Strategies for Monitoring and Management of Marine Fisheries Resources of the Sultanate of Oman

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Abstract In a fisheries development plan, the prime objective set would be no depletion of commercially exploitable stocks through strategies of rational management of the resources. The Omani waters are highly productive with more than 1000 species of marine fish and invertebrates that constitute the major natural resources and are closely inter-linked with the socio-economic status of the country. The Omani government plans to develop a sustainable marine fisheries sector in term of food security, income, value addition, export, and employment. A number of management and monitoring problems that exist in the Oman fisheries sector are addressed and suitable strategies are suggested to effectively solve the problems through direct and technical measures. The main target beneficiaries of this strategic plan are the population of Sultanate of Oman in general and fishermen and others connected with the fishing industry in particular.

Keywords Oman marine fisheries sector · Management and monitoring issues · Strategies for sustainable development

List of Abbreviations

Bv	Virgin stock biomass
CPUE	Catch per unit effort
DGFRD	Director General of Fisheries Research and Development
DMSF	Department of Marine Science and Fisheries of Sultan Qaboos University
EEZ	Exclusive economic zone

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EL	Ecology Laboratory of MSFC
FAO	United Nations' Food and Agriculture Organisation
GDP	Gross domestic product
GoSO	Government of Sultanate of Oman
IUU	Illegal, unreported and unregulated fishing
MoAFW	Ministry of Agriculture and Fisheries Wealth
MBL	Marine Biology Laboratory at MSFC
MSFC	Marine Science and Fisheries Centre
MSY	Maximum sustainable yield
NIWA	National Institute of Water and Atmospheric Research
OMLRDC	Oman Marine Living Resources Data Centre
PY	Potential yield
SQU	Sultan Qaboos University
UNDP	United Nations Development Programme
VMS	Vessel monitoring system

1 Context

1.1 Description of the Fisheries Resources Sector

The Sultanate of Oman has a lengthy coastline of 3165 km starting from the Strait of Hormuz in the north to the border with Yemen in the south. It has about 0.3 million km^2 of exclusive economic zone (EEZ) for economic development and management of the resources therein. The Omani waters are highly productive and rich in biodiversity with more than 1000 species of fish and marine invertebrates. Marine fisheries constitute the major natural resources of Oman and are thus closely interlinked with the economy of the country.

The Oman fisheries sector can be grouped as (1) artisanal, (2) coastal and (3) industrial. The artisanal sector accounts for about 84% of landings, supporting about 47,899 Omani and 4699 expatriates with about 22,720 small fishing boats, 688 artisanal fishing vessels and 134 coastal and industrial fishing vessels operating different types of gears like drift gillnets, set gillnets, encircling nets, fish traps, beach seines, handlines and longlines (Government of Sultanate of Oman (GoSO) 2016) along the coast of Oman covering the fisheries regions such as Musandam, Al-Batinah, Muscat, Sharqiyah, Al Wusta and Dhofar (Fig. 1).

The total fish catch trend from Omani waters for the period 2006–2016 is shown in Fig. 2. The fisheries of the Sultanate witnessed a higher growth rate of 12% during 2011–2016 in fish production, value and contribution to gross domestic product (GDP). During 2016, while small and large pelagics contributed to about 43% and 28% respectively, the demersal fish and shellfish together formed about 26% of the total landings, and the rest was by other fishes.
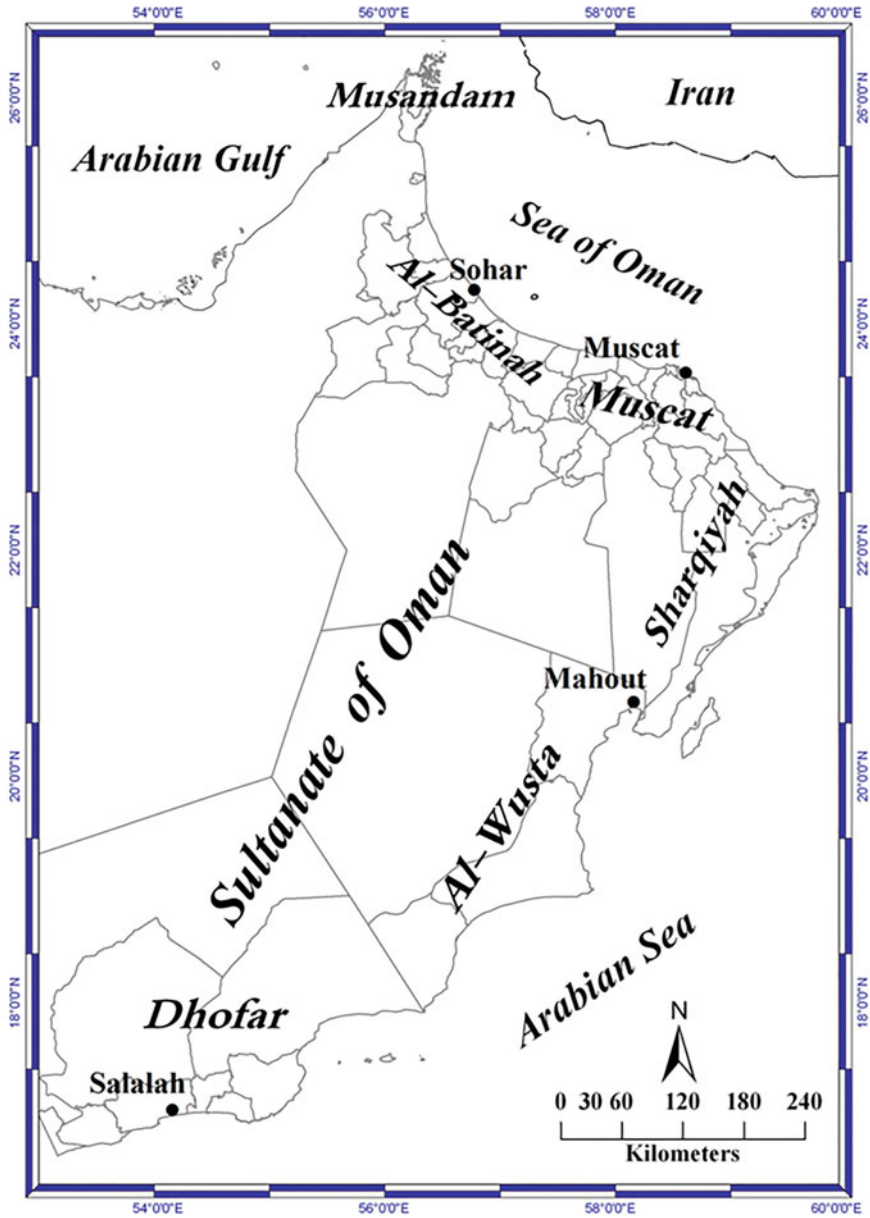
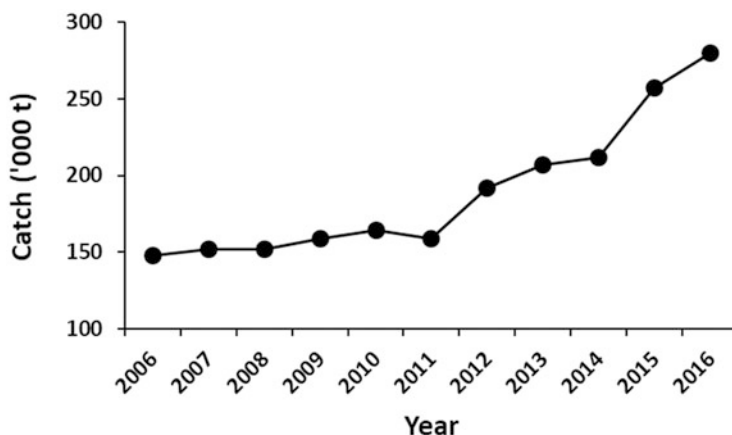**Fig. 1** Map showing the fisheries regions of Oman

Fig. 2 Fish catches in Oman during 2006–2016

Substantial quantities of marine products are being exported from Oman to several countries. During 2004, the export of fish fetched only about OMR 6.24 million which increased to OMR73 million during 2016 by exporting about 152,000 tonnes. Though, the all-fish landings show an increasing trend in the country (GoSO 2016), catches of certain commercial species have drastically declined. The notable examples for reduced catches are the king seerfish, *Scomberomorus commerson* that fluctuated from 28,000 t in 1988 to 7011 t in 2016 and the lobster *Panulirus* spp. from 2000 t in 1988 to 485 t in 2016. However, this decline has been compensated to some extent by the spurt in their value.

1.2 Existing Regulation and Policy

Several fisheries regulations and policies are enforced by the ministry to manage the fisheries resources and obtain sustainable harvest. To protect overfished stocks of lobster, only trap fishing is permitted. However, regulations on catching egg-bearing females and young lobsters measuring less than 80 mm carapace length are enforced. Closed seasons for fishing of lobsters, abalone and shrimp are also in vogue in Oman.

The Ministerial Decision No. 4/94 and subsequent related amendments empower the Directorate General of Fisheries Research and Development (DGFRD) to enforce appropriate laws and regulations related to fisheries sector. The activities included in particular the quota allocation of demersal and large pelagic fishes, monitoring and control of foreign fleet by employing on-board fisheries observers to reduce by-catch discards, restricting the number and type of vessels permitted to operate, restricting the fishing area, regulating the depth of net operation,

requirement for production and location reports and enforcement of legal mesh size of the cod end and the belly part of the net. The operation of the industrial fleet was strictly restricted beyond 10 nautical miles away from the coast at depths more than 50 m in the Arabian Sea. A portion of the harvested fish catch by the industrial fleet was to land in Oman for further sorting and processing, and a percentage of landed value was charged as fish levy by the government. For safe sea food consumption, the Ministerial Decision No. 12/2009 has listed several quality control regulations. In addition, a number of penalties for contravening fisheries laws also exist in Oman.

During 1998, the Ministry of Agriculture and Fisheries Wealth (MoAFW) imposed a closed season between July and November for the industrial demersal fisheries to protect stocks for increased recruitment. This strategy had a positive impact on the traditional fisheries landings; however, a decrease in industrial fleet landings by about 25,000 t was evident. However, to protect marine resources, the government by the Ministerial Decision No. 20/2009 stopped the licences for foreign trawlers since 2011. However, following the ban on trawlers, a well-equipped moderate-sized fleet for coastal fishing activities has been promoted for demersal and large pelagic fish.

To avoid the conflict between the traditional fishing boats and coastal fishing vessels, zoning of operation for both the sectors has been assigned (Ministerial Decision No 368/2013). While the artisanal or traditional fishing vessels in the coastal governorates should limit their fishing activity within 7 nautical miles from the shore, coastal fishing vessels should limit the operation within 12 nautical miles from the shores. However, few exceptions have also been indicated for certain areas. The decision also prohibits the operation of artisanal and coastal fishing vessels within 2 nautical miles in all directions from seamounts and corals reefs. Installation of tracking devices in all the fishing vessels has also become mandatory.

The Sultanate has ratified a number of international treaties and conventions related to management and exploitation of commercial fisheries. The endorsement by Oman to implement the objectives and principles listed in the United Nations' Food and Agriculture Organisation's (FAO) 'Code of Conduct for Responsible Fisheries' on 10–11 March 1999 and of Indian Ocean Tuna Commission signed on 05 April 2000 necessitates Oman to promote best management practices for conservation and sustainability of fisheries resources for the present population and future generations.

Oman is a signatory of the FAO agreement to fight illegal, unreported and unregulated (IUU) fishing. To curtail the IUU fishing activities, certain actions like monitoring access to the ports and using the Air Force, Navy and Coast Guard to control illegal boats are undertaken.

1.3 External Assistance and Local Fisheries Resources Assessment Projects

While there was no direct external assistance to the fisheries sector in the past, there were a few externally funded technical assistance programmes for conducting fisheries surveys in the Omani waters. They are shown below.

1. Regional Fisheries Survey and Development Project (1981). FAO/FI:DP/RAB/71/278/16.
2. UNDP/FAO (1986). The pelagic and demersal fish resources of Oman. *R/V Dr. Fridtjof Nansen* 1983–1984. Dec.1986. UNDP/FAO GLO/82/001.
3. Stromme, T. (1986). Pelagic and demersal fish resources of Oman. Results of the *R/V Dr. Fridtjof Nansen* surveys in Oman 1983–1984. Final Report. Institute of Marine Research, Bergen, Norway.
4. RDA International (1988). Sultanate of Oman fisheries development master plan. Contribution No. 8–88, RDA International, CA, USA.
5. Johannesson, K. A. (1995). Oman Fish Resources Assessment Survey. Assessment of major fish stocks of demersal, small pelagic and mesopelagic species; *R. V. Rastrelliger* acoustic and trawling survey results. November 1989–November 1990. FAO/UNDP project (FI:DP/OMA/88/005 Technical Report 1).
6. Parsons, A.D. and Hooker, P.J. (1995). Fisheries management plan for the industrial demersal trawl fisheries in the Sultanate of Oman. Chemonics International contract No. 272-0106-C-00-1002-00.
7. During 2015, Oman has approached the World Bank for support in revamping its fisheries sector, as the country embarks on a major investment programme to boost its seafood output.
8. Besides the Fish Resources Assessment Survey of the Arabian Sea coast of Oman funded by the government during 2007–2008 employing *RV Al Mustaqila 1* (NIWA 2009a, b, c, d, e), few GCC-funded regional projects on king seerfish and demersal fisheries resources survey in Arabian Gulf and the Sea of Oman were also carried out. The Oman Government has also supported a number of fisheries research projects on lobster, demersal fishes, small pelagics, elasmobranchs and tunas. All the projects aimed at management of resources and planned to build up the fisheries database.

1.4 Socio-economic Context

The Omani Government plans to develop a sustainable marine fisheries sector in terms of food security, income, value addition, export and employment. At present, there are 24 ports on the coasts of Oman. The investment in fisheries sector is aimed to raise fish and fisheries production from 279,610 t in 2016 to 480,000 tonnes by 2020 creating 20,000 new jobs with a return of about OMR 739 million ($1.9 bn).

The average annual per capita consumption of fisheries products was estimated at 28 kg which is above the global average of about 20 kg per person.

The government had subsidized the vessel purchase during the1980s under the fisheries development programme. The use of natural fibre for net making has been replaced by multifilament nylon since the 1960s. As the traditional boats are small, the mean crew size may not exceed two. Most of the fishers possess different types of gears as many of the fisheries in Oman are considered seasonal.

The artisanal fishermen are a vital part of the fisheries sector in the Sultanate. There is an indication that the average age of active fishermen is increasing in the country. This shows that the younger generation is reluctant to take up the employment in fisheries sector. The employment in the direct fishing industry and the associated and auxiliary industries like boat building, net making, ice plants, processing, transporting, etc. is very large. Socio-economic conditions and the extent, nature and availability of natural resources are interdependent. Hence, rational management of natural resource sectors, like fisheries sector, could prevent the outward migration of skilled labour and restore the favourable socio-economic conditions.

1.5 Technical Context

The current situation of monitoring and management of the marine fisheries resources sector of Oman is provided below.

1.5.1 Monitoring of Fisheries Resources

Various aspects of monitoring of the fisheries resources sector are being handled by the Department of Statistics of the MoAFW on a regular basis.

Catch Statistics

There is an impression with many that the landing records are erroneous.

Estimation of Standing Stock and Potential Yield

During the past 25 years, two major fisheries resources surveys have been conducted in Omani waters. The survey conducted by *FRV Rastrelliger* during 1989–1990, 1995 was extensive and covered the EEZ of Oman in the Sea of Oman and Arabian Sea. Through this survey, the potential yield (PY) estimates of fishes were made mostly groupwise and based on virgin stock biomass (Bv). Though it has been mentioned in the survey report that attempts were made to estimate the potential

yield based on the length based stock assessments, no information is available till date.

The survey conducted by the NIWA during August 2007–September 2008 in the Arabian Sea coast of Oman, generated voluminous data on the key species of demersal, small pelagic and mesopelagic fisheries resources. The database included information on the length frequency, length-weight relationships, spawning season and length at first maturity and scaled length frequency data of key species. Based on catch composition and catch rates, the estimates of biomass for key species/groups have been presented in the final reports of the survey. This survey also missed the opportunity of estimating the potential yield of any of the fish species/groups. In the above fisheries surveys, swept area and acoustics techniques were adopted, and aspects related to the feeding biology of the species have been ignored.

The ministry has brought out the estimates of the biomass of benthic fishes as 330,000 tonnes, of which about 95,000 tonnes can be harvested. While the stock of small pelagic fish has been estimated to be more than 1.9 million tonnes, the potential yield would be around 970,000 tonnes. Myctophids form an unfished biomass in Omani waters, and there are vast differences in their estimates of biomass among various surveys that ranges from 0.5 million tonnes to 20 million tonnes (Jayabalan 2011). For planning development and successful management of fisheries resources of Oman, it is inevitable that the potential yields of fishes have to be re-estimated.

From fisheries research projects carried out at the Marine Science and Fisheries Centre (MSFC), the maximum sustainable yield (MSY) and population characteristics for the following commercially important species such as Geelbek croaker *Atractoscion aequidens*, spangled emperor *Lethrinus nebulosus*, soldier bream *Argyrops spinifer*, brown-spotted grouper *Epinephelus gabriellae*, tiger-toothed croaker *Otolithes ruber*, largehead hairtail *Trichiurus lepturus*, mullet *Crenimugil crenelabis*, white-spotted rabbitfish *Siganus canaliculatus*, longnose trevally *Carangoides chrysophrys*, small spotted grunt *Pomadasys commersonnii*, Santer seabream *Cheimerius nufar*, soldier bream *Argyrops filamentosus* and Arabian pandora *Pagellus affinis* are available (MSFC-Demersal fisheries project Phase 1, 1999–2003; Al-Marzouqi et al. 2009a, b).

Projects on lobster *Panulirus homarus* fisheries and stock characteristics were also carried out (Al-Marzouqi et al. 2008a, b). The cuttlefish *Sepia pharaonis* was studied for the biology and stock characteristics from the Arabian Sea coast of Oman (Al-Marzouqi et al. 2009c). The population dynamics of the king seerfish *S. commerson* from Oman has been studied by the Sultan Qaboos University (Al-Oufi, et al. 2004) and in a GCC funded regional project (Jayabalan et al. 2011). The elasmobranch fisheries resources of Oman were also investigated (Henderson et al. 2008). Information on the biology and stock assessment of small pelagics such as Indian oil sardine *Sardinella longiceps*, Indian mackerel *Rastrelliger kanagurta* and Indian scad *Decapterus russelli* is also available from the Omani coasts of the Arabian Sea and Sea of Oman (Zaki et al. 2011a, b). A project on the management of exploited coastal tuna fisheries resources of the Sultanate of Oman was implemented during 2011–2014, and the catch rates of

kawakawa and long tail tuna were estimated (Al-Kiyumi et al. 2013; Al-Siyabi et al. 2014).

Collection of Fisheries Biological Data

For meaningful estimations of the stock and potential yield of the fisheries resources of the country, information on the maturation and spawning, age and growth, length/age at capture, etc. need be gathered. Studies of biology of few selected commercially important fish and shellfish have been/are being carried out by the MSFC and Department of Marine Science and Fisheries (DMSF) of the Sultan Qaboos University (SQU). Such studies are concerned with the size composition of the catches, age and growth, food and feeding and maturation and spawning in respect of the selected species. However, the Omani waters support the commercial fisheries of more than 200 species, for most of the species biological information is lacking.

Pollution Monitoring Studies

Pollution monitoring studies are yet to start. A continuous monitoring of the health of the coastal waters needs to be implemented.

1.5.2 Management of Fisheries Resource

The responsibility of management of marine fisheries resources in the EEZ of Oman rests with the Ministry of Fisheries. The difficulties involved in the management of marine fisheries are related mainly to the number and type of user groups and the distribution and recruitment pattern of the fish stocks. Resource use conflict may arise in the fisheries where the same stock is exploited by different user groups particularly the artisanal and mechanized sectors. The situation will be further complex if the resource is a migratory one.

The status of the more important management issues is given below.

Limitation of Fishing Zones

The details of this aspect have been provided in Sect. 1.2. The limitation of fishing zones for the artisanal and industrial fleet has avoided the clash of interest between the sectors.

Closed Season

The prohibition of fishing by the traditional gears in the lobster, abalone and shrimp fisheries is enforced. However, violations are widely common.

A closed season between July and November 1998 for the industrial demersal fisheries was enforced in the interest of protecting the fish stocks for enhanced recruitment. This strategy had a positive impact on the traditional fisheries landings. However, the industrial trawlers were banned from fishing in the Omani waters since 2011.

Licencing and Registration of Boats

The fishing boats of various types are registered with the MoAFW paying a nominal annual licencing fee. However, it is evident that not all the boats have been registered and licence issued.

Restriction on Mesh Size

Though for industrial trawlers, there was legal mesh size in the cod end as well as the belly of the net, in the absence of specific recommendations based on scientific observation, the ministry has not yet promulgated any minimum mesh size for the artisanal gears.

Catch Quota

Limit on catch (quota) was in force for the discontinued industrial fleet. The artisanal fisheries sector still operates on the open access character.

2 Strategies for Fisheries Management and Development

2.1 Justification

One of the prerequisites for successful maintenance of commercial fisheries at a sustainable level is to ensure the well-being of fish stocks, which in turn would depend on the continuing prevalence of responsible fisheries and environmental conditions in their habitats. The low densities of population, strict regulation of trawling and minimal environmental pollution in Omani waters have indicated that the existing fishing effort might not be the reason for fluctuations in the catches. Hence, rational management and monitoring of the marine fisheries resources have been given prime consideration in any fisheries development plan.

2.2 Target Beneficiary

The main target beneficiaries of this strategic plan are the population of Sultanate of Oman in general and fishermen and others connected with the fishing industry in particular.

2.3 Objectives

2.3.1 Overall Development Objective

The development objective (or long-term goal) of this strategic plan is set as:

• No depletion of exploitable stocks of commercially important finfishes and shellfishes through the rational management of the resources in the Omani waters

2.3.2 Immediate Objective

The immediate objective is:
    Potential of major commercial species maintained or increased through:

• Prevention of overfishing
• Protection of the fisheries environment from degradation

3 Main Issues Identified and Suggested Remedial Measures

A number of management and monitoring problems that exist are required to be addressed and satisfactorily solved by the end of the execution of the strategic plan. The instruments available for regulation of fishing activities by the industrial fleet were satisfactorily enforced. However, most of the management problems are related to the unorganised artisanal fisheries sector. The main problems are as follows.

3.1 Management Issues

1. Open access fisheries for large number of fishing units to exploit the fisheries resources.
2. No mesh size restriction for fleet and minimum legal size of fish species.
3. Not all the boats have been registered and licensed to fish.
4. Closed season for finfish harvest to be suggested and observed effectively.

5. Weak inspection machinery for enforcing regulation.
6. Lack of fisheries oceanographic studies.
7. Aspects of eco-labelling of fisheries products.

3.2 Monitoring Issues

1. Different estimates of MSY, standing stock and PY made by different individuals and groups
2. Disputable catch statistics
3. Lack of comprehensive biological data in respect of several commercially important species of fishes
4. Lack of operational fisheries sector database

3.3 Tackling of Management Problems

3.3.1 Formulation of Regulations

One of the main constraints affecting the effective management of the fisheries resource is the lack of detailed specific regulations to ensure that there shall be no depletion of the fish stocks of any kind and the socio-economic status of the traditional fishermen not adversely affected.

While there will be need to generate the required scientific data for formulating some of the needed regulations, the rest can be formulated straightway on the basis of existing knowledge. However, formulated regulations will succeed while the fishermen themselves would willingly accept them. Regulations to be formulated for the management problems are given below.

3.3.2 Delimitation of Fishing Zones

In order to prevent overfishing in the traditional fishing zone of the 50 m depth range or 10 n. miles from the shore and to avoid future conflict between the users of different types of gears in a fishing ground due to overlapping of the fishing activity, it is highly imperative to work out a rational delimitation of the fishing grounds.

3.3.3 Licencing and Registration

Licencing and registration of all the fishing vessels could be an efficient tool in controlling their number beyond the optimum level. To help in taking quick management decisions, it is essential to make it mandatory for all vessels to register with the MoAFW.

3.3.4 Regulation of Mesh Size of Net/Legal Size of Fish and Number of Fishing Gear

There is no regulation regarding the minimum permissible mesh size of the nets in the artisanal fisheries sector. Detailed studies are needed to be carried out for prescribing the minimum permissible mesh size for various nets, particularly for specific species.

While the mesh size regulation is suggested to avoid the 'growth overfishing' of the commercially important fish species, the minimum legal size suggested would help avoid 'recruitment overfishing'.

The marine fisheries of Oman like in any other tropical multispecies fisheries harvested by multigear, information on fishing effort in the form of number of gear or number of operations is needed. Hence, standardization of fishing effort in terms of widely used gear can be worked out for commercially important species. Calculation of standard effort is needed for suggesting the required effort level to be employed for sustainable harvest.

3.3.5 Closed Season

Peak breeding activity in most of the fish species will take place during a particular season when the environmental conditions are favourable for better survival of the eggs and larvae. It is generally suggested that during the monsoon season, most of the fish and shellfish populations spawn. For most species as the biological information is lacking, studies on this line have to be initiated to find out the seasonality of spawning. The season of peak spawning in fishes has to be totally banned for fishing activity as a management measure.

3.3.6 Inspection

At present, the MoAFW is carrying out inspection on the use of legal gear admissible in fisheries. However, use of destructive fishing gears in shrimp and lobster fisheries is reported.

Fisheries management strategies generally depend on one or more of the direct or technical conservation measures, which, to be effective, must be enforced in toto. However, the most important aspect of enforcement is educating the user groups of the resources, and prosecution should be regarded as the last resort. Hence, the users of the fisheries resources should be made familiar with regulations and the seasons for their imposition.

3.4   Addressing Monitoring Problems

3.4.1   Estimation of Catch Statistics

There is an urgent need to review the data collection process to plug the loopholes and generate reliable data for management purposes.

At present, the marine fish catch statistics are being regularly published by the MoAFW. A suitable stratified multistage sampling design needs to be developed for estimating gear-wise and groupwise catch statistics of marine finfishes and shellfishes, including total landings, total effort and catch per unit effort (CPUE).

Recently, the Omani Government initiated the logbook data collection procedure, the vessel monitoring system (VMS) and port sampling and observer programmes for monitoring and quality data collection for the tuna fisheries.

3.4.2   Assessment of Standing Stock and Potential Yield

As mentioned under Sect. 1.5.1, the MSY, standing stock, PY, etc. have been estimated based on rather limited data, since the area covered by the exploratory surveys may not be comprehensive and adequate.

Estimation of fisheries resource potential is possible through (1) the catch and effort data collected from commercially exploited resources; (2) exploratory surveys like swept area techniques and acoustic survey; and (3) primary productivity estimations. There is, therefore, a case for working out a methodology acceptable to all concerned.

3.4.3   Biological Data

Data acquisition on the breeding biology of the commercially important finfish and shellfishes is one of the most important requisites for management decisions. The information already available on the maturation and spawning of fishes from Omani waters is scanty. No accurate information based on direct year-long observation is available on the duration and area of breeding of important species. Such information is vital for formulating certain management measures relating to closed season, restricted fishing, etc.

Biological studies (food and feeding, age and growth, fecundity and reproduction, length frequency, etc.) on most of the commercially important species need to be initiated.

3.4.4 Database

The MoAFW is yet to have an operational database on information relating to various fisheries' parameters, such as MSY, standing stock, PY, fish landings in space and time, operational fishing capacity, etc.

4 Outputs and Activities

4.1 Outputs

4.1.1 An Improved and Operational Monitoring System

The present status of monitoring system in the fisheries sector of the country and the main issues to be tackled have been indicated in some earlier sections (Sects. 1.5 and 3). As the governmental and academic institutions are involved in estimating the monitoring parameters, it is necessary to evolve an improved and operational monitoring system, wherein the methodologies employed are standardized by common consent and the job of each participating institution clearly defined.

The data that will thus be generated continuously are required to be made use of for establishing an operational fisheries database. These data relating mainly to species composition of landings, seasonal abundance, catch per unit of effort, standing stock, catchable potential, fishing intensity, biological parameters, environmental parameters, etc. constitute the essential tools to understand the status of the fisheries resources whether the stock is rationally exploited or underexploited or overexploited and the fish habitat. All these will help to formulate necessary management protocol thereof.

4.1.2 Management Plan for Fisheries Conservation Prepared and Implementation Initiated

The existing management policies and activities and the main problems thereof have also been described in Sects. 1.1 and 3. While the government extended certain facilities in the interest of healthy growth of the fishing industry, steps taken specifically and directly for fisheries conservation are not comprehensive enough.

Some of the management measures, as indicated in detail under Sect. 4.2. (activities), need be formulated immediately, while certain measures can be formulated and implemented after generating more information through research. Another important aspect is the enactment of regulatory measures to legally enforce the suggested conservation measures. This will ensure the sustainable development of the fisheries resources on a continuing basis.

4.2   Major Activities to be Carried Out

The following major activities are to be carried out to achieve the outputs indicated in Sect. 4.1.

4.2.1   Monitoring System

Undertake baseline studies on breeding grounds, breeding seasons and nursery grounds of commercially important species of finfishes and shellfishes

Detailed information on the breeding biology of commercially important finfishes and shellfishes in time and space and on their nursery grounds is of prime requisite in formulating suitable management measures to ensure their continuous availability on a sustainable basis. Such management options should include protection of spawning population through declaration of closed season or restricting certain types of fishing gears. Also, the protection of breeding and feeding grounds from pollution and physical disturbance need be ensured.

The information currently available on the breeding ground and time of breeding of most of the commercially important fish species is inadequate. Though the exact location and extent of breeding grounds are not known for any of the species, many fish eggs and larvae have been encountered in the inshore waters. It is pertinent to believe that the tropical fishes generally have protracted spawning season, and individuals may spawn more than once during the spawning season.

Due to the paucity of information on the breeding and feeding grounds, it is proposed to carry out in the first phase a comprehensive year-round survey in the waters of Oman up to a depth of 100 m from the shore for generating accurate information on the location and extent of breeding ground and location of nursery grounds for the major finfishes and shellfishes. This work is proposed to be entrusted with the Marine Biology Laboratory of MSFC subject to the availability of seaworthy vessel for this work.

Undertake baseline studies to evaluate sources, magnitude and impact of specific threats to the breeding and nursery grounds of commercially important species of finfishes and shellfishes due to waste water pollution, habitat disturbance, fishing practice, etc.

The early life history stages of fishes like eggs and larvae are highly susceptible to adverse environmental conditions. The breeding population is also sensitive to changes in certain environmental parameters and hence be easily caught by fishing nets. This work will consist of an initial survey to locate and evaluate the sources of threat followed by bioassay studies with fishes and fish food organisms as test animals to evolve pollution abatement measures. This work is proposed to be entrusted with the Ecology Laboratory (EL) of MSFC.

Undertake detailed study on the biology and population parameters of important species

Information on the biological characteristics such as length frequency, length-weight relationship, size and age at first maturity, spawning frequency, fecundity, age and growth, food and feeding and population parameters like recruitment, fishing, natural and total mortality coefficients, etc. are essential for effective management of fisheries of any species. Few species have been studied in the above lines in the Marine Biology Laboratory (MBL) of MSFC. Hence, study of biology and population parameters may be assigned to MBL.

Review existing procedures to assess fish stocks, MSY, etc.; prepare recommendations for improved assessment procedures relating to main species by regions and season including recommendations for overcoming identified constraints for their implementation

The procedures and status of the fish stock estimations have been discussed in Sect. 3.4. The reasons for improved techniques of assessment of the fish stocks have been indicated, and the stock of fishes in different regions and seasons need be assessed. MBL/MSFC is the right institution to carry out this work.

Review the existing procedures for collection of catch statistics; recommend on potential improvements

As detailed in Sect. 3.4, the current procedures of fish catch statistics lead to erroneous estimates.

As the marine fisheries of Oman are supported by multispecies and harvested by multigear almost the year-round, a sound technique for collection of catch and effort data is essential. A 'stratified multistage sampling technique' needs to be developed for estimating gear-wise and groupwise catch statistics of marine finfishes and shellfishes, including total landings, total effort and CPUE.

For this, a frame survey along the coast of Oman covering six fisheries regions such as Musandam, Al-Batinah, Muscat, Sharqiyah, Al Wusta and Dhofar has to be conducted, and based on the information gathered, a sampling design involving both space and time stratifications will be developed. For space stratification, each region will be divided into different zones depending on the intensity and type of fishing. Each zone will consist of certain number of fish landing centres. Each 10-day period in a month will form the time stratum.

From the first 5 days of a month, a day will be randomly selected which along with subsequent 6 days will form the first cluster. Similarly, two more 6-day clusters will be formed from other two groups of 10 days in such a way that there are 10 days gap between the starting days of two consecutive clusters.

From a zone, three landing centres will be selected at random for observation over a 6-day period, and each centre will be observed for continuous 2 days: the first day from 12.00 h to 18.00 h and the second day from 06.00 h to 12.00 noon.

On the day of observation, based on the number of boats engaged in fishing, the sample number of boats (units) to be observed will be fixed depending on the intensity of landings. If the total number of boats landed will be 10 or less, the total landings from all the boats will be taken for catch composition and other particulars, and if the total number of boats exceeds 10, then subsampling will be done suitably. From these sample units, details such as type of craft, gear used and species composition will be noted. Number of fishing units landed during the observation

period (i.e. during 6 h duration) will also be recorded. Fish landings at night between the first and second days of observation will be recorded based on enquiry on the second day morning.

From the catches of sample boats on the observation day (6 h duration) in a landing centre, the catch for all the boats landed will be estimated. By adding the estimated landings for the two 6 h periods and the night landings, if any (another 12 h), the catch for the day (24 h) in the centre will be calculated. By adopting appropriate raising factors, the zonal landings for the month will be estimated. By adding the estimates of different zones for all the months, the annual landings of the regions and the country will be computed.

Note
1. For adoption of this sampling technique, several visits are needed to the landing centres in all the six fisheries regions to fine-tune/suitably modify the technique in a satisfactorily workable condition.
2. Suitable proformas for recording the catch, effort, depth of operation, distance from shore, number of hauls, etc. are to be developed.

Make annual species/groupwise assessment of standing stock and potential yield and of fish landings in time (monthly) and space (depth zone)

The assessment of standing stock and catchable potential in the EEZ shall be made every year. The MoAFW will collect the catch statistics.

Establish and make operational database on fish stock evaluation, fish landings (region-wise) and operational fishing capacity (broken up into categories of vessels, fishing gear and area/zones of operation)

The data on fisheries assessments and the information on fishing capacities shall be used to establish an operational fisheries database to be preferably named as 'Oman Marine Living Resources Data Centre' and abbreviated as OMLRDC.

4.2.2 Management Plan

Formulate necessary regulations, and implement institutional and information framework able to prepare and enforce regulations of the fisheries

The existing status of fisheries regulations and the problems associated with them have been referred to in Sects. 1.2 and 3.3. Due to conflicting interest on fisheries resources, it is highly imperative to formulate, promulgate and strictly implement necessary regulations in order to be able to manage the fisheries towards sustainable development.

While the government has to wait for future research results for formulating some regulations, immediate action could be initiated to register all the fishing vessels and issue licence, mesh size regulation, closed season and establishment of sea patrolling unit for enforcing the regulations in the Oman waters.

Establish fishing zone according to depth

At present the artisanal and industrial vessels are allowed to fish in well-demarcated depth/distance zones. This should continue. As tourism is encouraged

by the Sultanate, demarcation of zones for swimming and water sports would be a future need.

Regulate fishing effort

By making it mandatory to register all fishing boats with the MoAFW and assigning each boat a registration number which to be prominently displayed on the hull.

Dividing the boats into different categories such as:

1. Length of the vessel (or load capacity)
2. Horse power of the engine
3. Fishing gear to be operated

Regulate catches of commercially important species through:

1. Prescribed minimum mesh size
2. Prescribed maximum number of craft/gear
3. Observance of closed season/area

Minimum Mesh Size

Only very few gears are specifically meant for a single species (e.g. lobster trap); others land a variety of species. The mesh size prescribed will retain the particular size of fish irrespective of their age or maturity condition. Hence, the catch of a single net would contain both mature fish of small variety and immature fish of large variety. It is therefore not an easy task to prescribe a specific mesh size. However, the least that can be done in this regard is to suggest minimum mesh size for some principal gears which land large quantities of varieties of fishes.

Maximum Number of Craft/Gear

In the open access fisheries situation, regulating the fishing effort is a difficult task. Hence, it is desirable to educate the fishermen with facts of fish stocks and reasons for regulations. A self-imposed effort regulation may be encouraged.

Observation of Closed Season/Area

This aspect has been discussed already in Sects. 1.2, 1.5.2 and 3.3. Closed season for lobster, abalone and shrimp fisheries is enforced. However, violations are widely common. Biological information to be gathered through the project will help to suggest the closed season/area to protect the spawning stock as well as spawning and nursery grounds.

Ensure observation of regulations and restrictions through regular inspection

To carry out inspection at the landing site, MoAFW personnel are employed. However, an additional sea patrolling unit would strengthen the implementation of fisheries regulatory measures.

Introduce economic instruments (incentives)

This is also a very difficult proposition. However, reduction in the number of fishing operations and shifting from overexploited ground to new less exploited area may be encouraged by providing incentives of a suitable kind. This has to be undertaken by the government.

Prepare and initiate training programmes on such issues as:

1. Enforcement of fishing regulations for the land-based and sea patrolling units
2. Environmental friendly shrimp culture and mariculture for the benefit of fishermen

Training for the fisheries regulation enforcement personnel can be handled by the MoAFW.

Training of fishermen in shrimp culture/mariculture of edible molluscs can be carried out jointly by MSFC and Aquaculture Centre. If necessary services of consultants may be deployed for periodic training programmes.

5 Organisational Set-Up

5.1 Institutional Framework

The MoAFW with its technical wing (MSFC, Aquaculture Centre and Quality Control Centre) is the nodal agency for development of fisheries and aquaculture and implementation of fishermen welfare programmes and formulation of fisheries plans, negotiating for foreign/international/technical assistance and collection and publication of fisheries statistics.

The SQU, an autonomous body under the Government of Oman, carries out fisheries research on an ad hoc basis. It has a major educational and research department in the form of Department of Marine Science and Fisheries, College of Agriculture.

5.2 Implementation

The strategic plan needs to be implemented within the overall organizational framework. The Director General, Fisheries, will have the overall responsibility for coordination and monitoring of the activities. However, a working group constituted by the DGFRD and having representation from MoAFW, MSFC and SQU will be in immediate charge of coordination and monitoring of the fisheries project. Besides, formation of a consultancy team under the team leader would also require for providing consultancy services in specified areas. Their activity will also be coordinated by the working group.

6   Strategy

6.1   Overall Strategy

The overall strategy is to scientifically manage and conserve fisheries resources to obtain MSY taking into consideration the use of the resource for developmental purposes and the impact of developmental activities on the resource. The essential aspect of the strategy is to strike a balance between the reduction in the stock size due to fishing and natural mortality on the one hand and the replenishment capacity of the fish stock through individual growth and recruitment on the other, so that the former is always a little less or equal to the latter. The second aspect is to ensure that the impact of the developmental activities (such as industry and domestic discharge, physical disturbance, etc.) is always well below the assimilation capacity of the environment.

To achieve the above-stated objectives, the strategy to be employed consists of the following:

- To undertake surveys and studies to strengthen the information base on fish habitats, including initial baseline studies on the current status and future studies on likely impacts of future developmental activities
- To carry out year-round survey to locate and to delimit exact breeding and nursery grounds of the entire major commercially important species of finfishes and shellfishes and to delineate the duration and peak period of spawning
- To collect data on the biological and population parameters of all the important species
- To evolve and implement viable methodologies for regular and continuing appraisal of the status of the resource like standing stock, catchable potential, etc. and for the collection of fish catch statistics
- To formulate and strictly enforce suitable management and conservation measures (e.g. restricted fishing zone, registration of boats, observance of closed area/ season, etc.)
- To provide economic incentives (facilities, subsidies, etc.) to the fishermen to comply with the management regulations
- To provide training opportunities to fishermen to encourage them to take up eco-friendly shrimp farming and mariculture
- To get maximum inputs from participating institutions, their expertise and technology
- To strengthen the capability of participating institutions.
- To establish an operational national fisheries database (OMLRDC)
- To create/enhance the awareness on the environmental impact on fish productivity

6.2 Implementation Strategy

A suitable strategy implementation plan and milestone of activities need to be developed with required manpower for conducting:

- Baseline studies on breeding biology and nursery ground.
- Baseline studies to evaluate the impact of threats to breeding and feeding grounds.
- Detailed study on biology and population parameters of important species.
- Revise existing procedures for assessing fish stocks, and prepare recommendations for improvement.
- Revise existing procedures for assessing potential yield, and prepare recommendations for improvement.
- Revise existing procedures for collection of catch statistics, and prepare recommendations for improvement.
- Estimation of species-wise annual yield, standing stock and catchable potential.
- Establishment of operational database on fisheries resource.
- Formulation of necessary regulations and implementation.
- Establish fishing zone according to depth.
- Regulate fishing effort.
- Regulate catches of commercially important species.
- Ensure observance of conservation regulations through regular inspection.
- Continuously monitor and assess trends in order to issue special intermediate regulations.
- Introduce economic instruments (facility, subsidy, etc.).
- Prepare and initiate training programmes.

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