**Doctoral Thesis (Abridged)**

# A Novel Approach for Monitoring Small-Scale Fisheries with GPS, GIS, and Remote Sensing Techniques

**(GPS，GIS，リモートセンシングを用いた小規模漁業モニタリングの新しいアプローチ)**

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## Note:

Only the second chapter is presented here in full detail. Other chapters cannot be made public because they are scheduled to be published in the near future. However, a shortened version of the thesis is presented here.

# Contents

## Thesis Summary

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## (GPS，GIS，リモートセンシングを用いた小規模漁業モニタリングの新しいアプローチ)

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Small-scale fisheries worldwide are less investigated although they provide most of the production from the sea to local people and secure employment for 98% of fifty one million fishers in the world. Most of these fisheries are located in developing countries where scientific researches in fisheries management lack official support and fisheries scientists are underqualified. Accordingly, it is difficult for scientists and fishery managers in these countries to apply the same approaches used for large-scale fisheries in developed countries. Tropical small-scale fisheries are highly heterogeneous with respect to a wide variety of fisheries characteristics. It is necessary to examine the heterogeneities of small-scale fisheries, which haven’t been investigated. For this purpose, a novel approach using GPS, GIS and remote sensing techniques was developed

in this study. Yemen's small-scale fisheries as an ideal type of a small-scale fishery were chosen as a case study to explore the potential of the approach for monitoring of small-scale fisheries. The recent decline of fish resources of Yemen coupled with uncontrolled growth of fishing fleets are major obstacles for development of sustainable fisheries. Both stock status and current exploitation levels of major fisheries are unknown. Lack of scientific researches and effective management policies jeopardizes the sustainability of Yemeni small-scale fisheries and coastal ecosystems. In order to conserve the coastal fisheries resources and ecosystems on which coastal inhabitants are dependent for subsistence, it is necessary to determine the exploitation levels of fisheries resources. Spatio-temporal distributions of fishing efforts and catch per unit effort (CPUE) can provide a detailed picture of exploitation patterns and pressure levels on different fish stocks. The details are described as follows.

The study describes the status of Yemeni fisheries and highlights their current problems and priority research areas. It also analyses the different components of the fisheries management system of Yemen and highlights its strengths and weaknesses. Yemen's coastline exceeds 2,500 km extending along the Red Sea, Gulf of Aden and Arabian Sea. Stock status of commercially exploited fish species is unknown and no active management plans enforced anywhere in Yemen. Furthermore, fishing efforts, namely number of fishing boats, have increased four-fold between 2000 and 2010 while the CPUE has decreased significantly during the same period. According to official statistics, total fish production of Yemen has reached a peak of 256,000 tons in 2004 and thereafter dropped to 180,000 tons in 2007 and to 127,000 tons in 2008. To ensure sustainable exploitation in such data poor situations, it is greatly needed to study the characterization of fishing effort and fishermen's use of resources and fishing grounds.

This study aims to develop a novel approach for monitoring small-scale fisheries and their CPUEs, integrating GPS acquired location data of fishing boats, GIS that relate position data with catch and environmental data and remote sensing techniques that provide environmental data. Using this approach, we described the spatio-temporal distribution of fishing grounds and how the fishing grounds are formed and influenced by the environmental conditions and the implications for fishery management were explored. This study selected two representative small-scale fisheries from the Red Sea of Yemen.

The novel approach developed here is designed for obtaining positions of small-scale fishing boats and analysing fishing grounds with GPS, GIS software and satellite images of sea surface temperatures and chlorophyll monitored by MODIS satellites and provided by National Aeronautics and Space Administration, United State of America. The GIS software used bottom topography data of ETOPO1 for fishing ground analysis. The ETOPO1 is a one arc-minute global relief model of Earth's surface that integrates land topography and ocean bathymetry provided by National Geophysical Data Center, United States of America. Forty GPS loggers were used and one GPS logger was given to each voluntary boat, which reported catch of each trip during acquisition of boat positions with the logger. These data were analysed with GIS software (ArcGIS 10.0, ESRI). Catch data were collected on each trip, which include the catch composition by species and weight.

The novel approach was applied to a case study of Indian mackerel (*Rastrelliger kanagurta*) fisheries in Yemeni Red Sea to describe the spatio-temporal distribution of fishing grounds and to investigate the roles of environmental variables in the formation of fishing grounds and their dynamics in time and space. For this purpose, 20 GPS loggers were used to collect the data on boat location and speed at 5-seconds intervals for purse seine fishing gear targeting the Indian mackerel. The overall lengths of the boats belonging to the voluntary skippers were between 12 and 15 m. Fishermen used purse seine nets, which had an average horizontal length of 407 m and vertical depth of 16.3 m. Fishing is conducted only during the nighttime between sunset and sunrise and one trip is confined to only one night and the fishing usually stops from day 7 to day 17 during the lunar nights. Twenty GPS loggers were used for eight months to collect the position data on the Indian mackerel fishery. Fishing hauls were easily recognized with boat speed recorded by the high resolution GPS recordings. The mean number of fishing hauls per day was 2.65±1.4 hauls/day and the mean hauling speed (encircling speed) was 13.2 m/s. The mean catch/haul and mean catch/day were 98.6±70.4 kg and 212.5±154.5 kg, respectively. Geospatial analysis using GIS and remote sensing data and bottom topography showed that fishing grounds of Indian mackerel were concentrated in high chlorophyll waters and along the SST fronts. Especially in October, most of the catch originated from areas in inshore waters inside two semi-enclosed bays. Inshore movement of Indian mackerel was synchronized with the highest annual chlorophyll concentration. This indicates a specific behaviour of this species, probably associated with spawning which occur around this period.

The novel approach was also applied to a case study of pharaoh cuttlefish (*Sepia pharaonis*) in Yemeni Red Sea to describe their spatio-temporal distributions. The overall lengths of most fishing boats targeting this species were 7-m. Fishermen used a hook and line with artificial lures to fish cuttlefish. Data on more than 2000 fishing trips of 40 voluntary boats between June 2012 and May 2014 were collected by providing the volunteers with GPS loggers. Boat positions were recorded using the GPS logger at 1-

minute intervals for monitoring fishing activities of boats targeting pharaoh cuttlefish. Boat positions data were processed with the GIS software to remove non-fishing periods based on boat speeds below 3 km/hr because the boats are usually drifting while fishing. The catch of every trip measured at a landing port was divided on all the fishing points of the trip according to the time. Maps of the monthly and seasonal spatio-temporal distribution of CPUEs showed that a time series graph of monthly CPUE had two peaks, one in March/April and the other in August/September. The cuttlefish in the study area has two fishing seasons per year, the first started from mid-January until May and the second from July until September. Distribution of fishing activities was highly confined to shallow bottom depths within 20 m. Since *Sepia* sp. live in offshore waters and move to the coastal areas for spawning, this suggests that the two peaks in March/April and in August/September correspond to two spawning times of this species, which may produce two different cohorts of cuttlefish.

Essential information and knowledge on stock status are not available in most developing countries. Simple and inexpensive methods of fish abundance estimation are desired in such situations. This study developed a novel approach to monitor fishing effort distributions in time and space with the use of mobile GPS loggers. High-resolution data has enabled us to detect the exact fishing locations and to estimate fishing effort. The GPS data of purse seines have included a variety of helpful information. The diameter of fishing haul gives a good indication of the size of fishing gear used. After-haul drifting chart gave an indicator of wind speed and direction. Speed chart of fishing boat indicates the optimum speed for fishing efficiency. The high correlation between satellite derived chlorophyll and Indian mackerel distribution introduces opportunities to investigate the spatio-temporal distributions of this species and will aid to formulate management plans. The concentration of hauling locations around sea surface temperature fronts can be utilized to characterise the potential fishing zones and this will greatly minimize search costs and the time spent in the sea for fishermen. The spatio-temporal distribution of CPUE of pharaoh cuttlefish revealed their aggregation sites and the coincident overfishing during this study. The results suggest the use of spatial and/or temporal ban on fishing for cuttlefish in the critical spawning and nursery areas of this species.

Finally, this study highlights the necessity of involvement of fishermen in the collection of data for scientific purposes. Fishing boats can play as platforms for data collection on the resource exploitation. This new approach will minimize research costs and give an opportunity to collect data on small-scale fisheries not only in developing countries but also in developed countries.

# CHAPTER 2

# Characterization of fisheries management in Yemen

## 2.1. Introduction

While most of the world fish production originates in small-scale fisheries of developing countries (FAO, 2014), fisheries management in these countries adopts the same methods of fisheries management used for commercial fishes caught by large-scale fisheries in the developed countries (Ruddle and Hickey, 2008). Policy makers in developing countries do not search for alternative approaches and think that the formal stock assessments methods used for commercial fishes in developed countries are the only way to manage the fishery resources in their countries (Mahon, 1997). This has resulted in most of these fisheries unmanaged (Svendrup-Jensen, 1999). Policy makers, scientists and fishery managers should realize the differences in scale and nature between the small-scale fisheries and large-scale fisheries. They need to understand the context in which small-scale fisheries operate and try to develop management systems suitable to the context of these fisheries.

Fisheries management in Yemen until 1999 was the responsibility of the fisheries department of the Ministry of Agriculture before the establishment of the Ministry of Fish Wealth (MFW). The authorities' policy has been development-oriented, in which high emphasis is placed on the economic benefits gained from the fishery. Throughout the past 20 years, the fisheries policy has encouraged investments in the fisheries sector, increases in fish production, and the development of the fishing industry (Bonfiglioli and

Hariri, 2004). While the policy encourages sustainable use of fisheries resources, neither detailed fishery management plans (FMPs) nor operational objectives exist to address policy objectives. Moreover, planning and policymaking is practiced without proper knowledge of the resources (Wagenaar, D'Haese, 2007). During the last few years, the national authority started to transfer management responsibilities from the central level to the local level, and has already established local fisheries authorities to be responsible for fisheries management at the local level. This restructuring is part of decentralization process aimed to improve management of the sector. However, transfer of responsibilities is said to be slow (Setlur, 2013).

The aim of this chapter is to analyze the overall management of the fisheries sector, and to critically review the existing legislative, policy and regulatory frameworks, the compliance and enforcement mechanisms, and the impacts that these arrangements have on the nature and extent of illegal, unreported, and unregulated (IUU) fishing. The chapter proceeds, at first, by describing the fisheries management from a developing country perspective, with emphasis given to the inherent problems and recommendations on approaches to fisheries management, which fit their context. Second, it gives a description of the context in which fisheries in Yemen are operated, details the contributions of the fisheries to the society and to the economy, and the problems arising from both outside and inside the sector. It also presents the historical development of the fisheries, distinguishes the two small and large-scale subsectors, and describes the key fish species of the fisheries. Then it describes the fisheries management in Yemen, with emphasis given to the policy and regulatory frameworks and how appropriate these tools are. This is followed by a description of the compliance and enforcement tools in both the small and industrial subsectors. Finally, the chapter presents the current status of IUU fishing, its different types, situations where it occurs and the drivers and incentives behind its occurrence.

## 2.2. Fisheries management in a developing country context

In the typical context of fisheries in developing countries, management has been challenging due to the complex nature of the inherent social-ecological systems (Mahon et al., 2008; Garcia, 2003). These are frequently described as labor intensive, multi-species and multi-gear fisheries sparsely distributed along the coast and associated with high levels of community dependence (Panayotou, 1982; Charles, 1991; Charles, 2001). In such a context, it is difficult to control fishermen's behavior or to enforce regulations (Raakjær, 2003).

In the northwest Indian Ocean, fisheries management is characterized by the following four factors (Morgan, 2006): (a) the almost total absence of comprehensive stock assessments upon which management decisions must be based, combined with a generally poor statistical database on landings (and their composition) and fishing efforts; (b) the regional and shared nature of many of the fish stocks which are asymmetric to the poorly developed institutions for regional management; (c) the development strategy of national fisheries legislation and policy in most countries despite the apparent over- or fully exploited status of many fish stocks; and (d) a general lack of success at the regional and national levels in measuring and controlling fishing capacity, particularly in the small and important artisanal sector.

In the developing countries, poor management arises in part from the governance or policy-making authorities, in which the lack of the political capacity or will affects the quality of the fisheries management (Carbonetti et al., 2014). In these cases, stakeholders are rarely considered in planning or in decision-making, which results in low compliance with the regulations. Besides, limited monitoring and/or enforcement of the regulations, creates incentives, which favor non-compliance (Hatcher and Pascoe, 2006). Moreover, the management authorities in most developing countries lack the capacity to prepare fishery management plans and this is due to the lack of the necessary expertise and essential fund for research, monitoring and enforcement.

The approach of fishery managers to conservation and management in developing countries frequently appears to be driven by the perceived need for stock assessment, rather than by the need to implement the most effective management regime possible, based on what is feasible and affordable, given the nature of the fishery and the human resources available (Mahon, 1997; Mackinson, 2011). This mismatch partially arises from the fact that the fishery managers and scientists were educated in the west or received training on management approaches used in the developed countries (Ruddle and Hickey, 2008; Mahon, 1997), which requires intensive researches and substantial fund beyond the capacity of most developing countries. Finally, these approaches do not necessarily fit the context of fisheries of the developing countries. The provisions of the Code of Conduct for Responsible Fisheries as they relate to the uncertainties and the lack of data in the developing countries, recommend adopting the precautionary approach to fisheries management (FAO, 1995). Management tools within this suggested approach do not require much data to formulate, are easy to monitor fisheries resources and activities and easy to enforce with limited expertise and funding requirements. The code also stresses the importance of research and capacity building for those countries.

Scientists from the developed countries increasingly recognize the failure of fisheries management (Andrew, 2007; Tim, 1998; Daw, 2005). They further express their concern that the science they have produced may not serve the needs of researches on small stocks in many developing countries (Ruddle and Hickey, 2008; Mahon, 1997). In searching for innovative approaches, they called upon a multi-disciplinary approach which takes into account the social, economic and ecological systems in which these fisheries occur (Hughes, et al., 2005; Caddy, 1999; Berkes, 2003; Kates et al., 2001; Hauck, 2008). In this stream, community-based management or participatory management has grown out of developing country needs, and has involved stakeholders as partners in fisheries management (Mahon, 1997; Mackinson et al., 2011; McCay and Jentoft, 1996). Taking into account the fast population growth in these countries, it is necessary to realize that the resources at some point in time will fall short and will not be capable of delivering the same benefits to this growing population. Therefore, it is necessary to adopt sustainable management approaches and this inevitably requires to gradually reduce dependence on the resources. Thus, developing countries should search for suitable cost-effective management approaches besides the above-mentioned.

## 2.3. Fisheries status and historical development

Yemen is located in the southwest corner of the Arabian Peninsula and is bounded by 2,520km of coastline that extends along the Red Sea, the Gulf of Aden, and the Arabian Sea. The fisheries sector is considered particularly important because it provides various social and economic benefits to the coastal communities and to the wider community. At both national and local levels, fisheries contribute to food security, employment, domestic income, foreign exchange earnings, and fiscal revenues. The fishing industry is dominated by the small-scale sector, which currently supports the livelihoods of an estimated 83,157 small-scale fishermen and 583,625 of their dependents, for a total of about 667,000 people (IFAD, 2010; MFW, 2012). In addition, an unknown but relatively a large number of people are also engaged in post-harvest processing, marketing, and value addition (Bonfiglioli and Hariri, 2004). The fisheries sector contributed 1.9% of Yemen's $26.24 billion gross domestic product in 2009 (YFSP, 2010). Next to oil exports, fisheries constitute the second largest export earner and account for 1.5% of the national labor force, supporting the livelihoods of 3.2% of the national population (MFW, 2012). The fisheries industry, with its largely rural location, remains the largest if not the sole source of income for coastal communities (YFSP, 2010).

The major challenges hindering economic development in Yemen include political instability, a lack of security, and widening areas of conflicts (IMF, 2012). Within the fisheries sector, poor governance, the absence of appropriate legislation, and inadequate infrastructures have been major problems (Hariri, 2000) that undermine the social and economic contributions of the fisheries sector. Recently, frequent fuel and electricity shortages, paired with subsequent price increases, have increased hardship among fishermen (World Bank, 2012). Widespread piracy in the Gulf of Aden and the Arabian Sea has been a major concern and has restricted productivity of fishermen from these areas (IFAD, 2010; MFW, 2012). According to the Yemeni government figures released in July 2009, piracy in the Gulf of Aden has cost the country an estimated $200 million in lost fishing revenue and other revenue (Boucek, 2009).

Moreover, Yemen has the world's fourth fastest growing population (3.0% in 2013) (UNDP, 2013) and the corresponding increase in unemployment rates (17.8% in 2010; 29% in 2012) (WB, 2013) will pose more threats to the already overexploited fishery resources and will cause further damage to the important coastal habitats. A national assessment carried out by the United Nations Development Programme in 2010 to assess progress in Yemen toward achieving Millennium Development Goals found that Yemen is unlikely to achieve most of the Goals by 2015 due to chronic underdevelopment, security problems, and a lack of financial resources (WB, 2012).

Recently, a new national fisheries strategy (2012–2025) has been formulated and has identified fisheries as a potential sector to food security and to create more employment opportunities (MFW, 2012). The strategy has identified short-term, mid-term, and long-term objectives and a timeframe to achieve these objectives. This strategy and its announced objectives recognize the major uncertainty of the sector, in which production estimates are highly uncertain and the stock status of most species is unknown. However, the strategy did not prioritize objectives nor did it introduce practical solutions to the major obstacles encountered in the sector, particularly the poor governance and uncertainty of the overall performance of the sector. Moreover, the strategy did not account for the high vulnerability and low resilience inherent in fisheries resources in general.

Prior to unification in 1990, the two separate entities of Yemen pursued different fisheries development policies; while the state in the north adopted a policy of supporting artisanal sector development, the state in the south pursued a policy of supporting large-scale industrial fishing (Morgan, 2006). After unification, the authorities encouraged a policy of supporting the artisanal sector development and gradually eliminated the agreements with the industrial fleets. As a result, the number of fishermen and fishing boats has increased rapidly and production estimates reached a peak of 256,300 tons in 2004 before dropping to 130,591 tons in 2008 (MFW, 2012). The catch per unit of effort

(CPUE) has simultaneously decreased with time (MFW, 2012; Tesfamichael et al., 2014; Tesfamichael, 2012).

In the absence of proper governance, industrial fleets have caused not only fish stock depletion but also major destruction to fish habitats (Shaher, 2007; Gladstone et al., 1999). In line with the announced fisheries strategy that gives preference to the artisanal sector, new licences for industrial vessels have not been granted since 2004. Currently, there is no licensed industrial fishing in Yemen and there are only a few coastal fishing fleets with illegal licences (using licences of artisanal boats) in the Gulf of Aden and the Arabian Sea. Industrial fleets are registered to fish for almost all different kinds of fish, including pelagic fish. However, reporting of catches have never included any pelagic fish. Moreover, it is believed that these trawlers are poaching significant quantities of tuna and tuna-like species. Furthermore, significant quantities of fish are being captured illegally by unlicensed industrial fleets; these fish are being transferred directly to other countries (Hariri, 2000; Feidi, 1998).

Due to the limited employment opportunities available to the coastal inhabitants, increased domestic demand, and the open-access nature of fisheries, the number of fishermen has increased rapidly. Moreover, the return of one million expatriates from Saudi Arabia after the 1991 gulf crisis (Baldwin, 2005) has also added to the numbers of workers entering artisanal fishing (Shaher, 2007; Gladstone et al., 1999). Subsequently, fishermen numbers have increased three-fold between 1990 and 2010. Most of the recent growth has occurred in the Red Sea region where both fishermen and fishing boats numbers have increased four-fold between 2000 and 2010 (MFW, 2012). This rapid growth in the past decade is attributed, in part, to changes in national policy that have led to a reduction of the industrial fleet.

Fish exports have witnessed significant increases and reached 110,000 tons in 2010, which is nearly 58% of the total fish production (MFW, 2012). This increase is attributed to the sector's increased productivity and increased compliance with international standards of quality control applied to fish exports. Despite the recent decrease in total catch compared with 10 years ago, fish exports have increased constantly; this increase seems to occur at the expense of local consumption and has caused significant increases in fish prices in local markets (SMEPS and KIT, 2009).

Artisanal fishing accounts for well over 90% of the total production (IFAD, 2010). The key fisheries resources, shown in Table 2.1, include pelagic fishery for tuna and tuna-like species and demersal fishery for fish, cuttlefish, shrimp, and lobster. Tuna and tuna-like species and cuttlefish are prevalent in the Gulf of Aden and the Arabian Sea, whereas demersal fish are more abundant in the Red Sea.

Key pelagic species include yellowfin tuna, longtail tuna, little tuna, narrow-barred Spanish mackerel, Indian mackerel, anchovy, and sharks; key demersal fish species include emperors, groupers, snappers, and jacks (IFAD, 2010; Hariri et al., 2000). Despite the lack of comprehensive stock assessment studies and reliable catch statistics, it is believed that most fish stocks, except small pelagic species for which there is no market demand, are either fully exploited or overexploited (Morgan, 2006); interviews with fishermen and different stakeholders confirm these beliefs. Cuttlefish (*Sepia pharaonis*) has been harvested since 1967 by industrial fleets in the Gulf of Aden and the Arabian Sea region. The intensive trawling on their spawning aggregations has led to overfishing and a major decline of the fishery by 1982–1983 with reported annual landings falling from around 9,000 to 1,500 tons. Landings of the rock lobster (*Panulirus homarus*) virtually collapsed to near zero in the late 1990s from peaks of around 400 tons in the early part of the decade. This collapse was attributed to the widespread use of nets rather than traditional traps to capture lobsters (Morgan, 2006). Large-scale harvest of sea cucumbers started in 2003 with the advent of air compressors, which facilitated diving; this process led, a few years later, to the collapse of the fishery (PERSGA, 2009).

Many important demersal fish stocks and some pelagic species, such as Indian mackerel (Gladstone, 1999), narrow-barred Spanish mackerel, and sharks (Shaher, 2007; Pramod et al., 2008), have experienced severe overfishing. The lack of FMPs, widespread IUU fishing, uncontrolled growth of fishing effort, and weak compliance and enforcement arrangements have led to significant economic losses associated with the suboptimal use of the resources, which has in turn resulted from weak and ineffective governance and subsequent overfishing.

Small-scale fishermen typically use two types of fishing boats: small fiberglass boats called "*huris*" in Arabic, 7–16m long, with outboard engines and 2–6 crew members, and larger wooden boats called "*sambuks*" in Arabic, 10–20 m long, with inboard or outboard engines and with a crew from 10 up to 25 or more (Bonfiglioli and Hariri, 2004; IFAD, 2010). *Huris* were traditionally used for single day trips in inshore waters, within 40 kilometers of the shore (Bonfiglioli and Hariri, 2004). However, due to overfishing and decreasing CPUE, and increasing operation costs (particularly fuel prices), fishermen tend to spend longer (up to 10 days) at sea in an attempt to harvest more catch to get a better return on their investments. *Sambuks* are used for longer trips ranging from a few days to three weeks (Bonfiglioli and Hariri, 2004; IFAD, 2010).

Fishing is highly seasonal, with activity restricted by the monsoon winds (the northeast winter monsoon ranges from November to February and the southwest summer monsoon ranges from June to September) (Bonfiglioli and Hariri, 2004). As a result, fishermen tend to relocate their fishing activities (Wagenaar and D'Haese, 2007) or shift their fishing gear to target different species. Shifting of either fishing gear or target species is also frequent with seasonal changes in fish production; fishermen shift when the fishery is not profitable and return when it is profitable again. For example, fishermen targeting demersal fish along the Red Sea typically shift to cuttlefish following a decrease in demersal fish catches.

## 2.4. Assessment of the current status of fisheries management

Fisheries management usually must have a policy framework which sets objectives to achieve and mechanisms to follow in decision-making. Next, it must have a suite of laws and regulations to control stakeholders' behavior. Finally, it must have an enforcement power to ensure compliance and implementation of these rules in practice. How appropriate these tools are to a specific fishery, will determine the type and success of the resulted management.

### *2.4.1. Legal, policy, and regulatory framework*

The stated objectives of the fisheries sector include protection of fish resources and the environment, the encouragement and regulation of investments in fishing and marketing, provision of post-harvest facilities, setting measures and norms to regulate fishing with a gradual replacement of industrial fishing by artisanal fishing, and the encouragement of aquaculture investments. Despite these stated objectives, the policy during the past three decades has been development-oriented and has centered on encouraging investment in fisheries exploitation and increasing fish production. To ensure sustainable resource conservation and management, the fishery should have an effective legal and administrative framework and an appropriate compliance and enforcement tools to ensure the subsequent implementation of the legislation.

The regulation of exploitation of fish resources is controlled by the law no. 2 of 2006, which, when issued, cancelled the law no. 42 of 1991 and the law no. 43 of 1997. This law prescribes the requirements of fishing boats with regards to fishing, specifies the powers of the minister and the competences of the MFW, the competences of the branches of the MFW in coastal cities (currently contained within the Fisheries Authorities), and specifies the requirements of coastal and industrial vessels and the penalties for violations of the provisions of this law.

Fishing vessels are classified according to boat length and engine power. An artisanal boat can have an overall length up to 21 m and outboard engine up to 150 hp; coastal boats can be up to 40 m long with outboard engines up to 1100 hp. Industrial boats can be up to 70 m long with outboard engines up to 3000 hp. To reduce conflicts among different categories of fishing vessels, the law has specified different areas for each vessel category. The first 5 miles from the coast is allocated to artisanal boats, beyond 5 miles for coastal boats and beyond 12 miles for industrial boats.

FMPs addressing different key species are lacking, which is due, in part, to limited knowledge about resources. This lack of knowledge results from the limited human and institutional capacity in terms of developing species-specific management plans. There are very few management measures with provisions provided for in the fisheries legislation. Closed seasons, where fishing is prohibited, are the most widely used management measures to protect and conserve the most important commercial species. Closed seasons are currently used to manage shrimp, rock lobster, and cuttlefish resources (Morgan, 2006).

Opening and closing of seasons are regularly announced by the MFW upon receiving the initial information and advice from the Marine Science and Biological Research Authority. The discarding of fish is prohibited in all fisheries. The collapse of the sea cucumber fishery led, in 2007, to a complete ban on the capture and trade of all sea cucumbers within the country (PERSGA, 2009).

Management measures related to the valuable rock lobster include minimum size of 19 cm, gear type is restricted to traps only, quantity of gear is restricted to 60 traps per boat, and a prohibition on the taking of egg-bearing lobsters. If egg-bearing lobsters are accidentally captured, they must be returned to the sea. Measures targeting pelagic species are lacking, except for a law prohibits the use of light when using purse seine nets.

While the power and ability to execute within the current legislation are given to the minister and the ministry, only minimal action has been taken. Managing the fisheries, issuing any urgent norms, or making any required reforms or amendments have been limited. For example, while the law gives the minister the right to issue the specifications pertaining to different fishing gear, fishing gear remains largely unregulated. No specifications have been made regarding net sizes, mesh sizes, the minimum sizes of different species allowed to catch, specific areas for different fishing gear, or sensitive areas where trawling is prohibited.

Even though the fisheries act (no. 2/2006) is relatively new, it does not seem to integrate many of the recent changes in international policy, including the 1982 United Nations Convention on the Law of the Sea (UNCLOS), FAO Compliance Agreement, UN Fish Stock Agreement, and the 1995 FAO Code of Conduct for Responsible Fisheries. By signing these treaties, countries have agreed to adopt the new policy and have shown their commitment to address sustainable conservation and exploitation of marine resources to maintain their productivity for future generations. In order to ensure Yemen's commitment, the fisheries act is supposed to make the necessary amendments in the fisheries governing laws to meet these emerging fisheries policies. It is necessary that the fisheries law be broadly based on the precautionary approach, particularly in the case of least developed countries such as Yemen where the status of most fish stocks is unknown and funds for research are lacking. During the last two decades, aquaculture development, though stressed in policy, did not make any progress and the lack of aquaculture legislative framework has been one of the major obstacles to aquaculture development. Therefore, it is necessary to investigate these obstacles and make the necessary legislative and regulatory reforms to address these issues.

### *2.4.2. Compliance and enforcement*

Enforcement of regulations by the enforcement authorities is weak, which results in fishermen having a low compliance with regulations. Compliance and enforcement tools prescribed by the law include instruments for both artisanal and industrial fisheries. In the artisanal sector, monitoring is restricted to random dockside inspection and routine inspection at landing sites, and inspection is not strictly enforced. On-land enforcement tools consist of on-land observers and quality observers.

The tasks allocated to the on-land observers include reporting of illegal fishing gear, reporting of unlicensed fishing boats, illegal fishing during the closed seasons, capture of illegal species or sizes, unloading at unofficial landing sites, reporting of illegal means of transporting fish, and reporting of any violations to the laws and regulations of the fishery.

Compliance and enforcement tools within the industrial fisheries include the requirement of the coastal and industrial boats to take onboard 2–4 observers, the use of Vessel Monitoring System, the real-time reporting of catches at sea, and the unloading of fish should be at specified ports in Yemen.

Coastal and industrial boats are required to keep logbooks, in the format specified by the MFW, to record the catch in terms of species and quantity, the coordinates of each of the fishing locations, and the depths and times spent fishing. However, logbooks are not used with the artisanal boats, even though the law entitles the MFW to ask artisanal boats larger than 15 m long to keep logbooks to record the specifications of the catch.

Enforcement incentives provided for in the law are generally low and lack publicity. The law has specified a reward, 10% of the reported infringement, for any person detected and reported any violations to the laws and regulations of the fisheries. However, reporting of violations still occurs infrequently, in part due to the lack of publicity of these rewards and a lack of trust in competent authorities.

The penalties are sometimes not severe enough to ensure compliance with and enforcement of regulations. Moreover, the fines are not prescribed for different levels of violations and sometimes do not differentiate between the artisanal and industrial fishing activities. The law did not empower to the MFW to judge on violations instead of lengthy court cases.

In case of industrial fleets and companies, sanctions for violations include provisions for the revocation or suspension of the authorization to fish and are sometimes as severe as the confiscation of the boat and its equipment. However, on-board observers and inspectors rarely report the violations and are sometimes forced not to report. If violations are indeed communicated to authorities, penalties are rarely enforced. Similarly, reporting of violations and enforcement of regulations is largely lacking within the small-scale sector, which affects compliance levels among fishermen. In fact, the level of compliance of fishermen with laws and regulations has been negatively affected by the widespread corruption in the policymaking authorities, in the judicial systems, and in everyday local administrations.

### *2.4.3. Present status of IUU fishing*

It is obvious that fish stocks have been depleted in many areas in the world's oceans and seas due to poaching, smuggling, overfishing, and violation of local, regional, and international laws (MRAG, 2005; Öztürk, 2013). IUU fishing is most detrimental and most likely occurs in countries where governance is weak and corruption is rampant, such as most developing countries (Sundström, 2012; Agnew, 2009). This widespread IUU fishing in many developing countries has several severe environmental, social, and economic consequences, including unfair competition, loss of biodiversity, loss of income, and even loss of human lives (Öztürk, 2013).

IUU fishing is a major issue and a source of serious concern for Yemeni fisheries. Such fishing undermines the contribution of fisheries to the food security, to income and livelihood and to the national economy. The widespread IUU fishing in Yemen is one of the major consequences of the weak governance reflected in the weak legislative, policy, and regulatory frameworks. There is no national plan to combat IUU fishing. Sanctions are not specified for different types of violations and, where stated, are not sufficient to act as deterrents with the level of violations. The drivers behind IUU fishing include the lack of political will to prevent, deter, and eliminate IUU fishing, low levels of fines, the absence of effective monitoring, control, and surveillance (MCS) activities, and the weak enforcement of the laws and the regulations.

IUU fishing in Yemen may occur in different forms. Illegal fishing practices within the small-scale sector include discarding of significant quantities of fish during bottom trawling and purse seining, the use of light when fishing using purse seines, the use of small-mesh nets, and the use of destructive fishing gear (particularly in sensitive habitats such as coral reef areas). In case of industrial fisheries, due to weak MCS systems, violations include operating in areas allocated for artisanal fishermen and causing destruction to their fishing gear, fishing during the closed season, transshipment at sea, under-reporting, discarding large quantities of fish, and unloading at ports unspecified by the managing authority. Moreover, significant poaching by unlicensed foreign trawlers and purse seiners has been reported.

Discarding of fish, despite it is banned, is widely practiced by both industrial and artisanal fisheries. It is associated with almost all activities of industrial fishing and with certain fishing gear in the artisanal sector. For example, the small-scale bottom trawl fishery for shrimp is usually associated with discards of large quantities of small and juvenile demersal fish several times larger than the target species (Pramod et al., 2008).

The MFW reports that fishermen and/or the fisheries cooperatives tend to misreport catches to avoid paying the levy (IFAD, 2010; Hariri, 2000; Pramod et al., 2008). In one case study, which highlights the level of misreporting, the Indian Ocean Tuna Commission (IOTC) estimated the catch for tuna and tuna-like species caught by artisanal boats in the year 2004 at around 42,000 tons, which is five times higher than the official reported figures (Herrera and Lepere, 2005). Under-reporting or non-reporting typically increases in remote areas where fish are sold directly to the traders or are sold in the sea to a receiving boat or sold at unofficial landing sites. Hence, the catch from these areas does not enter into the official statistics and production estimates from these areas are estimated only if transported to the main cities or from the export figures at export outlets. It is noteworthy that significant quantities of small or low-value fish are usually sold directly to traders originated from the countryside and that these quantities typically do not pass through the catch-collection system.

Landing sites along the Gulf of Aden are operated by the cooperatives that provide a wide range of services, including auctioning, marketing, facilities provision, maintenance, health care, and credit provision. However, cooperatives along the Red Sea are non-functional and provide far fewer services (Qasem, 2007). Landing sites and auction yards in remote areas do not have the necessary facilities such as ice plants, storage, and marketing services. Moreover, cooperatives in these areas typically are not active and fishermen membership rates are very low. These areas mostly lack basic infrastructure. As a result, fishermen refuse to pay the levies imposed by the authorities. These practices lead to significant losses on both sides; the fishermen side and the state side. Fishermen get paid less for their catch because the prices are under the control of the traders, who dictate the prices, and the state loses control over the data collection system and loses the levies. Furthermore, this process minimizes the funds available for fisheries management and belittles the economic potential of the fishery.

Due to the weak MCS systems, many foreign vessels used to fish illegally in the Yemeni waters and the catch from these vessels was typically transferred to the receiving country, where the catch was unloaded (Feidi, 1998). Until the process was stopped in 2004, industrial fishing was carried out according to the agreements signed with these fleets to fish in the Yemeni waters; however, many other foreign vessels are still frequently reported to illegally operate due to the low chances of being discovered and the weak enforcement of laws and regulations.

This practice of illegal transfer of the catch into or out of Yemen contributes significantly to the current uncertainty in catch statistics. Direct transfers from Yemen into other countries, mainly Egypt, were estimated in 1999 at up to 40,000 tons per annum (PERSGA, 2009; WB, 1999) and this quantity typically did not enter into the official catch statistics. Moreover, a large quantity of fish originating from Eritrea is illegally transferred and sold in the Yemeni market, where market circumstances are better than in Eritrea (Moussalli and Haile, 2001). However, no accurate estimates are available for this amount. This amount, regardless, will not significantly affect the total catch of Yemen because of the relatively small production estimate of Eritrea, which is currently between 4,000 and 12,000 tons per year (Tesfagiorgis, 2010).

Table 2.1. Key species in the artisanal fishery and their contribution in catch and value in 2012

| *Fish Group* | *Species* | *Catch (tons)* | *% of total* | *Value (USD, in millions)* | *% of total* | *Group total (tons)* | *% of total* |
|---|---|---|---|---|---|---|---|
| | Yellowfin tuna | 35669 | 15.6 | 149.7 | 27.828 | | |
| | Longtail tuna | 4823 | 2.1 | 18.9 | 3.512 | | |
| *Large* | Little tuna | 6823 | 3.0 | 28.6 | 5.323 | | |
| *Pelagics* | King fish | 6033 | 2.6 | 25.3 | 4. 707 | 67178 | 29.38 |
| | Cobia | 613 | 0.3 | 2.6 | 0.478 | | |
| | Spotted shark | 13217 | 5.8 | 46.2 | 8.593 | | |
| *Small Pelagics* | Indian mackerel | 14708 | 6.4 | 17.1 | 3.187 | 70448 | 30.81 |
| | Spined anchovy | 55740 | 24.4 | 65.0 | 12.080 | | |
| *Demersal Fish* | Charcoal grouper | 2826 | 1.2 | 9.2 | 1.715 | | |
| | Snapper | 4930 | 2.2 | 14.7 | 2.735 | 11724 | 5.13 |
| | Gold band fusilier | 3968 | 1.7 | 13.9 | 2.580 | | |
| *Multi-species* | Other kinds | 61552 | 26.9 | 100.4 | 18.673 | 61552 | 26.92 |
| *Crustacean* | Painted spiny | 122 | 0.1 | 0.9 | 0.169 | | |
| | lobster | 1624 | 0.7 | 8.3 | 1.549 | 1918 | 0.84 |
| | Shrimp | 172 | 0.1 | 0.2 | 0.037 | | |
| | Crabs | | | | | | |
| *Cephalopods* | Cuttlefish | 15679 | 6.9 | 36.5 | 6.796 | 15685 | 6.86 |
| | Octopus | 6 | 0.0 | 0.0 | 0.003 | | |
| *Sea Cucumber* | Sea cucumber | 29 | 0.0 | 0.1 | 0.025 | 29 | 0.01 |
| *Multi-species* | Other kinds | 121 | 0.1 | 0.1 | 0.016 | 121 | 0.05 |
| *Total* | Total | 228,655 | | 537.8 | | | |

# Bibliography


Acker J, Leptoukh G, Shen S, Zhu T, Kempler S (2008) Remotely-sensed chlorophyll a observations of the northern Red Sea indicate seasonal variability and influence of coastal reefs. J. Mar. Sys. 69: 191–204.

Agnew DJ, Pearce J, Pramod G, Peatman T, Watson R, et al. (2009) Estimating the Worldwide Extent of Illegal Fishing. PloS ONE 4: e4570.

Agnew, D. J., Hill, S. L., Beddington, J. R., Purchase, L. V., & Wakeford, R. C. (2005). Sustainability and management of southwest Atlantic squid fisheries. *Bulletin of Marine Science*, *76*(2), 579-594.

Alabsi, N., & Komatsu, T. (2014). Characterization of fisheries management in Yemen: A case study of a developing country's management regime. *Marine Policy*, *50*, 89-95.

Al-Mahdawi, G. J., & Mehanna, S. F. (2010). Stock assessment of the Indian mackerel Rastrelliger kanagurta (Cuvier, 1816) in the Yemeni coast of Red Sea, Al-Hodeidah Region. In *Proceedings of the 3rd Global Fisheries and Aquaculture Research Conference, Foreign Agricultural Relations (FAR), Egypt, 29 November-1 December 2010*. (pp. 220-230). Massive Conferences and Trade Fairs.

Anderson, S. C., Flemming, J. M., Watson, R., & Lotze, H. K. (2011). Rapid global expansion of invertebrate fisheries: trends, drivers, and ecosystem effects. *PLOS one*, *6*(3), e14735.

Andrew, N. L., Béné, C., Hall, S. J., Allison, E. H., Heck, S., & Ratner, B. D. (2007). Diagnosis and management of small-scale fisheries in developing countries. Fish and Fisheries, 8(3), 227-240.

Anon (2010). Joint data collection between the fishing sector and the scientific community in Western Waters. Final report to the European Commission Directorate - General for the Fisheries and Maritime Affairs . Contract SI2.491885, Ref. FISH/2007/03 ; 267 p.

Aoyama, T., & Nguyen, T. T. (1989). Stock assessment of cuttlefish off the coast of People's Democratic Republic of Yemen. *J. Shimonoseki Univ. Fish*, *37*, 61-112.

Atmadja S.B., Sadhotomo B. and Suwarso (2003) Reproduction of the main small pelagic. Dalam: Potier M. and Nurhakim S. (eds) Biology, Dynamics, Exploitation of the Small Pelagic Fishes in the Java Sea. 2nd edition. The Agency for Marine and Fisheries Research, Jakarta: 69-96.

Bal, D. V., & Rao, K. V. (1984). *Marine fisheries*. Tata McGraw-Hill Publishing Company.

Baldwin-Edwards, M. Migration in the Middle East and the Mediterranean (pp. 1–38). Geneva, Switzerland: Global Commission on International Migration; 2005.

Becker, J. J., D. T. Sandwell, W. H. F. Smith, J. Braud, B. Binder, J. Depner, D. Fabre, J. Factor, S. Ingalls, S-H. Kim, R. Ladner, K. Marks, S. Nelson, A. Pharaoh, G. Sharman, R. Trimmer, J. vonRosenburg, G. Wallace, P. Weatherall., Global Bathymetry and Elevation Data at 30 Arc Seconds Resolution: SRTM30_PLUS, revised for Marine Geodesy, January 20, 2009 .

Berkes, F. (2003). Alternatives to conventional management: Lessons from small-scale fisheries. *Environments*, *31*(1), 5-20.

Berkes, F. (Ed.). (2001). *Managing small-scale fisheries: alternative directions and methods*. IDRC.

Bertrand, S., Díaz, E., & Lengaigne, M. (2008). Patterns in the spatial distribution of Peruvian anchovy (Engraulis ringens) revealed by spatially explicit fishing data. *Progress in Oceanography*, *79*(2), 379-389.

Board, O. S. (2000). *Improving the Collection, Management, and Use of Marine Fisheries Data*. National Academies Press.

BOBLME (2012) Report of the Indian Mackerel Working Group Meeting, 28-29 May 2012, Colombo, Srilanka: BOBLME-2012-Ecology-05.

Boletzky, S. v. (1986). Reproductive strategies in cephalopods: variation and ¯exibility of life-history patterns. In *Advances in Invertebrate Reproduction*, vol. 4 (eds. M. Porchet, J. C. Andries and A. Dhainaut), pp. 379-389. Elsevier Science Publishers B.V. (Biomedical Division). Amsterdam.

Boletzky, S. V. (1987). Fecundity variation in relation to intermittent or chronic spawning in the cuttlefish, Sepia officinalis L. (Mollusca, Cephalopoda). *Bulletin of marine science*, *40*(2), 382-388.

Bonfiglioli A, Hariri KI. 2004. Small-scale fisheries in Yemen: Social assessment and development prospects. Washington, DC: World Bank. Accessed from: http://documents.worldbank.org/curated/en/2004/12/8013081/small-scale-fisheries-yemen-social-assessment-development-prospects; 113pp; [accessed October 2013].

Boucek, C. Yemen: Avoiding a downward spiral. Vol. 12. Carnegie Endowment for International Peace; 2009.

Boyle, P., & Rodhouse, P. (2005). *Cephalopods: ecology and fisheries*. John Wiley & Sons.

Brill, R. W., & Lutcavage, M. E. (2001, July). Understanding environmental influences on movements and depth distributions of tunas and billfishes can significantly improve population assessments. In *American Fisheries Society Symposium* (pp. 179-198). American Fisheries Society.

Brown, O.B. and P.J. Minnett. 1999. MODIS Infrared Sea Surface Temperature Algorithm, Version 2.0. Algorithm Theoretical Basis Document, ATBD25. University of Miami, Miami, FL. Under Contract Number NAS5-31361.

Caddy, J. F. (1999). Fisheries management in the twenty-first century: will new paradigms apply?. Reviews in Fish Biology and Fisheries, 9(1), 1-43.

Carbonetti, B., Pomeroy, R., & Richards, D. L. (2014). Overcoming the lack of political will in small scale fisheries. Marine Policy, 44, 295-301.

Castello, Leandro, et al. "Accounting for heterogeneity in small-scale fisheries management: the Amazon case." *Marine Policy* 38 (2013): 557-565.

Castillo J., M.A. Barbieri & A. González. (1996). Relationships between sea surface temperature, salinity, and pelagic fish distribution off northern Chile. ICES Journal of Marine Science, 53: 139-146.

Cember, R. P. (1988). On the sources, formation, and circulation of Red Sea deep water. *Journal of Geophysical Research: Oceans (1978–2012)*, *93*(C7), 8175-8191.

Charles, A. T. (1991). Small-scale fisheries in North America: Research perspectives. La Recherche Face à la Pêche Artisanale, 157-184.

Charles, A. T. (2001). Sustainable Fishery Systems (Fish and Aquatic Resources Series 5).

Chassot, E., Bonhommeau, S., Reygondeau, G., Nieto, K., Polovina, J. J., Huret, M., Dulvy, N. K., Demarcq, H. (2011). Satellite remote sensing for an ecosystem approach to fisheries management. *ICES Journal of Marine Science: Journal du Conseil*, *68*(4), 651-666.

Clifford, M., Horton, C., Schmitz, J., & Kantha, L. H. (1997). An oceanographic nowcast/forecast system for the Red Sea. *Journal of Geophysical Research: Oceans (1978–2012)*, *102*(C11), 25101-25122.

Cushing, D. H. (1990). Plankton production and year-class strength in fish populations: an update of the match/mismatch hypothesis. *Advances in marine biology*, *26*, 249-293.

Daw, T., & Gray, T. (2005). Fisheries science and sustainability in international policy: a study of failure in the European Union's Common Fisheries Policy. Marine Policy, 29(3), 189-197.

De Lury, D.B. (1947). On the estimation of biological populations. Biometrics, 3, 145–167.

Dörner, H., Graham, N., Bianchi, G., Bjordal, A., Frederiksen, M., Karp, W. A., ... & Gudbrandsen, N. H. (2014). From cooperative data collection to full collaboration and co-management: a synthesis of the 2014 ICES symposium on fishery-dependent information. *ICES Journal of Marine Science: Journal du Conseil*, fsu222.

FAO (2012a) Glossary. Available at http://www.fao.org/fi/glossary/ (accessed February 2014).

FAO (Food and Agriculture Organization of the UnitedNations) (2001). The living marine resources of the Western Central Pacific. Volume 6. Bony fishes part 4 (Labridae to Latimeriidae), estuarine crocodiles, sea turtles, sea snakes and marine mammals. Dalam: Carpenter, K.E. and V.H. Niem (eds). 2001. FAO Species Identification Guide for Fishery Purposes, Rome: 3381-4218.

FAO Fisheries and Aquaculture Department (2007). The State of World Fisheries and Aquaculture 2006. *Food and Agriculture Organization of the United Nations, Rome*.

FAO, Fisheries Statistics-Food and Agriculture Organisation of the United Nations, http://www.fao.org, May 2014.

FAO. Code of Conduct for Responsible Fisheries. Accessed from: ftp://ftp.fao.org/docrep/fao/005/v9878e/v9878e00.pdf; 1995 [accessed October 2013].

Feidi IH. Fisheries Development in the Arab World, In: Transformations of Middle Eastern Natural Environments: Legacies and Lessons, (Eds.) Albert J, Bernhardsson M, Roger Kenna R. Marine Environments 1998; 103(4): 388–406.

Fiedler, P. C. (1983). Satellite remote sensing of the habitat of spawning anchovy in the Southern California Bight. *Calif. Coop. Ocean. Fish. Invest. Rep*, *26*, 202-209.

Fiorentino, F., Patti, B., Colloca, F., Bonanno, A., Basilone, G., Gancitano, V., ... & Mazzola, S. (2013). A comparison between acoustic and bottom trawl estimates to reconstruct the biomass trends of sardine and anchovy in the Strait of Sicily (Central Mediterranean). *Fisheries Research*, *147*, 290-295.

Fisheries Sector Strategy Note, Report 19288-YEM, World Bank, 14 June 1999.

Fox, W. W. (1974). An overview of production modeling. *Collective volume of scientific papers*, *3*, 142-156.

Freon, P., & Misund, O. A. Dynamics of pelagic fish distribution and behaviour: effects on fisheries and stock assessment. 1998.

Fréon, P., Cury, P., Shannon, L., & Roy, C. (2005). Sustainable exploitation of small pelagic fish stocks challenged by environmental and ecosystem changes: a review. *Bulletin of Marine Science*, *76*(2), 385-462.

Fu, G., Baith, K. S., and McClain, C. R. "SeaDAS: The SeaWiFS Data Analysis System", Proceedings of "The 4th Pacific Ocean Remote Sensing Conference", Qingdao, China, July 28-31, 1998. 73-79.

Gabr, H. R., Hanlon, R. T., Hanafy, M. H., & El-Etreby, S. G. (1998). Maturation, fecundity and seasonality of reproduction of two commercially valuable cuttlefish, Sepia pharaonis and S. dollfusi, in the Suez Canal. *Fisheries Research*, *36*(2), 99-115.

Ganga, U. 2011. Investigations on the biology of Indian Mackerel Rastrelliger kanagurta (Cuvier) along the Central Kerala coast with special reference to maturation, feeding and lipid dynamics.

Garcia SM, Zerbi A, Aliaume C, Do Chi T, Lasserre G. The ecosystem approach to fisheries. Issues, terminology, principles, institutional foundations, implementation and outlook. FAO Fisheries Technical paper 2003, no. 443. Rome: FAO; 2003. 71p.

George, K C (1964) Our current knowledge on the food and feeding habits of the Indian mackerel, *Rastrelliger kanagurta* (C.). In: Proceedings of the Symposium On Scombroid Fishes, Part 2, MBAI, 12-15 January 1962, Mandapam.

Gerritsen, H. &Lordan, C. Integrating vessel monitoring systems (VMS) data with daily catch data from logbooks to explore the spatial distribution of catch and effort at high resolution. ICES J. Mar. Sci. 68, 245–252 (2010).

Gladstone W, et al. Sustainable use of renewable resources and conservation in the Red Sea and Gulf of Aden: issues, needs and strategic actions. Ocean & Coastal Management 1999; 42.8: 671-697.

Goñi, R., Alvarez, F., & Adlerstein, S. (1999). Application of generalized linear modeling to catch rate analysis of Western Mediterranean fisheries: the Castellón trawl fleet as a case study. *Fisheries Research*, *42*(3), 291-302.

Gordon, H. R., and Wang, M. 1994. Retrieval of water-leaving radiance and aerosol optical thickness over the oceans with SeaWiFS: a preliminary algorithm. Appl. Opt. 33, 443-452.

Griffin, W. L., Shah, A. K., & Nance, J. M. (1997). Estimation of standardized effort in the heterogeneous Gulf of Mexico shrimp fleet. *Marine Fisheries Review*, *59*(3), 23-33.

Gulland, J. A. (1956). *On the fishing effort in English demersal fisheries*. Fish. Invest., London Ser. 2(20): 1-41.

Hall, K. C., & Fowler, A. J. (2003). Fisheries biology of the cuttlefish, Sepia apama Gray. *South Australian waters. FRDC final report. South Australian Research and Development Institute, Adelaide.*

Hariri, K. I., Nichols, P., Krupp, F., Mishrigi, S., Barrania, A., Ali, A. F., & Kedidi, S. M. (2000). Status of the living marine resources in the Red Sea and Gulf of Aden region and their management. *Strategic Action Programme for the red Sea and Gulf of Aden, final Report*, 151pp.

Hatcher, A., and Pascoe, S. 2006. Non-compliance and fisheries policy formulation. In The Knowledge Base for Fisheries Management, pp. 355–373. Ed. by L. Motos, and D. Wilson. Developments in Aquaculture and Fisheries Science, 36. Elsevier, Amsterdam.

Hauck, M. (2008). Rethinking small-scale fisheries compliance. Marine Policy, 32(4), 635-642.

Hauge, K. H., Cleeland, B., & Wilson, D. C. (2009). Fisheries Depletion and Collapse.

Herrera M, Lepere L. 2005. Revised catch estimates for tuna and tuna-like species caught by artisanal boats in Yemen. WPTT-04. Indian Ocean Tuna Commission, Victoria, Seychelles.

Hilborn, R., & Walters, C. J. (Eds.). (1992). Quantitative Fisheries Stock Assessment: Choice, Dynamics *and Uncertainty/Book and Disk*. Springer.

Hinton, M. G., & Maunder, M. N. (2004). Methods for standardizing CPUE and how to select among them. *Col. Vol. Sci. Pap. ICCAT, 56*(1), 169-177.

Hughes, T. P., Bellwood, D. R., Folke, C., Steneck, R. S., & Wilson, J. (2005). New paradigms for supporting the resilience of marine ecosystems. Trends in ecology & evolution, 20(7), 380-386.

Hunsicker, M. E., Essington, T. E., Watson, R., & Sumaila, U. R. (2010). The contribution of cephalopods to global marine fisheries: can we have our squid and eat them too?. *Fish and Fisheries*, *11*(4), 421-438.

IFAD. Fisheries investment project, Republic of Yemen. Accessed from: http://www.ifad.org/operations/projects/design/101/yemen.pdf; project final design report; 92pp; 2010 [accessed October 2013].

Ish, T., Dick, E. J., Switzer, P. V., & Mangel, M. (2004). Environment, krill and squid in the Monterey Bay: from fisheries to life histories and back again. *Deep Sea Research Part II: Topical Studies in Oceanography*, *51*(6), 849-862.

Johnson, T. R. (2009). Cooperative research and knowledge flow in the marine commons. *International Journal of the Commons*, *4*(1), 251-272.

Johnson, T. R., & van Densen, W. L. (2007). Benefits and organization of cooperative research for fisheries management. *ICES Journal of Marine Science: Journal du Conseil*, *64*(4), 834-840.

Kates, R. W., *et al.* 2001. Sustainability science. Science 292*:* 641–642.

Keyl, F., & Wolff, M. (2008). Environmental variability and fisheries: what can models do?. *Reviews in Fish Biology and Fisheries*, *18*(3), 273-299.

Kolding, J., Béné, C., & Bavinck, M. (2014). Small-scale fisheries. *Governance of Marine Fisheries and Biodiversity Conservation: Interaction and Coevolution*, 317-331.

Kurien, J., & Willmann, R. (2009). Special Considerations for Small-Scale Fisheries Management in Developing Countries. *A Fishery Manager's Guidebook, Second Edition*, 404-424.

Lablache, G. (1987). Preliminary assessment for the indian mackerel (Rastrelliger Kanagurta) in Seychelles waters.

Large, P. A. (1992). Use of a multiplicative model to estimate relative abundance from commercial CPUE data. *ICES Journal of Marine Science: Journal du Conseil*, *49*(3), 253-262.

Lasker, R. (1981). The role of a stable ocean in larval fish survival and subsequent recruitment. *Marine fish larvae: morphology, ecology and relation to fisheries*, 80-89.

Leslie, P.H. & Davis, D.H.S. (1939). An attempt to determine the absolute number of rats on a given area. Journal of Animal Ecology, 8, 94–113.

Link, J. S., Nye, J. A., & Hare, J. A. (2011). Guidelines for incorporating fish distribution shifts into a fisheries management context. *Fish and Fisheries*, *12*(4), 461-469.

Loefflad, M. R., F. R. Wallace, J. Mondragon, J. Watson, and G. A. Harrington. 2014. Strategic plan for electronic monitoring and electronic reporting in the North Pacific. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-276, 52 p.

MacCall, A. D. (1976). Density dependence of catchability coefficient in the California Pacific sardine, Sardinops sagax caerulea, purse seine fishery. *Calif. Coop. Oceanic Fish. Invest. Rep*, *18*(136.148).

Mackinson, S., U. R. Sumaila, and T. J. Pitcher. 1997. Bioeconomics and catchability: fish and fishers behaviour during stock collapse. Fish. Res. 31: 11–17.

Mackinson, S., Wilson, D. C., Galiay, P., & Deas, B. (2011). Engaging stakeholders in fisheries and marine research. Marine Policy, 35(1), 18-24.

Madhupratap, M., Shetye, S. R., Nair, K. N. V., & Sreekumaran Nair, S. R. (1994). Oil sardine and Indian mackerel: their fishery, problems and coastal oceanography. *Current Science*, *66*(5), 340-348.

Mahon, R. (1997). Does fisheries science serve the needs of managers of small stocks in developing countries. Canadian Journal of Fisheries and Aquatic Sciences, 54(9), 2207-2213.

Mahon, R., McConney, P., & Roy, R. N. (2008). Governing fisheries as complex adaptive systems. Marine Policy, 32(1), 104-112.

Maillard, C., & Soliman, G. (1986). Hydrography of the Red-Sea and exchanges with the Indian-Ocean in summer. *Oceanologica Acta, 9*(3), 249-269.

Maravelias, C. D., & Reid, D. G. (1995). Relationship between herring (Clupea harengus, L.) distribution and sea surface salinity and temperature in the northern North Sea. *Sci. Mar*, *59*(3-4), 427-438.

McCay, B. J., & Jentoft, S. (1996). From the bottom up: Participatory issues in fisheries management. Society & Natural Resources, 9(3), 237-250.

McCluskey, S. M., & Lewison, R. L. (2008). Quantifying fishing effort: a synthesis of current methods and their applications. *Fish and Fisheries*, *9*(2), 188-200.

Mendelssohn, R., & Cury, P. (1987). Fluctuations of a fortnightly abundance index of the Ivoirian coastal pelagic species and associated environmental conditions. *Canadian Journal of Fisheries and Aquatic Sciences*, *44*(2), 408-421.

Merrett, N. R., & Thorp, C. H. (1965). A revized key to the Scombroid fishes of East Africa with new observations on their biology. *Journal of Natural History, 8*(90), 367-384.

Ministry of Fish Wealth. Catch Statistics of Yemen 1990–2010. Ministry of Fish Wealth, Department of Planning and Fish Projects. Yemen; 2012.

Ministry of Fish Wealth. National Fisheries Strategy (2012–2025). Yemen; 2012.
Accessed from:
http://www.undp.org/content/dam/yemen/PovRed/Docs/Yemen_Fisheries%20Strategy.pdf ; 41pp; [accessed November 2013].

Morcos, S. A. (1970). Physical and chemical oceanography of the Red Sea. *Oceanogr. Mar. Biol. Ann. Rev*, *8*, 73-202.

Morgan G. Country Review: Yemen. In: De Young C. (Ed.) Review of the state of world marine capture fisheries management: Indian Ocean. FAO Fisheries Technical Paper. Rome, Italy, FAO. 2006; 488: 337–348.

Morgan, G. R. (2006). Subregional review: northwest Indian Ocean. Review of the State of World Marine Capture Fisheries Management: Indian Ocean. FAO Fisheries Paper, (488), 51-66.

Moussalli E, Haile T, 2001. Ex-post Evaluation of the Semhar Fisheries Rehabilitation Project ERI/92/001(UNDP) ERI/92/C01 (UNCDF) and Capacity Building for the National Marine Resources Programme ERI/94/001 (UNDP), 53 pp.

MRAG Ltd. Review of impacts of illegal, unreported and unregulated fishing on developing countries. Final report for the UK's Department for International Development (DFID) by the MRAG Ltd; 2005, 176p.

Murray, S. P., & Johns, W. (1997). Direct observations of seasonal exchange through the Bab el Mandab Strait. *Geophysical Research Letters*, *24*(21), 2557-2560.

Murray, S.P., Hecht, A. and Babcock A. (1984). On the mean flow in the Titan Strait in winter. J. Mar. Res., 42:265-287.

Nabhitabhata J, Nilaphat P (1999) Life cycle of cultured pharaoh cuttlefish, *Sepia pharaonis* Ehrenberg, 1831. Phuket Mar Biol Cent Spec Pub 19:25–40

Nair, K. P., Srinath, M., Meiyappan, M. M., Rao, K. S., Sarvesan, R., Vidyasagar, K., ... & Sathianandan, T. V. (1993). Stock assessment of the pharaoh cuttlefish Sepia pharaonis. *Indian Journal of Fisheries*, *40*(1&2), 85-94.

Neumann, A. C., & McGill, D. A. (1961). Circulation of the Red Sea in early summer. *Deep Sea Research (1953)*, *8*(3), 223-235.

Nishida, Tom, and Anthony J. Booth. "Recent approaches using GIS in the spatial analysis of fish populations." *Spatial processes and management of marine populations. Alaska Sea Grant College Program AK-86-01-02* (2001): 19-36.

OECD (2008). Fishing for coherence in West Africa: policy coherence in the fisheries sector in seven West African countries. Publications de l'OCDE.

Oktaviani, D., Supriatna, J., Erdmann, M., & Abinawanto, A. (2014). Maturity Stages of Indian Mackerel Rastrelliger kanagurta (Cuvier, 1817) In Mayalibit Bay, Raja Ampat, West Papua. *Int. J. Aqu. Sci*, 5(1), 67-76.

O'Reilly, J.E., and co-authors, 2000. Ocean color chlorophyll a algorithms for SeaWiFS, OC2, and OC4: Version 4. In: SeaWiFS Postlaunch Technical Report Series, edited by Hooker, S.B and Firestone, E.R. Volume 11, SeaWiFS Postlaunch Calibration and Validation Analyses, Part 3. NASA, Goddard Space Flight Center, Greenbelt, Maryland. 9-23.

Öztürk B. Some remarks of illegal, unreported and unregulated fishing in the Turkish part of the Black Sea. J. Black Sea/Mediterranean Environment 2013; 19.2: 256-267.

P Anderson, R., Dudík, M., Ferrier, S., Guisan, A., J Hijmans, R., Huettmann, F., ... & E Zimmermann, N. (2006). Novel methods improve prediction of species' distributions from occurrence data. *Ecography*, *29*(2), 129-151.

Palialexis, A., Georgakarakos, S., Lika, K., & Valavanis, V. D. (2009). Use of GIS, remote sensing and regression models for the identification and forecast of small pelagic fish distribution. In *Proceedings of the Second International Conference on Environmental Management, Engineering, Planning and Economics (CEMEPE 09), June* (pp. 21-26).

Panayotou, T., 1982. Management concepts for small-scale fisheries: economic and social aspects. FAO Fish. Tech. Paper 228. Rome, Italy.

Panjarat, S. (2008). Sustainable fisheries in the Andaman Sea coast of Thailand. *Division for Ocean Affairs and the Law of the Sea Office of Legal Affairs. The United Nations, New York*.

Patzert, W. C. (1974, February). Wind-induced reversal in Red Sea circulation. In *Deep Sea Research and Oceanographic Abstracts* (Vol. 21, No. 2, pp. 109-121). Elsevier.

Payne, A. G., Agnew, D. J., & Pierce, G. J. (2006). Trends and assessment of cephalopod fisheries. *Fisheries Research*, *78*(1), 1-3.

Peck, M. A., & Hufnagl, M. (2012). Can IBMs tell us why most larvae die in the sea? Model sensitivities and scenarios reveal research needs. *Journal of Marine Systems*, *93*, 77-93.

Peck, M. A., Huebert, K. B., & Llopiz, J. K. (2012). Intrinsic and Extrinsic Factors Driving Match-Mismatch Dynamics During the Early Life History of Marine Fishes. *Advances in Ecological Research*, *47*, 177.

PERSGA. Sea Cucumber Fisheries of Yemen. Status and Recommendations. 2009, 132p.

Piatkowski, U., Pierce, G. J., & Morais da Cunha, M. (2001). Impact of cephalopods in the food chain and their interaction with the environment and fisheries: an overview. *Fisheries Research*, *52*(1), 5-10.

Pierce, G. J., & Guerra, A. (1994). Stock assessment methods used for cephalopod fisheries. *Fisheries Research*, *21*(1), 255-285.

Pierce, G. J., Valavanis, V. D., Guerra, A., Jereb, P., Orsi-Relini, L., Bellido, J. M., ... & Zuur, A. F. (2008). A review of cephalopod—environment interactions in European Seas. In *Essential Fish Habitat Mapping in the Mediterranean* (pp. 49-70). Springer Netherlands.

Pomeroy, R. S., & Andrew, N. (Eds.). (2011). *Small-scale fisheries management: frameworks and approaches for the developing world*. Cabi.

Pramod G, et al. Sources of information supporting estimates of unreported fishery catches (IUU) for 59 countries and the high seas; Fisheries Centre, University of British Colombia, Canada, 2008.

Qasem A., Ahmed FM. Social and economic conditions for fishermen in Yemen, 2007, Accessed from: http://www.yemen-nic.info/upload/iblock/fb3b6250387406fce4f2aee8339e6808.pdf; 97pp; [accessed December 2013].

Raakjær Nielsen, J. (2003). An analytical framework for studying: compliance and legitimacy in fisheries management. Marine Policy, 27(5), 425-432.

Raitsos, D. E., Pradhan, Y., Brewin, R. J., Stenchikov, G., & Hoteit, I. (2013). Remote sensing the phytoplankton seasonal succession of the Red Sea. *PloS one*, *8*(6), e64909.

Ralston, D. K., Jiang, H., & Farrar, J. T. (2013). Waves in the Red Sea: response to monsoonal and mountain gap winds. *Continental Shelf Research*, *65*, 1-13.

Rao, K. V. (1962). Food of the Indian mackerel, Rastrelliger kanagurta (Cuvier) taken by drift-nets in the Arabian Sea off Vizhingam, south Kerala. *Indian Journal of Fisheries*, *9*(2), 530-541.

Rao, K. Virabhadra. 1962. Distribution of the young stages of the mackerel, *Rastrelliger kanagurta* (Cuvier) in the Indian inshore waters. *Proc. Symp. Scombroid Fishes* , part 1: 469 – 482.

Republic of Yemen, Program Note, International Monetary Fund. 2012. Accessed from: https://www.imf.org/external/np/country/notes/pdf/yemen.pdf; 2pp; [accessed December 2013].

Richardson, A. J., Mitchell-Innes, B. A., Fowler, J. L., Bloomer, S. F., Verheye, H. M., Field, J. G., ... & Painting, S. J. (1998). The effect of sea temperature and food availability on the spawning success of Cape anchovy Engraulis capensis in the southern Benguela. *South African Journal of Marine Science*, *19*(1), 275-290.

Rocha, F., Guerra, A., & Gonzalez, A. F. (2001). A review of reproductive strategies in cephalopods. *Biological Reviews of the Cambridge Philosophical Society*, *76*(03), 291-304.

Rodhouse, P. G. (2001). Managing and forecasting squid fisheries in variable environments. *Fisheries Research*, *54*(1), 3-8.

Rodhouse, P. G. et al. (2014). Environmental effects on cephalopod population dynamics: implications for management of fisheries. *Advances in Cephalopod Science: Biology, Ecology, Cultivation and Fisheries*, 99.

Rodhouse, P. G., Pierce, G. J., Nichols, O. C., Sauer, W. H., Arkhipkin, A. I., Laptikhovsky, V. V., ... & Downey, N. (2014). Environmental effects on cephalopod population dynamics: implications for management of fisheries. *Advances in Cephalopod Science: Biology, Ecology, Cultivation and Fisheries*, 99.

Ruddle, K., & Hickey, F. R. (2008). Accounting for the mismanagement of tropical nearshore fisheries. Environment, Development and Sustainability, 10(5), 565-589.

Rudershausen, P. J., Mitchell, W. A., Buckel, J. A., Williams, E. H., & Hazen, E. (2010). Developing a two-step fishery-independent design to estimate the relative abundance of deepwater reef fish: Application to a marine protected area off the southeastern United States coast. *Fisheries Research*, *105*(3), 254-260.

Saitoh, S. I., Mugo, R., Radiarta, I. N., Asaga, S., Takahashi, F., Hirawake, T., ... & Shima, S. (2011). Some operational uses of satellite remote sensing and marine GIS for sustainable fisheries and aquaculture. *ICES Journal of Marine Science: Journal du Conseil*, *68*(4), 687-695.

Sanders, M. J. (1981). Revised stock assessment for the cuttlefish Sepia pharaonis taken of the coast of PDR of Yemen. FAO, Tech. pap. RAB 77/008, pp. 43.

Sanders, M. J., & Bouhlel, M. B. (1981). Project for development of fisheries in areas of the Red Sea and Gulf of Aden. Interim report of a mesh selection study conducted in the People's Democratic Republic of Yemen on the cuttlefish Sepia pharaonis.

Sanders, M. J., & Morgan, G. R. (1989). *Review of the fisheries resources of the Red Sea and Gulf of Aden* (No. 304). Food & Agriculture Org.

Santos, A. M. P. (2000). Fisheries oceanography using satellite and airborne remote sensing methods: a review. *Fisheries Research*, *49*(1), 1-20.

Schön, P. J., Sauer, W. H. H., & Roberts, M. J. (2002). Environmental influences on spawning aggregations and jig catches of chokka squid Loligo vulgaris reynaudii: A? black box? approach. *Bulletin of marine science*, *71*(2), 783-800.

Setlur,Banu. 2013. Yemen, Republic of - fisheries resource management and conservation: P086886 - implementation status results report: Sequence 17. Washington, DC: World Bank. http://documents.worldbank.org/curated/en/2013/10/18420270/yemen-republic-fisheries-resource-management-conservation-p086886-implementation-status-results-report-sequence-17

Shaher S. Biology and status of shark fishery in Yemen. IOTC-2008-WPEB-05; 2007.

Shettle, E. P., and R. W. Fenn. 1979. Models for the Aerosols for the Lower Atmosphere and the Effects of Humidity Variations on Their Optical Properties. AFGL-TR-79-0214 Environmental Research Papers No. 676.

SMEPS and KIT. Analysis of 5 value chains in Yemen (Fish, Honey, Coffee, Wheat and Qat), Report for the World Bank, 2009.

Sofianos, S. S., & Johns, W. E. (2002). An oceanic general circulation model (OGCM) investigation of the Red Sea circulation, 1. Exchange between the Red Sea and the Indian Ocean. *Journal of Geophysical Research: Oceans (1978–2012)*, *107*(C11), 17-1.

Sofianos, S. S., & Johns, W. E. (2003). An oceanic general circulation model (OGCM) investigation of the Red Sea circulation: 2. Three-dimensional circulation in the Red Sea. *Journal of Geophysical Research: Oceans (1978–2012)*, *108*(C3).

Souvermezoglou, E., Metzl, N., & Poisson, A. (1989). Red Sea budgets of salinity, nutrients and carbon calculated in the Strait of Bab-El-Mandab during the summer and winter seasons. *Journal of Marine Research*, *47*(2), 441-456.

Stefánsson, G. (1996). Analysis of groundfish survey abundance data: combining the GLM and delta approaches. *ICES Journal of Marine Science: Journal du Conseil*, *53*(3), 577-588.

Sundström A. Corruption and regulatory compliance: Experimental findings from South African small-scale fisheries. Marine Policy 2012; 36.6: 1255-1264.

Svendrup-Jensen, S. (1999). Policy issues deriving from the impact of fisheries on food security and the environment in developing countries. In *ICLARM Conference Proceedings (Philippines)*.

Tesfagiorgis GM. Eritrea (Africa in Focus), 2010, ABC-CLIO, 424p.

Tesfamichael D, Pitcher TJ, Pauly D. Assessing Changes in Fisheries Using Fishers' Knowledge to Generate Long Time Series of Catch Rates: a Case Study from the Red Sea. Ecology and Society 2014; 19(1): 18.

Tesfamichael D. Assessment of the Red Sea ecosystem with emphasis on fisheries, 2012, 241pp, PhD thesis, the University of British Columbia, Vancouver, Canada.

Tim Lauck, Colin W. Clark, Marc Mangel, and Gordon R. Munro 1998. Implementing the precautionary principle in fisheries management through marine reserves. Ecological Applications 8:S72–S78. http://dx.doi.org/10.1890/1051-0761(1998)8[S72:ITPPIF]2.0.CO;2

Ulltang, O. 1976. Catch per unit of effort in the Norwegian purse seine fishery for Atlanto-scandian (Norwegian spring spawning) herring. FAO Series, FIRS/T155: 91–101.

UNDP, Human Development Report. 2013. Accessed from: http://hdr.undp.org/sites/default/files/reports/14/hdr2013_en_complete.pdf; 202pp; [accessed November 2013].

Van der Lingen, C. D. (2002). Diet of sardine Sardinops sagax in the southern Benguela upwelling ecosystem. *South African Journal of Marine Science*, *24*(1), 301-316.

Wagenaar A, D'Haese M. Development of small-scale fisheries in Yemen: An exploration. Marine Policy 2007; 31.3: 266-275.

Wang, J., Pierce, G. J., Boyle, P. R., Denis, V., Robin, J. P., & Bellido, J. M. (2003). Spatial and temporal patterns of cuttlefish (Sepia officinalis) abundance and environmental influences– a case study using trawl fishery data in French Atlantic coastal, English Channel, and adjacent waters. *ICES Journal of Marine Science: Journal du Conseil*, *60*(5), 1149-1158.

Witt, M. J., & Godley, B. J. (2007). A step towards seascape scale conservation: using vessel monitoring systems (VMS) to map fishing activity. *PloS one*, *2*(10), e1111.

World Bank. 2012. Yemen - Joint social and economic assessment for the Republic of Yemen. Vol. 1 of Yemen - Joint social and economic assessment for the Republic of Yemen. Washington, DC: World Bank. Accessed from: http://documents.worldbank.org/curated/en/2012/08/17060779/yemen-joint-social-economic-assessment-republic-yemen-vol-1-2; 199pp; [accessed October 2013].

World Development Indicators. December 2013. Accessed from: http://knoema.com/WBWDIGDF2013Dec/world-development-indicators-wdi-december-2013; [accessed November 2013]

Wyrtki, K. (1971). Oceanographic atlas of the international Indian Ocean expedition.
Yemen Fisheries Support Programme (YFSP). Yemen; 2010. Accessed from: http://ec.europa.eu/europeaid/documents/aap/2010/af_aap_2010_yem.pdf; 24pp; [accessed November 2013].

Yohannan, T. M. and Nair, P. N. R. 2002. Status of exploitation of mackerel occurring in the Indian seas. Proceedings of the National Workshop on Scombroids, Kochi, 19-20th September 2000.