muscat	4591	0	3	4	15	1602
Alsharqiah	7153	0	20	222	122	2649
Alwusta	4240	0	1	58	4	1602
Dhofar	5720	2	11	72	0	1854
Total	**37,520**	**274**	**57**	**458**	**197**	**12876**

Table 2: The Estimated Regression Coefficients for Fisheries Production Functions in Oman using Schaefer Model by State

State	Constant	v	v^2	R^2	DW
Musandam	-3950.1	12.4650 (2.065)**	-0.0043 $(-1.589)^{NS}$	0.787	1.900
Albatinah	29159	6.1770 $(1.876)^{NS}$	-0.006 (-2.638)***	0.526	1.906
Muscat	35827	-40.4400 $(-1.562)^{NS}$	0.0196 (2.073)**	0.759	1.778
Alsharqiah	10133	7.1850 $(0.4136)^{NS}$	0.0002 $(0.0588)^{NS}$	0.439	1.860
Alwusta	12913	12.5220 $(0.3564)^{NS}$	- 0.0076 $(-0.4378)^{NS}$	0.392	1.601
Dhofar	-31542	66.7140 (3.261)*	-0.0213 (-2.915)*	0.447	1.845

Numbers in brackets are t- values of regression coefficients

* significant at 0.01 p.l

** significant at 0.05 p.l

*** significant at 0.1 p.l

^{NS} not significant

Table 3: The Estimated Maximum Sustainable Yield (MSY), Economic Sustainable Yield (ESY) for Catch (mt) and Effort (no. of vessels), Maximum Carrying Capacity (MCC) and Economic Rent

State	V_{msy}	Q_{Msy}	V_{Esy}	Q_{Esy}	V_{mcc}	Econ Rent π (RO)
Musandam	1,429	4,959.0872	1,161	4,646.4590	2,500	2,435,478.82
Albatinah	1,883	46,608.062 2	1,428	34,636.595 2	6,507	63,320,788.44
Muscat	na	na	na	na	na	not optimum
Alsharqiah	na	na	na	na	na	not optimum
Alwusta	824	18,070.915 0	319	16,134.255 3	1647	24,220,539.28
Dhofar	1,566	20,696.941 2	1,176	11,754.222 6	3,132	25,383,827.65

Note: * Estimated production functions for Muscat, Alsharqiah do not have maximum fishing effort (catch/ landings). Fisheries resources for these states are considered under exploitation.

na: Not available because MSY, ESY, MCC do not exist.

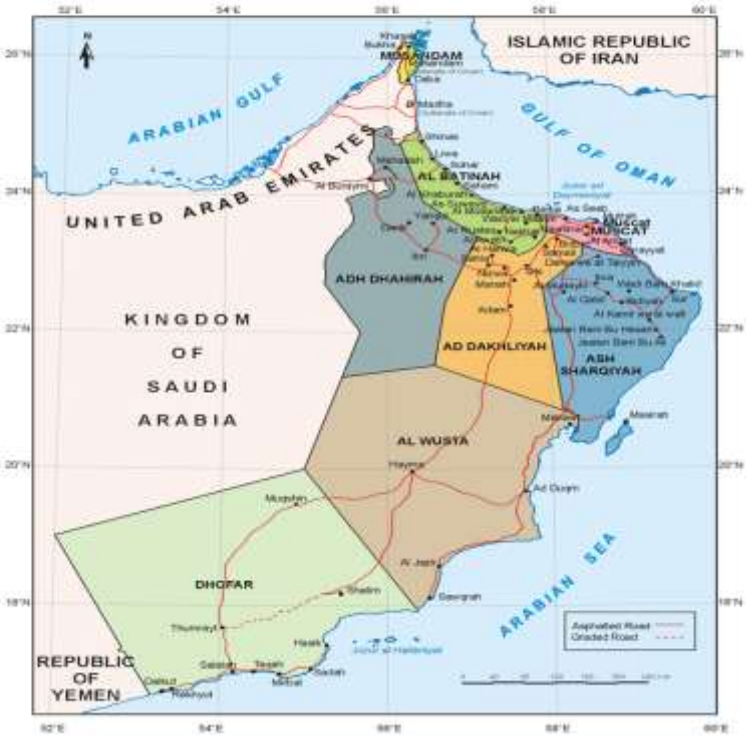

Figure 1. Map of the Sultanate of Oman.
Source:www.nsaom.org.om/english/omanadmin.htm

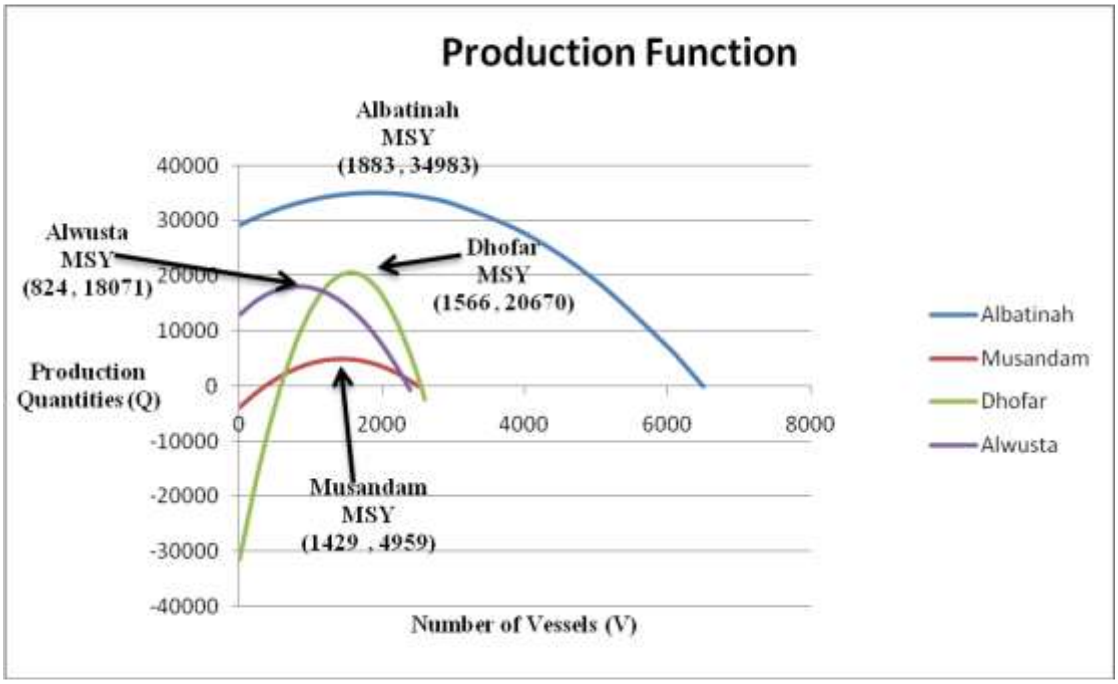

Figure 2: Fisheries Production Function by State in Oman