DATA-POOR FISHERIES: CASE STUDIES FROM THE SOUTHERN MEDITERRANEAN AND THE ARABIAN PENINSULA

by

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Abstract

Considerable gaps of knowledge regarding the state of the marine fisheries occur in most economically developing countries despite the importance of fisheries as a source of food security and livelihood for their inhabitants. Global studies in fisheries science have often disregarded the data-poor fisheries in economically developing countries due to a combination of factors including the high cost and data requirements of classical stock assessments. However, other methods, less costly and equally reliable, such as the catch reconstruction approach combined with catch-based indicators and the most recent 'CMSY' stock assessment method have been developed to help assess the state of marine living resources. The countries of the Southern Mediterranean and the Arabian Peninsula (SMAP) are examples of where marine fisheries are not as well assessed as in other regions, aggravated by the frequency of political and socio-economic instability, the latest being the so-called "Arab Spring", which has deeply impacted the regions. The "catch reconstruction" method, which improves official catch statistics, is applied here to re-estimate marine fisheries catches for the SMAP for 1950-2015 and to reconstruct a century of Mediterranean marine fisheries catches for Egypt (i.e., 1917-2017) to which two catch-based indicators, i.e., the Marine Trophic Index and the Mean Temperature of Catch were also applied. In the third part of this thesis the CMSY method is used to assess several commercially important fish stocks of the SMAP to provide decision makers with alternative policy options for better fisheries management and more effective marine conservation strategies.

Lay Summary

Often, studies in the field of fisheries sciences that claim to inform on the state of world marine fisheries exclude those in economically developing countries. This is due to a combination of factors, but mainly because in order to study a fishery using mainstream methods one would need extensive amounts of hard-to-acquire data that economically developing countries cannot afford to obtain. In this study the health of fisheries of countries of the Southern Mediterranean and the Arabian Peninsula is evaluated using newly developed methods that are based on the quantity and species composition of fish caught in every country. Such information is relatively easy to obtain and is here improved for the time period of 1950-2015. The same is applied to the Mediterranean Egyptian fisheries but for the time period of 1917-2017. Finally, the health of the fisheries for 10 fish species is evaluated using a new method called CMSY.

Preface

I am the sole author of all chapters of this thesis. I completed the research contained in all of its chapters, including the design, data collection, and analysis.

Dr. Daniel Pauly, Dr. U. Rashid Sumaila, Dr. Eddie Allison and Dr. Philippe Le Billon contributed with their expertise and advice with ideas, methods and data interpretation. Except for the conclusion, all of the chapters will be submitted for publication.

The work completed for the country of Oman part of Chapter 2 has been published in Khalfallah, M., Zylich, K., Zeller, D. and Pauly, D. 2016. Reconstruction of Domestic Marine Fisheries Catches for Oman (1950-2015). *Frontiers in Marine Science* 3(152): 11.
I conducted the data collection and most of the analysis of the data and the writing of the manuscript. The co-authors helped with some of the data analysis and editing of the manuscript.

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List of Abbreviations

CAPMAS – Central Agency for Public Mobilization And Statistics

CIESN – The Center for International Earth Science Information Network

CPUE – Catch per unit of effort

EEZ – Exclusive Economic Zone

EU – European Union

FAO – Food and Agricultural Organization of the United Nations

GAFRD – General Authority for Fish Resources Development

GDP – Gross Domestic Product

MTC – Mean Temperature of Catch

MTI – Marine Trophic Index

n.e.i –FAO's term for taxa 'not elsewhere identified'

NIOF – National Institute for Oceanography & Fisheries

SMAP – Southern Mediterranean and Arabian Peninsula

UN – United Nations

UNCLOS – United Nations Convention on the Law of the Sea

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Finally, I would like to thank those who were at the origin of it all, my beloved grandmothers, Khadouja Nacef and Hadhemi Aycha Bel-Haj Kacem, and my dear grandfathers, who no longer walk this earth, Mohamed Khalfallah and Mohamed Bechir Bouzaiane.

To my parents, Majed and Nejiba,

To my grandmothers, Khadouja and Hadhemi,

To my grandfathers, Mohamed Bechir and Mohamed,

Chapter 1: Introduction

Synopsis: In this chapter, I introduce the theoretical framework of this thesis as well as the geographic area on which this work focuses. I also briefly present the other chapters of this thesis.

Many of the contemporary issues[1] confronting policy makers and the public are global in nature, even when they are differently affecting various parts of the globe and the people living therein. This has led to a rise in the worldwide demand for global solutions, and to the emergence of 'global studies' as a field attempting to address these global issues[1]. Global studies emerged gradually as a result of globalisation, and its characteristics as a field have been debated over the years, e.g., Riggs (2004), Nederveen Pieterse (2013), Misco (2013), Juergensmeyer (2013), and Steger (2013).

We define here global studies on the basis of 5 criteria (or characteristics) agreed upon by the International Global Studies Consortium of Tokyo in 2008 (Juergensmeyer 2014). These criteria stipulate that global studies are:

- Transnational: Issues tackled by global studies should not be bound to a certain culture, region or nation but exist across national boundaries and cultures;
- Interdisciplinary: Different disciplines, e.g., economics, politics, sciences, etc., are necessary to study and analyze a global issue;

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[1] United Nations (Online) 'Global Issues Overview' available at https://www.un.org/en/sections/issues-depth/global-issues-overview/ [accessed on 20-01-2020]

- Contemporary and Historical : Studying historical patterns of a global issue is essential to identify and analyze the present and future ones;
- Critical and Multicultural: Global Studies are not global if they are Eurocentric or Western-centric, and should rather account for the different perspectives of different cultures (when applicable) and give equal representation to the different regions when examining an issue;
- Globally Responsible: According to this additional criterion researchers in global studies should aim to help solve global issues and be 'global citizens'.

Fisheries scientists can meet the aforementioned criteria, and thus perform global studies, e.g., Allison (2001); Allison and Ellis (2001); Pauly *et al.* (2005); Dyck and Sumaila (2010); Sumaila *et al.* (2010); Sumaila *et al.* (2011); Sommerville *et al.* (2014); McClanahan *et al.* (2015); Tai *et al.* 2017); Sumaila *et al.* (2020) . Among other things, marine ecosystems are all connected and form one global ocean; thus, various threats in a part of the ocean can have negative consequences for the other parts. This makes most issues in marine fisheries potentially global in nature (Pauly et al. 2015).

The industrialization of fisheries, i.e., the first deployment of large vessels relying on fossil energy, began for many of the world's countries after the Second World War (Platteau 1989; Pauly *et al.* 2002; Anticamara *et al.* 2011; Watson *et al.* 2013; Sumaila *et al.* 2016). This has allowed the spread of industrial fishing activities from coastal waters to the fish refuges of deep seas, and from economically developed countries[2] (mostly in the northern hemisphere) to the waters of economically developing countries[1] (Pauly *et al.* 2005; Swartz *et al.* 2010).

Signs of overfishing were hidden by the capacity of economically developed countries to compensate for the missing fish by increasing their fishing effort, fishing in previously less exploited or unexploited waters, e.g., waters nearby economically poorer developing countries, or importing fish from economically developing countries (Pauly *et al.* 2005; Sumaila and Tipping 2016). In the early 1970s, one of the most important fisheries in the world at that time, i.e., the Peruvian anchoveta, collapsed (Muck 1989; Watson and Pauly 2001). The number of collapsing major fish stocks has since only increased (Pauly *et al.* 2005; Froese *et al.* 2012), e.g., the Atlantic cod fishery (Walters and Maguire 1996). By the late 1980s, it was no longer possible to compensate for the missing fish by moving further and deeper into the ocean (Pauly *et al.* 2005; Worm *et al.* 2009), yet, world fisheries catches seemed to continue to increase as reported by the Food and Agriculture Organization of the United Nations (FAO), i.e., the only institution monitoring official global fisheries statistics (Froese *et al.* 2012; Pauly and Zeller 2016a).

However, Watson and Pauly (2001) discovered that this apparent increase in yield was due to the over-reporting of catches by China. This over-reporting was so strong that when corrected, the

[2] Other more updated countries classifications now exist but in this work the economically developing/developed countries categorization will be used (See report by the United Nations www.un.org/en/development/desa/policy/wesp/wesp_current/2014wesp_country_classification.pdf). It should be noted that the World Bank does not use this classification when presenting its data (see https://datahelpdesk.worldbank.org/knowledgebase/articles/906519)

trend of global fisheries catches turned out to be decreasing, confirming the suspicion that fish stocks are being depleted all over the world (Watson *et al.* 2001; Watson and Pauly 2001; Watson *et al.* 2013; Pauly and Zeller 2016a). This discovery, subsequently confirmed by 'catch reconstructions' for all of the world's maritime countries (Pauly and Zeller 2016a, 2016b), has led to a global concern for the situation of marine living resources and an increasing interest in improving fisheries management worldwide, e.g. Sustainable Development Goal 14 (Life Below Water). Despite their efforts, most countries and particularly the economically developing parts of the world seem unable to effectively manage their fisheries as a result of a combination of factors, which are discussed further in this contribution (Platteau 1989; Ascher 1999; Pauly 2010; Al-Abdulrazzak and Pauly 2013).

Meanwhile, approaches applied to examine global fisheries can be summarized in mainly 3 types as per Pauly *et al.* (2015):

1) Census-like studies: These studies are based on standardized information applicable to all countries around the world, such as those performed by the United Nations (UN) and its 'technical organizations', such as the FAO. For instance, the FAO has made catch data available annually for every maritime country around the world since 1950, making them the only easily accessible information in relation to world fisheries (see Garibaldi 2012, and Pauly *et al.* 2013);

2) Model-based studies: Here, spatial models are parametrized with local data sets, which are then extrapolated to the entire ocean;

3) Sample-based studies: These consist in studies based on samples that are geographically representative and allow imputation or extrapolation to the entire ocean components. Sample-

based studies or ‘case studies’ have often represented the most commonly used methodology to examine global marine fisheries.

Each of these approaches has advantages and disadvantages. Thus, (1) has the disadvantage that if the countries submit data that are biased in similar ways, the overall result will be biased as well. I will show in Chapter 2 and Chapter 3 that this biasing effect is very strong with fisheries catch data submitted to the FAO by its member countries. With (2), bias can occur if the major part of the datasets used to parametrize the models are derived for a region that is not representative of the global ocean as a whole. Obviously, this can be countered by increasing the weight, within a model, of data from outlying regions. However, this approach is not further discussed here. The approach in (3), based on sample or better ‘case studies’ is the one most commonly used in fisheries, and the one where gross errors most frequently occur. A case in point is a major paper in fisheries science titled ’Rebuilding Global Fisheries’ that used this approach and wherein half of the oceans, mostly within economically developing countries, were represented by only 7 case studies, while the remaining half, mostly in western countries, were represented by 59 case studies (Figure 1).

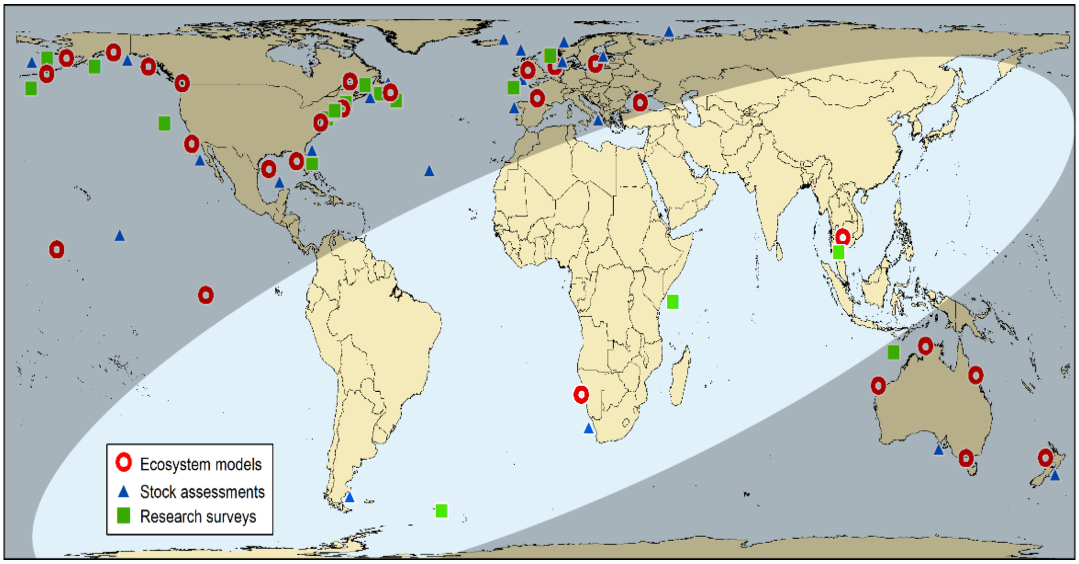


Figure 1. The illustrated geographic bias in the paper 'Rebuilding global fisheries' by Worm et al. (2009) (figure from Pauly et al. (2015), reproduced with permission).

Another case was pointed out in the recently published paper on global recreational fisheries by Freire *et al.* (2020), which, based on a census-based study of 125 countries, estimated the world's current marine recreational catch at 0.9 million tonnes per year, while a previous 'study' had proposed a catch of 10.9 million tonnes per year based on an extrapolation from one country: Canada (see Cooke and Cowx (2004)).

Numerous factors have contributed to the 'non-global' aspect of most fisheries studies meant to be global, and this is related to the existence of data-poor fisheries in most economically developing countries, as will be elaborated in the next section.

1.1 Data-poor fisheries

Fisheries are often categorized by fisheries scientists and managers in two main groups: data-rich fisheries, and data-poor fisheries. Numerous studies have attempted to find solutions to improve the management of the data-poor fisheries, e.g., Pilling et al. (2008); Dowling et al. (2015); Froese et al. (2017); Zhou et al. (2017); Gill et al. (2019), and debates have emerged from these studies regarding methods and indicators that could help better inform on and manage 'data–poor fisheries', e.g., see Branch et al. (2011), Pauly et al. (2013a), and Geromont and Butterworth (2014). It seems, however, that the fundamental issue behind these debates and disagreements is caused by the assumption that data-poor fisheries have the same characteristics and occur within similar contexts everywhere, which is not really the case.

Data-poor fisheries in economically developed countries are quite different from data-poor fisheries in economically developing countries. Data-poor fisheries in economically developed countries are data-poor relatively to data-rich fisheries within these same countries or regions, but are often data-rich compared to data-poor fisheries in economically developing countries. Indeed, they are usually classified as data-poor only because they lack formal stock assessments and information on fisheries reference points, as pointed out by Pilling et al. (2008), Smith et al. (2009) and Geromont and Butterworth (2014). However, often such fisheries have some other information such as catch per unit of effort (CPUE), fishing effort, biological data, etc., that is still informative on the state of the fishery, and that most data-poor fisheries in economically developing countries usually do not have, even for major fisheries and stocks (Pauly *et al.* 2013).

Therefore many studies that claim to provide solutions for data-poor fisheries provide in fact solutions for data-poor fisheries in data-rich regions and countries, and hence, these solutions cannot for the most part be applied for 'data-poorer' fisheries.

Here, we define data-poor fisheries in the context of economically developing countries where information as basic as CPUE and species disaggregation of catch is scarce or unavailable. Thus, while data-poor fisheries in economically developed countries are usually limited to those exploiting species of little commercial value (Dowling *et al.* 2015), this is not the case in economically developing countries, where most (if not all) fisheries are data-poor (Pauly *et al.* 2013).

The main factors that contribute to the scarcity of data for data-poor fisheries within economically developing countries are:

i. The artisanal and rural nature of most fisheries and the difficulty to monitor them: Most fisheries within the economically developing countries are small-scale (Allison and Ellis 2001; Chuenpagdee *et al.* 2006; Pomeroy and Andrew 2011; Pauly and Zeller 2016b). These small-scale fisheries are often community-dependent, multi-gear, multi-species, and geographically spread along coastal regions, making it difficult to properly monitor them (Béné 2006). These artisanal fisheries are often socio-rural in nature and are very rooted in the everyday life of the local communities (Panayotou 1982; Allison and Ellis 2001; Mahon *et al.* 2008). Family members sometimes take part in the different fishing activities, including pre- and post-harvest tasks. Landing and processing sites in many economically developing countries are not limited to the official ports and could be anywhere along the coast (Alder and Sumaila 2004; Weeratunge *et al.* 2010). Fishing in many economically developing countries is practiced as a part-time job or as an opportunistic livelihood activity when regular preferred sources of income are temporarily or permanently unavailable (Pauly 1997; Allison and Ellis 2001). Commonly, people involved in such fishing activities likely do not possess fishing licenses (Pomeroy and Andrew 2011). Many of them do not even consider themselves as fishers, and therefore, do not acknowledge their activities as fishing (even when asked), as the author observed during field work in Tunisia.

ii. Absence or rarity of formal stock assessments: Stock assessments are the formal process leading to the estimation of the absolute fish stocks biomass exploited by fisheries. Stock assessments are probably the best indicator of the state of marine resources, and usually form the basis of fisheries policies (Mahon 1997; Pauly *et al.* 2002; Kleisner *et al.* 2013). Indicators based on stock assessments require intensive data of which the collection and analysis are rather very costly. The most economically developed and wealthiest countries have the resources and tools to base their fisheries management and decision making on fisheries stock assessments. This is not the case for most economically developing countries (Pomeroy and Andrew 2011; Costello *et al.* 2012; Pauly *et al.* 2013). Furthermore, due to their high cost, when stock assessments are carried out, they focus only on species targeted by industrial fisheries, e.g., through trawl surveys (Mahon 1997; Schuhbauer *et al.* 2017). Management decisions for a whole fishing industry including for the artisanal fisheries are then mostly based on assessments performed for industrial fisheries.

iii. Small scientific research output in fisheries sciences from economically developing countries compared to economically developed countries: Despite the recent increase in scientific publications in the field of fisheries sciences originating from economically developing countries, there is still a large difference between the research output in these countries relatively to economically developed countries (Jarić *et al.* 2012; Aksnes and Browman 2015). The lack of financial resources generally, and specifically of scientific research funding is deemed as one of the main factors behind this situation. According to Annan (2003) less than 1% of the Gross Domestic Product (GDP) is spent by economically developing countries on scientific research, compared to 2-3% in economically developed countries. Also, governmental investment in science in economically developing countries is strongly influenced by political, economic and/or societal instability. Scientific research in general is often financially deprioritized by governments when turmoil occurs given that other more urgent matters such as people's safety and food security require attention (Pauly 2001). In some dictatorships within economically developing countries scientific research could put the safety of scientists in jeopardy, hence limiting scientific research, e.g., the recent arrest of environmental scientists in Iran for 'collaborating' with the United States (Cunningham 2019; Cunningham and Guarino 2019).

When scientific funding opportunities are presented by economically more developed countries, they are often designed such as to provide solutions to issues from a western, sometimes neo-colonial, perspective (Bailey *et al.* 1986; Costello and Zumla 2000; Dahdouh-Guebas *et al.* 2003). Researchers and/or research centres from foreign countries sometimes monopolize the scientific research of a certain field within countries that their home countries previously colonized. In these research centres, it is then difficult for any research that is not linked to the former colonizer to take place. This scientific neo-colonialism to whom I was myself witness has been frequent in several African countries like Tunisia (Boshoff 2009; Durokifa and Ijeoma 2018). When students from economically developing countries leave to study abroad, they are often trained to work on data-rich regions, using high-end costly methods (Mahon 1997; Pauly 1997). Then, if and when they return to their home country, they find themselves unable to apply what they learnt abroad given the lack of financial resources and different socio-economic context (of the fisheries or other sectors).

Finally, another key factor that contributes to the relatively smaller scientific research output in economically developing countries consists in the inability of scientists within these countries to access scientific papers and to publish in international peer-reviewed journals due to their high cost and sometimes to language barriers (Gibbs 1995; Salager-Meyer 2008; Lillis and Curry 2010; Burton 2011). As a result scientists including fisheries scientists often publish in their own language and their publications remain inaccessible to the international scientific community. The phenomena of predatory journals, i.e., a fake academic publishing business that charges low fee for quick publication without peer review, was born from the demand for affordable journals (Xia *et al.* 2015; Demir 2018). Many scientifically valid articles with useful fisheries data on the data-poor fisheries of economically developing countries are published in these predatory journals (some of which were used as reference in Chapter 4). Other than the inability to properly publish, most scientists from economically developing countries are unable to access the scientific literature given that their institutions often cannot afford the high cost of accessing articles (Gibbs 1995; Burton 2011). The inability to access scientific literature has been a real struggle for many, including myself when I was a student in Tunisia, which put limits to the scientific research. Open access journals that have been growing in numbers in the past years have helped resolve this issue (Björk *et al.* 2010; Matheka *et al.* 2014).

As a result of the above-mentioned factors which have to lack data, fisheries in economically developing countries are often truly data-poor. In the absence of data, many approaches are somewhat developed by fisheries managers and policy makers, such as attempting to regulate fisheries following observation-based or even random decisions, e.g., seasonal closures for certain species and/or areas, arbitrary quota, etc. (Eggert and Greaker 2009). Sometimes, a certain passive behaviour develops towards finding alternative more affordable methods to fisheries management (Carbonetti *et al.* 2014). Also, most fisheries decision makers around the economically developing world tend to follow a top-down approach to policy making that excludes stakeholders of community-based fisheries and focuses on large-scale fisheries and assessed fish stocks, if there are any (Béné 2006; Alabsi and Komatsu 2014). Often, fisheries strategies are abstract, difficult to apply or even out of touch with the real issues facing small-scale fisheries. This leads to low or no compliance of the stakeholders with the fisheries local laws and regulations, and thus to an increase in illegal, unreported and unregulated fishing activities (Hatcher and Pascoe 2006). As a result, over 80% of world fisheries are unassessed because they mostly occur in economically developing countries (Costello *et al.* 2012).

Alternative indicators to formal stock assessment, which may be somewhat less informative than the classical methods of stock assessment, but far less demanding in terms of data, have been developed and offer a way to evaluate the state of marine resources at local, regional, and global levels. Some of these indicators are based on fisheries catch data, which can be found in most countries (Froese *et al.* 2012; Kleisner *et al.* 2013). In 1950, the FAO started issuing annual compendia of world fisheries catches, the FAO 'Yearbook of Fisheries Statistics'. Since then, each country has been submitting annually its national fisheries statistics to the FAO. The FAO fisheries catch database is available publicly for all fishing world countries and has been the only source of information on global fisheries catches (Froese *et al.* 2012; Pauly and Zeller 2016a).

As important as this data is, it is somewhat incomplete. Most countries around the world collate only commercial landings, excluding other non-commercial and non-reported commercial fisheries catches that tend to be high in economically developing countries, as well as discards. The FAO explicitly requires countries to not submit information on discards and usually does not separate small-scale fisheries catches from large-scale ones (Pauly and Zeller 2016a). In addition to the factors explained above, this makes catch data from economically developing countries particularly inaccurate. Yet, catch data remains the most affordable and easily accessible fisheries data, not only for economically developing countries, but for all the world's maritime countries (Pauly *et al.* 2013).

The catch reconstruction approach, which will be defined in Chapter 2, is a tentative way to improve historical and current fisheries catch data, by taking into account all fisheries sectors and by improving the taxonomic disaggregation of catch. When reconstructed, catch data are used to derive catch-based indicators and are then used in conjunction with a recently developed method ('CMSY'), improved from an earlier method called "Catch-MSY" (Froese *et al.* 2017). This contribution aims to fill some of the knowledge gaps for a selected group of data-poor fisheries in economically developed countries, the Southern Mediterranean and the Arabian Peninsula (SMAP).

1.2 'The Southern Mediterranean and the Arabian Peninsula' context

The Southern Mediterranean and the Arabian Peninsula (SMAP) region stretches from the strait of Gibraltar in the west to the Persian Gulf in the East, and from the Mediterranean Sea in the North to the Sahara in the southwest and the Indian Ocean in the southeast (Figure 2). Seventeen coastal countries constitute the SMAP: Morocco (Mediterranean coast), Algeria, Tunisia, Libya, Egypt, Jordan, Palestine, Lebanon, Syria, Iraq, Kuwait, Saudi Arabia, Bahrain, Qatar, United Arab Emirates (UAE), Oman, and Yemen.

Figure 2. The 17 countries of the 'Southern Mediterranean and the Arabian Peninsula' regions (SMAP), and their Exclusive Economic Zones (EEZs).

The selection of these countries was based on the following criteria:

- All of these countries are Arabic speaking and share somewhat similar socio-economic, cultural and political aspects. Israel is not included in this study given that its fisheries are not as data-poor as other Southern Mediterranean fisheries and that it is historically and geo-politically different from neighboring regions, beside not having Arabic as a main language;
- Only countries of the Southern Mediterranean and the Arabian Peninsula and their EEZs that are part of the areas 37 and 51 are incorporated. Hence, Egypt is a Southern Mediterranean country and its non-Mediterranean EEZ, which is in the Red Sea and is part of the area 51, is included. In contrast, the Atlantic EEZ of the Southern Mediterranean country Morocco is not accounted for in this study given that it is neither part of the areas 37 nor 51.

The SMAP countries share a great deal of common history, culture and traditions. They are surrounded by three large marine ecosystems (LME), i.e., the Mediterranean Sea, the Red Sea, and the Arabian Sea (www.seararoundus.org). The information on the population, area, Economic Exclusive Zone (EEZ) [3], and continental shelf are summarized for each of the SMAP countries in Appendix A.

Although most Southern Mediterranean countries rely to a certain extend on their fishing industry (Papaconstantinou and Farrugio 2000; Lleonart and Maynou 2003; Franquesa R. *et al.* 2008), most countries of the Persian Gulf depend on petroleum rather than on fishing (Metz 1993). During the first half of the 20th century, the oil industry flourished in the Arabian countries of the Persian Gulf, which previously depended exclusively on trade and fishing (Metz 1993; Feidi 1997). Inasmuch as petroleum is not a renewable resource, the fishing industry in these countries could regain its economic importance once the oil and gas resources are exhausted. This is already the case in some countries such as Oman, whose government is investing in fisheries as an economic alternative to petroleum (Hayes 2013; Khalfallah *et al.* 2015).

The countries of the SMAP regions have been subject to all sorts of political, societal and economic turmoil, at least since the 1950s; the most recent being the so-called "Arab spring" that

[3] The United Nations Convention on the Law of the Sea (UNCLOS) defined in 1982 the EEZ (www.un.org). Some countries claimed officially their EEZ according to this convention, while others did not, especially in case of disputed areas. The way EEZ were assigned in the catch reconstructions is outlined in Chapter 2 of this thesis.

took place in 2011 involving several countries of the SMAP. The latter, combined with the threats global oceans are currently facing, are likely to have strong impacts on fish stocks (Hendrix and Glaser 2011; McClanahan *et al.* 2015; Belhabib *et al.* 2018; Belhabib *et al.* 2019) . The SMAP is predicted to be one of the regions most affected by climate change in the world (Lelieveld *et al.* 2016; Waha *et al.* 2017).

The Arab Knowledge Report emphasizes this issue of Gap of Knowledge in the countries of the SMAP regions (Bilawi *et al.* 2014), which also extends to the fisheries, this report is part of the Arab Human Development Reports (AHDR) (www.arab-hdr.org), provided by the United Nations Development Programme, according to which, the Knowledge Index[4] (KI) indicated a bad performance by the so-called "Arab countries" compared to most regions of the world (www.WorldBank.org). According to this report, the average number of scientific research articles produced in the "Arab countries" is about 41 scientific research papers for every million people; a great difference when compared with a world average of 147. While the global average of GDP spent on research and development is 2.13% in 2012, "Arab countries" spent only between 0.03% and 0.7% on research and development (Bilawi *et al.* 2014). In most of the so-called "Arab countries" the management of the scientific research sector is under the authority of a major governmental institution. Thus, the advancement of scientific research depends strongly on the encouragement and investment of the government in scientific research and development.

[4] The Knowledge Index is defined by the World Bank as "measurement of the country's ability to generate, adopt and diffuse knowledge" (www.worldbank.org).

Within some of the countries of the SMAP, particularly in western Mediterranean area, governments have succeeded in implementing strong research institutions which encourage and employ local researchers to study important fields such as agronomy and fisheries. For example, in Tunisia, the number of researchers per 100 inhabitants was estimated to be 0.37 in 2012 compared to an average of 0.05 for the so-called "Arab World" and 0.35 for other regions in the world (Bilawi *et al.* 2014). However, in the rest of the SMAP, particularly in the Arab countries of the Persian Gulf, there is a tendency of importing foreign universities and research centres, rather than creating their own institutions. There is also a tendency within these countries to employ consultants and experts outside of Academia leading to a lack or absence of knowledge transfer (Bilawi *et al.* 2014). Since the so-called 'Arab Spring' an increasing number of scientists has been attempting to immigrate to economically more developed countries (Brainard 2019)

The bias in the so-called global studies, discussed earlier in this chapter, also extends to regional waters that are shared between economically developed and developing countries such as the Mediterranean basin. The Mediterranean Sea is shared between European economically developed countries in the North of which almost all are members of the European Union, and economically developing countries in the South. Often fisheries studies that claim to be covering the Mediterranean actually cover only the Northern Mediterranean, e.g., Vasilakopoulos *et al.* (2014); Damalas *et al.* (2015). According to Lleonart *et al.* (1998), and justify their bias by the lack of information on fisheries in Southern Mediterranean countries. In this thesis, it is argued that the problem of scarcity of data is not a real issue and that data that is not appropriate for classical stock assessments is available but has been under-utilized.

The SMAP countries are a good example of data-poor regions where fisheries are important and where other issues outside of fisheries, e.g., political, economic and societal, have contributed to the worsening of knowledge gaps regarding their fisheries.

This thesis aims to provide colleagues that work on data-poor fisheries with affordable and relatively easy to apply tools that can help assess the state of the marine data-poor fisheries within economically developing countries.

1.3 Thesis overview

This thesis comprises three main chapters, this introduction, and a concluding chapter. The first chapter (this introduction) consists of the general framework of this work. In the second chapter, the methodology of catch reconstruction is updated and marine fisheries catches are reconstructed for the countries of the SMAP (excluding the Mediterranean EEZ of Egypt) are either completed for 1950-2015 or improved and updated to 2015, 2016, or 2017. In the third chapter, the catches of Egypt in the Mediterranean were reconstructed for 1917-2017 and applied to catch-based indicators, i.e., the Marine Trophic Index (MTI) to see if fishing down is occurring in the Mediterranean Egyptian waters, and the Mean Temperature of Catch (MTC) to evaluate the impact of climate change in the region. In the fourth chapter, reconstructed catch data of 10 fish stocks from the SMAP are assessed using the recently developed 'CMSY' method. Finally, the fifth chapter is a summary and discussion of the findings of this thesis.

Chapter 2: Marine Fisheries Catch Reconstructions Through Uncertainties

2.1 Introduction

Synopsis: In this chapter, I present the catch reconstruction approach that I updated, and for which I introduced a more detailed method for computing uncertainty score estimate. Then i I applied this catch reconstruction approach to 17 countries from the Southern Mediterranean and the Arabian Peninsula.

The Southern Mediterranean and the Arabian Peninsula regions (SMAP) border three large marine ecosystems (LME): the Mediterranean Sea, the Red Sea, and the Arabian Sea, which includes the Persian Gulf (www.seaaroundus.org). All of these LMEs harbour high levels of biodiversity and endemism. Around 19-20% of marine species in the Mediterranean basin are endemic (Boudouresque 2004; Coll *et al.* 2010). Around 13% of marine fishes of the Red Sea and 14% of the fish populations shared between the Red Sea and the Gulf of Aden are also endemic (DiBattista *et al.* 2016). This number was estimated at 14.6% for the Red Sea by Bogorodsky and Randall (2019). Endemism for fishes is lower within the Arabian Sea LME, with around 3-4% of the Persian Gulf fishes being endemic (DiBattista *et al.* 2016).

Some of the oldest human civilizations developed around the SMAP regions, notably Mesopotamia, Ancient Egypt, Carthage and the early Persian civilization. Therefore, these seas were not only a major food source (Horton 1987; Addis *et al.* 2009; Lotze *et al.* 2011), but also represented a main route for trade and migration that contributed to the shaping of human history

(Mitchell 2011). The oldest known fishing boat in the world was discovered in Kuwait and is around 7,000 years old (Lawler 2002). A 2,500 year-old boat was also discovered in Oman (Lawler 2002). Fishing gears such as beam-trawls and seines were already in use in Egypt around 2660-2180 BC (Aleem 1972b). Bluefin tuna in the Mediterranean has been commercialized (at least) since the 8th century BC by Carthaginians and other Mediterranean civilizations (Lleonart *et al.* 1998; Addis *et al.* 2009). Fishing still plays a major part in the economy and society of the modern countries of the SMAP (Feidi 1997; Lleonart *et al.* 1998). The characteristics of the southern Mediterranean Sea fisheries, and the Arabian Sea and Red Sea fisheries are presented here separately. The factors that accounted for the selection of the SMAP countries are explained in Chapter 1.

The Mediterranean Sea is a semi-enclosed sea with an overall narrow continental shelf and forms, with the Black Sea, FAO Area 37[5]. This chapter focuses on eight southern Mediterranean countries: Morocco, Algeria, Tunisia, Egypt, Palestine, Lebanon and Syria (Chapter 1, Figure 2). Although Mediterranean countries have established territorial waters and in some cases 'Exclusive Fishing Zones', most have not officially claimed Exclusive Economic Zones (EEZs) (Lleonart *et al.* 1998; Cacaud 2005). In this study the Southern Mediterranean countries were assigned theoretical EEZs according to the basic UNCLOS principles of 200 nm or mid-line

[5] FAO Major Fishing Areas (online) available at http://www.fao.org/fishery/area/search/en [accessed 10/11/2019];

between neighboring countries as mapped by the Flanders Marine Institute[6] (see Chapter 1. Figure 2).

This EEZ assignment has no legal standing and is purely used to spatially assign catch data (Zeller *et al.* 2016c). Mediterranean fisheries are mostly multi-species and multi-gear with the use of many traditional fishing gears (Lleonart *et al.* 1998; Swan and Gréboval 2003). The Mediterranean basin is currently facing several threats, mainly overfishing (Lleonart *et al.* 1998; Papaconstantinou and Farrugio 2000; Vasilakopoulos *et al.* 2014), pollution, e.g., plastic (Compa *et al.* 2019), mercury (Cinnirella *et al.* 2013) and oil (Kostianoy and Carpenter 2018), and climate change (Giorgi and Lionello 2008; Coll *et al.* 2010; Cramer *et al.* 2018).

The Red Sea and the Arabian Sea are both part of the FAO Area 51[1], which covers the Western Indian Ocean. These two LMEs surround the nine countries of the Arabian Peninsula: Jordan, Saudi Arabia, Yemen, Oman, UAE, Bahrain, Qatar, Kuwait, and Iraq (Chapter 1. Figure 2). The Egyptian Red Sea EEZ is also included, as explained in Chapter 1.

The Red Sea separates the African continent from the Arabian Peninsula. Since 1869 the Red Sea has been connected to the Mediterranean through the Suez Canal (see Chapter 3). Coral reef formation in this region is one of the most species-rich in the world and is increasingly threatened by climate change and more particularly ocean acidification (Fine *et al.* 2019). The

[6] Flanders Marine Institute (2020): MarineRegions.org. Available at www.marineregions.org. [accessed 18/01/2020].

fishing industry within the Red Sea involves a historically important traditional artisanal fishery and a more recent but exponentially developing industrial trawl fishery (Head 1987; Tesfamichael and Pauly 2016). With a growing population along its coast, the Red Sea is facing the consequences of increasing anthropogenic activities (Frihy *et al.* 1996; Tesfamichael and Pauly 2016).

The Arabian Sea includes the Persian Gulf, the Gulf of Oman, and the Gulf of Aden. This region covers the EEZs of the Persian Gulf countries, which depend heavily on the oil industry. Before the discovery and exploitation of petroleum, these countries depended mainly on fishing and trade (Metz 1993; Al-Abdulrazzak *et al.* 2015). Climate change is one of the main threats to the Persian Gulf and the Arabian Sea in general (Wabnitz *et al.* 2018).

Most countries of the SMAP regions have experienced at least one major political and/or socio-economic disturbance since the 1950s. Between the late 19th century and the mid-20th century, most of these countries were fighting for independence from colonial countries, i.e., mainly France, Italy and Britain. Most recently, in 2011, a so-called "Arab Spring" sparked a wave of uprisings starting from Tunisia and spreading throughout the SMAP regions. Other countries have almost been entirely involved in continuous turmoil for the past seven decades, e.g., Palestine since 1948 and Iraq, which has had a war or other sort of political instability almost every decade since the mid-20th Century. In the aftermath of the 2011 events, Syria, Yemen, and Libya have been in some ongoing war and/or insurgency. When countries are dealing with upheaval, scientific research is most likely deprioritized due to lack of financial means and prioritization of more urgent matters such as safety, food and water security. Consequently, fisheries research and thus, fisheries management are affected.

Classical methods of stock assessments, which have been considered as the basis of fisheries management strategies, are then difficult to apply due to high cost and other data requirements. Marine fisheries catches are hence the only available, inexpensive, and easily obtainable information on marine fisheries for most economically developing countries, as discussed in Chapter 1. Marine fisheries catches have been made available since the 1950s by the FAO, which collects them annually from all maritime countries around the world. Most countries collect their fisheries statistics following a bottom-up approach starting from the boats in the landing sites to the concerned ministries that later pass them to the FAO (Figure 3).

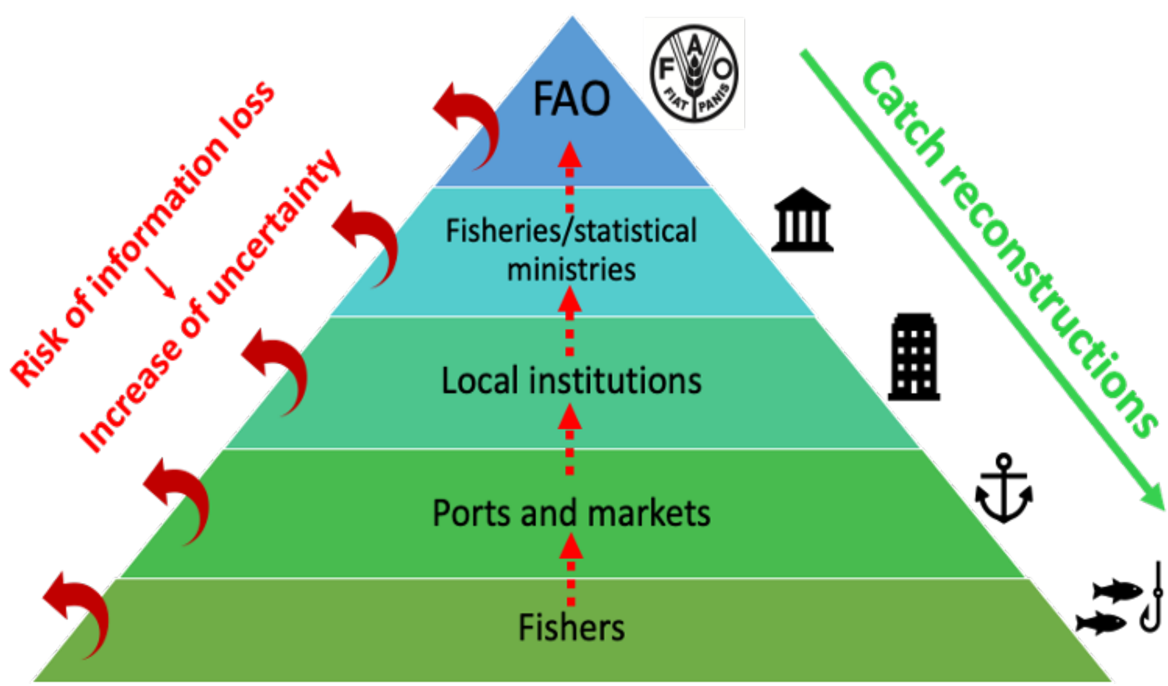


Figure 3. Bottom-up fisheries collection process versus the catch reconstruction approach.

However, information is often lost thought the process of data collection. Furthermore, official catches always exclude discards and, most commonly, recreational and subsistence landings (Pauly and Zeller 2016a). Unreported and illegal fisheries catches are usually difficult to obtain and thus, almost never accounted for in official fisheries statistics. Moreover, catch statistics are not reported by sectors, of which there are no international, regional or sometimes local fixed definitions. As a result, official statistics only report a part of the catch that could be minor compared to the real amount of marine living resources withdrawn by the fisheries (Figure 4).

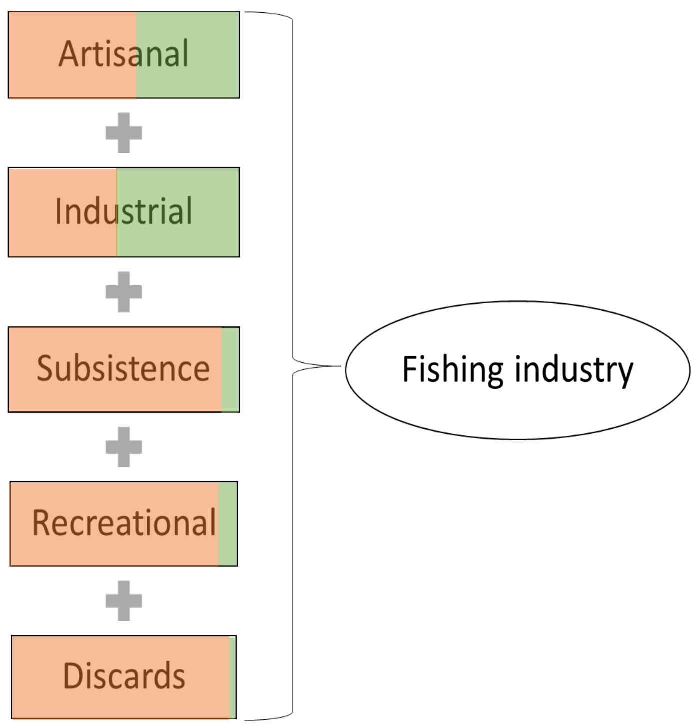


Figure 4. The five main sectors of the fishing industry for most world maritime countries. The green represents what is included in official fisheries statistics. Note that this diagram is not proportionally representative. However, the industrial fishery is often the best monitored sector compared to the artisanal one. Rarely, some countries might report recreational and subsistence landings and would seldom report their discards.

To improve the quality of the marine fisheries catch database worldwide, the *Sea Around Us* (www.seaaroundus.org) has been reconstructing fisheries catches by maritime country for nearly 15 years. For each fishing country, all existing marine fisheries components, i.e., reported and unreported large- and small-scale commercial, recreational, subsistence, and illegal landings as well as discards, are re-estimated using the reported FAO data as a comparative baseline. The catch reconstruction approach follows a top-bottom approach to try to retrieve the information that was lost or not accounted for during the fisheries statistics collection process (Figure 3).

The first part of this work was completed for the marine fisheries of over 200 countries and territories for the period of 1950-2010 (Pauly and Zeller 2016b). The resulting 'reconstructed catches' provided a more complete and realistic estimate of the amount of fish extracted from the world's seas and oceans. This approach also focused on improving the taxonomic catch disaggregation of the world's fisheries catches. As rough as these estimates may have been, they were always better than assigning a value of "zero" to poorly documented fisheries, i.e., assuming that such fisheries do not generate any catches, and thus do not exist.

For the purpose of this chapter, the methodology of the catch reconstruction was updated and improved. Marine fisheries catches for 3 of the SMAP countries, i.e., Iraq, Libya, Oman, and the Fujairah Emirate (of the UAE) were fully reconstructed for 1950-2015, 2016 or 2017. It should be noted that marine fisheries for the Egyptian Mediterranean EEZ were reconstructed for the century of 1917-2017 as part of the third chapter of this thesis and the marine fisheries catch reconstruction for Oman was published in a peer-reviewed journal (see Khalfallah et al. (2016)).

Previously completed catch reconstructions for five countries, i.e., Bahrain, Jordan, Lebanon, Morocco (Mediterranean) and Tunisia, for 1950-2010 by other authors were re-written and updated to 2015, 2016 or 2017, depending on the available data at the time of writing. Catch reconstructions for the remaining countries, i.e., Algeria, Egypt (Red Sea), Kuwait, Palestine, Qatar, Saudi Arabia, Syria, UAE (excluding the Fujairah Emirate) and Yemen were simply updated to 2015, 2016, or 2017, again depending on the available data. Oman, Saudi Arabia, Yemen, UAE and Egypt have two distinct fisheries (in different ecosystems) and their catch reconstructions were then completed by the corresponding EEZ. A new two-criteria-based method for uncertainty quantification was also applied to the total reconstructed catches of the FAO Areas 37 and 51 of the SMAP regions.

The Methods section presents an updated catch reconstruction template that was applied to the countries of the SMAP region as summarized in the Results section of this chapter.

2.2 Methods

The catch reconstruction approach is usually completed following a seven-step methodology as outlined by Zeller *et al.* (2007) and Zeller *et al.* (2015):

1) Review of existing reported catch time series from FAO, national and other sources;

2) Extensive research to identify the fishing sectors in the country and thr missing data from the reported statistics, e.g., missing fisheries sectors and species, time gaps, etc.;

3) Search for alternative information sources to fill the gaps of previously identified missing data. This step also requires considerable search through all manner of literature, as well as consultations and collaborations, when possible, with local experts;

4) Identification of spatial and/or temporal anchor points for missing data segments;

5) Interpolation between the previously identified anchor points.

6) Estimation of the final total catch data by associating reported catches with the reconstructed missing components; and

7) Assess uncertainty for the different reconstructed sectors and time segments.

These steps were slightly updated in the herein chapter as summarized in Figure 5:

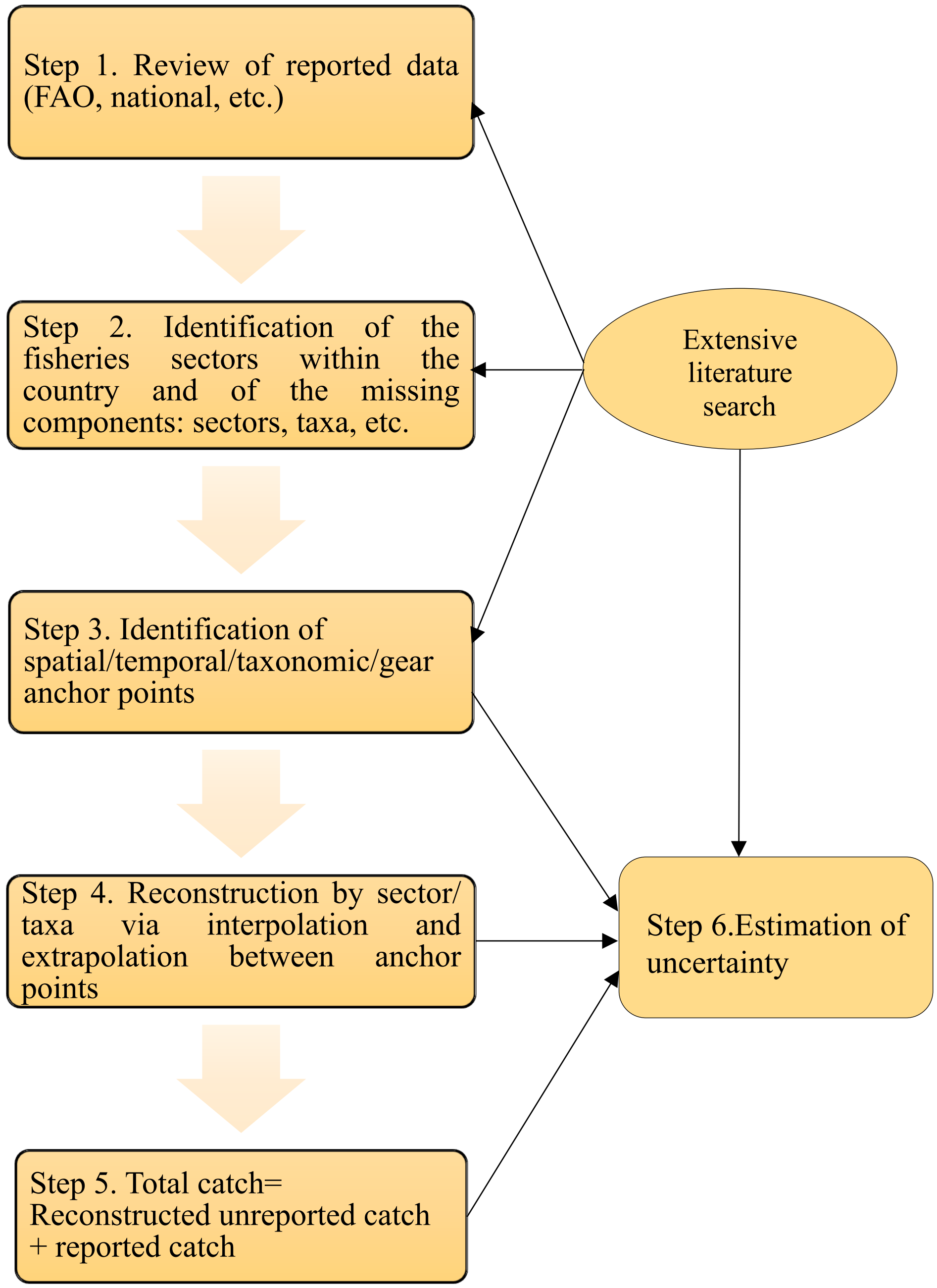


Figure 5. Diagram of the updated catch reconstruction methodology based on Zeller *et al.* (2007) and Zeller *et al.* (2015).

2.2.1 Review of reported data

Reported marine fisheries catches for the 17 countries of the SMAP regions were available by year and taxa from the FAO Fishstat database, and occasionally from national and other sources. When two or more data sources were available for the same country, the datasets were compared. If they were similar (which was usually the case) the more taxonomically detailed data were used as a baseline to the reconstructed catch. In some cases, the reported baseline had to be adjusted, e.g., Iraq (see Subsection 2.4.1.4.) and Oman (Khalfallah *et al.* 2016).

When a country has more than one EEZ, but is part of the same FAO Area, i.e., Area 37 or Area 51, reported catches had to be reassigned to each fishery. For instance, Saudi Arabia shares coasts in the Persian Gulf and the Red Sea, both part of the FAO Area 51 (see subsection 2.4.1.12.; Tesfamichael and Rossing 2012a; Tesfamichael and Pauly 2013) and Oman and the UAE have EEZs in the Persian Gulf and the Gulf of Oman, also both part of the FAO Area 51 (Al-Abdulrazzak 2013a; Khalfallah *et al.* 2016). Finally, Morocco shares coasts with both the Atlantic Ocean and the Mediterranean basin; here, only the Mediterranean fishery is taken into account, as explained in the 'Introduction' section.

The species composition for reported catch of earlier years was often not very informative. The FAO often reports only few to one taxonomic group, i.e., 'Marine fishes unidentified', for the first decades. In this case, species composition for later years and/or from different sources was applied to disaggregate catches for earlier years. Generally, whenever better information on species composition was found it was used to improve the overall taxonomic disaggregation of the reported baseline.

2.2.2 Defining fisheries sectors and identification of missing components

Current definitions of each of the large- and small-scale fishing sectors vary between countries and regions as official standardized and global definitions of these sectors are virtually nonexistent (Pauly and Zeller 2016b; FAO 2017). When completing the catch reconstructions the countries' definitions of the different sectors were adopted. If national definitions did not exist regional ones were retained (Zeller *et al.* 2016a). Notwithstanding the latter, all trawling activities, whether conducted by multi-gear boats or by trawlers, were deemed large-scale, conforming with the general principles of the catch reconstructions and according to Martín (2012a). All marine fisheries landings, whether sold outside of, or through official markets, were considered commercial in contrast to fish caught for personal consumption or leisure, which were categorized as 'subsistence' and 'recreational' fisheries respectively.

The subsistence fishery engages people who fish primarily for their family and personal consumption rather than for commercial purposes. This sector also includes fish consumption by the onboard crew of the fishing boat. The recreational fishery covers fishing activities for leisure rather than necessity, and of which catch is not sold. It also includes underwater sport fishing.

By definition fisheries 'catches' do not only consist of landings but also of fish discarded at sea. Hence, large- and small-scale fisheries catches also comprise discards (Zeller and Pauly 2016).

Note that discards are often, if mistakenly, used as a synonym of bycatch. However, in this study, bycatch is considered as non-targeted catch. If bycatch is rejected at sea, it is discards. If it is sold, it is commercial catch; and if it is used for personal consumption, it is subsistence catch. Hence, bycatch does not really exist as a separate category in this study.

The following sectors were usually the missing component from the reported data: unreported commercial large- and small-scale, subsistence, recreational, and discards.

2.2.3 Extensive literature search and anchor points

Information sources used to identify anchor points for catch reconstruction purposes can be classified into four groups according to certainty scores (Table 2):

2.2.3.1 Peer-reviewed journals and official reports

This category includes information obtained from articles that were published in peer-reviewed journals. It also comprises available information from official governmental and intergovernmental reports, data, and other items (e.g., FAO reported data, national statistics, etc.). Colonial archives are also included in this category. It should be noted that these governmental and intergovernmental reports, although not independently reviewed, such as the case for peer-reviewed journals, are often internally reviewed by local scientists.

2.2.3.2 Non-governmental and private studies

This includes information from Non-Governmental Organizations (NGO), e.g., World Wide Fund for Nature (WWF), Oceana, etc. and non-peer-reviewed studies that also include technical reports and working papers from laboratories and universities, e.g., UBC's Fisheries Centre Research Report (FCRR). Such studies are particularly important in the economically developing world where publishing in peer-reviewed journals is often difficult (see Chapter 1).

2.2.3.3 Personal observations and communications

Knowledge from local experts and scientists has been essential to the completion of catch reconstructions when the prior information sources were unavailable. Personal observations were also occasionally used.

2.2.3.4 Mass media

This encompasses using available information from newspapers, videos, blogs, etc. This information source is only used in the absence of any other information sources, as was the case for the post-2011 fisheries in Libya (see subsection 2.4.1.8.).

2.2.4 Catch reconstruction approaches

Catch reconstructions were completed following different methods that can be summarized in roughly 4 approaches according to their certainty level (Table 2):

2.2.4.1 Direct use of information

This consists of using the information as it was reported for the appropriate time segment, area, sector or taxa. For instance, if a report claims that 50% of reported catch were artisanal for 1950-1960, the information would then be applied as is. This approach has the highest certainty level.

2.2.4.2 Applying a catch per unit of effort (CPUE)

This approach consists of reconstructing the catch of a certain sector/taxa by multiplying a catch per unit of effort (CPUE) by the corresponding fishing effort. This method proved to be most useful in the estimation of unreported catches of the industrial sector, e.g., when trawl surveys were available. The unreported industrial catch was then obtained by subtracting the reported commercial industrial catch from the total reconstructed industrial catch. This was also occasionally used for the small-scale sector. However, economically developing countries tend to not invest as much in this sector. When the CPUE and fishing effort were available for only one to a few years, interpolations and conservative assumptions were performed (see subsection 2.3.4.4.).

2.2.4.3 Applying a per capita catch rate to a population

This approach consists of reconstructing catches by applying a *per capita* catch rate to a certain population. This was commonly applied to estimate subsistence catches by applying a subsistence *per capita* catch rate to the rural coastal population of the country in question, which was available through the 'Socioeconomic Data and Applications Center' for the years 1990, 2000, and 2010 (CIESIN, 2012). National authorities sometimes provided this information. Occasionally, when information on recreational fisheries were lacking this approach was used to estimate recreational catches. The population participation rate in recreational fishing was estimated by country/region by Cisneros-Montemayor and Sumaila (2010).

2.2.4.4 Assumption approach

This approach was used when all other approaches were impossible to apply due to a lack of information. This is particularly the case for countries that have gone through political and socio-economic instabilities. In some countries, national institutions were destroyed and archives and information were lost (See Pauly 2001). Hence, very conservative assumptions were made to reconstruct fisheries catches. This approach was also often applied to disaggregate catches of the different sectors, particularly for the early decades. When catch data was interpolated between anchor points or extrapolated for certain years it was considered to be part of this approach.

2.2.5 Quantifying uncertainty

In order to assess the quality of the catch reconstructions it was necessary to add a certain measure of uncertainty. Zeller *et al.* (2015) drew on uncertainty-level categorizations developed by Funtowicz and Ravetz (1990) and adopted by the Intergovernmental Panel on Climate Change to assess uncertainty (Mastrandrea *et al.* 2010). This allowed the computation of uncertainty ranges that were scaled based on the Monte-Carlo simulations by Ainsworth and

Pitcher (2005) and Tesfamichael and Pitcher (2007). Table 1 summarizes the uncertainty scores originally used for catch reconstructions.

Table 1. Uncertainty scores as per Zeller and Pauly (2015).

Score		+/- (%)	Corresponding IPCC criteria*
4	Very high	10	High agreement & robust evidence
3	High	20	High agreement & medium evidence **or** medium agreement & robust evidence
2	Low	30	High agreement & limited evidence **or** medium agreement & medium evidence **or** low agreement & robust evidence.
1	Very low	50	Low agreement & low evidence

The different catch reconstruction approaches and categories of information sources were assigned different certainty levels based on Table 1. These certainty scores were used to assess the confidence intervals for the different spatial/temporal/taxonomic/gear anchor points for each catch reconstruction as summarized in Table 2.

Table 2. Uncertainty scores applied to information sources and catch reconstruction approaches.

Sources	Approaches	Score
- Peer-reviewed journals and official reports	Direct use of information	4
- NGOs/ Private studies	CPUE x Fishing effort	3
- Personal observations and communications	*Per* capita catch method	2
- Mass media	Assumptions	1

In opposition to the previously used system of uncertainty measure, this method allows a better and easier uncertainty estimate based on two criteria. By correlating the different scores associated to each of the information sources and reconstruction approaches, Table 3 was obtained.

Table 3. Relationship between the uncertainty scores of information sources and catch reconstruction approaches.

Approach / **Source**	Direct use of information	CPUE x Fishing effort	*Per* capita catch method	Assumptions
Peer-reviewed journals and official reports	4-4	4-3	4-2	4-1
NGOs/ Private studies	3-4	3-3	3-2	3-1
Personal observations and communications	2-4	2-3	2-2	2-1
Mass media	1-4	1-3	1-2	1-1

These uncertainty scores were associated with percentage confidence intervals (Table 1). This allowed the estimate of a final score by averaging the percentage confidence interval. For instance, if an information source has a score of 3, i.e., percentage confidence interval of ±20%, and a reconstruction approach has a score of 4, i.e., percentage confidence interval of ±10%, their final confidence interval would by the average of ±20% and ±10%, i.e., ±15%. This was summarized in Table 4. Based on Table 1, a confidence interval system was created as summarized in Table 5.

Table 4. Relationship between uncertainty scores of information sources and catch reconstruction approaches.

Source \ Methods	Direct use of information (E)	CPUE x Fishing effort (F)	*Per* capita catch method(G)	Assumptions (H)
Peer-reviewed journals and official reports (A)	(AE) ±10 %	(AF) ±15 %	(AG) ±20 %	(AH) ±30 %
NGOs/ Private studies (B)	(BE) ±15 %	(BF) ±20 %	(BG) ±25 %	(BH) ±35 %
Personal observations and communications (C)	(CE) ±20 %	(CF) ±25 %	(CG) ±30 %	(CH) ±40 %
Mass media (D)	(DE) ±30 %	(DF) ±35 %	(DG) ±40 %	(DH) ±50 %

Table 5. Confidence intervals according to the updated uncertainty score system where [] = endpoint included; and][= endpoint excluded.

Confidence interval +/- (%)	**Score**
[10-20[	Very high
[20-30[	High
[30-40[	Low
[40-50]	Very low

It should be noted that some exceptions might apply to the quality of the source used. Sometimes reported data needed to be adjusted before used as a baseline, as was the case for the UAE, which over-reported their catch by including their imports (Al-Abdulrazzak 2013a). This is not common, but should be considered when reviewing reported data.

2.3 Results

2.3.1 Country level results

The methods that were developed above were applied to the 17 SMAP countries. The account for each of them is presented in a form a mini report featuring a country specific background and approach, and country specific results. The following section summarizes the overall result for the SMAP regions as whole. For countries with two separate EEZs, two catch reconstructed were completed/updated.

2.3.1.1 Algeria

Background

Algeria is a North African country bordered by the Mediterranean Sea in the north. The Algerian government claimed an Exclusive Fishing Zone of 95,000 km^2 in 1994, which is characterized by a narrow continental shelf of around 10,500 km^2 (Figure 6; www.seaaroundus.org). Because of this narrow continental shelf, the main fishery in Algeria is small-scale, multi-species, and multi-gears (Oliver 1983; Coppola 2001; Zeghdoudi 2006). The large-scale sector consists of industrial bottom trawling which targets valuable commercial species (Maurin 1962; Belhabib *et al.* 2013b).

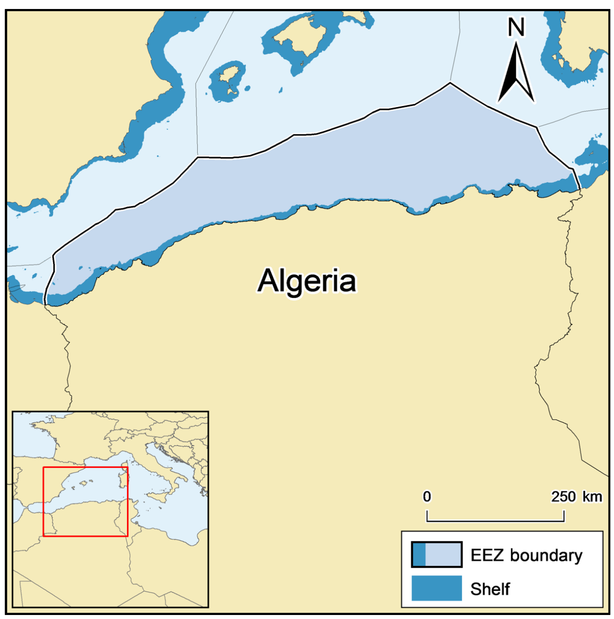


Figure 6. The EEZ and shelf area of Algeria.

In 1962, Algeria gained its independence, which led to many fishers leaving the country (Boude 1987). In the mid-1970s, the Algerian fishing industry was privatized, and thus neglected by the government who targeted its investment towards the oil industry. During the 1980s, the crush of oil prices around the world caused socio-economic instability to the then oil-dependent Algeria.

In an attempt at economic reform, the Algerian government started a program of fisheries subsidies in 1988 (Belhabib *et al.* 2013b). This economic crisis triggered the start of the Algerian civil war or "black decade" in the early 1990s, i.e., almost a decade-long series of terrorist attacks throughout the country, which strongly impacted the Algerian fishing industry (Belhabib *et al.* 2013b). Many Algerians found refuge around the coastal cities, hence increasing the demand for seafood and consequently the fishing pressure (Belhabib *et al.* 2013b). This increase of fishing pressure combined with a limited fisheries statistics monitoring system and important governmental subsidies, have likely put the Algerian fish stocks at risk of overfishing. The fishing industry contributes with around 1.3% to the total GDP for Algeria (Breuil 1997).

Marine fisheries catches were reconstructed by Belhabib *et al.* (2013b) for 1950-2010 and are here updated to 2016.

Country specific implementation

Reported marine fisheries catch data were available by year and taxa for 2011-2016 and were used here as the reported baseline. Marine landings were also available by year and commercial group for 2009-2013 from the Algerian National Office of Statistics (ONS; www.ONS.dz).

Reported commercial catch

The percentage contribution of each of the artisanal and commercial sectors to the reported FAO data for 2000-2010 were extrapolated to 2016. They were then applied to the FAO reported data of 2011-2016 to split it into artisanal and industrial. Note that 'nei' refers to 'not elsewhere included'.

The FAO reports two taxonomic groups of sharks, i.e., 'Catsharks, nursehounds nei' and 'Dogfish sharks nei', one taxonomic group of rays 'Rays, stingrays, mantas nei', and one taxonomic group combining both catch of rays and sharks, i.e., 'Sharks, rays, skates, etc. nei'. According to Hemida (2005), rays represent 2.11% of sharks and ray catches. This was applied to the taxonomic group 'Sharks, rays, skates, etc. nei'.

According to Belhabib *et al.* (2013b), 37% of sharks and rays originated from the small-scale fishery and the remaining from large-scale. This was applied to all FAO reported catches of sharks and rays, i.e., to the three groups of sharks and to the both taxonomic categories of rays as per Belhabib *et al.* (2013b).

Unreported commercial catch and discards

The number and type of commercial boats was available through the ONS (www.ONS.sz) and the Ministry for fishing and fisheries resources (MPRH, www.mpeche.gov.dz) for 1999-2013 (Table 6), but was unavailable for 2014-2016.

Table 6. Number of fishing boats by type in Algeria (www.ons.dz, www.mpeche.gov.dz).

Year	Industrial boats		Artisanal boats
	Trawlers	Purse Seiners	
1999	305	635	1,484
2000	318	643	1,545
2001	338	660	1,663
2002	352	692	1,836
2003	354	712	2,210
2004	358	747	2,524
2005	403	836	2,731
2006	435	906	2,825
2007	476	972	2,972
2008	487	1039	2,897
2009	494	1077	2,935
2010	502	1102	2,561
2011	512	1143	2,646
2012	521	1202	2,665
2013	526	1231	2,796

According to the previous reconstruction by (Belhabib *et al.* 2013b), active trawlers represented 76% of total trawlers and active artisanal boats represented 89% of the total artisanal fleet. Although the number of boats has likely increased since 2013, it was assumed to have remained similar to 2013 in 2014-2016.

The catch per unit of effort (CPUE) for unreported artisanal catch was estimated using the catch data from the previous reconstruction and the number of active artisanal boats, for 1999-2010. The obtained CPUE was extrapolated to 2016 and applied to the number of artisanal active boats for 2011-2016. The same method was applied to reconstruct industrial catch for 2011-2016.

The taxonomic compositions used for unreported commercial artisanal and industrial catch for 2010 was applied here to each sector.

Subsistence catch

Belhabib *et al.* (2013b) assumed that subsistence catch in the 2000s was equivalent to 193 t, i.e., estimated as 10% of the subsistence catch of 1927 t in 1970. This was assumed to have remained the same for the 2011-2016. The same taxonomic disaggregation for 2010 was also used here.

Recreational catch

The recreational catch was estimated for 2011-2015 for Algeria by Babali *et al.* (2018). This catch included boat based recreational catch and spearfishing catch. It was assumed that the catch in 2016 remained similar to 2015. Taxonomic disaggregation was also obtained from Babali *et al.* (2018).

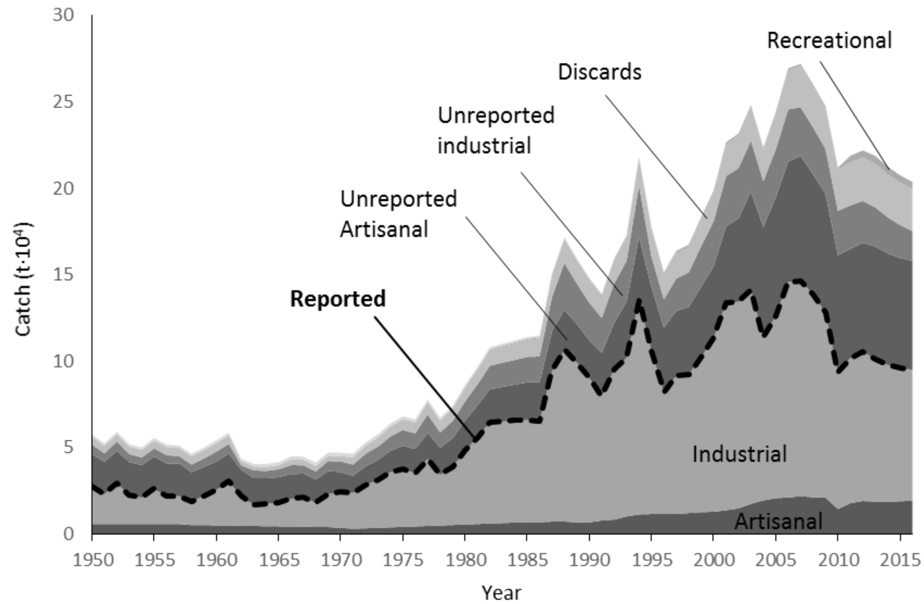
Discards

Industrial discards were estimated similarly to industrial unreported catch. Using the numbers of purse seiners and active trawlers and the discards for purse seiners and trawlers for 1999-2010 from the previous reconstruction by Belhabib *et al.* (2013b), it was possible to estimate the discarded CPUE. The estimated discarded CPUE for trawlers was constant for 1999-2010 and equivalent to 46.5 $t \cdot year^{-1} \cdot trawler^{-1}$. This CPUE was applied to the number of active trawlers for 2011-2016. The estimated discarded CPUE for purse seiners was extrapolated to 2016 and applied to the numbers of purse seiners for 2011-2016. Industrial discards are the sum of discards by trawlers and purse seiners. The same species composition used for discards for 2010 was applied here.

Country specific results

Marine fisheries catches were reconstructed for Algeria for 2011-2016 including: reported industrial catch (~37.8 %), reported artisanal catch (~8.7 %), unreported artisanal catch (~29.8 %), unreported industrial catch (~10%), industrial discards (~11.6 %), recreational catch (2 %), and subsistence catch (~0.1%) (Figure 7a). Sardines (Clupeidae) were the most important taxon caught by the Algerian fishing industry for 2011-2016. This taxon is comprised mainly of European pilchard (*Sardina pilchardus*, ~ 30 % of total catch). Other families were caught in high quantities: Sparidae, Carangidae, and Scombridae (Figure 7b).

a)



b)

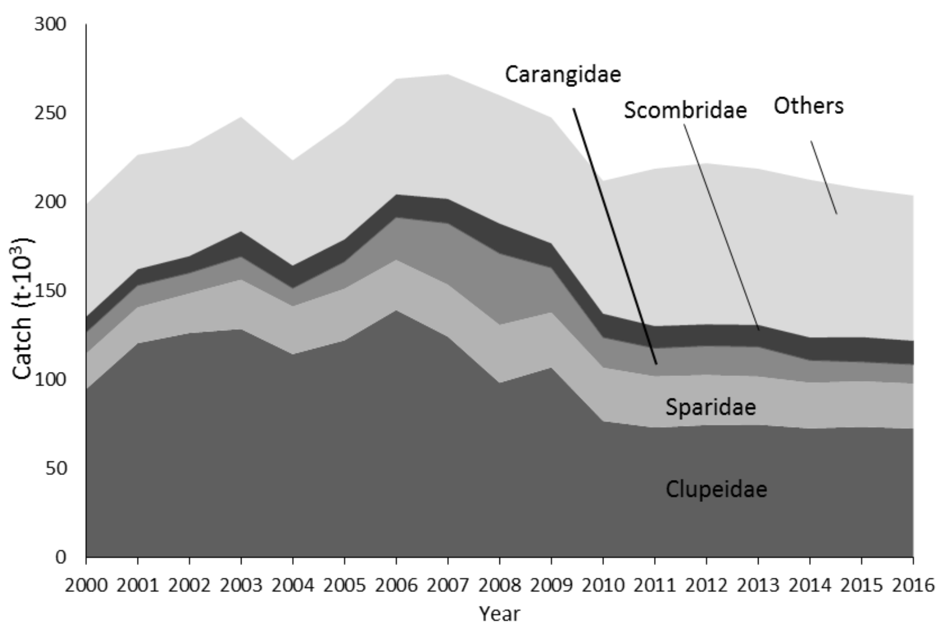


Figure 7. Reconstructed marine fisheries catches for Algeria by (a) sectors plus discards for 1950-2016, and (b) major taxa for 2000-2016. Reported landings by the FAO on behalf of Algeria are overlaid as a dotted line. Note that the 'others' category includes 95+ additional taxonomic groups.

2.3.1.2 Bahrain

Background

Bahrain (meaning 'two seas'" in Arabic) is the only island country and smallest country of the Persian Gulf (Figure 8). Because of its relatively small EEZ, i.e., 8,826 km^2 (www.seaaroundus.org), Bahrain shares most of its fish stocks with neighboring countries, e.g., Qatar (Morgan 2006a).

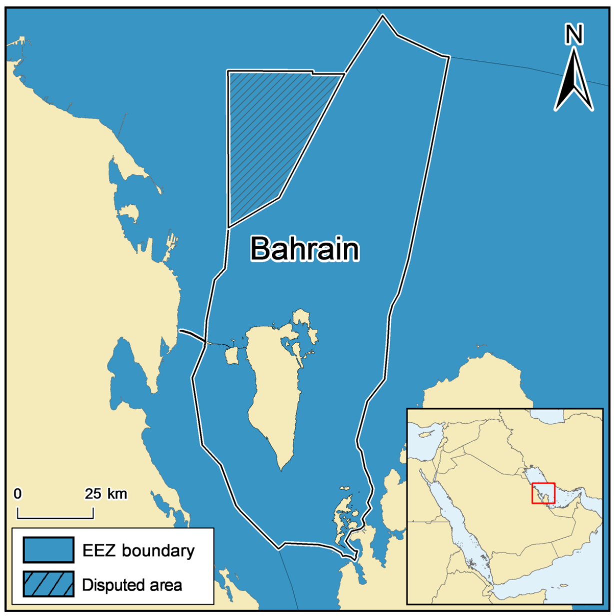


Figure 8. The EEZ and shelf area of Bahrain.

Bahrain has a very rich maritime and fishing history, particularly during the pre-oil era. Fishing and pearling represented then some of the very popular livelihood sources in the region. Most of the fishers and pearl divers switched to employment opportunities brought by the oil industry.

Pearling boats decreased from 2,000 boats in the late 1920s to only 12 by 1953, which disappeared in the next few years (Metz 1993; Morgan 2006). The shrinking of the fishing industry, overall with the increase of the demand for seafood led the country to import its fish. During the late 1960s, the fishing industry was industrialized with the introduction of shrimp trawlers. But due to inefficient management, the shrimp fishery almost collapsed by the end of the 1970s. This pushed the government in the early 1980s to invest more in developing and better managing the fishing industry, e.g., modernizing fish equipment, training the fishers, etc. (Metz 1993; Abdulqader 2001; Morgan 2006). Detailed descriptions of the shrimp and other fisheries of Bahrain will be given in the methods section.

Marine fisheries catches were reconstructed for 1950-2010 (Al-Abdulrazzak 2013) and are here partially re-estimated and entirely updated to 2015.

Country specific implementation

The FAO has made available marine fisheries catches for Bahrain by taxa and year for 1950-2015. These data were used as reported baseline for some years of the study period. Total commercial reconstructed catch and FAO reported catch were compared. When FAO reported landings were lower than the reconstructed commercial landings, the discrepancy was considered unreported catch.

Industrial fishery

Experimental trawling started in the end of 1966 and commercial trawling launched a few months later, i.e. March 1967. The Bahraini trawl industry was operated by the Bahrain Fishing Company (FAO 1978). This consisted of 8 large steel outrigger trawlers, which doubled in number in 1968. In 1976, 15 of these trawlers were operating in the Bahraini waters and represented nationally the 'industrial steel trawl fishery'. In 1971, a so-called 'artisanal trawl fishery' was launched. By 1976, it consisted of 26 operating wooden trawlers locally known as '*Banoush*" that almost tripled in number during the next 7 years, i.e., 68 operating *Banoush* trawlers in 1983. The *Banoush* trawlers evolved from non-motorized trawlers in the 1970s to fully equipped industrial boats in present times (Abdulqader 2001). Abdulqader (2001) mentions that the *Banoush* trawl industry has developed considerably over the years and that it is not artisanal anymore but rather a 'commercial' one. It should be noted that in this study all trawling is considered industrial as per Martín (2012), regardless of the national or regional definitions.

By 1978, the shrimp catches became unprofitable due to very low shrimp yields. A short-term ban was then enforced on shrimp fishing in August 1979. A second permanent ban has been imposed on the trawl industry since 1998. This ban, however, only involves the 'industrial steel trawl fishery' consisting of large steel trawlers (Abdulqader 2001; FAO 2003; Ali and Abahussain 2013). *Banoush* trawlers had been progressively replacing the steel trawlers and generating most of the shrimp landings, while the steel trawlers were mostly catching finfish in shallow waters. This had led to conflicts between the two trawl industries resulting in the 1998 ban (Abdulqader 1995; Abdulqader 2001; Morgan 2006; Ali and Abahussain 2013). A seasonal ban on all shrimp fishing is in effect every year in Bahrain when the shrimp fishing season closes (Ali and Abahussain 2013).

According to Al-Abdulrazzak (2013), reported industrial catches were mainly those of the shrimp trawl industry and consisted of green tiger prawn (*Penaeus semisulcatus*). In the previous reconstruction, all pre-1998 green tiger prawn catches were assigned to the industrial sector, while the post-1998 ones were considered entirely artisanal. This is based on the fact that most sources, e.g. Abdulqader (2001); FAO (2003); Morgan (2006), mention that industrial trawling was banned in 1998 and that all fishing has been artisanal since. However, as mentioned earlier *Banoush* trawlers were not affected by this ban. Following the definition of trawlers adopted in this study as being all part of the industrial sector, regardless of local definitions, the industrial fishery consisting of *Banoush* trawlers is still considered active in Bahrain after the 1998 ban. The now banned steel trawlers also caught finfish as mentioned earlier. It seems that reported finfish catches by trawlers for the years preceding 1998 and reported shrimp catches by trawlers for 1998-2010 were mis-categorized in the previous reconstruction as artisanal.

The methods applied to reconstruct shrimp catch by trawl type, i.e., *Banoush* and steel trawlers, and fish catch by steel trawlers between 1967 and 2015 were summarized in Table 7.

Table 7. Methods applied to reconstruct commercial marine catches for Bahrain for 1950- 2015 by sector (Part 1/4). Note that the methods for the reconstruction of the artisanal commercial catches by *Hadrahs* are presented separately (see section '*Hadrah* fishery').

Year	**Artisanal catch (t)**		
1950-1966	Prior to 1967, landings were fully artisanal and shrimps were caught solely by the artisanal fishery (no trawling). The FAO reported catch data consisted solely of two categories the green tiger prawn and the broad category of Marine Fish non-identified for 1950-1969. The catch of the green tiger prawn was reported to be very high, i.e., increasing from 400 t in 1950 to 1,500 t in 1969, then decreasing to 380 t in 1970. Overall catches seemed to be increasing steadily between 1950 and 1970, without any sudden decrease. The high values of the shrimp catch were likely the result of poor taxonomic disaggregation. Thus the taxonomic disaggregation of the FAO reported catch was improved (see taxonomic disaggregation section).		
	Artisanal catch (t)	**Industrial catch (t)**	
		Steel trawl shrimp catch (t)	**Steel trawl fish catch (t)**
1967-1970	Artisanal catch = (FAO reported catch – FAO reported green tiger prawn catch) – reconstructed fish trawl catch	Abdulqader (1995) made available shrimp catches by the 'steel trawl' fishery for 1967-1993. This information was in the form of a figure from which the data were extracted using 'WebPlotDigitizer'[1]. After comparison of these data with other sources for later years, these data were used to reconstruct the shrimp catch by the steel trawl fishery (Data A, Table 8).	According to Musaiger (1988), industrial fish catches by steel trawlers in 1979 were 1,286 t which is equivalent to 36% of the artisanal FAO catch (excluding green tiger prawn), i.e., 3,520 t. Based on this, it was assumed that fish catch by steel trawlers represented 30% of FAO reported catch (excluding green tiger prawn).

[1] Ankit Rohatgi (2018) WebPlotDigitizer available at www.automeris.io/WebPlotDigitizer [accessed on 16/07/2018];

Table 7 (continued). Methods applied to reconstruct commercial marine catches for Bahrain for 1950- 2015 by sector (Part 2/4). Note that the methods for the reconstruction of the artisanal commercial catches by *Hadrahs* are presented separately (see section '*Hadrah* fishery').

Year	**Artisanal catch (t)**	**Industrial catch (t)**		
		***Banoush* shrimp catch (t)**	**Steel trawl shrimp catch (t)**	**Steel trawl fish catch (t)**
1971-1978	The same method used to reconstruct artisanal catch for 1967-1970 was applied here to reconstruct artisanal catches for 1970-1978.	Abdulqader (1995) made available shrimp catches by the *Banoush* fishery for 1979-1993. As with the shrimp steel trawl catch data for 1967-1993, these data were derived from a figure (Data A, Table 8). However, the *Banoush* fishery started in 1971 as mentioned earlier; thus, all shrimp trawl catch obtained from the same source for 1971-1978 were assigned to the 'steel trawl' shrimp fishery. Therefore, to estimate *Banoush* catches for this time period, it was assumed that the catches assigned to the steel trawl fishery in 1971-1978 involved both *Banoush* and 'steel trawl' fisheries. The percentage of *Banoush* shrimp catch from total shrimp catch was estimated to be 93.6% in 1979 (Musaiger 1988). An interpolation was then performed between 1970 and 1979, as in 1970 all trawl shrimp catch was 100% by steel trawl, i.e., *Banoush* shrimp catch was zero. . The percentages thus obtained were applied to shrimp catches initially assigned to steel trawl for 1971-1978.	Steel trawl shrimp catches for 1971-1978 were obtained by subtraction of the reconstructed *Banoush* shrimp catch from the shrimp catch initially assigned to steel trawl (Table 9).	The same method used to reconstruct steel trawl fish catch for 1967-1970 was applied here to reconstruct the steel trawl fish catch for 1970-1978.
1979, 1986	The artisanal marine fishery catch data was available for 1979 and 1986 from Musaiger (1988, Table 10).	The sum of *Banoush* and artisanal catch data were available for 1979 and 1986 from Musaiger (1988, Table 10) as 'artisanal' catch because the Bahraini government classifies the *Banoush* fishery as artisanal. However, as stated earlier, all trawlers are considered industrial here. Musaiger (1988) also made available artisanal catch (as defined here) for 1979 and 1986 (Table 10). Thus the *Banoush* shrimp catches were obtained as following: For (A): Sum of *Banoush* and artisanal catch; (B) artisanal catch; and (C) *Banoush* catch: C= A-B.	For: (D) Industrial catch including steel trawl shrimp and fish catch obtained from Musaiger (1988, Table 10); (E) steel trawl fish catch from Musaiger (1988, Table 10); and (F) steel trawl shrimp catch, the following was applied: (f) = (E)-(D).	The fish trawl fishery catch data was available for 1979 and 1986 from Musaiger (1988, Table 10).

Table 7 (continued). Methods applied to reconstruct commercial marine catches for Bahrain for 1950- 2015 by sector (Part 3/4). Note that the methods for the reconstruction of the artisanal commercial catches by *Hadrahs* are presented separately (see section '*Hadrah* fishery').

<table>
<tr><th rowspan="2">Year</th><th rowspan="2">Artisanal catch (t)</th><th colspan="3">Industrial catch (t)</th></tr>
<tr><th>Banoush shrimp catch (t)</th><th>Steel trawl shrimp catch (t)</th><th>Steel trawl fish catch (t)</th></tr>
<tr><td>1980-1985</td><td>Banoush and artisanal catch data were available for t1980-1985 from Musaiger (1988, Table 10) as a sum categorized as artisanal catch because the Bahraini government classifies the Banoush fishery as artisanal. However, as stated earlier, all trawlers are considered industrial here. The artisanal catches were obtained as following:
For (H): Sum of Banoush and artisanal catch; (I) reconstructed Banoush catch; and (J) artisanal catch: J= H-I.</td><td colspan="2" rowspan="2">The Banoush and steel trawl shrimp catches were estimated following the same methods and sources deployed to estimate them for 1971-1978 (Table 9). For 1998, the FAO reported green tiger prawn catch was used to represent total shrimp catch.
It should be noted that total shrimp catch data for 1980-1997 from Abdulqader (2001) (Table 8) was equivalent to the FAO reported green tiger prawn catch for the same time period.</td><td>The Sum of shrimp and fish industrial catch was made available for 1980 and 1985 from Musaiger (1988, Table 10). The fish trawl catch was obtained by subtracting the reconstructed shrimp trawl catch from the sum of shrimp and fish industrial catch.</td></tr>
<tr><td>1987-1998</td><td>Artisanal catch = (FAO reported catch – FAO reported green tiger prawn catch) – reconstructed fish trawl catch</td><td>According to Musaiger (1988), industrial fish catches by steel trawlers in 1986 were 1,304 t (Table 10) which is around 20% of the artisanal FAO catch (excluding green tiger prawn), i.e., 6,324 t.
Based on this, it was assumed that fish catch by steel trawlers represented 20% of FAO reported catch (excluding green tiger prawn).</td></tr>
</table>

Table 7 (continued). Methods applied to reconstruct commercial marine catches for Bahrain for 1950- 2015 by sector (Part 4/4). Note that the methods for the reconstruction of the artisanal commercial catches by *Hadrahs* are presented separately (see section '*Hadrah* fishery').		
Year	**Artisanal catch (t)**	***Banoush* shrimp catch (t)**
1999-2007	Artisanal catch = reported FAO catch – reconstructed *Banoush* shrimp catch	*Banoush* shrimp catches were estimated to be 2,473 t in 1998 and they were 4,442 t in 2008. Interpolation was then performed to obtain the *Banoush* catch for 1999-2007 (Table 8).
2008-2015	Artisanal catches were available for the 2008-2011 from and for 2012-2015 from Anonymous (2017).	*Banoush* shrimp catch were available for the 2008-2011 from and from Anonymous (2017, Table 8) for 2012-2015.

Table 8. Shrimp trawl catch for 1967-1998 for Bahrain, adapted from Abdulqader (1995, 2001).

Season	Data A (tonnes)			Data B (t)	Reconstructed catch (t)	
	Banoush trawl catch	Steele trawl catch	Total trawl catch	Total trawl catch	Year	Total trawl catch
1967/68	-	900	900	-	1967	900
1968/69	-	1,600	1,600	-	1968	1,600
1969/70	-	1,900	1,900	-	1969	1,900
1970/71	-	2,050	2,050	-	1970	2,050
1971/72		1,450	1,450	-	1971	1,450
1972/73		2,100	2,100	-	1972	2,100
1973/74		2,733	2,733	-	1973	2,733
1974/75		2,080	2,080	-	1974	2,080
1975/76		1,900	1,900	-	1975	1,900
1976/77		1,950	1,950	-	1976	1,950
1977/78		2,250	2,250	-	1977	2,250
1978/79		850	850	-	1978	850
1979/80	100	50	150	-	1979	150
1980/81	475	150	625	626	1980	626
1981/82	300	300	600	544	1981	544
1982/83	350	350	700	685	1982	685
1983/84	375	325	700	728	1983	728
1984/85	450	325	775	778	1984	778
1985/86	900	550	1,450	1,444	1985	1,444
1986/87	1,100	650	1,750	1,313	1986	1,313
1987/88	1,200	750	1,950	1,695	1987	1,695
1988/89	900	250	1,150	1,073	1988	1,073
1989/90	1,150	150	1,300	1,258	1989	1,258
1990/91	975	200	1,175	1,151	1990	1,151
1991/92	600	25	625	620	1991	620
1992/93	675	25	700	807	1992	807
1993/94	2,000	25	2,025	2,079	1993	2,079
1994/95	-	-	-	1,116	1994	1,116
1995/96	-	-	-	1,666	1995	1,666
1996/97	-	-	-	3,800	1996	3,800
1997/98	-	-	-	2,247	1997	2,247

The above data were reported by 'tonne per season'. Each season covers part of year (i) and part of year (i+1). The length of a season varied over time. In1967-1979 it lasted from September of year i to February of year i+1 (FAO 1978). In the 1990s, a season spread from July of year i to March of year i+1 (Abdulqader 2001). More recently, the shrimp fishing season has been closed between mid-March and mid-July (Ali and Abahussain 2013). The seasonal fishing ban extended in 2015 from four to six months (Anonymous 2015). Data A and Data B were almost equivalent to FAO reported tiger shrimp catch. It seems that national seasonal landings for Bahrain were reported by the FAO as annual landings, e.g., catch for season 1996/97 was reported by the FAO as catch of year 1996. Due to lack of information on how the seasonal catches were reassigned into annual catch, the seasonal reconstructed shrimp catch will be considered here as annual shrimp catch.

Table 9. Reconstructed shrimp catches for the *Banoush* and steel trawlers for Bahrain for 1967-2015.					
Year	***Banoush* shrimp catch (t)**	**Steel trawl catch (t)**	**Year**	***Banoush* shrimp catch (t)**	**Steel trawl catch (t)**
1967	-	900	**1992**	778	29
1968	-	1,600	**1993**	2,054	26
1969	-	1,900	**1994**	1,099	12
1970	-	2,050	**1995**	1,639	14
1971	151	1,299	**1996**	3,729	24
1972	437	1,663	**1997**	2,201	10
1973	853	1,880	**1998**	2,473	6
1974	865	1,215	**1999**	2,670	900
1975	988	912	**2000**	2,867	1,600
1976	1,217	733	**2001**	3,064	1,900
1977	1,638	612	**2002**	3,261	2,050
1978	707	143	**2003**	3,457	1,299
1979	263	18	**2004**	3,654	1,663
1980	475	150	**2005**	3,851	1,880
1981	272	272	**2006**	4,048	1,215
1982	343	343	**2007**	4,245	-
1983	390	338	**2008**	4442	-
1984	452	326	**2009**	5066	-
1985	896	548	**2010**	6028	-
1986	1,229	623	**2011**	3849	-
1987	1,043	652	**2012**	3770	-
1988	839	233	**2013**	4310	-
1989	1,113	145	**2014**	4175	-
1990	955	196	**2015**	4979	-
1991	596	25	--	--	--

Table 10. Artisanal and Industrial catch for Bahrain for 1979 and 1986 from Musaiger (1988).			
Year	**Artisanal* catch (t)**	**Shrimp** catch (t)**	**Steel trawl finfish catch (t)**
1979	2,233	281	1,286
1986	4,901	1,852	1,304

*Total artisanal catch as defined here, i.e., excluding *Banoushs.*
**Total shrimp catch by both *Banoushs* and steel trawlers

Table 11. Artisanal and Industrial catch for Bahrain for 1979-1986 from Musaiger (1988).		
Year	**Artisanal + *Banoush* catch (t)**	**Steel trawl catch* (t)**
1979	2,496	1,305
1980	2,877	2,238
1981	3,599	2,148
1982	3,750	1,844
1983	3,303	1,509
1984	4,242	1,357
1985	6,185	1,578
1986	6,130	1,927

*Total steel trawl shrimp and finfish catch

Table 12. Trawl shrimp and artisanal catch from Anonymous (2017) and from a national report.*		
Year	**Trawl shrimp catch (t)**	**Artisanal catch (t)**
2008	9,733	4,442
2009	11,290	5,066
2010	7,462	6,028
2011	6,066	3,849
2012	23,326	3,770
2013	10,639	4,310
2014	11,678	4,175
2015	7,236	4,979

*Bahrain open data portal, information and egovernment authority available at http://www.data.gov.bh/en/Dashboards [accessed on 20/07/2018]

Industrial discards

Discards by trawlers were reconstructed using the same method as in the previous reconstruction. Al-Abdulrazzak (2013) estimated first the bycatch of the shrimp trawlers as being 15% of catches of green tiger prawns as per Abdulqader (2002). Then, based on Abdulqader (2002) and Kelleher (2005), Al-Abdulrazzak (2013) estimated discards to be 24 % of bycatch in 2000-2010. For earlier years, it was assumed that discards were about 80% of bycatch in 1950-1979 and 50% in 1980-1999. According to Grantham (1980), discards represented at least 40% of bycatch during the years following 1979. To remain conservative, it is here assumed that discards were 80% as per Al-Abdulrazzak (2013) in 1967-1979, as the shrimp trawl fishery started in 1967, 40% between 1980 and 1998, i.e., year the steel trawl fishery was banned, and 24% between 1999 and 2015. As per Al-Abdulrazzak (2013), a 3-year moving average was applied through the whole time period.

Artisanal fishery

The Bahraini artisanal fishery consists mainly of traditional tidal barrier traps, i.e., *hadrahs*, as well as other type of fishing gears such as hook and lines, wire traps, i.e. *gargoor*, gillnets, and ladles for jellyfish fishing (Musaiger 1988; Abdulqader 2001; Anonymous 2017). Methods applied to reconstruct the artisanal catches overall for 1950-2015 for Bahrain were summarized in Table 7. It should be remembered that here the artisanal fishery excludes the *Banoush* shrimp trawl fishery in opposition to the country’s definition.

Al-Abdulrazzak and Pauly (2014) estimated the number of *hadrahs* for the Persian Gulf countries, including Bahrain, via Google Earth, for the year 2005. According to this study, the number of *hadrahs* was 880 and their total catch was estimated to be 17,125 t·year^{-1}, in comparison to reported *hadrahs* catch of 1,960 t in 2005. Thus, unreported *hadrahs* catches amounted to 15,165 t·year^{-1}. Based on this study, it was possible to estimate the catch per unit of effort (CPUE) of *hadrahs* to be 19.5 t·*hadrah*$^{-1}$·year^{-1} in 2005. According to Musaiger (1988), the number of *hadrahs* in 1978 was 971. Although the CPUE of the *hadrah* fishery was likely to be higher in earlier decades due to an overall lower fishing pressure in Bahraini waters, the estimated CPUE of 2005 was applied to the number of *hadrahs* of 1978. The catch of *hadrahs in* 1978 was thus estimated to be 18,896 t. Musaiger (1988) also reported the catch by *hadrahs* for 1979 to be 570 t. By assuming that the number of *hadrahs* in 1978 and 1979 remained constant, it was possible to estimate the unreported catch of *hadrahs* for 1979 to be 18,326 t·year^{-1}.

To estimate the unreported catch by *hadrahs* for 1980-2004, an interpolation was performed between the anchor points. For 1950-1978 and 2006-2015, the same *hadrahs* catches as in 1979 and 2005, respectively, is assumed.

Recreational fishery

Al-Abdulrazzak (2013) estimated recreational catch to be around 4% the commercial catch. The same was applied here. It should be noted that recreational overfishing was mentioned by Morgan (2006) as recreational fishing has been gaining popularity over the years and particularly during the post-oil time period.

Subsistence fishery

According to Al-Abdulrazzak (2013) foreign workers represented 0.0046% of the population for 1960-2010. It was then assumed that foreign subsistence fishers take 5 kg·week^{-1}.

Taxonomic disaggregation

Around 95% of the commercial shrimp landings are of green tiger prawn. The other 5% is comprised mainly of western king prawn (*Melicertus latisulcatus) and* ginger shrimp (*Metapenaeus kutchensis*). Other smaller in size species such as the peregrine shrimp (*Metapenaeus stebbingi*), southern rough shrimp (*Trachysalambria curvirostris*), fiddler shrimp (*Metapenaeopsis stridulans*), and mogi velvet shrimp (*Metapenaeopsis mogiensis*) are often caught but partially or fully discarded (Abdulqader 2001). Based on this it was assumed that 95% of the industrial shrimp catch was composed of 95% of green tiger prawn, 2.5 % of western king prawn, and 2.5 % of ginger shrimp catch.

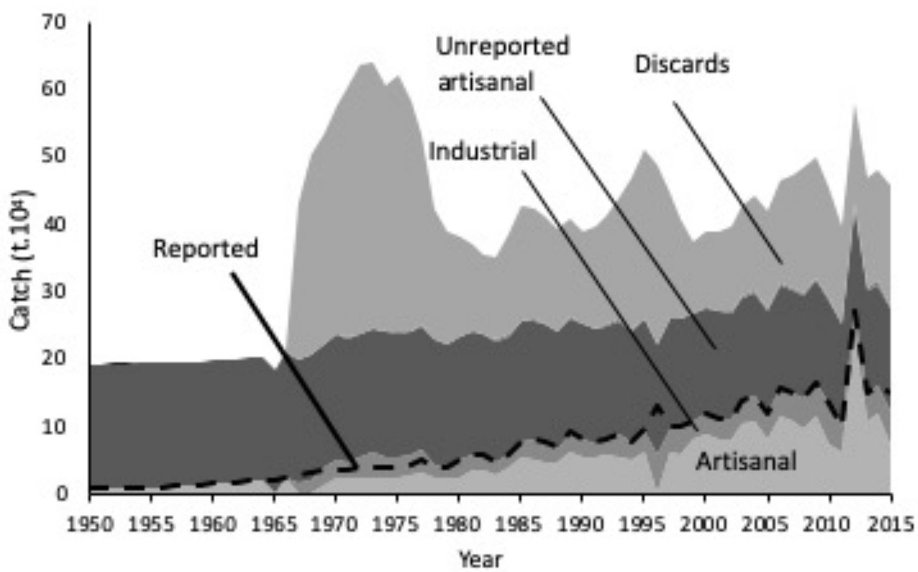
FAO reported catch data for 1950-1969 had a very poor taxonomic disaggregation consisting of green tiger prawn and the group 'marine fish non-identified'. The FAO reported species disaggregation of 1970 was applied to the artisanal catch for 1950-1969 and was, as well, applied to the fish trawl catch (excluding green tiger prawn). The same taxonomic disaggregation as that reported for 1970-2015 (excluding green tiger shrimp) was applied to the artisanal and fish trawl catches for the same time period.

The taxonomic disaggregations applied in the previous reconstruction to the subsistence, recreational, and unreported artisanal (*hadrahs*) catches as well as discards were applied here.

Country specific results

Marine fisheries catch for Bahrain were reconstructed for 1950-2015 and were estimated to be around 5.6 times the catch reported by the FAO on behalf of Bahrain. Reconstructed marine fisheries catches for Bahrain include the following components: reported commercial artisanal catches (~12%), reported commercial industrial catches (~6%), unreported commercial artisanal catches (~45%), recreational catches (~0.49%), subsistence catches (~0.01 %), and industrial discards (~37%) (Figure 9a). The main taxonomic groups that contributed the most to the reconstructed catches by the Bahraini fisheries are rabbitfishes (i.e., Siganidae, ~14%), followed by surmulets (i.e., Mullidae, ~6%), mojarras (Gerreidae, ~6%), and threadfin breams (Nemipteridae, ~6%) (Figure 9b).

a)



b)

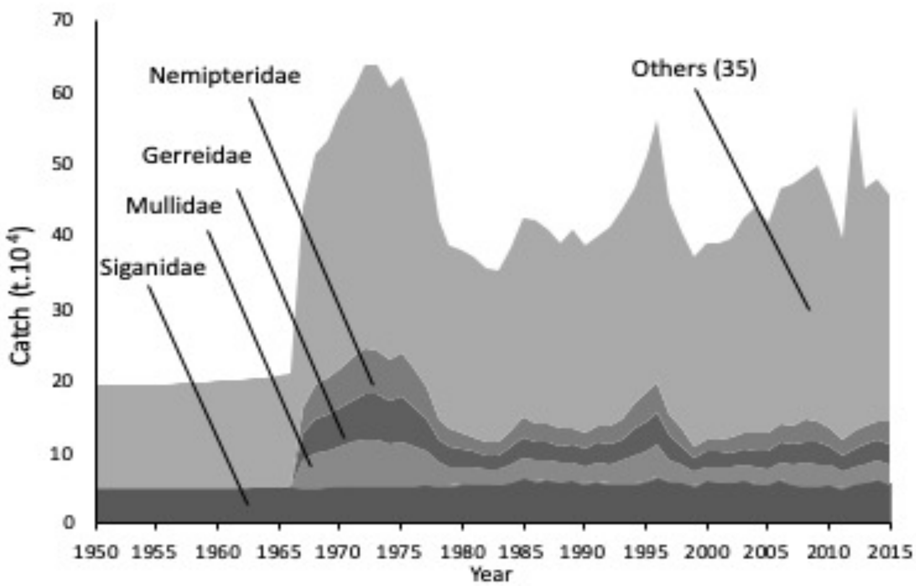


Figure 9. Reconstructed marine fisheries catches for Bahrain by a) sector with comparison to reported FAO data, and b) major taxa for the 1950-2015. Subsistence and recreational catches were included to graph (a) but are not visible because they are too small.

2.3.1.3 Egypt (Red Sea)

Background

Egypt is a Northeast African country that has a two-part EEZs, one of which is in the Red Sea and the other in the Mediterranean. Fish catches in Egypt come from 4 different sources: marine waters, lakes, fresh waters and aquaculture, which is now the most important fish source (CAPMAS 2019a). The Egyptian Red Sea fisheries (Figure 10) are the most important fisheries in the Red Sea notably because they use trawlers, which also operate outside their own EEZ (Awadallah and Sanders 1983).

Figure 10. The EEZ and shelf area of Egypt (Red Sea).

In 2011, Egypt witnessed a revolution followed by a military coup in 2013. This has led to instability in the country and even less enforcement or regulations for the fishing industry.

Consequently, the control of IUU fishing activities declined and became almost inexistent in certain areas (Viney 2011; Öztürk 2015).

The Egyptian fishing industry in the Red Sea comprises an industrial fishery deploying mainly purse seines and trawls, a small-scale fishery including commercial artisanal (locally known as semi-industrial), subsistence, and recreational fisheries.

Here, the fisheries catches for the Egyptian Red Sea EEZ were reconstructed for 2011-2017. This study is an improvement and an update of a reconstruction completed previously by Tesfamichael and Mehanna (2012) for 1950-2010 for the Red Sea EEZ of Egypt.

Country specific implementation

Reported marine landings were available by year and taxa for the Egyptian Red Sea EEZ for 1950-2017 from the Food and Agriculture Organization (FAO) Fishstat database. Landings for the same EEZ were made available for by the General Authority for Fishery Resources Development (GAFRD) and the Central Agency for Public Mobilization and Statistics (CAPMAS) for 2004-2017 (GARFD 2013, 2014, 2016; CAPMAS 2019a). FAO and local datasets were equivalent. The FAO data were used in this study as a reported baseline, to which unreported commercial (artisanal and industrial), subsistence and recreational catches were added, as well as major discards.

The reconstruction methods applied here were based on the methods used in the previous reconstruction by Tesfamichael *et al.* (2012a). The taxonomic disaggregation for all the reconstructed sectors was also similar to those applied in the previous reconstruction for 2010.

Large- and small-scale fisheries catches

According to Tesfamichael *et al.* (2012a), the catch contribution of industrial including trawlers and purse seiners, and of artisanal fisheries to total reported landings in 2010 were 24%, 29%, and 47%, respectively. These percentages were applied to the FAO reported catch data to split them into commercial large- and small-scale sectors. Unreported artisanal catches were re-estimated for the 1950-2010 in addition to 2011-2017. It was assumed that unreported artisanal catch decreased from 40% of reported catch in 1950 to 10% in 2010. Given the 2011 turmoil events in Egypt, it was assumed that the fraction of unreported artisanal catch increased to 20% of the reported artisanal catch in 2011, then decreased to 15% in 2012 and back to 10% until 2017.

According to Tesfamichael *et al.* (2012a), unreported catch by purse seiners and trawlers were 3% and 31% respectively. Although, it is most likely that these percentages increased during the 2011 turmoil and later, to remain conservative, it was assumed that they remained the same for 2011-2017.

It should be noted that in the previous reconstruction, part of the subsistence catches were classified as reported. These 'subsistence catches' were, however mis-categorized as artisanal, i.e., commercial catches. Subsistence catches are, by definition, non-commercial (see later section). Thus, reported 'subsistence catches' from the previous reconstruction was reclassified here as artisanal.

Discards

According to Tesfamichael *et al.* (2012a), discards were mainly from the trawl fishery, estimated to be 40% of total trawl reported and unreported catch. The same percentage was applied for 2011-2017.

Recreational catch

Because of the several events that took place in Egypt leading to a lack of security in the country, it was assumed that the participation rate in the recreational fishery decreased by 40% in 2011. The country became a bit more stable during the following years for the tourism sector. Thus, it was assumed that the participation rate increased by 10% in 2012 and by an additional 10% in 2013 and again in 2014. The participation rate was assumed to have remained the same as 2014 in 2015-2017. Also, the number of fishing days per year was assumed to have decreased from 250 in 2010 (Tesfamichaela and Mehanna 2012) to 150 in 2011 and then increased to 200 between 2012 and 2017. The per capita catch rate of 1 $kg \cdot day^{-1}$ applied by Tesfamichaela and Mehanna (2012) was applied here.

Subsistence

The subsistence fishery involves fish caught for personal consumption by rural coastal communities who do not have easy access to markets and lots of food sources in general. To estimate subsistence catches a subsistence per capita consumption rate was applied to the Egyptian rural population residing within a 5 km range from the Red Sea coast. Assessment of the total Egyptian coastal population within 5 km range from the coast were made available by the 'Socioeconomic Data and Applications Center' for the years 1990, 2000 and 2010 (CIESIN 2012b). The ratio of the total coastal rural population to the total rural population of Egypt for 1990, 2000 and 2010 was assumed based on the total rural population available via the World Bank for the whole of Egypt for 1960-2018. An extrapolation was performed to obtain the ratios for 2011-2017. The obtained ratios were then applied to the total rural population for 2011-2017.

The estimated total Egyptian coastal population includes the population on both the Red Sea and the Mediterranean coasts. It was then necessary to estimate the coastal rural Egyptian population for the Red Sea coast only.

Rural populations by province were made available for all Egyptian provinces for 2014[1] and 2018[2] by the Central Agency for Public Mobilization and Statistics (CAPMAS 2015, 2019b). The ratios of the rural populations within the Red Sea coastal provinces to the rural populations

[1] Population Estimates By Governorate (Urban /Rural) 1/1/2015; available at http://www.msrintranet.capmas.gov.eg/pdf/EgyptinFigures2015/EgyptinFigures/Tables/PDF/1-%20السكان/pop.pdf [accessed 20/11/2019]

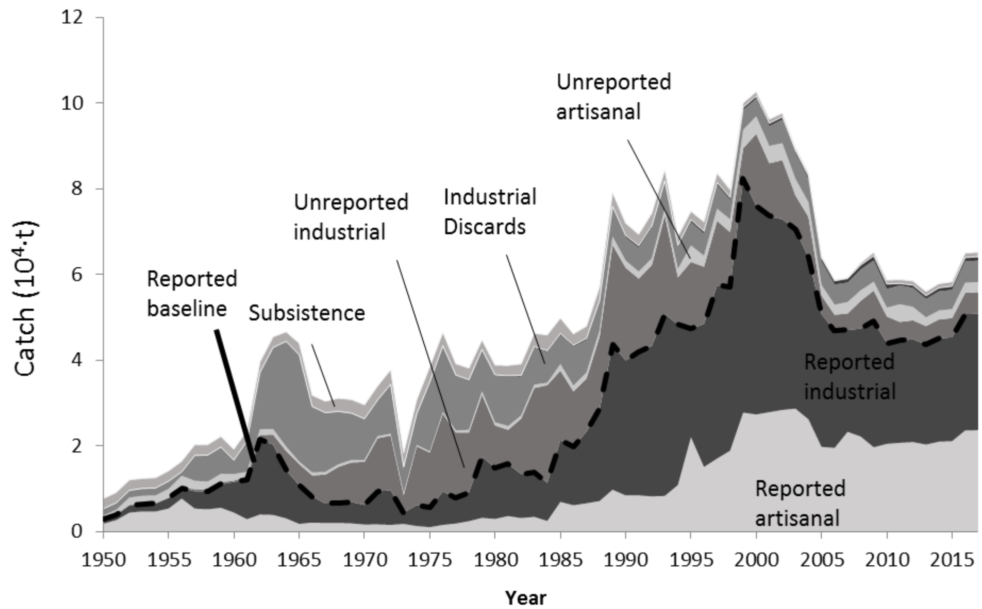
[2] Population Estimates By Governorate (Urban /Rural) 1/1/2019; available at https://www.capmas.gov.eg/Pages/StaticPages.aspx?page_id=5034 [accessed 20/11/2019]

within the total coastal provinces were estimated for 2014 and 2018. The ratios for 2011-2013 and 2015-2017 were estimated by extrapolation and interpolation. The ratios for 2011-2017 were applied to the Egyptian coastal population to estimate the Egyptian Red Sea coastal population for the study period. The per capita subsistence catch rate applied by Tesfamichael *et al.* (2012a) for 2010 was applied the estimates Red Sea Egyptian coastal rural population for 2011-2017.

Country specific results

Total marine catches were reconstructed for the Red Sea Egyptian EEZ for 2011-2017 and part of the previously reconstructed marine catches for 1950-2010 were adjusted. These catches include the following main components: reported industrial catch (37%), reported artisanal commercial catches (21%), unreported artisanal commercial catches (4%), unreported commercial industrial catches (18%), subsistence catches (4%), recreational catches (1%) and discards (15%) (Figure 11a). The catch composition suggested that jacks and pompanos (Carangidae ~15%) and Clupeidae (~12%) contributed the most to the Egyptian catches within in the Red Sea EEZ of Egypt between 1950 and 2017. These two groups are followed by barracudas (Synodontidae, ~7% of total catch), ponyfishes (Leiognathidae, ~ 6%), and Scombridae (~ 5%) (Figure 11b).

a)



b)

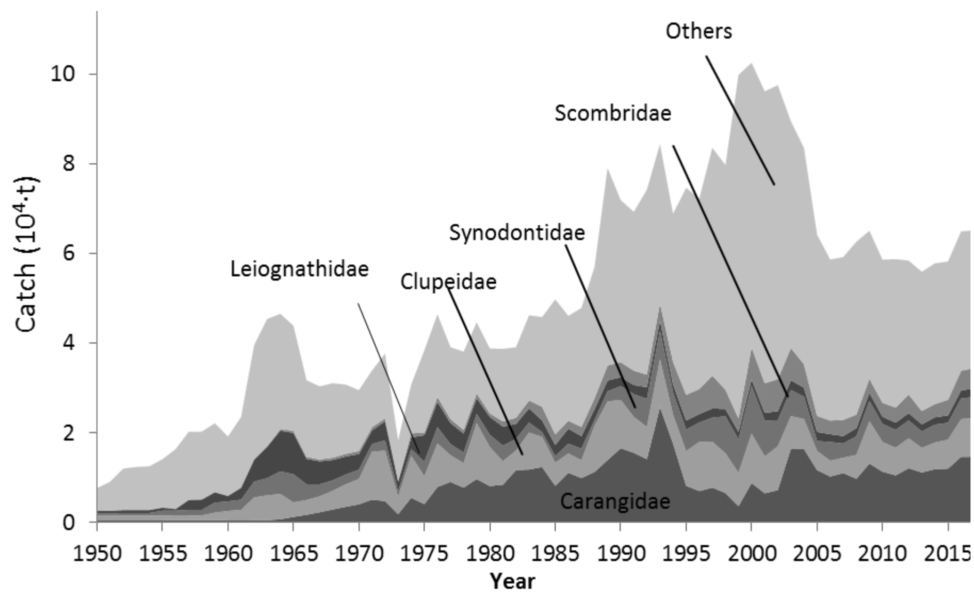


Figure 11. Reconstructed marine fisheries catches for Egypt's Red Sea for 1950 to 2017, by a) sector in comparison with FAO data; and b) by major taxa, with 'others' consisting of 48 additional taxa. Note that this update covers only 2011-2017. The data presented in those graphs for 1950-2010 are derived from Tesfamichaela and Mehanna (2012) and adjusted as required.

2.3.1.4 Iraq

Background

Iraq is characterized by important freshwater fisheries overshadowing a smaller, but relatively important marine fishery (Figure 12). The Iraqi EEZ is the smallest in the Persian Gulf, with an area of about 540 km^2 (www.seaaroundus.org/data/#/eez/368). Historically, the substantial water discharges of the Tigris and Euphrates Rivers through the Shatt Al-Arab River provided considerable nutrients to the fish fauna of the area, making it one of the richest of the Gulf. The flow of nutrients supported nurseries as well as feeding areas for several fish species, including the diadromous hilsa shad (*Tenualosa ilisha*). Due to damming, draining of marshes, and drought, these discharges have been decreasing. These activities led to the reduction of nutrient and water flows, deeply affecting the marine living resources of the northwestern Persian Gulf (Hussein and Ahmed 1995; Morgan 2006a; Al-Yamani et al. 2007)

Other factors have been affecting Iraqi marine fisheries as well, such as successive wars, political and socio-economic turmoil, and UN sanctions. Following the end of WWII and until the late 1970s, the Iraqi political climate was marked by several coups, coup attempts and civil wars (Metz 1988). In 1979, a coup d'état brought Saddam Hussein to power. In late 1980, Iraq entered a war against Iran that lasted for 8 years. In 1990, the invasion and occupation of Kuwait by the Iraqi Army, followed by a military response by a US-led coalition, resulted in the first Gulf war, which lasted for several months. Because of its invasion of Kuwait, Iraq was subject to UN sanctions between 1990 and 2003. In 2003, a US-led coalition invaded Iraq, marking the start of the second Gulf war, which lasted until 2011 and resulted in the end of Saddam Hussein's regime. This created a power vacuum in the country, leading to increasing violence between the different religious and/or ethnic groups. This Iraqi insurgency continued after the withdrawal of the US military from Iraq, which facilitated the invasion in 2014 of major Iraqi territories by the self-proclaimed Islamic State of Iraq and Syria (ISIS), escalating a previously unstable situation to an ongoing war. These events have affected the Iraqi marine fishing industry at different levels.

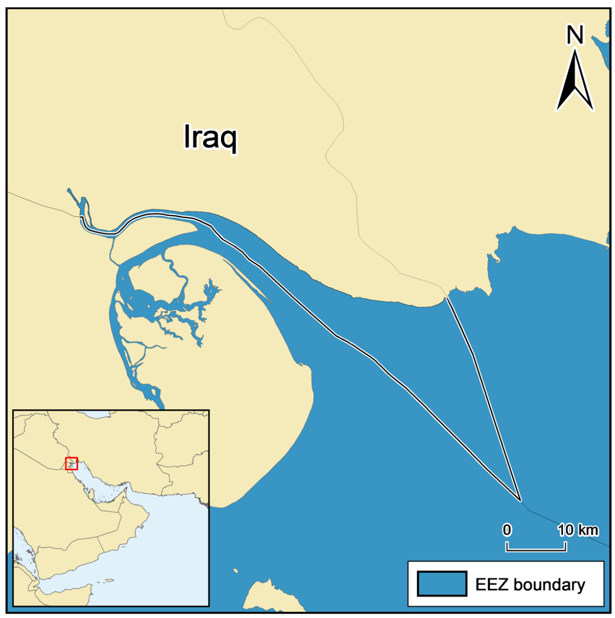


Figure 12. The EEZ and shelf area of Iraq.

The evolution of the Iraqi marine fishing industry (1950-present)

The first study of the Iraqi marine fishing industry was conducted by Amodeo (1956) an FAO collaborative project to assess the potential for developing the Iraqi fishing industry. According to this report, the Iraqi marine fishing industry during the 1950s was ‘primitive’ and ‘ill-equipped’, relying solely on traditional fishing gears operating in shallow waters. The report underlined the necessity for the Iraqi government to invest in the Iraqi marine fishing industry and to regulate fishing activities. Andersskog (1966) reported that the inefficiency of the fish marketing system in the 1960s was the biggest obstacle to the development of the fishing industry.

According to Metz (1988), the Iraqi government started investing in the development of the fishing industry in the 1970s. It is not clear, however, whether this statement refers to the freshwater or to the marine fishing industry. In 1976, the Iraqi government improved the national marine fisheries laws and regulations and took over the management of the marine fishing industry (Al-Assadi and Al-Matouri 2014).

In late 1980, Iraq entered a war against Iran. Consequently, marine areas were closed to fishing for almost 8 years (Ali et al. 2000; Mohamed et al. 2002b; Mohamed and Qasim 2014). After the Iraq-Iran war, only small-scale fishing re-established itself in 1989 (Ali et al. 2000). With the start of the first Gulf war in 1990, fishing almost completely ceased, until around mid-1991, i.e., fishing ceased between January and August 1990 and January and May1991 (Ali et al. 1998). By the end of 1991, fishing activities resumed (Ali et al. 1998; Mohamed et al. 2002b). The UN sanctions imposed on Iraq between 1990 and 2003 led to the intensification of marine fishing activities (Mohamed and Qasim 2014). Following the US-led coalition invasion of Iraq in 2003, fishing stopped for almost a year (Nasir and Khalid 2013). In 2011, all US forces withdrew from

Iraqi territories, yet the period between 2011 and 2014 was marked by violence and instability that facilitated the invasion of Iraq by ISIS in 2014. It is likely that the recent events have affected the Iraqi marine fishing industry. Information on this topic is, however, limited.

Marine fisheries sectors in Iraq

Although some sources suggest that the Iraqi marine fishing industry consists only of a traditional artisanal fishery, they also pointed out the use of trawl nets by traditional *dhows* (Jawad 2006; Morgan 2006a). Furthermore, several Iraqi studies acknowledged the existence of an active industrial fishery, operated not only by small, but also by large trawlers (Ali et al. 1998, 2000; Ali 2001; Mohamed et al. 2002a; Mohamed et al. 2002b; Mohamed and Qasim 2014). Thus, the fishing industry in Iraq comprises a major artisanal multi-gear and multi-species fishery, as well as a smaller, but still important industrial trawl fishery.

The marine fishing industry was entirely artisanal and very limited overall in the 1950s, relying mostly on permanent traditional traps, and occasional gillnets and driftnets deployed in shallow marine waters (Amodeo 1956). In the same period, the FAO introduced Iraqi fishers to the use of hook and line fishing to help increase yields (Amodeo 1956). Today, despite an increase in the number of artisanal boats and the relative modernization of the sector compared to the 1950s, the small-scale fishery still consists mainly of wooden launches and small boats deploying traps (e.g,, hadhra), gillnets, and hook and line (Mohamed et al. 2002a; Mohamed et al. 2002b; Al-Assadi and Al-Matouri 2014).

Information on the Iraqi large-scale marine fishery is sparse, and so is information on the introduction of the trawl fishery in Iraqi waters. In 1951, the Iraqi government launched an experimental/exploratory trawler 'Zubeidi' in Iraqi marine waters. This exploratory fishing failed to meet expectations and the experiment was stopped in 1952 (Amodeo 1956). No trawlers nor trawl nets were mentioned by Andersskog (1966) in his 'Report to the Government of Iraq' on Iraqi fisheries. According to Ali et al. (2000) and Mohamed et al. (2002b), small Iraqi trawlers were present in the 1970s, while Jawad (2012) mentions that a new fishing company started operating in Iraqi marine waters during the mid-1970s. The industrial fishery, i.e., trawl fishery, was government-owned between 1975 and 1990, and was privatized in the early 1990s (Ali et al. 1998; Mohamed et al. 2002b). Following the imposition of the UN sanctions on Iraq, trawlers started to be built domestically, particularly small trawlers (Mohamed et al. 2002a). All this information leads to the conclusion that an industrial fishery has existed at least since the mid-1970s.

Finally, there is apparently no recreational fishing in Iraq (Morgan 2006a); in contrast a subsistence fishery is likely to exist, but there is no information on it.

Marketing of fish in Iraq

During the 1950s and 1960s, fish marketing was largely undeveloped, with no adequate landing, storing or transport facilities (Andersskog 1966). The auction market for marine fish was mainly in Basrah. The city of Fao also had a landing site for marine fish but the landed fish was usually taken to Basrah. The Basrah auction market was important in Iraq but was far from being well equipped, and basic health standards were regularly breached (Andersskog 1966).

Until the mid-1970s, marketing of fish was private and independently managed. In 1976, fisheries became managed by the government and the 'General Enterprise for Fish' (المؤسسة العامة للاسماك) was created and given the responsibility of retailing and monitoring the marketing of landed fish. Meanwhile, the 'Agricultural Workers Union' (نقابة العمال الزراعيين) was created along with other fishers cooperatives and associations (Al-Assadi and Al-Matouri 2014). During the 1970s, the main fish market was still the Basrah auction market where catches were sorted and sold directly to the General Enterprise for Fish or the Agricultural Workers Unions. Some fish was also channeled to Fao (Al-Assadi and Al-Matouri 2014). Later on, likely following the first Gulf War, the main auction market moved from Basrah to Fao which is bigger and better equipped, permitting increased fishing activities in Iraqi marine waters (Ali et al. 1998; Mohamed et al. 2002b; Mohamed and Qasim 2014).

Country specific implementation

Reported marine fisheries catches were available from the FAO Fishstat database for 1950-2015 by taxa and year. They were used in this study as a baseline of 'reported landings', to which was added time series estimates of unreported large-scale commercial (i.e., industrial), small-scale commercial (i.e., artisanal) and subsistence fisheries landings, as well as estimates of major discards. The taxonomic composition of these data was improved using different local studies. The present catch reconstruction follows the reconstruction approach of Zeller *et al.* (2016b), which also defines 'catch' as consisting of both landed catch (i.e., landings) as well as discarded catch (i.e., discards).

Artisanal and industrial commercial fisheries

Standardized global definitions for the different fishing sectors do not exist (FAO 2017), i.e., definitions differ within and between countries and regions (Pauly and Zeller 2016). Thus, catch reconstructions generally retain and use national definitions of sectors if these exist, or substitute regional equivalents (Zeller et al. 2016). However, in line with general principles for all reconstructions in the Sea Around Us data, all trawling, whether conducted by *dhows* equipped with small trawl nets or by trawlers is considered industrial, as per Martín (2012). In this study, the marine artisanal fishery in Iraq combines all fishing activities that use traditional fishing gears, i.e., traps, gillnets, driftnets, hooks and lines, etc., while the industrial fishery consists of all trawling gear. Reported commercial catches represent fisheries catches that are channeled and sold through the official auction market and which are, hence, reported to the authorities. Fisheries catches sold directly to consumers without going through the regular auction route correspond to unreported commercial catches.

Reported large- and small-scale commercial catches

As discussed earlier, trawling likely did not occur in Iraqi waters during the 1950s and 1960s (Amodeo 1956; Andersskog 1966), and most sources only mention trawling activities in the Iraqi waters from the 1970s onwards (Ali et al. 1998, 2000; Mohamed et al. 2002b). Thus, here it was assumed that trawlers did not become officially active in Iraq until the early 1970s, except for the short period of non-commercial experimental trawling by the '*Zubeidi*' in 1951/1952. Therefore, all marine catches between 1950 and 1969 are considered small-scale.

The FAO data reports considerable catches during 1981-1988. However, as indicated above, it was very unlikely that any fishing activities occurred in Iraqi marine waters during the Iran-Iraq war, from late 1980 to the end of 1988. Civilians were not allowed to fish in what was at that time a battlefield (Laith A. Jawad, pers. comm.). Thus, it is more likely that the data presented by FAO on behalf of Iraq either over-reported marine catches, or more likely, confounded marine with inland water catches. This was corrected here by decreasing the FAO marine data by 90% over the period from 1981 to 1988. The remaining catches were classified as 'artisanal' (i.e., small-scale commercial).

The years 1988-1990 were considered a transitional period, and only artisanal fishing was thought to occur. By the end of 1991, industrial fishing activities were deemed to have re-initiated.

Information on the contribution of the large- and small-scale sectors to the Iraqi marine fishery is sparse. Morgan (2006) mentions that in 2002 catches originating from trawlers represent 23% of the 2002 catch, while artisanal catches (by gillnets) contributed the remaining 77%. According to Al-Assadi and Al-Matouri (2014), 90% of the fish available in the market originated from small-scale fisheries in 2011. Local sources estimate artisanal catches currently represent over 75% of total catch (Laith A. Jawad, pers. comm.). Thus, in order to approximately allocate the reported catch into artisanal and industrial sectors for the remaining time periods, i.e., 1970-1980 and

1991-2015, it was assumed that the contribution of artisanal catch decreased from 100% in 1969 to 90% in 1980. In 1988-1990, all catches were artisanal. Then, it was assumed that artisanal catches represented 90% of the catch in 1992; following the resumption of the trawl industry, this decreased to 75% by 2015.

Unreported large-scale commercial catches

Annual catches by trawlers were estimated by applying a CPUE estimate to the number of trawlers for the years 1970, 1980, 1994, 2001, 2008, 2011 and 2015. Industrial catches were reconstructed for the remaining years by performing interpolations between the different anchor points over time for large (or medium) and small trawlers (Table 13 and Table 14).

Table 13. Number and fishing effort of large and small trawlers operating in Iraqi marine waters.

Year	Type	Number	Fishing effort			Source
			hours·day^{-1}	days·month^{-1}	kg·hour^{-1}	
1989-1990	Large trawler (trawl survey)	-	-	-	330	Mohamed (1993)
1994	Large trawler	3	18	24	-	Ali et al. (1998); Mohamed et al. (2002b)
	small trawlers	25	14	24	-	
1995-1999	Small trawlers (trawl survey)	-	10	~30	26	Mohamed et al. (2002a)
		-	10	*10	-	Ali (2001)
2001	Small trawlers	1,500	-	-	-	Mohamed et al. (2002b)
2002	Trawler (type not specified)	50	-	-	-	Morgan (2006a)
2008	Trawler (type not specified)	751	-	-	-	Anonymous (2009)
2011	Trawler (type not specified)	751	-	-	-	Anonymous (2012)

*According to source: 12 0 days/vessel/ year

Table 14. Number, fishing effort and estimated catch of big and small trawlers operating in Iraqi marine waters.						
Year	**Type**	**Number of boats**	**Fishing (days·month^{-1} ·boat^{-1})**	**Fishing (hours·day^{-1} ·boat^{-1})**	**CPUE (kg·hour^{-1} ·boat^{-1})**	**Catch (t· year^{-1})**
1970	Large trawler	[1]	[9]	[12]	[300]	389
	Small trawlers	[1]	[7]	[12]	[26]	26
1980	Large trawler	[2]	[9]	[12]	[300]	778
	Small trawlers	[5]	[7]	[12]	[26]	131
1994	Large trawler	3	18	24	[300]	4,666
	Small trawlers	25	14	24	[26]	2,621
2002	Large trawlers	[25]	[18]	[24]	[150]	19,440
	Small trawlers	[500]	[10]	[10]	[13]	7,800
2008	Small trawler	751	[10]	[10]	[10]	9,012
2011	Small trawlers	751	[10]	[10]	[5]	4,506
2015	Large trawlers	[25]	[9]	[12]	[75]	2,430

* Annual total catch (t) = Number of boats·[(Fishing days·month^{-1}·12)·(Fishing hours·day^{-1})·(Kg·hour^{-1}. 10^{-3})]·boat^{-1}
[..] Based on different information sources in Table 13

According to Mohamed et al. (2002a) and Ali et al. (1998), the numbers of large and small trawlers in 1994 were 3 and 25, respectively (Table 13 and 14). Trawlers were inactive between late 1980 and 1991, as mentions earlier. Based on this information and to remain conservative, it was assumed that the number of large trawlers increased from 1 to 2 between 1970 and 1980 (Table 14). Small trawlers also operated during the 1970s (Mohamed et al. 2002b). However, the small trawl fishery gained importance after the Gulf War in 1992, especially because of the domestic construction of small trawlers (Mohamed et al. 2002a). Therefore, the number of small trawlers in Iraq for 1970-1980 was likely to be far less than in 1994. Hence, it was assumed that the number of small trawlers increased from 2 to 5 between 1970 and 1980 (Table 14). Interpolations were then performed between anchor points.

Estimation of the CPUE for 1970 and 1980 was based on information obtained for the years 1989-1990, 1994 and 1995 (Table13). The number of fishing days per month per boat, and fishing hours per day per boat were assumed to be half of those for 1994, for both small and large trawlers (Table 14). The catch per hour per boat would have been higher in 1970 and 1980 than in the late 1980s and 1990s, implying less fishing pressure in the past, but here it was assumed to have remained the same (Table 14).

No commercial fishing activities were assumed to have occurred in Iraqi marine waters between the late 1980s and 1988. Thereafter, only artisanal commercial fishing activities resumed between 1988 and 1990; and in 1990, the start of the first Gulf caused the interruption of all fishing activities for around a year. By the end of 1991, i.e. following the end of the war, fishing activities fully resumed in the Iraqi EEZ, and trawler construction flourished. Most of these trawlers were shrimp trawlers (Ali et al. 1998). The numbers of both large and small trawlers and their fishing effort are available for 1994 (Table 13). According to Mohamed et al. (2002a) and Mohamed (1993), the CPUE of large and small trawlers were 330 $kg \cdot hour^{-1}$ in 1989-1990 and 26 $kg \cdot hour^{-1}$ in 1995-2000, respectively (Table 14). Using this information, it was assumed that the CPUE of large and small trawlers in 1994 was 300 $kg \cdot hour^{-1}$ and 26 $kg \cdot hour^{-1}$, respectively (Table 14). Catches for both trawler types were estimated for 1994 by applying the CPUE of each type to the number of boats of the same type, as summarized in Table 14. To reconstruct catches for the early 1990s, an interpolation was performed between 1991 and 1994, assuming zero catches in 1991.

By 2001, the numbers of small trawlers had apparently increased to 1,500, compared to 25 in 1994 (Ali et al. 1998; Mohamed et al. 2002b; Table 13). Larger trawlers were estimated to be around 50 during the time period of 1995-1999 (Mohamed et al. 2002a) and in 2002 (Morgan 2006a; Al-Assadi and Al-Matouri 2014; Table 13). Hence, in order to conservatively estimate catches for the early 2000s (the year 2002 was chosen as anchor year), the number of small and large trawlers were assumed to have been around 500 and 25, respectively.

According to Ali (2001), small trawlers operated 120 days per year for 10 hours per day during 1995-1999. For the same period, Mohamed et al. (2002a) estimated small trawlers to also operate 10 hours per day, but for around 360 days per year. To remain conservative, it was assumed that in 2002, small trawlers operated 10 hours per day for 120 days a year with a catch of 13 $kg \cdot hour^{-1}$, i.e., equivalent to half the catch per hour in 1994. The number of fishing hours per day and number of fishing days per month used for 1994 were applied for the large trawls for 2002 with a catch of 150 $kg \cdot hour^{-1}$, i.e., equivalent to half the catch per hour in 1994. The lower CPUE rates were justified under the assumption that the rapid increase in the number of boast had quickly led to a declining catch rate. Catches by small and large trawlers for 1994-2002 were obtained by interpolation between the obtained anchor points of 1994 and 2002.

Due to the US-led invasion of Iraq in 2003, it is highly likely that no fishing activities occurred that year. Small quantities of fish were apparently landed in 2004 and overall catches were lower between 2003 and 2011 compared to earlier time period (Nasir and Khalid 2013). Information on fishing effort in 2004-2015 is sparse. Only the numbers of trawlers, most likely small trawlers, were available for 2008 and 2011, and for both years they were estimated to be 751 (Anonymous 2009, 2012).

To reconstruct catches by small trawlers for 2008, it was assumed that the 751 trawlers operated on average 10 hours per day for 120 days per year, i.e., the same effort as in 2002, and the catch rate was 10 $kg \cdot hour^{-1}$, i.e., lower than in 2002 because the growing number of operating trawlers increased the pressure on fish stocks (Table 14). Catches for 2003-2008 were obtained via interpolation, assuming zero catches in 2003. For 2011, it was assumed that small trawlers operated for the same time as in 2008 and yielded around 5 $kg \cdot hour^{-1,}$ i.e., half the value of 2008 because of the increasing pressure on fish stocks (Table 14). Interpolation was performed between 2008 and 2011. Catch for 2011-2015 by small trawlers were assumed equal to the catch of 2011.

The number of large trawlers was assumed to be around the same as in 2002, with trawlers operating only half the time in 2002 and yielding around 75 $kg \cdot hour^{-1}$, i.e., half the amount of 2002 because the pressure on fishing stocks was higher overall. Interpolation was performed between 2003 and 2015 for large trawlers, assuming zero catch in 2003.

The unreported commercial catches by trawlers were obtained by subtracting the reported industrial catches from the reconstructed industrial catches.

Unreported small-scale commercial catches

The artisanal (i.e., small-scale commercial) fishery in 1953 consisted mainly of 50 boats known as ‘boolams’ and deploying traps. The two most common types of traps were ‘mailan’ and ‘hadra’ (Amodeo 1956). The ‘mailan’ trap was of two types; ‘shore mailan’ deployed from the shore and the ‘sea mailan’ deployed from the ‘boolams’. On average, 12 ‘shore mailan’ operated in a given year and landed 77 t·year^{-1}. There were around 30 ‘sea *mailam*’ and they operated for 5-6 months a year, yielding 82 t·year^{-1}. Approximately 40 ‘*hadra*’ traps operated in marine and brackish waters, yielding up to 27 t·year^{-1} (Amodeo 1956); however, none of these *hadrah* were seen in Iraqi water by Al-Abdulrazzak and Pauly (2014), who used Google Earth to assess the presence of these gears in all countries in the Persian Gulf.

According to Amodeo (1956), the two main target species in the 1950s were hilsa shad and the silver pomfret (*Pampus argenteus*). Hilsa shad was caught using mainly stake nets known as ‘*odda*’, but also ‘shore *mailan*’ traps. Around 15 ‘*boolams*’, each of which deployed 100 ‘*odda*’, caught a monthly average of 1.6 tonnes per *boolam*. Fishing for hilsa shad occurred during their migration season. Fishing of the silver pomfret was performed by ‘floating cotton gillnets’. Around 6 Iraqi *boolams* were involved in this fishery in 1953, during which they yielded around 60 tonnes of silver pomfret. Amodeo (1956) also noted that in 1953, around 145 tonnes of silver pomfret were bought by Iraqi fishers from Iranian fishers and were sent to Iraqi markets. Using this information, the CPUE for each type of fishery is estimated for 1953 (Table 15). Fishing gears have not experienced large changes since the 1970s (Al-Dubakel 2011).

Table 15. Number, yield and calculated CPUE of different small-scale fisheries in Iraq in 1953 (Amodeo 1956).			
Type of fishery	**Number**	**Annual yield (t)**	**CPUE ($t \cdot year^{-1} \cdot boat^{-1}$)**
Shore *mailan*	12	77	6.42
Sea *mailan*	30	85	2.83
Hadrah	*20	27	1.35
Hilsa shad *boolams*	15	-	1.60
Silver pomfret *boolams*	6	60	10.00
**Hadrah* traps were also deployed in brackish and fresh waters, so to remain conservative, their number was halved.			

Fishing effort data for the artisanal fishery were available for the year 1994 (Hussein and Ahmed (1995) and the number of different types of artisanal boats was available for the years 2002 and 2011 (Mohamed and Qasim 2014), as summarized in Table 16.

Table 16. Artisanal fishing boat types and numbers in Iraq.				
Type / Year	**Fiberglass and speed boats**	**Dhows**	**Gillnet**	**Source**
1994	250	280	-	Hussein and Ahmed (1995)
2002	-	-	350	Morgan (2006a)
2011	538	-	-	Mohamed and Qasim (2014)

According to L.A. Jawad (pers. comm.), small artisanal boats usually do not report their catches and it is common among small-scale fishers to sell some of their catch to fishers from neighboring countries before even landing it. Thus, unreported commercial artisanal catches could reach similar or higher amounts than reported catches.

While some general information on the artisanal fishery is available, such as descriptions of the sector and its evolution over time (Amodeo 1956; Khayat 1978; Salman 1983; Al-Dubakel 2011; Mohamed and Qasim 2014), data on fishing effort of the artisanal fishery is sparse. In fact, the information summarized here used the only studies on the marine artisanal fishery of Iraq that appear to be available. Often, articles referring to the artisanal fishery in Iraq automatically include either the trawling industry or the freshwaters fishing industry.

Therefore, the obtained estimates of unreported artisanal commercial catches were based on conservative assumptions summarized in Table 17. Notably, it was assumed that unreported catches were around 30% of reported artisanal catches in 1950, decreasing to 20% in 1970, 15% in 1980 and then increasing to 20% after the Iran-Iraq of 1988-1990. In 1992, it was assumed that artisanal unreported catches to be around 20% of total catches, decreasing to 10% in 2002. In 2004, following the start of the second Gulf War, it was assumed that unreported catches to be around 20% decreasing to 10% in 2010. In 2011, the US-led coalition forces left Iraq but the Iraqi insurgency was still ongoing. Thus, it was assumed that artisanal catches were around 20% and increased to 30% in 2014 until 2015.

Table 17. Percentage of artisanal unreported commercial catch from the reported commercial catch for Iraq.

Years	**%**
1950	30
1970	20
1980	15
1988-1990	20
1992	20
2002	10
2004	20
2010	10
2011	20
2014-2015	20

Discards

One of the first studies on discards and bycatch in the Persian Gulf was conducted by Grantham (1980), based on a survey of the fisheries of the Persian Gulf countries. This study discussed the potential use and reduction of 'bycatch' in this region, defining bycatch as the 'incidental catches of non-target species that are subsequently discarded'. The definition of bycatch in Grantham (1980) overlaps with the herein definition of discards, i.e., the portion of catch that is rejected and thrown overboard (Alverson et al. 1994; Kelleher 2005).

While information on discards in Iraqi marine waters is sparse, some studies and surveys attempted to estimate the bycatch of certain marine Iraqi fisheries (Mohamed 1993; Mohamed et al. 2002a). In these studies, the term 'bycatch' is sometimes used as a synonym of discards and other times it includes both discards and what is referred to the as 'non-commercial species'. The 'non-commercial species' category appears to refer to the catch that is not sold/used for human consumption, but rather turned into fishmeal. Here, any catch, whether targeted or not, is considered commercial if sold, discard if rejected and subsistence if used for personal consumption. The 'non-commercial species' category is considered here as part of the commercial catches. Although not used for human consumption, 'non- commercial' catch is still landed and sold for fishmeal. Reconstruction of discarded catch is completed separately for the small- and large-scale fisheries.

According to Grantham (1980), Iran and Iraq reported the highest amount of bycatch in the Persian Gulf during the 1970s. Discards by trawlers in the Persian Gulf, during the 1970s, were estimated to be 50% of total industrial bycatch (Grantham 1980). Discards for the shrimp fisheries were estimated as 100,000 tonnes per year in Iraq's neighboring countries, i.e., Saudi Arabia, Kuwait, Iran and Bahrain (Kelleher 2005). The CPUE for discards by shrimp trawlers in the Persian Gulf during the early 1990s was estimated to be 4.17 $kg \cdot h^{-1}$ (Alverson et al. 1994). Thus, it was assumed that the large-scale discard rate was 4 $kg \cdot h^{-1}$ for both trawler types. Information summarized in Table 14 (i.e., number of fishing days per month and fishing hours per day) was applied to the discard rate for the whole study period.

Discarding within the Iraqi artisanal sector occurs, but is generally considered small. This discarding behaviour is mainly driven by the fact that most people residing around the EEZ of Iraq tend not to consume 'scaleless' fish due to religious belief (Jawad 2006). To remain conservative, it was assumed that small-scale discards represent 5% of the artisanal reconstructed commercial catch.

Subsistence fishery

Subsistence fishing refers to an activity whereby people fish mainly for their personal and family consumption and/or for bartering their catch against other foodstuff. To estimate subsistence catches, Al-Abdulrazzak (2013) applied an assumed subsistence catch rate of 0.5 $kg \cdot person^{-1} \cdot week^{-1}$ to the coastal Iraqi population living within 10 km of the coast and consisting of 0.001% of the total population. Here, the method of Al-Abdulrazzak (2013) was modified and subsistence catches were estimated by applying a per capita subsistence catch rate to the rural coastal population living within 5 km of the coast as derived for the years 1990, 2000, and 2010 from the 'Socioeconomic Data and Applications Center' (CIESIN 2012). To estimate the rural coastal population for 1990-2000 and 2000-2010, interpolations were performed between the three different anchor points.

To estimate the coastal rural population for 1950-1990 and 2010-2015, the total rural population for 1950-2015 was first estimated. The total rural population[1] as a percentage of the total population for Iraq was available via the World Bank for 1960-2016. This percentage was applied to the total Iraqi population[2], also available through the World Bank for 1960-2016 to obtain the rural population for 1960-2015. The rural population for the remaining time period, i.e., 1950-1959, was estimated by extrapolation of the 1960-2015 annual percentages of the rural population (from the total population) to 1950. The obtained percentages are then applied to the 1950-1959 total population (available through the United Nations[3]).

The annual percentages of the coastal population from the rural population were estimated for the years 1990, 2000, and 2010 based on CIESIN (2012). The obtained percentages were extrapolated to 2015 and back to 1950 and applied to the rural population for 1950-1989 and 2011-2015, thus obtaining the coastal rural population for the whole study period.

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[1] Rural population (% of total population): https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS [accessed on 11-20-2017];
[2] Total Population for Iraq: https://data.worldbank.org/indicator/SP.POP.TOTL [accessed on 11-20-2017].
[3] World Population Prospects 2017 : https://esa.un.org/unpd/wpp/Download/Standard/Population/ [accessed on 11-27-2017];

In a state of war, food security is usually affected negatively. Wars and turmoil could lead to an increase or a decrease in fishing activities, based on how geographically far the fishery is from the disturbed area. If the disturbance occurs geographically close to the fishery, fishing activities decrease and may even cease. If the turmoil or war occurs geographically far from the fishing area, fish becomes a substitute of other unavailable food, or populations affected by the war escape to coastal areas free of conflict (Jacquet et al. 2010).

The Iran-Iraq War and the Kuwait war both occurred around and near the coastal area of Iraq. Thus, it was assumed that subsistence fishing decreased by 90% during 1981-1988 and 1990-1991. The UN sanction led to the increase of fishing activities as fish became a substitute of other protein sources. The invasion led by the US seemed to have impacted coastal subsistence fisheries less than previous conflicts, and the later invasion by ISIS mostly occurred throughout the north of Iraq, geographically distant from the marine fishery. It was thus assumed that the subsistence fishery increased by 20% during the 1992-2015 time period.

The same assumed per capita subsistence catch rate of 0.5 kg·person^{-1}·week^{-1} applied by Al-Abdulrazzak (2013) was also used here.

Taxonomic composition

The taxonomic composition of FAO data for 1950-2003 consists of only one uninformative category, 'marine fishes nei' (i.e., not elsewhere included). It has, however, become more detailed since then.

Khayat (1978) reported the main taxonomic groups of marine fish sold by the private sector in Iraq from 1965 to 1974. According to Khayat, catches of hilsa shad (i.e., *Tenualosa ilisha*) dropped from 1234 tonnes in 1966 to 36 tonnes in 1967, and increased back to 1232 tonnes in 1968. This is most likely to be an error that was corrected here by performing an interpolation between 1966 and 1968. The percentage contribution of each taxonomic group to the total catch for 1965-1973 was then derived (Table 17).

Nasir and Khalid (2013) reported the taxonomic breakdown of the landings in Basrah over the 1990-2011 time period. The latter was improved and summarized in Table 18.

Table 18. Derived percentages of taxa landed by the private sector of the marine fisheries in Iraq (Khayat 1978).

Taxon \ Year	1965	1966	*1967	1968	1969	1970	1971	1972	1973
Tenualosa ilisha	76.2	78.2	76.3	81.9	70.6	95.2	97.9	91.7	92.2
Pampus argenteus	9.6	11.1	8.1	7.8	13.6	1.5	1.4	6.9	3.7
Chirocentrus dorab	2.8	2.1	4.9	2.3	0.4	0.0	0.0	0.0	0.0
Sparidentex datnia	3.0	0.2	1.1	0.4	0.6	2.5	0.0	0.1	0.1
Pleuronectiformes	0.4	0.8	0.3	0.3	0.0	0.0	0.0	0.0	0.1
Mixed fish	8.0	7.5	9.3	7.3	14.7	0.7	0.7	1.2	3.9

*Catch amounts for 1967 corrected by interpolation.

These studies, however, categorize all marine Iraqi fisheries as artisanal, i.e., including trawling, which is different from the fisheries sector classification in this study. Overall, information on the taxonomic composition of each of the artisanal and industrial catch is scarce. Therefore, the taxonomic disaggregation for 1965 and 1973 summarized in Table 17 were applied to the total reconstructed commercial large- and small-scale catch of 1950-1964 and 1974-1990, respectively. The taxonomic breakdown summarized in Table 18 was applied to total reconstructed artisanal and industrial catch for 1990-2003. Taher et al. (2011) reported the catch composition of a trawl fishery estimated through a trawl survey for 2008 and 2009. The FAO reported catch composition of the 2004-2015 was maintained for the reported industrial and artisanal catch. The taxonomic composition summarized in Table 19 is applied to the 'marine fishes nei' of the reported industrial catch and to the unreported industrial catch for 2004-2015. The taxonomic breakdown summarized in Table 18 is applied to the 'marine fishes nei' of the reported artisanal catch for 2004-2015 and to the unreported industrial catch for 1990-2003. The broad taxonomic disaggregation applied to the artisanal sector is pooled to the family level and applied to subsistence catch and discards for the entire 1950-2015 time period.

Table 19. Derived percentages of marine species landed in Iraq between 1990 and 2011 (Adapted from Nasir and Khalid 2013).

Common name	Scientific name	Catch (%)
Hilsa shad	*Tenualosa ilisha*	45.00
Greenback mullet	*Chelon subviridis*	17.48
Dorab wolf-herring	*Chirocentrus dorab*	3.96
Sin croaker	*Johnius* spp.	2.08
Bloch's gizzard shad	*Nematalosa nasus*	2.71
Johnius dussumieri	*Johnius sina*	2.70
Talang queenfish	*Scomberoides commersonnianus*	1.42
Silver pomfret	*Pampus argenteus*	0.71
Spangled emperor	*Lethrinus nebulosus*	0.51
Yellowfin seabream	*Acanthopagrus latus*	0.47
Narrow-barred Spanish mackerel	*Scomberomorus commerson*	0.39
Oriental sole	*Brachirus orientalis*	0.38
Compressed ilisha	*Ilisha compressa*	0.23
Orange-spotted grouper	*Epinephelus coioides*	0.18
Blotched croaker	*Nibea maculata*	0.11
Bartail flathead	*Platycephalus indicus*	0.09
Silver grunt	*Pomadasys argentens*	0.06
Threadfin & whiptail breams	*Nemipterus* spp.	0.03
Greater lizardfish	*Saurida tumbil*	1.95
Tigertooth croaker	*Otolithes ruber*	1.95
Shrimp scad	*Alepes djedaba*	1.95
Silver pomfret	*Pampus argenteus*	1.95
Indo-Pacific king mackerel	*Scomberomorus guttatus*	1.95
Striped piggy	*Pomadasys stridens*	1.95
Fourfinger threadfin	*Eleutheronema tetradactylum*	1.95
Cobia	*Rachycentron canadum*	1.95
Spottail needlefish	*Strongylura strongylura*	1.95
Hound needlefish	*Tylosurus crocodilus*	1.95
Largehead hairtail	*Trichiurus lepturus*	1.95

Table 20. Species breakdown of marine landings by trawlers in Basrah for 2008/2009.	
Scientific Name	**Percent of total catch**
Planiliza subviridis	45.7
Equulites klunzingeri	22.9
Johnius belangerii	7.8
Acanthopagrus latus	3.9
Thryssa mystax	2.9
Thryssa hamiltonii	1.8
Sillago sihama	1.7
Sillago arabica	0.7
Scomberoides commersonnianus	0.9
Lamna nasus	1.0
Platycephalus indicus	0.9
Ilisha melastoma	0.4
Ilisha megaloptera	0.1
Bagrus orientalis	0.3
Sparidentex hasta	0.3
Photopectoralis bindus	0.3
Chirocentrus dorab	0.1
Sigmops elongatus	0.1
Acanthurus dussumieri	4.2
Periophthalmus waltoni	0.5
Pseudobalistes fuscus	0.9
Pseudosynanceia melanostigma	2.6

Country specific results

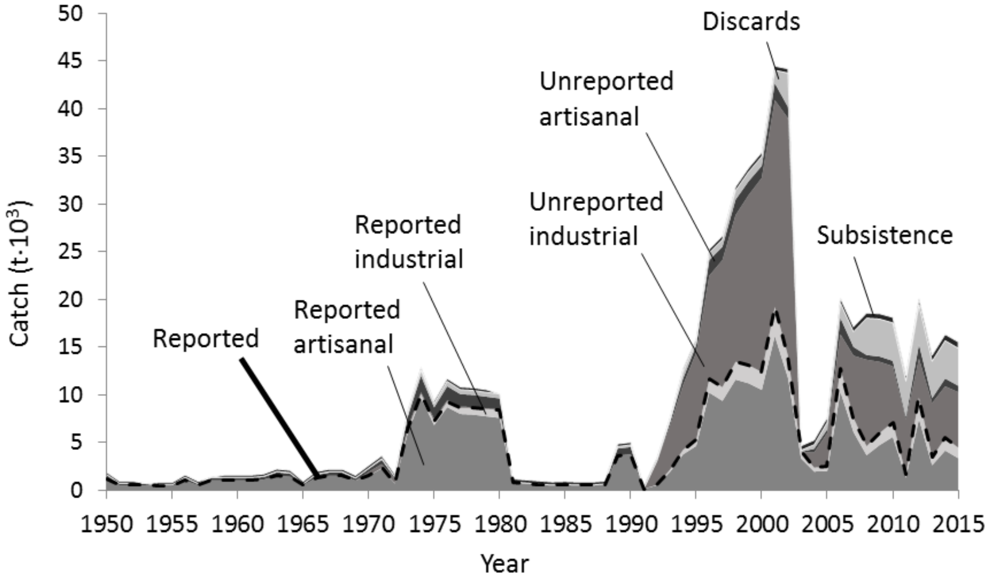
Total marine catches were reconstructed for Iraq for 1950-2015, including the following main components: reported commercial artisanal catches (~41%), reported commercial industrial catches (~6%), unreported commercial artisanal catches (~6%), unreported commercial industrial catches (~35%), subsistence catches (~3 %), and discards (~9%) (Figure 13a). The following taxonomic groups contributed the most to the catches by the Iraqi fishing industry: herring (i.e., Clupeidae, ~48%), mainly hilsa shad, followed by mullets (i.e., Mugilidae, ~20%), drums (Sciaenidae, ~5%), wolf herring (Chirocentridae, ~3%) and ponyfishes (Leiognathidae, ~3%) (Figure 13b). The reconstructed total catches were twice the landings reported by the FAO on behalf of Iraq, used here as a reported baseline, for 1950-2015.

Fishing activities were relatively low during the 1950s and the 1960s. Caches increased in the 1970s following the investment of the government at the time in the fishing industries in general including marine fisheries. Marine fisheries activities dropped considerably again during the 1980s following the Iran-Iraq war. This was the start of a long succession of decennial wars involving Iraq. Few years following the end of the Iran-Iraq war, Iraq entered a war against Kuwait in the early 1990s that ended after almost a year. However, the UN placed sanctions on Iraq, which led to a thriving domestic fishing boat manufacturing industry. Fishing activities developed again until the early 2000s when a US coalition invaded Iraq. The fishing industry progressively recuperated and remained relatively stable since then, despite the previous insurgency, the withdrawal of the US troops from Iraq, and the ISIS invasion of Iraq in 2014.

In Iraq, as it is the case in most unstable and economically developing countries, basing fisheries management on classical methods of stock assessments leads to the absence of management.

Nevertheless, by improving the monitoring of the main fisheries and putting in place institutions to enforce fisheries regulations and to watch for unreported and illegal fishing, it would be possible to obtain better catch data and even effort data. Such information could be used to assess the state of the fisheries, allowing to be put into place adequate management strategies. Unreported trawl fishing activities seem to be one of the main threats on the Iraqi marine fishing industry. Thus, it would be prudent to limit the trawl fishery and to support the artisanal fisheries.

a)



b)

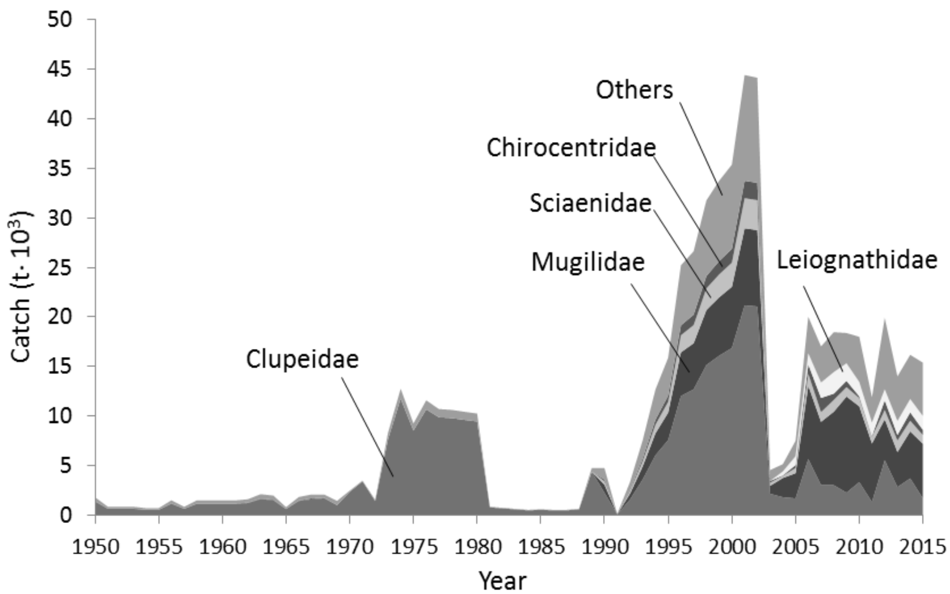


Figure 13. Reconstructed marine fisheries catches for Iraq for 1950-2015, by a) fisheries sectors plus discards. Landings as deemed reported by the FAO on behalf of Iraq are overlaid as a dotted line; and b) by major taxa. Note the 'others' category includes 34 additional taxonomic groups (23 additional families and a miscellaneous group).

2.3.1.5 Jordan

Background

Jordan is located in the Levantine area bordered in its southern-west by the Gulf of Aqaba in the Red Sea (Figure 14). Its EEZ is about 95 km^2 and shelters some of the most important coral reef systems in the world. Jordan also harbours the Dead Sea, i.e., the deepest hypersaline lake in the world. The Gulf of Aqaba is semi-closed and its waters renew once every two decades, allowing for high endemism and salinity in the region.

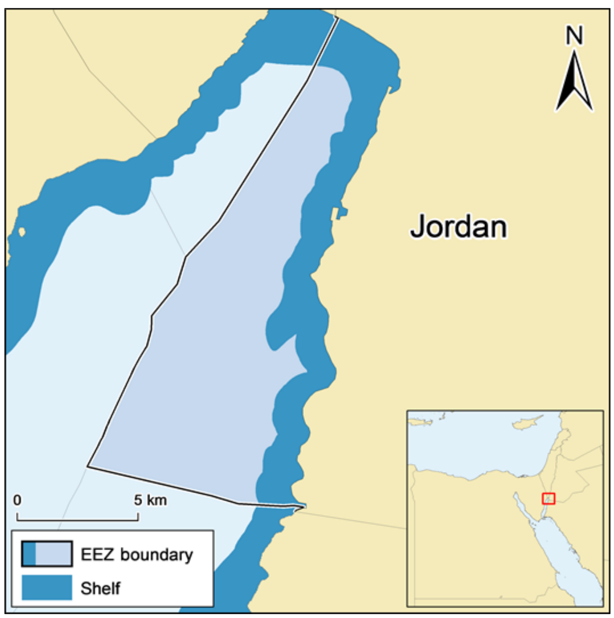


Figure 14. The EEZ and shelf area of Jordan.

These waters also support important sea grass beds along the coast, representing an important nursery for commercial fish species. This also makes the region very vulnerable to anthropogenic threats, e.g. pollution, overfishing, etc. (Khalaf and Disi 1997; Tesfamichael *et al.* 2012).

The Jordanian fishing industry is very small and entirely artisanal. Fishing does not play an important role in Jordan (Metz 1989a), with 85 fishers in 2001 from a population of 2.5 million (Morgan 2006c; www.worldbank.com). The different gears used include beach seines, gillnets, trammel nets, hand lines and longlines, and various traps. Illegal gears such as spear guns and dynamites are also deployed (Khalaf and Disi 1997). Thus, the Jordanian marine fishing industry is largely unregulated and unmonitored (Morgan 2006c). Aquaculture accounts for 50% of the total Jordanian fish production, and Jordan imports 98% of its fish (Barrania 1979; Sanders and Morgan 1989; Al-Zibdah *et al.* 2006; Morgan 2006c).

Jordan has been politically stable compared to its neighboring countries. However, because of the increasing pollution of Jordanian marine waters, many fishers have stopped their activities for an alternative source of livelihood (Ministry of the Environment 2002; Al-Ouran 2005).

There is an increasing recreational fishing activity in Jordan involving underwater fishing (FAO 2003a). Recreational and subsistence catches are not taken into account by the statistical system.

This catch reconstruction is an improvement and an update of the previous reconstruction completed by Tesfamichael *et al.* (2012a) for Jordanian waters to 2015.

Country specific implementation

Artisanal commercial fishery

According to PERSGA (2002), the collection of fisheries statistics ceased in 1985. The FAO fisheries catch data for 1950-1997 seems vague with one broad taxonomic group, i.e., ‘Marine fishes nei' (nei = not elsewhere included). However, other sources have made available fisheries catch data for different years from 1950-1997 (Table 21). These anchor points were used to reconstruct marine fisheries catch for the time period in question. Catches for the missing years were obtained by interpolation. Unreported catches were obtained by subtraction of the reported catch from the reconstructed one, when the reconstructed data were higher than the FAO data. Catches as reported by the FAO for the years 1998-2013 were used here as a baseline. However, for 2014 and 2015 the FAO reported the same catch amount with the same taxonomic disaggregation. National sources have made available marine fisheries yields for both years and they are slightly lower than what is reported by the FAO. Therefore, these values were used as anchor points for 2014 and 2015 (Table 21).

Smaller boats deploying handlines, which mostly fished in Jordanian waters, also existed. These boats do not usually report their catches as they sell it directly to consumers (Barrania 1979). Tesfamichael *et al.* (2012a) did estimate these catches using the same source, but classified them as subsistence. Here, such catches are categorized as unreported artisanal, as they are being sold and not used for personal consumption. Unreported artisanal catches by small boats (as redefined here) were estimated following the same method used by Tesfamichael *et al.* (2012a). According to Barrania (1979), 12 small boats caught an average of 6 to 10 kg per fishing day. Based on this it was assumed that the 12 boats caught an average of 8 kg per daytrip for around 200 daytrips per year in 1975. It was then assumed that these unreported catches were 10% higher in 1950 than those estimated for 1975 and 90% lower in 2015. Interpolation is then performed between the different anchor points. Unreported artisanal fishing still occurs, sometimes involving children. According to Chtioui *et al.* (2016) 28% of working children (i.e., about 78,000) participate in agricultural activities, including commercial fishing.

Following an agreement concluded between Jordan and Saudi Arabia in 1960, Jordanian fishers were allowed to fish along around 4 km of the Saudi coast (Gilberg 1966). This continued until 1985 (Barrania 1979; PERSGA 2002), although Sanders and Morgan (1989) mentions that such activities still occurred in 1986. The actual amount of fish caught by Jordanian fishers in foreign waters is not available. Barrania (1979) mentions that most larger boats, which were usually equipped with insulated ice boxes, used to fish in Saudi waters, i.e., 300 miles south of the Gulf of Aqaba. According to the same study, these boats caught an average of 180 $t \cdot year^{-1}$ during the 1960s and 1970s, while reported catches varied between 100 to 200 $t \cdot year^{-1}$. Smaller boats did also operate in the Saudi waters, but less frequently. Tesfamichael *et al.* (2012a) assumed that around 50% of the Jordanian marine fishery catches, including those reported by the FAO on behalf of Jordan, for 1950-1985 were caught in Saudi Arabia and adjusted the reconstructed catches accordingly. The same approach was applied here, but for the years 1960-1985, where 50% of reconstructed commercial reported and unreported catches by Jordan are assigned to Saudi Arabia. Foreign fishing is assumed to have decreased to 5% by 1989.

Table 21. Fisheries catches for 1950-2015 according to different sources Anchor points used to reconstruct marine catch in Jordan.

Year	Catch (t)	Source
1950-1954	-	Similar to 1956
1956	39	Gilberg (1966)
1957	86	
1958	48	
1959	50	
1960	121	
1961	133	
1962	188	
1963	161	
1964	174	
1965	181	
1966	194	PERSGA (2002)
1967-1971	-	Interpolation
1972	143	Barrania (1979)
1973	93	
1974	103	
1975	90	
1976	49	
1977	31	
1978	31	
1979-1982	-	Interpolation
1983	17	Chakraborty (1984)
1984-1985	-	Interpolation
1986	65	Sanders and Morgan (1989)
1987-1992	-	Interpolation
1993	103	FAO (2003)[4]
1994	-	Interpolation
1995	150	FAO (2003)[1]
1996-1997	-	Interpolation
1998	120	PERSGA (2002) and FAO Fishstat
1999-2013	-	FAO Fishstat
2014		National Report[5]
2015		

[4] 'Fishery country profile - Hashemite Kingdom Of Jordan' available at http://www.fao.org/fi/oldsite/FCP/en/JOR/profile.htm [Accessed July 9th, 2018]

[5] 'General statistics: Aquaculture production increased by 6.5% between 2014 and 2015' available at http://dos.gov.jo/new_site/dos_home_a/main/archive/news/2016/fish.pdf [Accessed July 10th, 2018]

Subsistence fishery

Tesfamichael *et al.* (2012a) reconstructed the catches of two different types of subsistence fisheries: Subsistence catch by smaller boats that is sold directly to consumers and that was re-estimated here as unreported artisanal; and subsistence catches by larger boats. Catches by larger boats are estimated following the same method as in the previous reconstruction, i.e. 10% of artisanal catches was consumed by crew and their family members.

The subsistence fishery also involves any fishing activity by people for their own consumption. Subsistence fishers fish out of necessity rather than for leisure (which would make their fishing recreational). To estimate these subsistence catches, a per capita subsistence catch rate was applied to the rural coastal Jordanian population. The Jordanian rural coastal population living within 5 km of the coast was obtained from the 'Socioeconomic Data and Applications Center' (CIESIN 2012a) for the years 1990, 2000, and 2010. To estimate the rural coastal population for 1990-2000 and 2000-2010, interpolations were performed between the three different anchor points. To estimate the coastal rural population for the years 1950-1990 and 2010-2015, a method similar to that applied for the Iraqi catch reconstruction (see subsection 2.4.1.4.) was used for estimating the rural coastal population of Iraq. The total Jordanian rural population[6] as a percentage of the total Jordanian population was available from the World Bank for 1960-2016. This percentage was first extrapolated back to 1950. It was then applied to the total Jordanian

[6] Rural population (% of total population): https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS [accessed on 11-20-2017];

population, available through the United Nations[7] for 1950-2015 to obtain the rural population for 1950-2015.

The annual percentages of the coastal population from the rural population were estimated for the years 1990 and 2010. The latter were then applied to the rural population for 1950-1989 and 2011-2015, respectively, thus obtaining the coastal rural population for the whole study period.

Most fish consumed in Jordan is imported, so the per capita consumption rate of local fish is relatively very low (Sanders and Morgan 1989; Al-Zibdah *et al.* 2006). According to Barrania (1979), the per capita consumption of fish in Jordan was 2 kg·year^{-1} during the 1970s. This increased slightly to 4 kg·year^{-1} in the years 1982-1984, of which less than 1% was from fresh local fish. Al-Zibdah *et al.* (2006) report a low per capita fresh fish consumption of 0.04-0.16 kg·year^{-1}. Based on this a conservative per capita subsistence consumption rate of 0.1 kg·year^{-1} was assumed.

Recreational fishery

Recreational catches were estimated by Tesfamichael *et al.* (2012a) for the years 1974-2010. Based there-on, a participation rate of 8% was applied to the population of Aqaba for the years 2011-2015 (Ghazal 2016). It was assumed that recreational fishers fish for 15 days·year^{-1} and that their catch rate decreased from 0.5 kg·day^{-1} in 2011-2015.

Discards

Because of the artisanal nature and small size of the fishing industry in Jordan, it is very unlikely that discarding occurs. Discards are negligible for Jordan according to Keller. However, high

[7] World Population Prospects 2017 : https://esa.un.org/unpd/wpp/Download/Standard/Population/ [accessed on 11-27-2017];

spoilage occurred during the 1970s, and spoilage rates were made available by Barrania (1979) for the years 1972-1978 (Table 22) which ranged from 54.1% in 1972 to 0.4 in 1978. This high discrepancy is likely due to misreporting of the amount of decayed fish for certain years. Spoilage rates were likely to be higher in earlier years and were likely still occurring at least until the late 1980s. Based on this it was assumed that spoilage rates decreased from 60% in 1950 to 54.1% in 1972 (as reported) to 5% in 1989 of total reconstructed commercial catch.

Table 22. Spoilage rates in the Jordanian catch (adapted from Barrania 1979).

Year	Percentage
1972	54.1
1973	1.7
1974	10.8
1975	27.9
1976	1.1
1977	-
1978	0.4

Taxonomic disaggregation

The taxonomic disaggregation of reported catch boils down to one broad category, i.e., Marine fishes nei, for 1950-1997. The species composition for this period was then improved and applied to commercial artisanal catches following the same methods as by Tesfamichael *et al.* (2012a) that shows the change of the Jordanian fishery from targeting reef-associated to pelagic fish (Table 23). The species disaggregation of subsistence catch is based on the same one as the commercial catches, pooled to the family level (Table 24).

The recreational taxonomic disaggregation is based on the Saudi's recreational fishery of the Red Sea: emperors 40%, sea breams 30%, groupers 20% and 'others' 10% (Tesfamichael and Rossing 2012b).

Table 23. Sources for taxonomic disaggregation for the Jordanian reconstructed commercial catch.

Time period	Source
1950-1984	Tesfamichael *et al.* (2012a) adapted from Barrania (1979) ; (Table 4)
1985-1989	Interpolation
1990-1997	Similar to the species composition of 1998
1998-2013	FAO Fishstat
2014-2015	FAO taxonomic disaggregation for 2014 and 2015 applied to the anchor points for the same years.

Table 24. Taxonomic disaggregation (%) for the artisanal commercial fishery of Jordan adapted from Tesfamichael *et al.* (2012a) and Barrania (1979).

Scientific name	Common name	Family	Catch (%)
Lethrinidae	Emperors	Lethrinidae	57.2
Lutjanidae	Snappers	Lutjanidae	18.4
Siganidae	Rabbit fishes	Siganidae	3.0
Carangoides spp.	Trevallies	Carangidae	2.9
Polysteganus coeruleopunctatus	Blueskin seabream	Sparidae	2.6
Lutjanus bohar	Two-spot red snapper	Lutjanidae	1.7
Sparidae	Porgies	Sparidae	1.7
Mullidae	Goat fish	Mullidae	0.4
Gerres oyena	Common silver-biddy	Gerreidae	0.3
Gymnocranius grandoculis	Blue-lined large-eye bream	Lethrinidae	0.3
Scaridae	Parrotfish	Scaridae	0.3
Epinephelus spp.	Grouper	Serranidae	0.3
Cephalopholis miniata	Coral hind	Serranidae	0.3
Serranidae	Grouper	Serranidae	0.3
Others	—	—	10.2

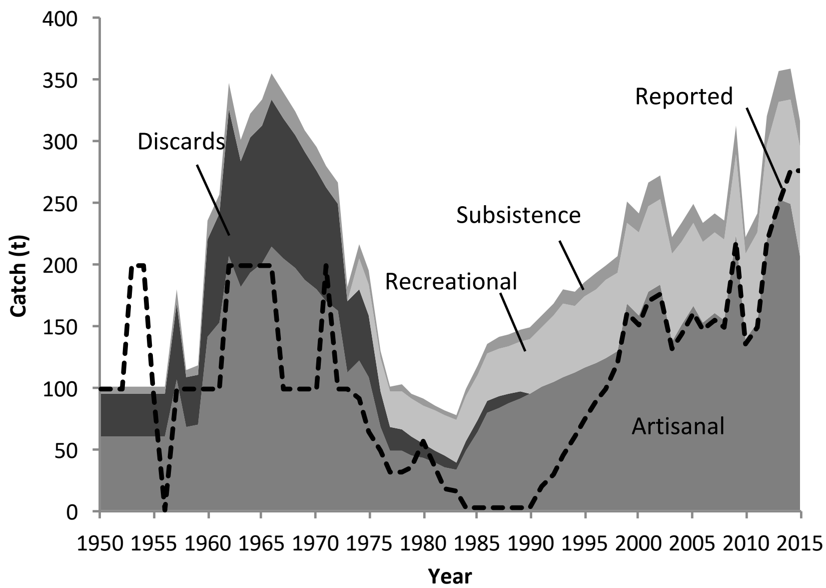
Comparison with FAO's data

Marine fisheries catches for Jordan were available by year and taxa from the FAO Fishstat database for the years 1950-2015. The FAO fisheries catch data are used here as the reported baseline for the years 1998-2013. The FAO data were compared to the reconstructed catches; when reconstructed catches were higher than the FAO catches, the difference was considered unreported. Conversely, when the FAO catches were higher than the reconstructed catches, the latter was considered reported.

Country specific results

Reconstructed marine fisheries catches for Jordan for 1950-2015 amounted to 1.9 the reported catch by the FAO on behalf of Jordan. This reconstruction is an improvement and update of a previously completed catch reconstruction for 1950-2010 by Tesfamichael *et al.* (2012a). It includes reported artisanal (~62%), discards (~15%), recreational (~17%), and subsistence (~6%) (Figure 15a). The following families contributed the most to the catch by the Jordanian fishing industry Lethrinidae (~33%), Scombridae (~23%), Lutjanidae (~8%) and Sparidae (~8%) (Figure 15b).

a)



b)

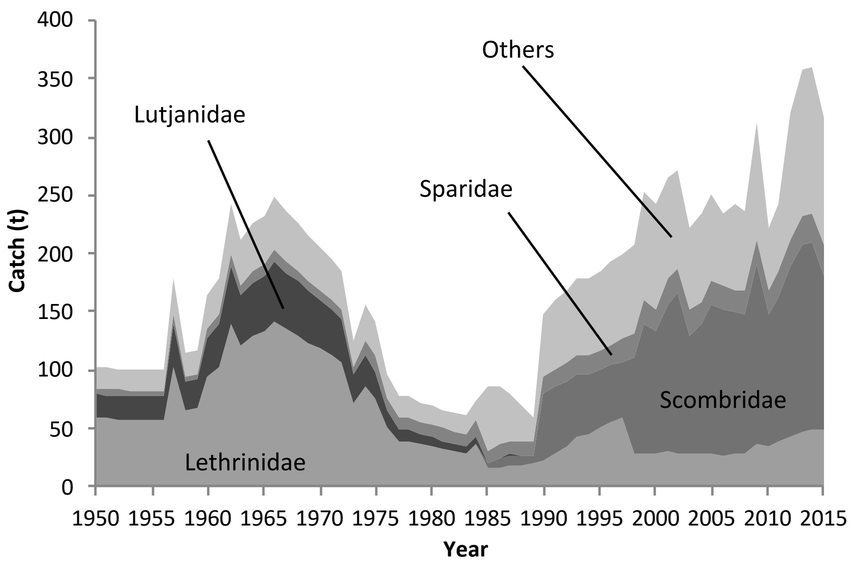


Figure 15. Reconstructed marine fisheries catches for Jordan for 1950-2015, by a) sectors plus discards. Landings as deemed reported by the FAO on behalf of Jordan are overlaid as a dotted line; b) by major taxa. Note the 'others' category includes 8 additional taxonomic groups.

2.3.1.6 Kuwait

Background

The state of Kuwait is a western Asian country situated in the Northern part of the Persian Gulf (Figure 16). It covers an area of around 18,000 km^2 and had a population of approximately 3.7 million according to a 2014 census (www.worldbank.org), most of which were not Kuwaiti citizens1. This country also includes 9 mostly uninhabited islands.

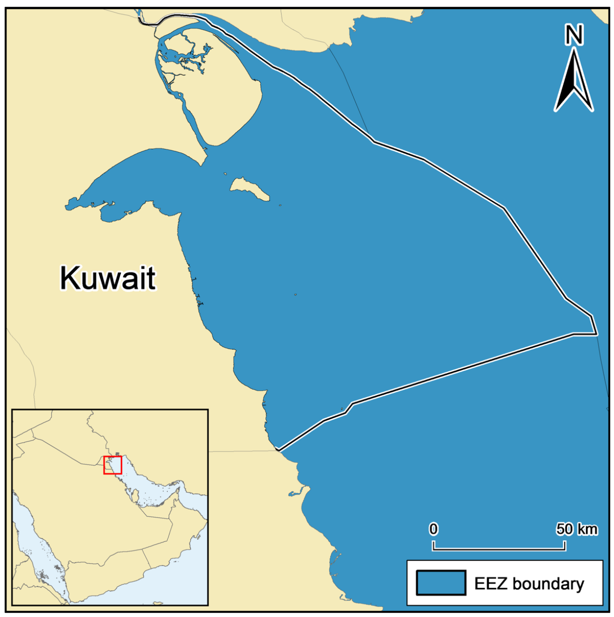


Figure 16. The EEZ and shelf area of Kuwait.

[1] http://www.bq-magazine.com/economy/socioeconomics/2015/08/kuwaits-population-by-nationality [accessed on the 25th of March 2016]

Kuwaiti fisheries are mainly small-scale, but some industrial shrimp fishing occurs. The small-scale sector includes commercial artisanal catches, as well as unreported commercial, subsistence and recreational catches (Al-Abdulrazzak 2013). The fisheries statistics collection system in Kuwait is not well developed. Here, an update is presented of the previously reconstructed catches for Kuwait by Al-Abdulrazzak (2013) for 1950-2010 to 2015.

Country specific implementation

Marine fisheries catches were available by year and taxa from the FAO Fishstat database for 2011-2015. These catches were used here as a baseline to which was added small- and large-scale commercial unreported catches, subsistence and recreational landings as well as and discards.

Industrial fishery

The industrial fishery consists of an industrial shrimp trawl fishery. According to Al-Abdulrazzak (2013c), 55% of the reported shrimp catches are industrial. Shrimp bycatch are equivalent to 10% of the reported catches of which 98% are discards and 2% are unreported catch. The same was applied here.

Artisanal fishery

According to Al-Abdulrazzak (2013c), the artisanal reported fishery consists of an artisanal shrimp fishery, a boat based finfish fishery, and a traditional fixed intertidal stake fishery. The artisanal reported shrimp fishery is estimated to be around 45% of the reported shrimp catches.

Shrimp artisanal bycatch were equivalent to be around 10% of the reported shrimp catches of which 98% were estimated to be discards and 2% unreported artisanal. The finfish fishery catches consists of the reported catches minus shrimp catches as per Al-Abdulrazzak (2013c). The skate fishery is assumed to be equivalent to 5% of the finfish catches.

Recreational and subsistence fisheries

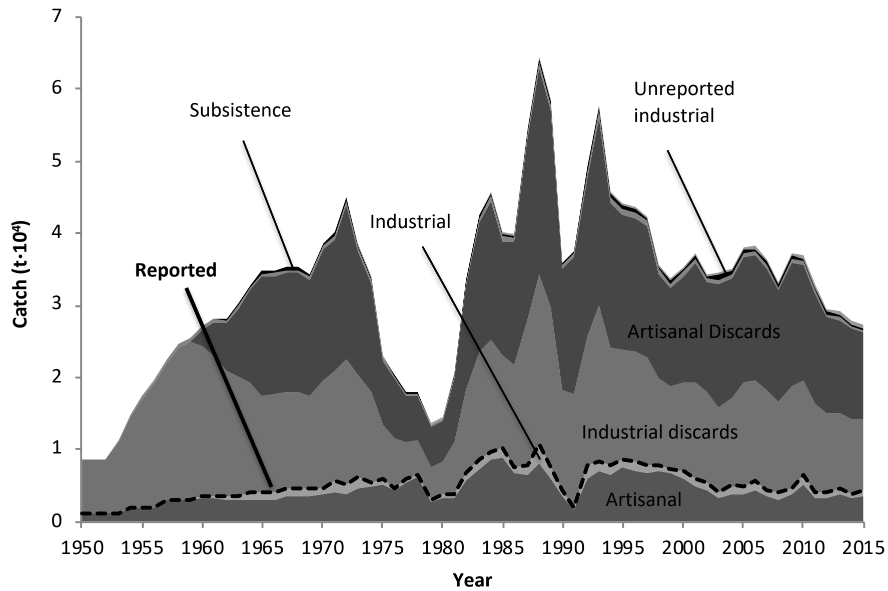
According to Cisneros-Montemayor and Sumaila (2010), 0.12% of the population participate in recreational fishing catching 1 kg per trip for 104 trips per year (Al-Abdulrazzak 2013c).

Subsistence fishers consist of foreign workers in Kuwait and make up 0.0015% of the population. Subsistence catches are assumed to be 3 kg per week (Al-Abdulrazzak 2013c).

Country specific results

Marine fisheries catches were reconstructed for Kuwait to be around 7 times the catches reported by the FAO on behalf of Kuwait. This catch reconstruction includes reported artisanal (~12%), reported industrial (~3%), unreported artisanal (~1%), unreported industrial (~1%), recreational (~2%) and subsistence (~<1%) catches, as well artisanal (~37%) and industrial discards (45%) (Figure 17a). The main taxonomic groups that contributed to the catch by the Kuwaiti fisheries are Ariidae, Elasmobranchii, Decapoda, Sciaenidae and Serranidae (Figure 17b).

a)



b)

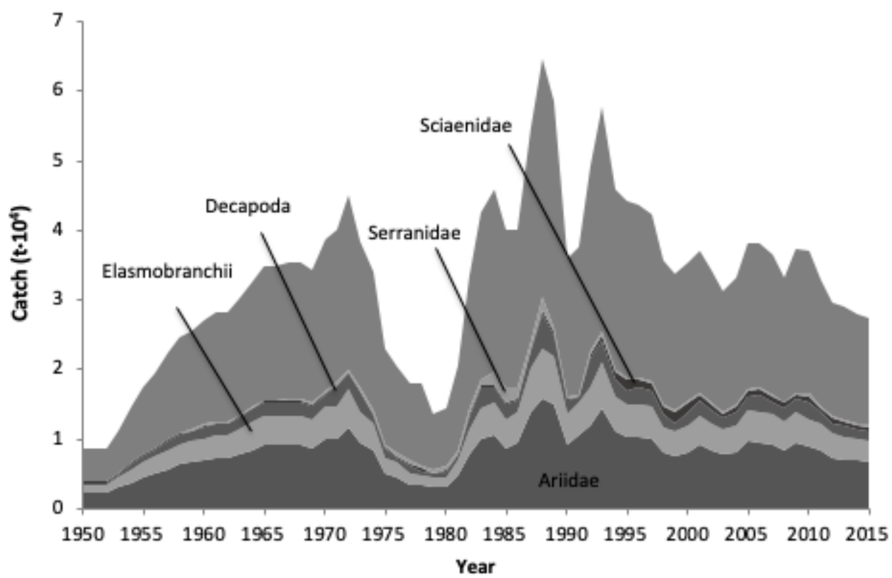


Figure 17. Reconstructed marine fisheries catches for Kuwait for 1950-2015, by a) fisheries sectors plus discards. Landings as deemed reported by the FAO on behalf of Kuwait are overlaid as a dotted line; b) by major taxa.

2.3.1.7 Lebanon

Background

Lebanon is a southeastern Mediterranean country, which, like most Mediterranean countries, does not have an officially claimed EEZ. In this study, a likely EEZ was assigned to Lebanon based on the UNCLOS principles of 200 nm or mid-line between neighboring countries (Figure 18). This EEZ assignment has no legal standing and is purely used to assist in the spatial assignment of catch data (Zeller *et al.* 2016c). That said, most fishing boats operate within 3nm from the coastline and very few reach 12 nm offshore (Lelli *et al.* 2006).

Lebanon has been subject to frequent political turmoil that has affected the fishing industry, especially in the south of the country, through oil spill and uncontrolled overfishing (Nader et al. 2014). The Lebanese fishing industry is fully artisanal and deploys mainly gillnets and trammel nets, but also traps, longlines, and surrounding nets (Sacchi and Dimech 2011). Marine fisheries catches for Lebanon were reconstructed by Nader et al. (2014) for 1950-2010. Here, similar methods, but new data, were used to improve and update the marine catch reconstruction for 2007-2010.

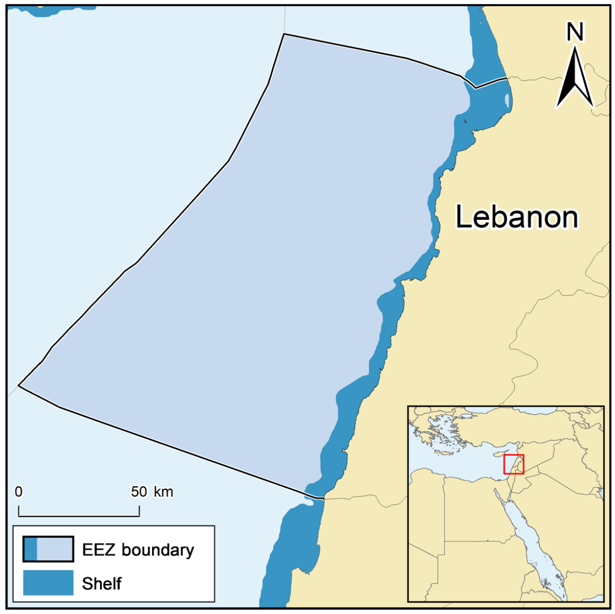


Figure 18. The EEZ and shelf area of Lebanon.

Country specific implementation

Official marine fisheries catches for Lebanon were available by year and taxa for 2007-2016. These catches represent the reported small-scale commercial portion of landings, to which were added subsistence, recreational, and small-scale unreported commercial catches as well as major discards. The reported data were deemed fully artisanal.

Small-scale commercial catches

The FLOUCA application allows the analysis and computing of catch and fleet data collected by surveys from major ports in Lebanon (Nader *et al.* 2012; Nader *et al.* 2014). In the previous reconstruction, commercial artisanal landings were estimated for 2007-2010 using FLOUCA-generated catch data for North of Lebanon. These data were extrapolated to the whole country using the number of boats and estimated CPUE (Nader *et al.* 2014). The resulting total catch for the whole country was almost twice the reported FAO catch for 2007-2010. These data were, however, corrected by the Lebanese Ministry of Agriculture (MoA) who adjusted the number of active fishing boats. This resulted in new FLOUCA-generated catches considerably lower than previously estimated.

The previously reconstructed data were obtained by extrapolation of FLOUCA-generated data for North Lebanon to the whole country assuming that "at last" 100% of the fishing fleet was operational. (For instance, the percentage of active vessels on which the extrapolation was based for 2017 ranged between 113-136%). This error was identified and corrected for 2018. The percentage of active vessels was re-estimated based on a monthly sample survey and amounted to an average of 70% in 2018. This is considerably less than the percentage of active vessels on which the previous FLOUCA analysis was based. The new FLOUCA-generated catch data for 2014-2017 were summarized in Table 25 and were on average 40% lower than the previous estimates.

Table 25. Number of licensed fishing vessels for 2012, 2014-2017 and 2018, and total catch for Lebanon for 2014-2017.

Year	Licensed fishing vessels	Total catch (t)
2012	2,653	-
2014	1,981	2,936
2015	2,005	3,653
2016	1,962	4,275
2017	2,193	3,536
2018	2,140	-

This study thus aims to rectify previously reconstructed catch for 2007-2010 and reconstruct catches for 2011-2016. According to the previous reconstruction the number of boats for all of Lebanon was 2,662 t in 2007-2010. To estimate the number of boats for the missing years, i.e., 2011 and 2013, an interpolation was performed between the number of boats for 2010 and 2012 and between those for 2012 and 2014. The CPUE for the Lebanese artisanal fishery for 2014-2016 were estimated and the lowest one, for 2014, was applied to the number of active fishing boats for 2007-2013.

The estimated data for 2007-2013 and FLOUCA-generated data for 2014-2016 were slightly higher than the FAO reported data for the whole 2007-2016 time period, excluding 2014 where the FAO data were higher than the FLOUCA-generated data. The catch discrepancy for catch for the whole study period (except for 2014) was assigned to unreported artisanal catch.

Nader *et al.* (2014) reconstructed catch data for 2000-2006 using different methods and sources than for the 2007-2010 FLOUCA-generated data. The resulting unreported catch for this was equivalent to 50% on average of reported catch. To estimate unreported artisanal catch while remaining conservative, a percentage of 40% was applied to the reported catch for 2007-2016.

Recreational fishery

Both recreational and subsistence catch were estimated by applying a per capita consumption rate to the coastal (urban and rural) population of Lebanon. The rural and urban coastal populations in a 10 km range for 2010 were obtained from the ‘Socioeconomic Data and

Applications Center' (CIESIN 2012b). Using the total population of Lebanon for 2010, it was possible to estimate the percentage of the coastal population to the total population in a 10 km range. This percentage was applied to the total Lebanese population for 2011-2016. This work was completed separately for the urban and rural coastal populations.

Recreational catch was obtained following the same method as Nader *et al.* (2014). According to Cisneros-Montemayor and Sumaila (2010), the percentage of people participating in recreational fisheries is 0.118%. This percentage was applied to the coastal population (urban and rural) *as* per Nader *et al.* (2014). Following the same source, the estimate the number of recreational fishers was assumed to complete 0.5 trips per month catching on average 2.5 kg per trip per year.

Subsistence catches were obtained following the same method as Nader et al. (2014). A per capita catch rate of 4 $kg \cdot person^{-1} \cdot year^{-1}$ (rural) and 0.5 $kg \cdot person^{-1} \cdot year^{-1}$ (urban) were applied to the rural and the urban coastal populations, respectively.

Discards

According to Kelleher (2005) discards for the Syrian artisanal fishery were about 0.5% of total catch. This was applied here to Lebanon, as in the previous reconstruction.

Taxonomic disaggregation

Following the previous reconstruction, the taxonomic disaggregation of the catch data supplied to FAO was applied to the reported catch, and the FLOUCA-generated catch composition was applied to the unreported artisanal catches. The taxonomic breakdown applied to subsistence and recreational fisheries followed the previous reconstructions.

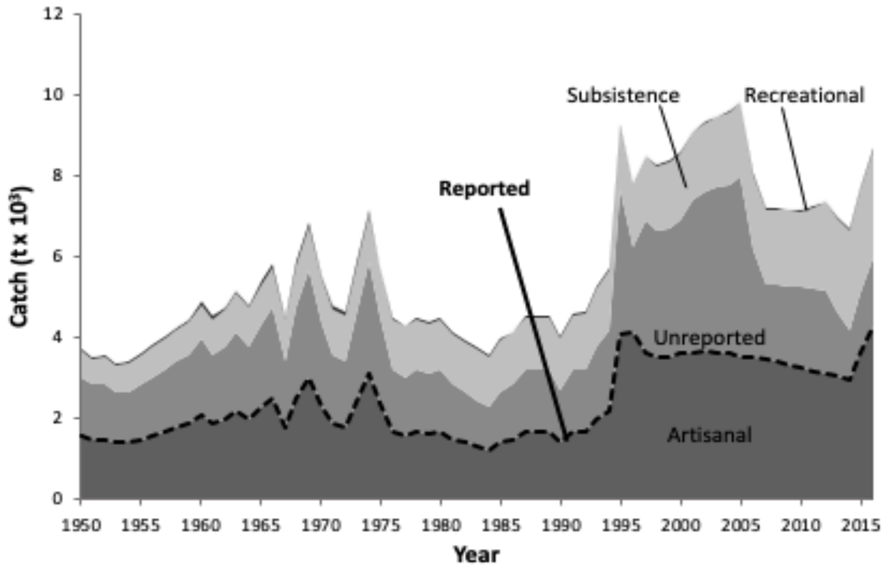
Discards were taxonomically disaggregated by re-expressing the artisanal catch in terms of fish families, and applying the resulting fractions to the discarded catch.

Country specific results

Marine fisheries reconstructed catch for Lebanon for 2011-2016 consisted of artisanal reported catches (~45 %), unreported artisanal catch (~22%), subsistence (~32 %), and recreational (~0.7%) catch as well as major discards (~0.3%) (Figure 19a).

The following groups contributed the most to the catch by the Lebanese fishing industry for 2011-2016: Clupeidae, Scombridae, Sparidae, Carangidae and Mugilidae (Figure 19b).

a)



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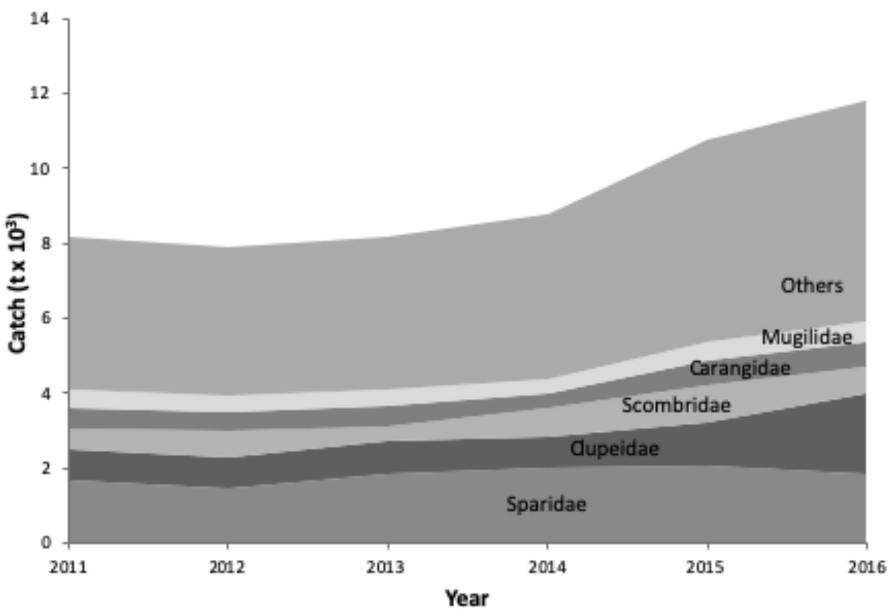

Figure 19. Reconstructed marine fisheries catches for Lebanon, by a) sectors for 1950-2016; and b) by major taxa for 2000-2016. Note the 'others' category includes 66+ additional taxonomic groups. Discards are represented here but are too small to be visible. FAO reported landings on behalf of Lebanon are overlaid as a dotted line.

2.3.1.8 Libya

Background

Libya is a North African country bordered by the Mediterranean Sea. With a land area of around 1.76 million km^2 and a continental shelf of 65,000 km^2, Libya is the fourth largest country in Africa, with the second largest continental shelf in the Mediterranean basin (www.seaaroundus.org; Figure 20).

Libya's domestic fisheries were fully artisanal and historically limited up to the 1960s. They consisted of a tuna fishery using traps known as "t*onnara*", a sponge fishery and a multi-gear and multi-species fishery. Notwithstanding the fact that some of these boats were owned and operated by non-Libyan fishers, their catch was landed and marketed in Libya, as these fishers were part of the historical Italian and Maltese diaspora of Libya (Serebetis 1952; Bourgeois 1958). Their catch is therefore considered domestic. On the other hand, foreign Maltese, Greek, and Italian, large-scale trawlers and longliners fished in the Libyan waters but landed their catch in their home countries. Foreign sponge fishing also occurred at least since the 19th century in Libya by foreign fishers until the late 1960s (Anderson and Blake 1982). The sponge fishery is however not accounted for in this study.

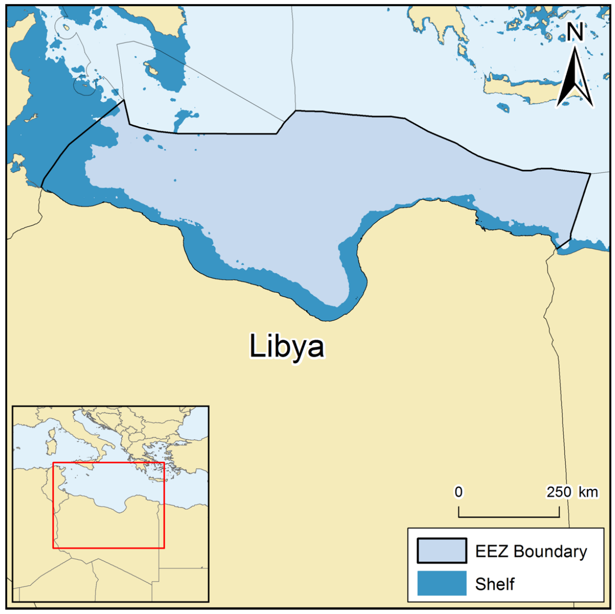

Figure 20. The EEZ and shelf area of Libya.

The main fishing port was in Tripoli on the Libyan western coast, also known as Tripolitania. Fishing was also present within Benghazi on the eastern coast, which is known as Cyrenaica (Serebetis 1952; Bourgeois 1958; Reynolds et al. 1995). During the 1970s, the fishing industry started developing with the introduction of the 'Libyan Fishing Company' in 1970, the 'Libya-Tunisia Company' in 1972 and the 'Libya-Greece Company' in 1978 (Anderson and Blake 1982). The number of domestic fishing boats in Libya amounted to 22 trawlers and 325 artisanal fishing boats in 1979 (Anderson and Blake 1982; Metz 1989b). The infrastructure of several ports was improved and several canning factories were built (Anderson and Blake 1982).

During the 1980s, the Libyan government signed several fishing agreements with neighboring Mediterranean countries, e.g., Tunisia and Spain, and one of the most important fishing ports in Libya known as Zuwara was modernized around the same time (Metz 1989b). In 1988, the

Secretariat of Marine Wealth (SMW) was created and assigned the role of developing the fishing industry (Reynolds et al. 1995).

In 2000, the Libyan government applied a decentralization policy and dissolved the SMW, whose functions were reassigned to local authorities (European Commission 2009). In February 2005, Libya declared an 'Exclusive Fishery Zone' of 62 nautical miles off the boundaries of territorial waters (Alsied 2006). In May 2009, the country claimed an Exclusive Economic Zone estimated at 355,120 km^2 (European Commission 2011, www.seaaroundus.org). Since 2011, numerous conflicts have taken place in Libya and have likely affected the Libyan fishing industry. With the chaos reigning across Libya, the war in Syria, and the deteriorating situation in several other countries in the southern Mediterranean region, a growing number of people have been seeking asylum by heading to Europe through Libya. Additionally, an existing but increasing flow of Sub-Saharan African migrants have also been taking the journey through Libya to Europe from before the 2011 civil war (Connor 2018).

In a country with a struggling economy, high unemployment rates and low control of illegal activities overall, for many, including fishers, smuggling has become an alternative livelihood opportunity. According to United Nations reports, i.e., the United Nations High Commissioner for Refugees (UNHCR) (Fleming 2015; UNHCR 2019), and other sources within the primary and grey literature (Martin 2014; Hammond 2015; Kareem *et al.* 2015; Kingsley 2015; Sengupta 2015; The Associated Press 2015a, 2015b; Scherer 2016) numerous fishing boats, e.g., trawlers and other wooden fishing boats, have, since 2011, been converted into people-smuggling boats.

While some of these boats were purchased from fishers in Egypt and Tunisia, the rest were from Libyans. Zuwara, once one of the principal fishing towns in Libya, has metamorphosed into a smuggling capital (Kingsley 2015).

The collapse of Gadhafi's regime in 2011 brought about the end of fisheries subsidies. Given that some fishing boats were converted for smuggling purposes, the number of active fishing boats declined. These boats have consequently become more valuable. As a result, some fishers unable to make a living through fishing and at risk of having their boats stolen, have sold them to smugglers or entered the business themselves (Anonymous 2015b; El-khamisi 2015). Fishing boats, mainly trawlers, were usually bought by smugglers with short notice (Kingsley 2015). Smugglers tend to obtain a fishing permit of three days and pay off the coastguard. Boats were often utilized more than once as smugglers found ways to recuperate them once refugees were rescued by the European coastguards or military (Kingsley 2015).

To combat smuggling, the European authorities have, in recent years, been sinking the boats once refugees are rescued. In 2015 the EU launched what is presently known as 'European Union Naval Force Mediterranean - Operation Sophia', aiming to end the smuggling industry by destroying fishing-smuggling boats while they are still onshore and empty. This has not only affected the fishing industry by reducing the number of fishing-smuggling boats overall and thus increasing the price of those that are left, but it has also led the smuggling industry to turn to a more dangerous but affordable option: inflatable boats or dinghies. Moreover, smugglers almost never leave the land and usually train one of the refugees who has some to no maritime knowledge on how to maneuver the boat (Kingsley 2015). A recent report by the UK parliament has claimed that the SOPHIA operation was a failure (European Union Committee 2017).

Due to the ongoing conflicts, several projects for the improvement of fishing infrastructures and facilities, which were launched at the time of Gadhafi's regime, have been aborted[1]. The Libyan fishing industry that used to rely considerably on foreign workers has lost most of its non-Libyan fishers, often Egyptians, who left the country. This depleted the workforce within the fishing industry (El-khamisi 2015).

Overall, fishing activities have been decreasing and fish has become less available in the market and less affordable for the population (Kingsley 2015). The fishing trade has slowed and fish has become expensive, e.g., the price for sardines increased by a factor of 20 between 2014 and 2015 (Corouge and Taquet 2011; El-khamisi 2015). This has led to the paradox of fishers discarding much of their catch because it would not sell (El-khamisi 2015).

Yet, less fishing does not mean less unreported and illegal fishing activities. During the years following 2011, violence and insecurity have prevailed and Libyan institutions and infrastructure have been destroyed or were non-functional for certain time periods (Engdahl 2013; Fetouri 2015; Squires 2015). Remaining active fishers would buy their fishing gears on the black market (El-khamisi 2015); there is no guarantee that such gear is regulated and there is no information

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[1] ليبيا مشاكل كبيرة تنتظر قطاع الصيد البحري [Libya -Major problems await the fishing sector] available at https://www.youtube.com/watch?v=yNmh33cmaZg [accessed on 29/09/2017]

on the type or the quantity sold. Illegal fishing practices, such as the use of explosives, is widespread across the country (Ponomarev 2011; El-khamisi 2015; AFP 2018).

During such activities, one should inquire into the whereabouts of the Libyan coastguards who are limited in number, under-resourced, overwhelmed by responsibilities, underpaid and sometimes not paid at all. They often have to deal with the smuggling of people and goods, illegal fishing, and terrorist groups. As a result, some coastguards work as part-time fishers, while others take bribes from smugglers or illegal fishers to let them freely practice their activities (Kingsley 2015; Micallef 2015).

In 2011, illegal fishing of bluefin tuna occurred within the Libyan waters (Black 2011; Anonymous 2013; El-khamisi 2015). Other neighboring countries also fish illegally in Libyan waters, e.g., Egypt and Tunisia (Anonymous 2015a; Reguly 2015).

The marketing of fish had improved over the years leading to the 2011 war, and facilities for distribution and handling of fish were created (Otman and Karlberg 2007). Prior to 2011, most Libyan marine catch was sold fresh at urban markets, but a fraction of the small pelagic fishes was channeled to canning plants (Reynolds *et al.* 1995). It was estimated that since 2011, Libya has been losing around 5 billion dollars a year because of foreign illegal fishing (Anonymous 2013).

This fisheries catch reconstruction aims on one hand to re-estimate the historical marine fisheries catches by Libya for 1950-2017. It also attempts to evaluate the short-term effect of the 2011-2017 turmoil in Libya on its fishery industry.

Country specific implementation

Reported marine fisheries landings data were available by taxon and year for 1950-2017 from the FAO Fishstat database. They were used in this study as the reported data baseline, to which were added estimates of reported and unreported commercial domestic and foreign large- and small-scale, recreational and subsistence catches, as well as major discards. Information from peer-reviewed along with grey literature were used while following the general catch reconstruction approach outlined in Zeller *et al.* (2007).

Domestic commercial fisheries in Libya

Libyan fishers deploy a variety of gears: '*lampara'* (light purse seine), trawls, '*tonnara'*, longlines, purse seines, etc. (Reynolds *et al.* 1995). Lamboeuf *et al.* (2001) classified the Libyan artisanal fleet into 4 categories according to gear, size, and targeted species (Table 26). Elmsallati and Eaton (2009) classified the Libyan fishing industry into an industrial fishery that includes tuna purse seiners, tuna longliners, and trawlers, and an artisanal fishery that includes *lampara* boats and other multi-gear multi-species artisanal fishing vessels. This classification was adopted here, especially that trawlers are always considered industrial in catch reconstruction studies as per Martín (2012b).

Table 26. Artisanal fishing vessels in Libya according to Lamboeuf *et al.* (2001).			
Vessel	**Gear type**	**Length (m)**	**Targeted taxa**
Batah	Trammel net and pots	6	Octopus
Flouka	Multi-gears	3-7.5	Multiple
Mator	Multi-gears (mainly hook & line, nets)	6-18	Multiple
Lampara	Large seine net	8-17	Small pelagic fish

The International Commission for the Conservation of Atlantic Tunas (ICCAT, see www.iccat.int) provides a gear disaggregation (i.e., into longlines, purse seines, or tuna traps) of the official catch for Libya for the following species: Atlantic bluefin tuna (*Thunnus thynnus*), blue shark (*Prionace glauca*), albacore (*Thunnus alalunga*), bigeye tuna (*Thunnus obesus*) and swordfish (*Xiphias gladius*). However, ICCAT landings of bigeye tuna were not reported inthe FAO official data. Thus, catch of this species was added to the FAO data and subtracted from the category 'Marine Fishes nei'.

For 1950-1969, all domestic Libyan catches were deemed artisanal given that only artisanal tuna traps, *lampara* and other artisanal gears were deployed. For the remaining study period (1970-2017), the gear disaggregation provided by the ICATT was used to split the landings of the species in question into industrial, i.e., tuna purse seines and longlines, and artisanal. Moreover, catches of round sardinella (*Sardinella aurita*) were deemed artisanal given that this species has always been targeted by *lampara* in Libya. Total landings by domestic trawlers were reported for 1974-1979 by Anderson and Blake (1982). For that time period, the FAO only reported three taxonomic categories: sardine, bluefin tuna and the 'Marine Fishes nei'. Given that the first two taxa were already disaggregated into the appropriate sector as previously explained, the industrial catch for 1974-1979 was subtracted from the third category of ‘Marine Fishes nei’. The remaining was classified as artisanal.

The methods applied to disaggregate the remaining reported FAO landings were based on the reconstruction of the domestic trawl landings. Trawl landings were then subtracted from the FAO landings (excluding the taxa previously disaggregated into the appropriate sector).

The steps on which reconstruction of the domestic trawl reported landings was based are as follow:

i. Identification of industrial fishing effort anchor points: This consists in the number of operational trawlers summarized in Table 27. For 2011, year of the outbreak of civil war in Libya, the numbers of domestic trawlers were assumed to be 40% lower than in 2010. In 2012, Libya’s situation somewhat stabilized, with better control of its waters compared to the previous year. Thus, the number of domestic trawlers was assumed to have increased by 15% in 2012. In 2013, the country’s situation deteriorated again; fishing boats were increasingly taken by smugglers or armed by militias. Thus, domestic trawlers were assumed to have decreased respectively by 30% in 2013 compared to 2012. The number of domestic trawlers was assumed to have remained similar to 2013 until 2017, as many sources in the grey literature insist on the decrease of fishing activities overall in Libya as a consequence of the decrease of the number of fishers by 65% in 2019 (Tarabols 2017, 2019);

Table 27. Number of trawlers in the domestic Libyan industrial fleet (when number is 0, it means that the sources explicitly mentioned the nonexistence of those boats at the time).

Year	Trawlers	Source
1950	0	Serebetis (1952)
1955	0	Bourgeois (1958)
1956	0	Bourgeois (1958)
1970-1971	7	Anderson and Blake (1982)
1972-1978	11	Anderson and Blake (1982)
1979	13	Anderson and Blake (1982)
1993	85[a]	Lamboeuf and Reynolds (1996)
1994	105	Elmsallati and Eaton (2009)
2000	105	Haddoud and Rawag (2007)
2002	65	Haddoud and Rawag (2007)
2003	123	FAO (2005)
2008	140	Sacchi (2011)

[a] 22 trawlers were active, 40 were inactive and the state of the remaining ones was not known to Lamboeuf and Reynolds (1996).

ii. Identification of the catch per unit of effort (CPUE, $t{\cdot}boat^{-1}{\cdot}year^{-1}$): The CPUE for the trawl fishery from nearby southern Tunisia were obtained from the official statistics reports of the Tunisian fisheries department, as summarized in Table 28 and provided by Ghassen Halouani (personal communication, April 26, 2014). Given that most fishing in Libya does occur close to the Southern Tunisia borders, along the western Libyan coast, where the sea is said to be more 'productive' and the grounds more suitable for trawling (Anderson and Blake 1982; Metz 1989b; Reynolds *et al.* 1995), the Tunisian trawl CPUE was assumed to be similar to the Libyan CPUE. It should be noted however that for 1974-1979 the trawl CPUE was obtained by dividing the domestic trawl catch, provided by Anderson and Blake (1982), by the available number of domestic trawlers for the correspondent years. When compared to the Tunisian CPUE for the same years, the estimated Libyan CPUE for domestic trawlers was slightly higher. The Libyan CPUE was then used as anchor points for 1974-1979.

Table 28. CPUE anchor points for the fisheries of southern Tunisia in $t \cdot boat^{-1} \cdot year^{-1}$ based on reports of the Tunisian Department of Fisheries (Ghassen Halouani, personal communication).

Year	CPUE of trawlers	CPUE of artisanal boats	CPUE of Lampara	Year	CPUE of trawlers	CPUE of artisanal boats	CPUE of Lampara
1974	46.04	2.26	41.67	1996	36.17	2.61	92.34
1975	50.32	3.09	46.04	1997	46.53	2.84	84.46
1981	51.30	5.35	-	1998	48.78	2.62	118.28
1982	57.26	5.36	-	1999	53.18	2.48	212.61
1983	61.50	5.96	-	2000	55.21	2.73	337.00
1984	68.33	5.66	-	2001	55.01	2.77	225.87
1988	46.73	6.10	153.39	2002	54.95	2.69	194.94
1990	37.00	4.02	163.28	2003	61.99	2.53	516.81
1991	30.66	3.75	165.36	2004	58.82	3.17	593.03
1993	39.72	3.17	71.61	2005	55.13	3.16	536.54
1994	33.21	2.67	76.79	2006	50.23	2.85	436.88
1995	34.06	2.24	72.68	--	--	--	

iii. Interpolations were performed between the anchor points for fishing effort and CPUE;

iv. Reported landings for domestic trawlers and artisanal boats including *lampara* were obtained by multiplying the annual number of active domestic trawlers by the correspondent CPUE;

v. For 1970-1974, reported artisanal landings were obtained by subtraction of the industrial catch from the FAO landings, excluding the taxonomic groups that were previously assigned to their proper sector. The reported catch of non-assigned taxonomic groups was distributed between the industrial and artisanal sectors according to their overall catch contribution to the reported landings.

Unreported domestic commercial industrial and artisanal catch

During the meeting of the 1980 General Fisheries Council for the Mediterranean (GFCM 1980), the Libyan delegate mentioned that Libyan fisheries statistics had been underestimated by about 50% for the past 10 years, i.e., beginning from 1970 when the domestic trawl fishery was introduced. Other sources, e.g., (Anonymous 2013, 2017) mention the increase of unreported and illegal catch within the Libyan EEZ in the past years as a consequence to the instability in the country. Some Libyan boats would even fish and sell their fish to foreigners while they were at sea. Based on this information and the estimates obtained in the herein study, it was assumed that unreported catch was about 50% for 1950-1985, interpolated to 30% for 1990 and to a conservative 15% in 2010. Domestic unreported catch was then assumed to have decreased by

50% in 2011 compared to 2010 due to the civil war, increasing back to 30% of catch in 2012-2017. The same taxonomic disaggregation applied to the reported landings is applied to the unreported landings.

Foreign fisheries

The number of foreign trawlers was estimated at 10 and 60 in 1950 and 1956, respectively (Serebetis 1952; Bourgeois 1958). This number, however, only includes Greek trawlers; the number of Italian trawlers operating in the Libyan waters was unknown (Serebetis 1952; Bourgeois 1958). The number of foreign trawlers was not available for any other year.

Nonetheless, landings of Greek trawlers from the Libyan waters in the early 1950s were estimated to be between 6,000 t and 10,000 t while Italian trawlers caught up to 400 kg per 5 hours of daytime trawling (Bourgeois 1958). Reynolds *et al.* (1995) mentions foreign trawlers operating within the Libyan waters without licenses and catching around 3,000 t of demersal species in the early 1990s, which is around the same amount caught by domestic trawlers in Libyan EEZ. According to the same source, both foreign and domestic trawlers caught around 11.000 t combined during the mid-1990s. Foreign tuna purse seiners and longliners were introduced in Libyan waters at a certain point, but information on their activities is scarce.

The Libyan government banned foreign tuna fishing in from its EEZ, except for French trawlers (Grémillet and Lescroël 2011). Based on this information, it was very conservatively assumed that foreign trawlers fished around 6,000 t in 1950, decreasing to 3,000 t in 1993 and then to

1,000 t in 2010. Foreign trawl catch was assumed to have increased to 2,000 t in 2011 and decreased back to 1,000 t in 2012-2017.

The same taxonomic disaggregation applied to the domestic trawl reported landings, was applied here.

Subsistence fishery

Subsistence fishing in Libya was not mentioned in many studies. One of the only mentions was regarding a Yugoslav refugee who lived in the east of Libya and who lived off fish (Serebetis 1952). This practice has likely been common within rural people living within a 5 km range off the Libyan coast who do not have easy access to markets.

To estimate subsistence catches, a subsistence per capita consumption rate to the Libyan rural coastal population was assumed. This population was estimated by 'Socioeconomic Data and Applications Center' to be 86,226 in 1990, 102,609 in 2000, and 125,931 in 2010 (CIESIN 2012). Interpolations were performed to obtain the rural coastal population for 1991-1999 and 2001-2009.

To obtain the coastal rural population for 1950-1989, the percentage of the rural coastal population compared to the total Libyan population for the year 1990 was assumed and applied to the total population for 1950-1989 (available at www.un.org). Due to the civil war and the resulting refugee crisis, the estimation of the coastal population for 2011-2017 was different from previous years. Up to two million out of the 6 million Libyan population fled the country in

2011, i.e., around 30% of the total population (Gall 2014). Between 600,000 and one million of these refugees were in Tunisia in 2013 (Mandraud 2014). According to UNHCR 607,000 people returned to Libya in 2011, followed by an additional ~178,500 in 2012, 5,350 in 2013 and ~450,000 in 2016, and ~150,000 in 2017. The population that remained in Libya for 2011-2012 was estimated based on the latter. The percentage of the coastal rural population to the total population of 2010 was then applied to the new estimate of the total Libyan population for 2011-2017.

According to Bourgeois (1958), the annual seafood per capita consumption rate was estimated at 0.8kg in Libya and was 2kg in Tripoli (Serebetis 1952). The apparent per capita consumption rate increased to 7.2 kg in the early 2000s (FAO 2005). As no data on subsistence catch rate is available for Libya, a constant annual per capita subsistence catch rate of 2 kg for the whole of 1950-2017 was assumed. The taxonomic disaggregation of the subsistence catches follows the same approach as for unreported artisanal commercial catches.

Recreational fishery

Recreational fishing in Libya was mentioned very briefly by Serebetis (1952), and Anderson and Blake (1982). Lamboeuf and Reynolds (1996) mention that 166 'utility leisure' boats that were part of the commercial fishery would sometimes participate in recreational fishing. No other information on this fishery was available in the literature. A very conservative 1% of total artisanal landings was applied to estimate recreational catch in Libya, with similar taxonomic disaggregation.

Discards

Discards include non-commercial species, and damaged and undersized fish (GFCM 2011). Discards are especially important in the trawl fishery (Carbonell *et al.* 1998; Lleonart *et al.* 1999; Machias *et al.* 2001; Kelleher 2005a). Of the 300 species caught within the eastern Mediterranean, only about 10% are always marketed and 30% are occasionally retained, according to the size at which they are caught and to the market demand. Moreover, at least 60% are always discarded (Machias *et al.* 2001). Industrial discards were assumed to be 60% of total domestic and foreign trawl catch for 1970-2017. A conservative 5% discard rate was applied to the artisanal fishery (excluding tuna traps and sardine catch by *lampara*). This rate was increased to 10% for 2012-2017 as many fishers would discard their catch because they could not sell it.

Country specific results

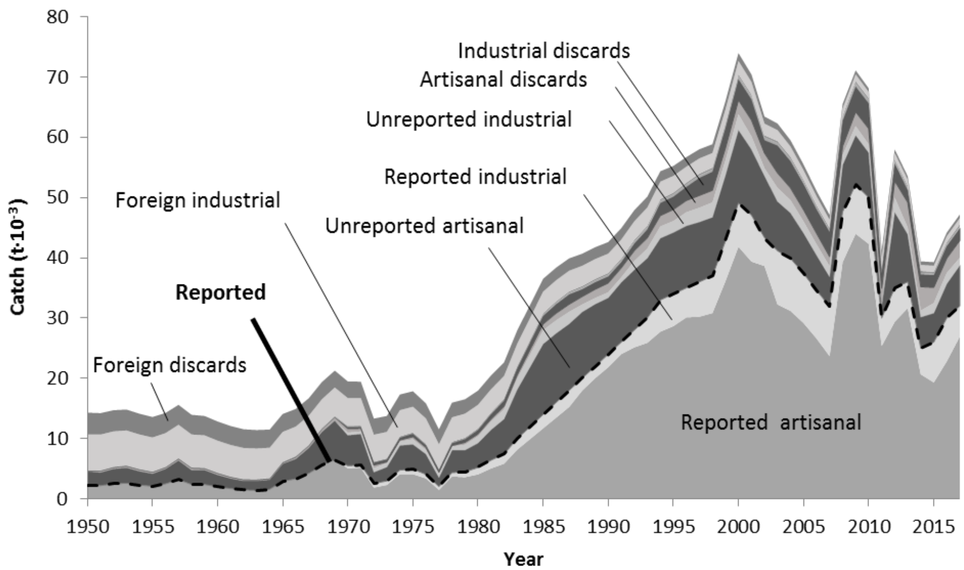
The reconstructed total catches increased from around 14,500 $t\cdot year^{-1}$ in 1950s-1960s (2,762 $t\cdot year^{-1}$ reported) to approximately 16,000 $t\cdot year^{-1}$ in the 1970s (4,130 $t\cdot year^{-1}$ reported). During the 1980s, the reconstructed catch reached around 32,000 $t\cdot year^{-1}$ (13,099 $t\cdot year^{-1}$ reported) and over 53,550 $t\cdot year^{-1}$ during the 1990s (32,575 $t\cdot year^{-1}$ reported). During the 2000s, the catches increased rapidly to a first peak of around 62,000 $t\cdot year^{-1}$ in 2000s (42,419 $t\cdot year^{-1}$ reported), and to 45,240 $t\cdot year^{-1}$ in 2011-2017 (30571 $t\cdot year^{-1}$ reported) (Figure 21a). Thus, reconstructed total catches were 1.9 times the landings reported by the FAO on behalf of Libya, with the major difference being due to unreported artisanal catch and to foreign trawl fisheries in the early years.

Total marine catches of Libya, as reconstructed for 1950-2017, consisted of the following sectors reported artisanal (~45%), reported industrial (~8%), subsistence (~0.6%), recreational (~0.6%), unreported artisanal (~18%), unreported industrial (~3%), domestic industrial discards (~4%), artisanal domestic discards, (~3.6%) and foreign industrial (~10%), foreign industrial discards (~6.2 %),

The catch composition suggested that round sardinella (*Sardinella aurita*) contributed the most to the catch by the Libyan fishing industey, representing 19% of total catches, followed by porgies and seabreams (Sparidae, 16%), tunas and mackerels (Scombridae 9%, mostly *Thunnus thynnus* and *Scomber colias*), and jacks (Carangidae, 7%) (Figure 21b).

Here, this study shows that the artisanal fishery dominates Libyan fisheries, while industrial fishing is not as important in terms of catches. In 2011, with the start of the civil war in Libya, fisheries catches declined by 40% between 2010 and 2011 according to the FAO data on behalf of Libya. However, this reconstruction suggests that this decline was closer to 30%. In 2012, Libya became relatively more stable. This affected the landings, which increased compared to 2011, by 14% according to the FAO and by almost 30% according to this study.

a)



b)

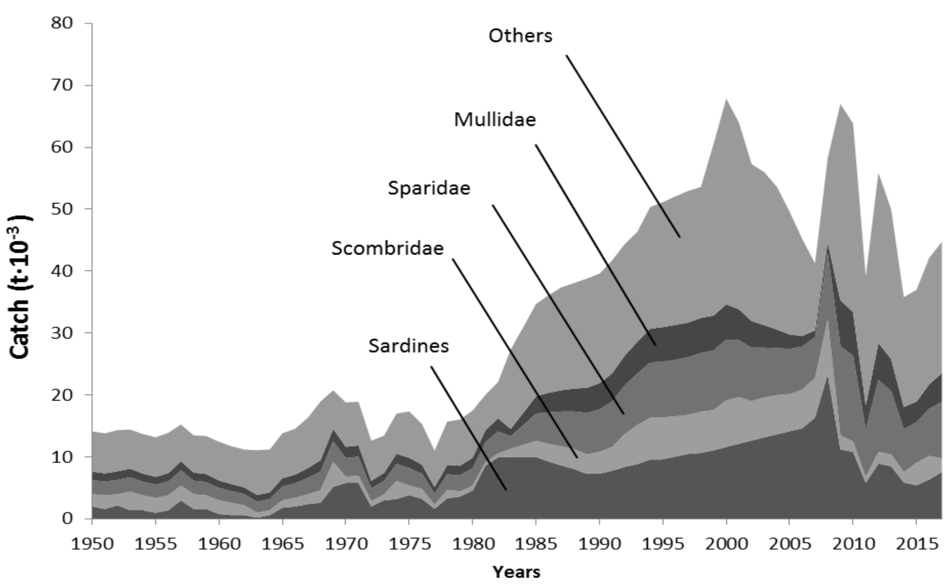


Figure 21. Reconstructed marine fisheries catches for Libya by a) sectors, plus discards, for 1950-2013. Landings reported by FAO on behalf of Libya are overlaid as a dotted line. Note that subsistence catches are too small to be visible; and b) by main taxonomic group; note the 'Other' includes 53 additional taxonomic groups.

2.3.1.9 Morocco (Mediterranean)

Background

Morocco has two different EEZs: A Mediterranean EEZ bordered by the Strait of Gibraltar, and a much larger Atlantic Ocean EEZ; this account deals only with the former (Figure 22). Three main fisheries exist in Morocco as defined by national authorities: the artisanal fishery, the coastal fishery, and the offshore fishery (Doukkali and Kamili 2018). The artisanal fishery consists of small wooden boats between 5 and 6 meters (INRH 1999). The coastal fishery consists of medium-sized boats, of between 16 and 22 meters, and consist mainly of trawlers, purse seiners, and longliners (Srour *et al.* 2002; DPM 2017). The offshore fishery consists of different types of trawlers, e.g., pelagic trawlers, shrimp trawlers, etc., of which many have onboard freezers. This boat category does not occur in the Moroccan Mediterranean EEZ (DPM 2017). Similar to the previous reconstruction, the nationally defined as 'artisanal' sector is classified here as the small-scale fishery, but that which is defined as 'coastal' is deemed large-scale, i.e., 'industrial'.

This study is an update to 2016 of the marine fisheries catch reconstruction completed by Belhabib *et al.* (2013a) for the Mediterranean EEZ of Morocco.

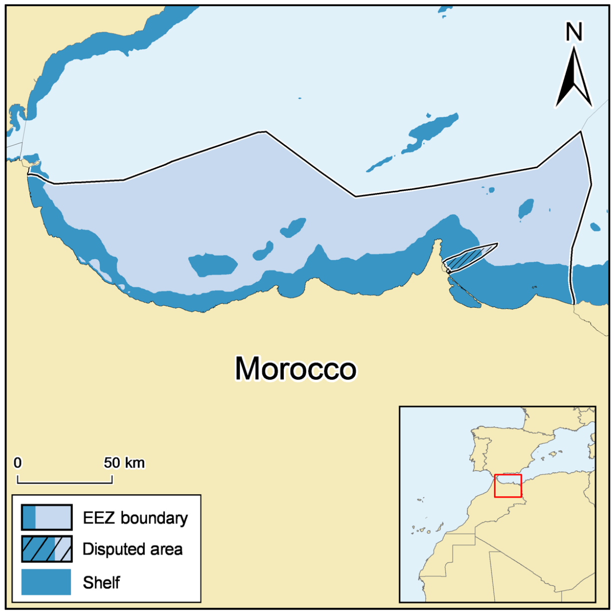


Figure 22. The EEZ and shelf area of Morocco (Mediterranean).

Country specific implementation

Reported data

Marine fisheries landings were available per year and taxa for the Mediterranean EEZ of Morocco for 2011-2016 via the FAO Fishstat database. A new value for total reported landings was made available by the most recent FAO Fishstat database. Marine catch data were also available for 2011-2016 through reports by the Moroccan National Fisheries Office (Office National des Pêches; ONP 2013, 2014, 2015, 2016) and by the National Department of Fisheries (Département de la Pêche Maritime; DPM 2015, 2016, 2017). When both datasets were compared the FAO data were slightly higher than the reported national landings. Given that the FAO data have a better and more detailed taxonomic disaggregation than the national data, they were used here as the reported baseline. FAO database includes all commercial fisheries data without differentiating between the large- and small-scale landings. Similarly, the national catch data reports the both nationally defined as "coastal" and "artisanal" fisheries landings combined for the Moroccan EEZs. Information regarding the contribution of each of these sectors to the total reported catch was scarce. The nationally defined 'artisanal' fishery is a mostly informal sector, somewhat excluded from the official data collection system. It is also common for this kind of fishery to sell its catch directly to consumers without going through the official marketing supply chain (Idrissi *et al.* 2001; Belhabib *et al.* 2013a; Idrissi *et al.* 2015; INRH 2017).

The traditional fishing boats land their catch in 6 ports and in over 80 sites some of which are hardly or fully inaccessible (Srour *et al.* 2002; DPM 2017). Nonetheless, artisanal landings were mentioned to be still partially reported (INRH 2017). According to the same source, reported small-scale catch of pelagic species in 2014 were around 25% times the reported landings for all Moroccan waters including the Mediterranean and the Atlantic EEZs (i.e., reported data for 2014 was 11,000 t and re-estimated catch was around 43,000 t). In the previous reconstruction artisanal reported catch data represented an average of 26% of reported data for 2006-2009. It was thus assumed that 25% of reported catch for 2011-2016 were reported. The FAO taxonomic disaggregation was split accordingly between the artisanal and industrial sectors.

For 2010, the small-scale reported landings were obtained by subtraction of the reported large-scale landings estimated in the previous reconstruction for 2010 from the total FAO reported landings.

Unreported small-scale fishery

To reconstruct artisanal commercial landings, Belhabib *et al.* (2013a) applied a CPUE of 3 $t \cdot boat^{-1} \cdot year^{-1}$ to the number of artisanal boats. The same method was applied here. The number of operational artisanal boats for the Mediterranean fishery were available for 2011-2016 from the DPM (2012, 2015, 2016, 2017), the DFP (2015) and Anon. (2012a). To account for unlicensed artisanal fishing boats, Belhabib *et al.* (2013a) applied an adjustment factor of +30% to the number of artisanal boats in 2010. Unreported small-scale catch for 2010-2016 were estimated by subtraction of the reported small-scale landings from the reconstructed artisanal catch. The same taxonomic disaggregation applied in the previous reconstruction for 2010 to unreported small-scale landings was applied here.

Unreported large-scale fishery

Unreported large-scale landings were considered for the coastal driftnet fishery and the coastal pelagic and demersal fishery as suggested by Belhabib *et al.* (2013a).

For the coastal demersal and pelagic fishery, it was assumed that 10% of reported large-scale catch was unreported. The same taxonomic disaggregation applied for 2010 was applied here.

For the large-scale driftnet fishery targeting mainly swordfish (*Xiphias gladius*), a CPUE of 20.9 $t \cdot boat^{-1} \cdot year^{-1}$ was applied to the number of driftnets, i.e., 300 in 2010. The landed bycatch of this fishery was also estimated based on the previous reconstruction where the following percentages were applied to the reconstructed catch of swordfish: 6% of Atlantic bonito (*Sarda sarda*), 5% of pelagic stingrays (*Pteroplatytrygon* spp.), and 0.5% of common dolphinfish (*Coryphaena hippurus*). Additional landed bycatch was estimated in the section on discards.

Subsistence and recreational fisheries

Total subsistence landings for 2004-2009 by Belhabib *et al.* (2013a) were estimated to be 13% of total artisanal reported and unreported commercial catch. To estimate subsistence catch, this percentage was applied here to total artisanal catch for 2010. The same taxonomic disaggregation applied to subsistence landings in the previous reconstruction was applied here.

Recreational landings originated from two different sources: underwater spearfishing and rod-fishing. The same methods used in the previous reconstruction were used here. For spearfishing a CPUE of 20.6 $kg \cdot day^{-1}$ was applied to the number of underwater spearfishing licenses of 180 in 2010 (assumed constant for 2011-2016). For rod-fishing, a CPUE of 58.8kg $\cdot fisher^{-1} \cdot day^{-1}$ was applied to the number of rod-fishing licenses of 5,000 in 2010 (assumed constant for 2011-2016) and to 70 fishing days. The same taxonomic disaggregation applied in the previous reconstruction for the recreational fishery was applied here.

Discards

Discards for the small-scale fishery were assumed to be 19% of total small-scale catch as per Belhabib *et al.* (2013a). The same percentage was applied here for 2010-2016 to the small-scale reported and unreported commercial fisheries combined, using the same taxonomic disaggregation as the previous reconstruction.

According to the previous reconstruction, there were three discarded fisheries components:

(1) Demersal shrimp trawl fishery discards were estimated to be 43% of trawl shrimp catch in the 2000s;

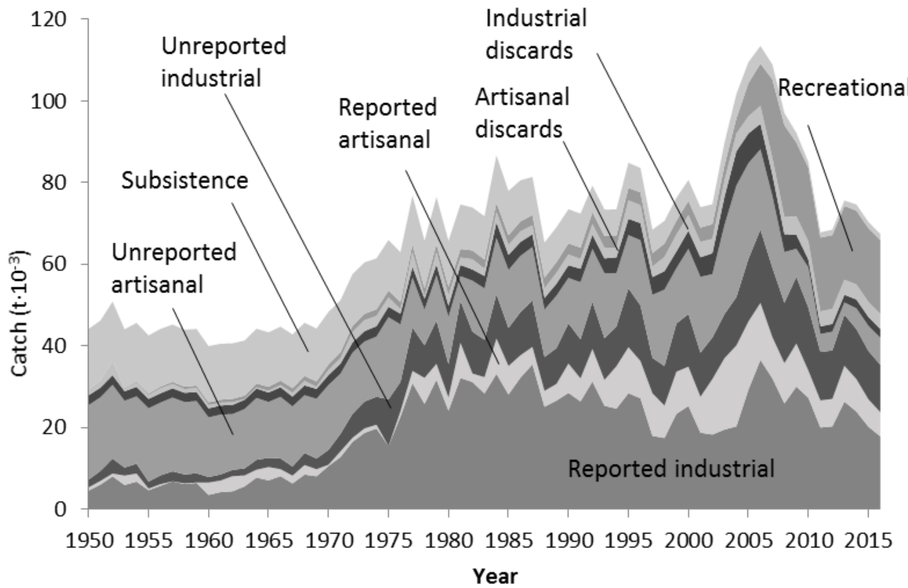
(2) Discards of the small pelagic industrial fishery were estimated to be 2.5% of the sardine landings in the 2000s;

(3) Discards from the driftnet swordfish fishery were estimated on two different levels. An average of 67.5% was applied to the swordfish landings to estimate the shark bycatch, which was considered to be 50% discarded and 50% of the landed bycatch (assigned as large-scale commercial). The species composition, according to the previous reconstruction, was 33% blue shark (*Prionace glauca*), 36% shortfin mako shark (*Isurus oxyrhinchus*) and 31% common thresher (*Alopias vulpinus*). Discards of the ocean sunfish (Mola mola) were estimated to be 25% of industrial driftnets swordfish catch.

Country specific results

Marine fisheries landings were reconstructed for the Mediterranean EEZ of Morocco for 2010-2016 including: reported small-scale (~10%), reported large-scale (~31%), unreported small-scale (~8%), unreported large-scale (~17%), subsistence (~2%), and recreational (~25%) catches, and major discards (~8%) (Figure 23a). The following families contributed the most to catches by the Moroccan fishing industry within the Moroccan Mediterranean EEZ: Clupeidae, Sparidae, Scombridae and Carangidae (Figure 23b).

a)



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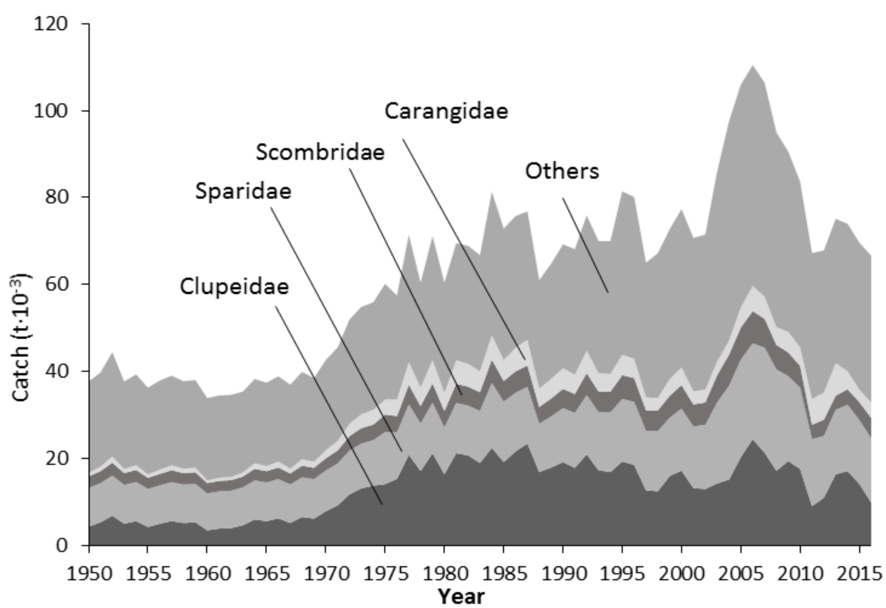


Figure 23. Reconstructed marine fisheries catches for Morocco's Mediterranean EEZ for 1950-2016 by a) sectors; and b) major taxa.

2.3.1.10 Palestine

Background

Stretching along the Palestinian coast, the Gaza Strip is a densely populated narrow land situated on the East-South of the Mediterranean basin (Figure 24). Since 2007, Gaza has been under a blockade by the Israeli Government, which has been imposing heavy restrictions on Palestinian fisheries.

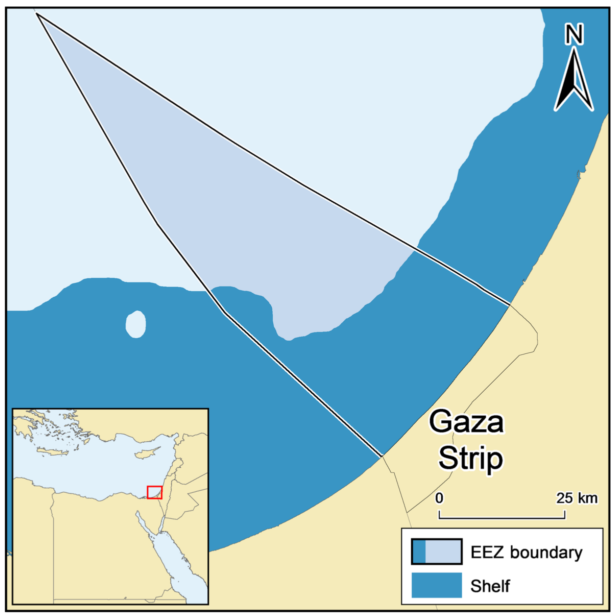


Figure 24. The EEZ and shelf area of Palestine.

In spite of the 1993 Oslo accords that allow Palestinian Fishers to access marine waters up to 20 nm offshore, the Israeli government has been increasingly limiting Palestinian fishers from accessing their fishing grounds, i.e., making them unable to reach over 85% of their EEZ (Melon

2011; UNRWA 2016; Feidi 2018; Martin *et al.* 2018; United Nations 2018). Instead, Palestinian fishers can only operate in the “designated fishing zones” that have been put in place by the Israeli authorities. Following a ceasefire agreement that ended Israel's 2014 offensive on Palestine, these zones were fixed to 6 nm and seasonally extended to 9 nm in the southern Gazan coast for sardine fishing (United Nations 2018). Overall, the designated fishing area for Gazan fishers has ranged between 3 nm and 12 nm since the start of the blockade as per the decisions of the Israeli authorities (Palestinian Central Bureau of Statistics 2015; United Nations 2018).

Despite being an indispensable source of livelihoods, fishing remains an extremely risky activity for Palestinian fishers. Over the years, various attacks by the Israeli military have occurred against Palestinian fishers. According to the United Nations (2018), the Palestinian Centre for Human Rights (2011, 2016b) and several other sources (Melon 2011; Tramel 2012; Feidi 2018), the Israeli naval forces often opened fire on fishers within the current allowed limits, putting their lives in danger on a near-daily basis, e.g., 139 and 126 cases of firing against Palestinian fishers were reported for 2015 and 2016, respectively (Palestinian Centre for Human Rights 2016a, 2017). Fishing boats and equipment are often confiscated and sometimes destroyed, e.g., a total of 27 and 39 fishing boats and equipment were confiscated in 2015 and in 2016 respectively (Palestinian Centre for Human Rights 2016a, 2017).

The Israeli authorities often justify the use of live fire as a necessary measure to deter potential “security threats,” a policy that has in effect destroyed much of the agricultural and fishing sectors of the impoverished Palestinian territory (Palestinian Centre for Human Rights 2016a, 2017).

The fishing sector improved during the late 1990s and early 2000s (Ali 2002), but has deteriorated particularly since the mid-2000s when fishing activities were restricted for several months (Isaac *et al.* 2007; Feidi 2018). This preceded the establishment of the blockade on Gaza in 2007. The number of fishermen increased progressively from 2,543 in 2002 to 3,097 in 2010 to 3,617 in 2016[1]. This increase is not due to the improvement of the Palestinian fishing industry, but rather to the deterioration of the economy in Gaza making fishing one of the only available livelihood opportunities (Feidi 2018). Israel has also imposed heavy restrictions on the import of necessary materials to repair fishing boats and equipment (Melon 2011; United Nations 2018).

Besides the restrictions imposed on the Palestinian fisheries and the risks taken by Palestinian fishers to earn their living, the fishing zone in Gaza suffers from pollution due to several factors, e.g., dumping of poorly treated domestic wastewater and industrial waste in the sea (Elnabris *et al.* 2013) .

Official fisheries data collected by the Palestinian Ministry of Agriculture in the Gaza Strip does not monitor, estimate or report catches from the small-scale sectors, i.e., commercial artisanal

[1] Palestinian Central Bureau of Statistics (2017) 'Basic Changes for the Fishery in Palestine, 2002-2016' available at http://www.pcbs.gov.ps/Portals/_Rainbow/Documents/Fish-2016-E-Time%20Series.html [accessed on October 26th, 2008].

and subsistence fisheries (Abudaya *et al.* 2013b). Thus, effective management of small-scale fisheries is difficult to establish.

Total marine fisheries catches were estimated by Abudaya *et al.* (2013b) for 1950-2010. Here, the catch reconstruction for Palestine to 2015, which included reported and unreported large and small-scale sectors, is updated.

Country specific implementation

Reported marine fisheries catches were made available by year and taxa by the Food and Agriculture Organization (FAO) on behalf of Palestine (Gaza strip) for 2011-2015. National marine fisheries landings for 2011-2015 were also available by taxa and year, for 2011-2015, from the Palestinian ministry of Agriculture (General Directorate of Fisheries) and the Palestinian Fishers Syndicate. The national and FAO data are similar. Thus the FAO data is used here as a baseline to which was added small-scale commercial and subsistence catches.

The large-scale fishery

The large-scale sector consists essentially of trawling, i.e., bottom trawling and shrimp trawling (Abudaya *et al.* 2013b). According to Abudaya *et al.* (2013b) the reported FAO fisheries data only covers the large-scale commercial fishing sector. Based on this the reported FAO data were deemed large-scale for 2011-2015.

The small-scale commercial fishery

The small-scale commercial fishery plays an important role along the nearshore of the Gaza Strip and provides an important source of food and livelihood to the people of Gaza. Most people engaging in small-scale fisheries sell the bulk of their catch along the coast and the roads, rather than retaining it for self-consumption. Besides mentioning that the small-scale commercial fishery is not monitored, Feidi (2018) mentions the presence of around 2000 unlicensed fishers on the Gazan coast. In the previous reconstruction, a catch per unit of effort (CPUE) per fisher was applied to the total number of fishers. The reported categorized industrial catches were then subtracted from the total reconstructed catches to obtain the small-scale catches.

In the absence of information on small-scale CPUE and on small-scale catches in general in Gaza for 2011-2015, the CPUE of reconstructed catch for the year 2010 (lowest CPUE since the start of the blockade, i.e., 1.06 $tyear^{-1} \cdot fisher^{-1}$) was applied to the number of fishers for 2011-2015. The reported catch was subtracted from the total reconstructed catch to obtain the small-scale catch.

The number of fishers was obtained from the Palestinian Central Bureau of Statistics1. The number of fishers for 2013 was not available so an interpolation was applied between the number of fishers in 2012 and 2014.

The subsistence fishery

Subsistence catches were estimated following the method used by Abudaya *et al.* (2013b), i.e., assuming they represent 3 % of the reconstructed small-scale catches.

Taxonomic disaggregation

The official Palestinian records indicated the appearance of two new fish species from the Red Sea, i.e., pearly-finned cardinalfish (*Jaydia poecilopterus)*, with a catch of less than 1 t in 2012, and yellow-lip threadfin bream (*Nemipterus aurifilum)*, whose catches are given in Table 29. The taxonomic disaggregation for small-scale commercial and subsistence fishing sectors were based on the previous reconstruction by Abudaya *et al.* (2013b).

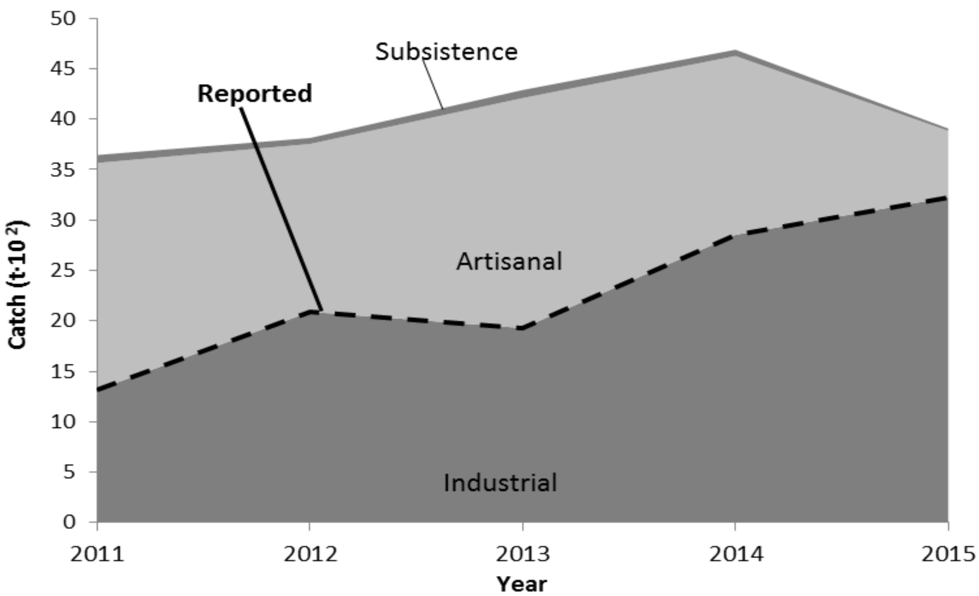
Table 29. Catch of *Nemipterus aurifilum* in the waters of the Gaza Strip, Palestine.

Year	Catch (t)
2010	22.0
2011	1.1
2012	0.2
2013	19.7
2014	1.1
2015	31.0

Country specific results

Total reconstructed marine fisheries catch for 2011-2015 were 1.6 times the catches reported by the FAO on behalf of Palestine including industrial (~60%), artisanal commercial (~39%,) and subsistence catches (~1%) (Figure 25a). Total catches were dominated by Clupeidae (~15%), Myliobatidae (~9%), Scombridae (~7%), Portunidae (~5%), and Sparidae (~3%) (Figure 25b). The discrepancy between the reported and reconstructed fisheries catch data is due to the non-monitoring and non-reporting of small-scale fisheries.

a)



b)

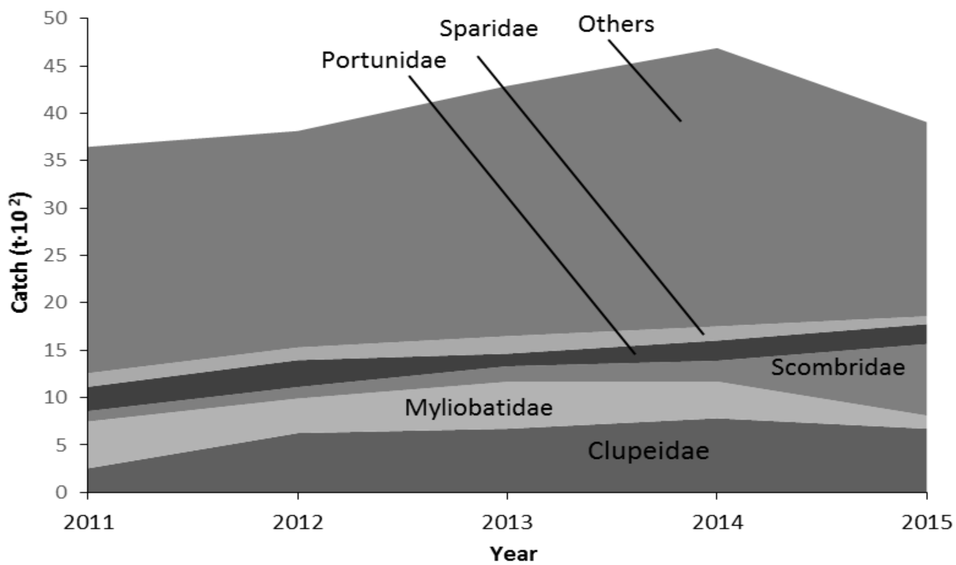


Figure 25. Reconstructed marine fisheries catches for Palestine (2011-2015), including a) the reported national landings of the large-scale commercial (i.e., industrial) sector, reported catches to the FAO on behalf of Gaza, as well as the unreported small-scale sector catches (artisanal and subsistence); and b) total reconstructed catch by major taxa, with 'others' representing 23 individually reported taxa and a miscellaneous marine fishes group.

2.3.1.11 Qatar

Background

The state of Qatar occupies a small peninsula of 11,600 km^2 in the western part of the Persian Gulf (Figure 26). This country is mostly inhabited by non-Qatari citizens[1], with an overall population of around 2 million in 2014 (www.worldbank.org), and only 12% of this population being Qatari citizens. The Qatari marine boundaries with Bahrain were established only in 2001 (Al-Abdulrazzak 2013b), and its EEZ is equivalent to almost 32,000 km^2 (www.seaaroundus.org).

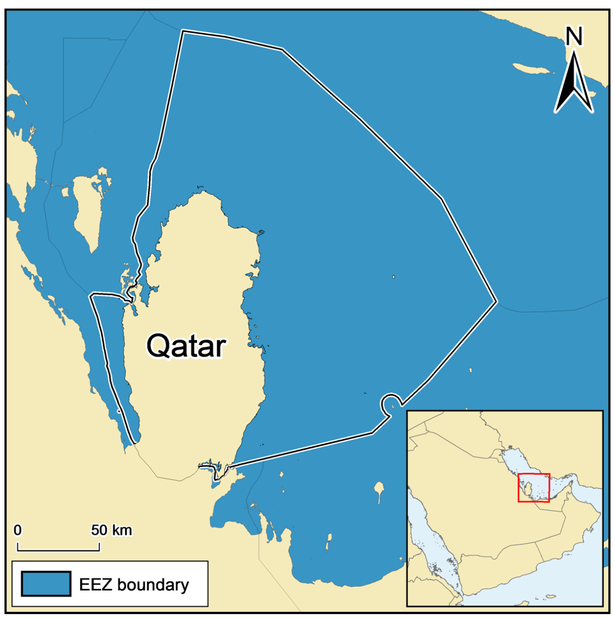


Figure 26. The EEZ and shelf area of Qatar.

[1] http://www.bq-magazine.com/economy/2013/12/population-qatar [accessed on the 25th of March 2016]

Country specific implementation

Reported catches by the FAO on behalf of Qatar were deemed entirely artisanal and used as a baseline to this reconstruction. Unreported, recreational and subsistence catch as well as discards were reconstructed using the same methods applied by Al-Abdulrazzak (2013c).

Unreported catches

Unreported shark fishing occurs in the Qatari waters, and following the methods used by Al-Abdulrazzak (2013c) it is assumed that the per capita shark rate of unreported shark catch was around 60% of the catch rate of reported catch shark in Qatar.

Unreported catch of *hadrah* (tidal weirs) are estimated to be 286 t.year^{-1} *as* per Al-Abdulrazzak and Pauly (2014). According to Al-Abdulrazzak (2013c), 56 illegal driftnets catching the equivalent of 20% of reported catch. The same was applied here.

Recreational and subsistence fisheries

According to Cisneros-Montemayor and Sumaila (2010), 0.12% of the Qatari population is involved in recreational fishing activities. According to Al-Abdulrazzak (2013c), recreational catches are assumed to be 1 kg of fish per trip along with 104 fishing trips per year. The same was applied here

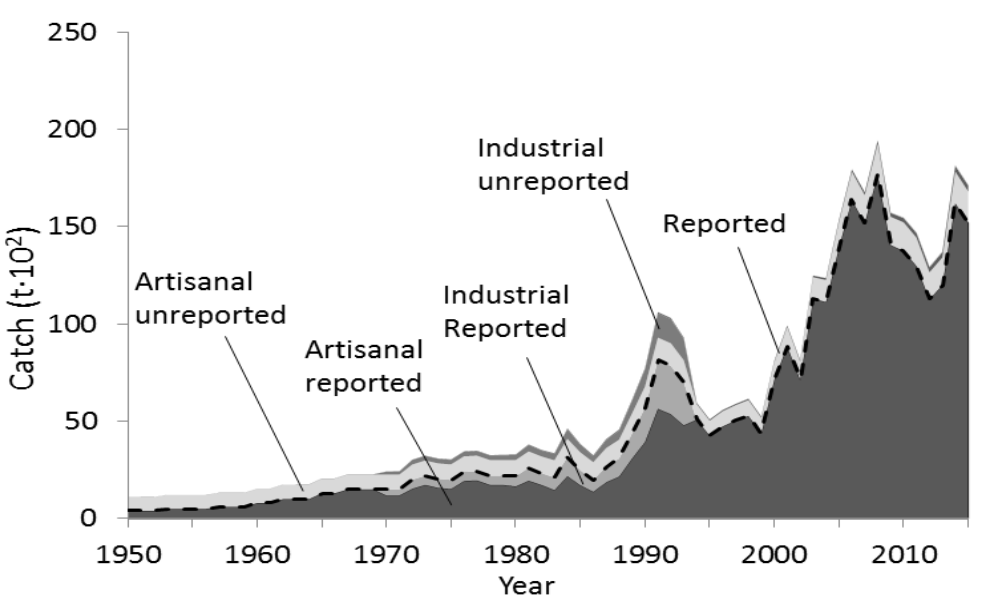
Discards

According to Al-Abdulrazzak (2013c) artisanal discards are equivalent to 4% of artisanal catches.

Country specific results

Reconstructed marine fisheries catches for Qatar amounted to 1.13 times the landings reported by the FAO on behalf of Qatar for 2011-2015. This reconstruction includes reported artisanal (~88%), unreported artisanal (~10%), recreational (~1.8%) and subsistence (~0.2%) (Figure 27a). Industrial fishing in Qatar has not occurred in recent years (Al-Abdulrazzak 2013b). The families contributing most to the catch were the Lethrinidae, Scombridae. Carangidae and Sparidae (Figure 27b).

a)



b)

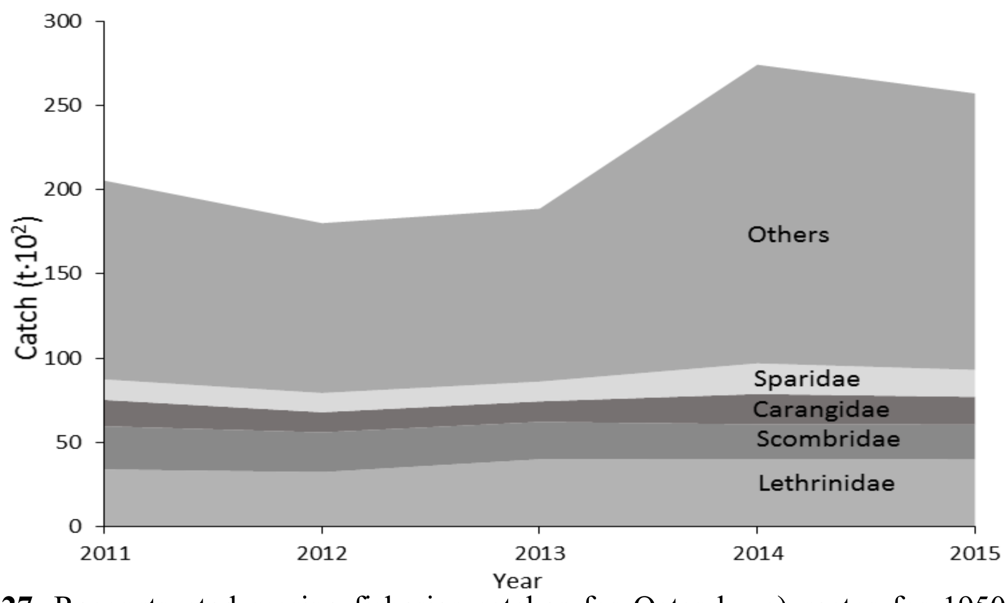


Figure 27. Reconstructed marine fisheries catches for Qatar by a) sector for 1950-2015 with reported landings overlaid as a dotted line; and b) by sector for 2011-2015, with 'others' representing 23 individually reported taxa and a miscellaneous marine fishes group.

2.3.1.12 Saudi Arabia

Background

Saudi Arabia is the largest country of the Arabian Peninsula and has two EEZs, one in the Red Sea and another in the Persian Gulf (Figure 28). The artisanal fishery is the oldest sector of the Saudi fishing industry and involves mainly traps but also other gears, such as gillnets and lines. This sector is relatively more important in the Persian Gulf than it is in the Red Sea (Tesfamichael et al. 2012a; Tesfamichael and Pauly 2013). The industrial fishery is mainly a trawl fishery. Recreational and subsistence fisheries also exist, but are not monitored, as is also the case for discards. Marine fisheries for both EEZs are described in detail in the previous reconstructions for 1950-2010 (Tesfamichael et al. (2012a) and Tesfamichael and Pauly (2013).

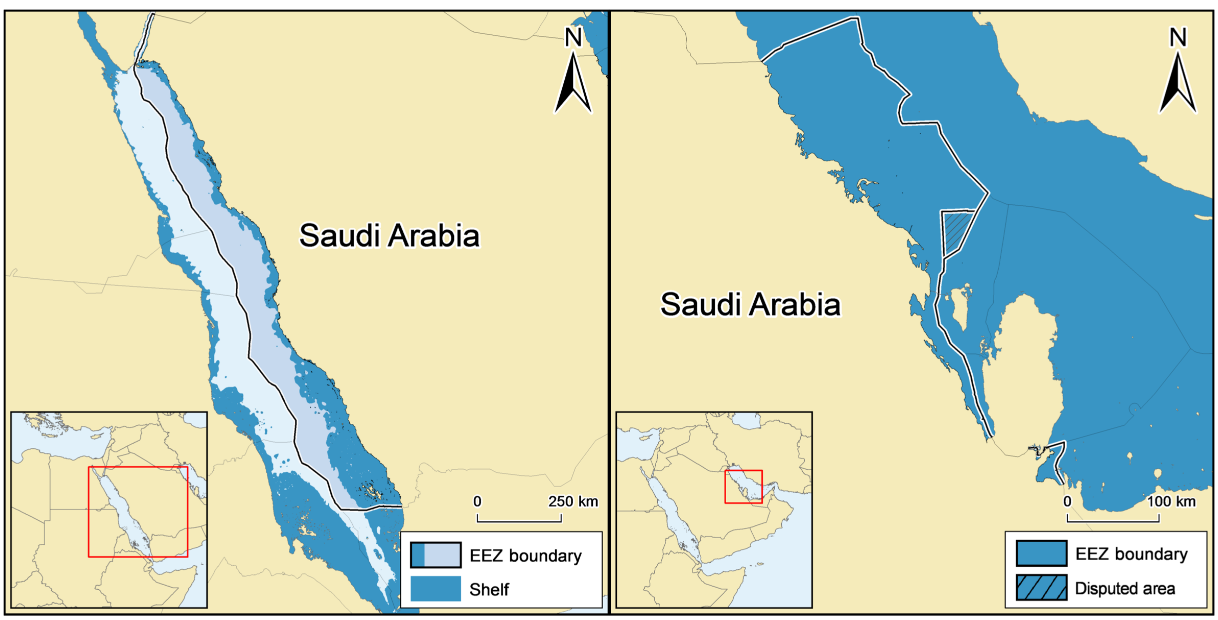


Figure 28. The EEZs and shelf areas for Saudi Arabia in the Red Sea (left) and the Persian Gulf (right).

Country specific implementation

Marine fisheries catches for Saudi Arabia were reported by year and taxa for 2011-2016 by the FAO Fishstat database and were considered here as the reported baseline. These data were reported for the FAO Area 51, i.e., Indian Ocean, as a whole and not by EEZ. It was then necessary to split the FAO reported data into the Red Sea and the Persian Gulf catches. The Saudi 'Ministry of Environment, Water, and Agriculture' has made available official landings for the Red Sea and the Persian Gulf EEZs separately for 2011-2013 (www.data.gov.sa). National and FAO data were equivalent for 2011. However, the FAO data were higher than the national for 2012 and 2013. The Red Sea and the Persian Gulf catch contributions to the total national landings were estimated to be around 40% and 60%, respectively. These percentages were applied to the FAO catch data for 2011-2016.

Commercial catches

FAO marine fisheries catches represent large- and small-scale commercial fisheries yields combined. In order to reconstruct each of the large and small-scale sectors, it was necessary to split reported catch into both sectors.

The catch contribution of large and small-scale commercial catch to the total reported catch of the Persian Gulf for 2005-2010 were 99.5% and 0.5%, respectively, as per Tesfamichael and Pauly (2013). These percentages were applied to the reported catch for the Persian Gulf EEZ of Saudi Arabia for 2011-2016. For the Red Sea, reported large-scale catch were obtained by extrapolating reported industrial catch as estimated by Tesfamichael *et al.* (2012a) to 2016.

Reported artisanal catch were obtained by subtraction of the reported industrial catch from the reported catch for the Red Sea EEZ of Saudi Arabia.

Total reconstructed artisanal catch from the previous reconstruction for the Red Sea was extrapolated to 2016. The unreported artisanal catch was obtained by subtraction of the reported artisanal catch from the total extrapolated reconstructed catch for 2011-2016. Artisanal unreported catch for the Persian Gulf was estimated by Tesfamichael and Pauly (2013) to be 13% of artisanal reported landings. Based on this, the unreported artisanal catch for the Persian Gulf EEZ of Saudi Arabia was assumed to be 15% of reported artisanal landings. The same taxonomic compositions applied for artisanal landings in the previous reconstructions for both EEZs for 2010 were applied here to disaggregate artisanal catch.

Subsistence catches

Subsistence catch were estimated to be around 10% of artisanal catch as per Tesfamichael and Pauly (2013) and Tesfamichael *et al.* (2012a). The same taxonomic disaggregation applied to the subsistence catch in the previous reconstructions was applied here for each EEZ.

Recreational catches

In the previous reconstruction for the Red Sea EEZ of Saudi Arabia, recreational catch was estimated using the recreational catch of 1,500 t available for 1998 and the Saudi population fishery (Tesfamichael *et al.* (2012a). The per capita recreational catch rate thus obtained was applied to the Saudi population to obtain the reconstructed catch. The same was applied here using the Saudi population for 2011-2016.

The number of recreational boats in the Red Sea and the Persian Gulf EEZs in 1996 were 2,446 and 2,528, respectively (Tesfamichael and Pauly (2013). Although it is very likely that the number of boats has increased considerably since, it was assumed that the same number of boats for 2011-2016 as for 1996. The recreational CPUE for the Red Sea EEZ was estimated using the recreational reconstructed catch for 2011-2016. The estimated CPUEs were then applied to the number of recreational boats for the Persian Gulf for 2011-2016 assumed to be the same as in 1996. The same taxonomic disaggregation applied for recreational catch in the previous reconstruction was applied here.

Discards

Reconstructed discards for Saudi Arabia were only industrial, given that artisanal discards are negligible. For both EEZs, discards were estimated to be 5.8 % of the industrial shrimp catch. The same taxonomic disaggregation applied for previous discards was applied here.

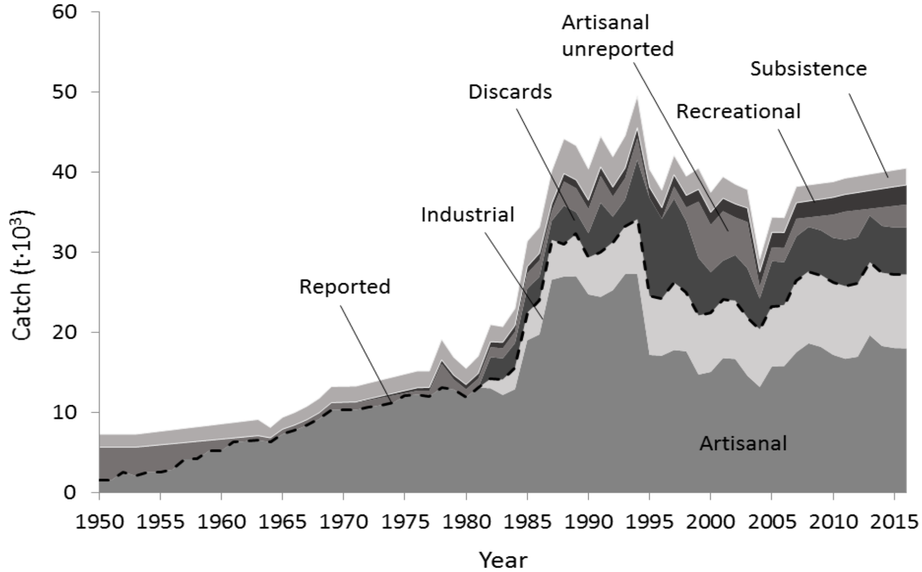
Country specific results

Marine fisheries catches were reconstructed for the Red Sea and the Persian Gulf EEZs of Saudi Arabia for 2011-2016. For the Red Sea, the reconstruction covers the following fisheries: reported artisanal (~76%), reported industrial (~0.3%), unreported artisanal (~11%), industrial discards (~0.7%), subsistence (~ 7.6%), and recreational (~4.4%) (Figure 29a).

The reconstruction for the Persian Gulf includes the following fisheries: reported artisanal catch (~45%), reported industrial catch (~23%), unreported artisanal catch (~7%), industrial discards (~14%), subsistence catch (~5%), and recreational catch (~6%) (Figure 30a).

The families contributing most to catches in the Red Sea EEZ of Saudi Arabia are Penaeidae (~13%), Lethrinidae (~16%), Scombridae (~12), Sparidae (~11%), and Carangidae.(~8%) (Figure 29b) and in the Persian Gulf EEZ are Scombridae (~21%), Carangidae (~10%), Lethrinidae (~13%) and Serranidae (11%) (Figure 30b).

a)



b)

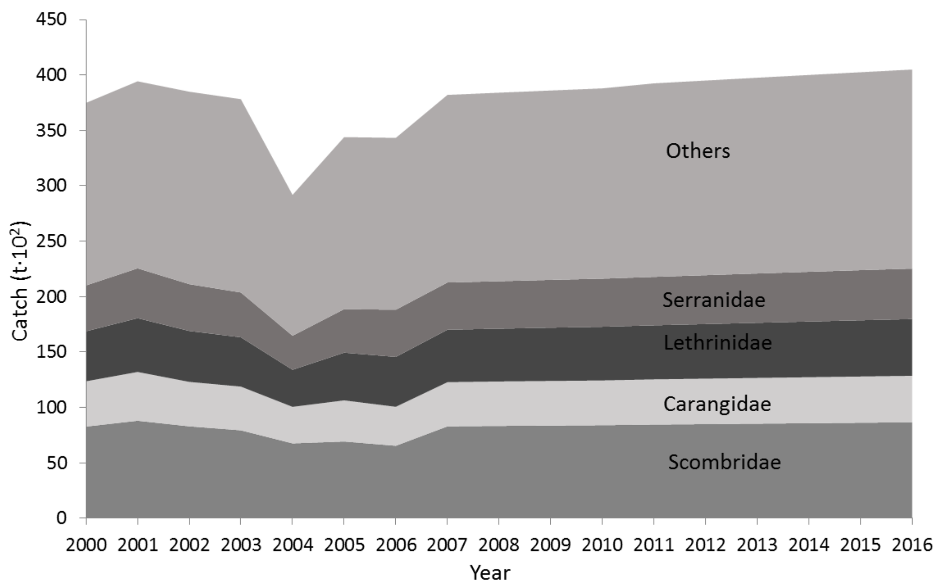
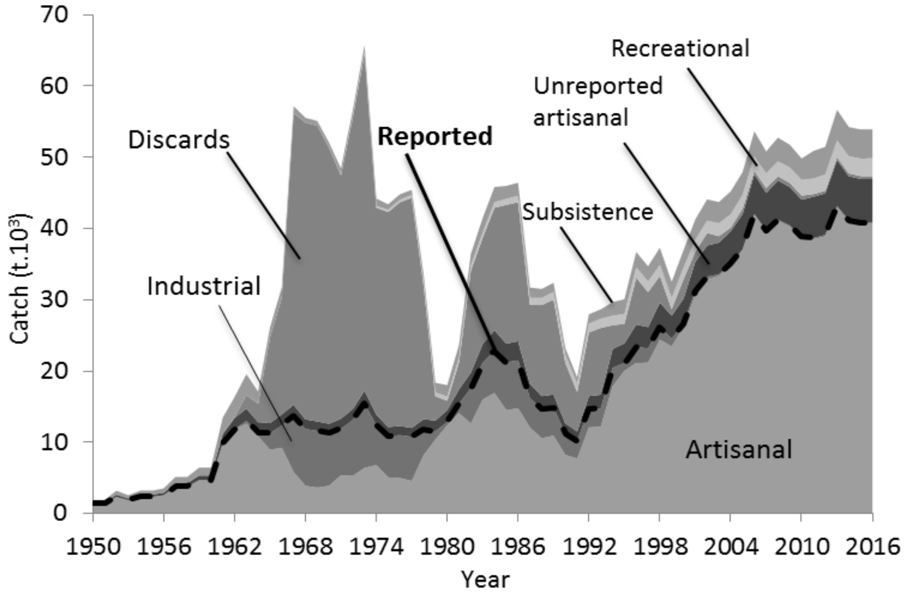


Figure 29. Reconstructed marine fisheries catches for Saudi Arabia (Red Sea) by a) fisheries sectors plus discards. Landings as deemed reported by the FAO on behalf of Saudi Arabia are overlaid as a dotted line for 1950-2016; and b) by major taxa for 2000-2016. Note the ‘others’ category includes 41+ additional taxonomic groups.

a)



b)

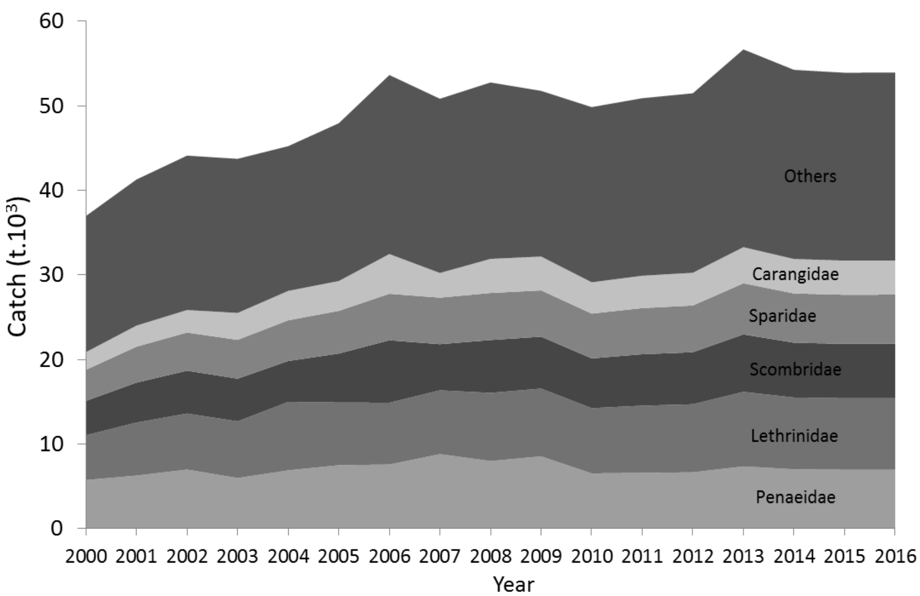


Figure 30. Reconstructed marine fisheries catches for Saudi Arabia (Persian Gulf) by a) fisheries sectors plus discards. Landings as deemed reported by the FAO on behalf of Saudi Arabia are overlaid as a dotted line for 1950-2016; and b) by major taxa for 2000-2016. Note the 'others' category includes 33+ additional taxonomic groups.

2.3.1.13 Syria

Background

Syria is located in the Levantine Basin, at the very east of the Mediterranean basin (Figure 31). It has an area of around 185,000 km^2 and a population of about 22 million in 2014 (www.worldbank.org). Syria has an EEZ of around 10,200 km^2 (www.seaaroundus.org). Since 2011, Syria has been suffering from a civil war.

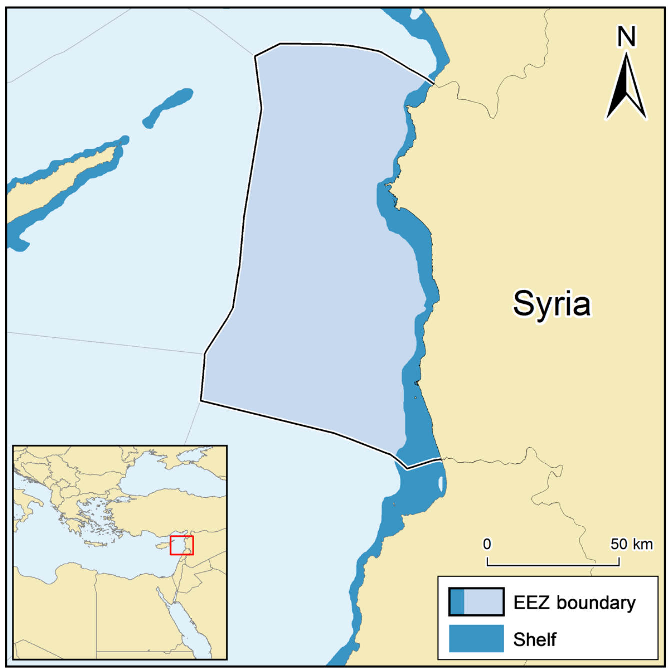


Figure 31. The EEZ and shelf area of Syria.

The Syrian fishery is mainly small-scale, multi-gear and multi-species. It includes, however, a small but heavily-subsidized industrial bottom trawl fishery (Saad 2010). Fishery statistics have been collected since 1965 from fish market managers. A large number of landing sites as well as fishing vessels are not monitored, in addition to recreational and subsistence catches, which are not accounted for (Margetts 1968; Ulman *et al.* 2015). Seafood consumption in Syria has been reported as low as 1 kg annually per person and the fishing industry contributes to only 0.002% of the Gross National Product (Ulman *et al.* 2015).

Syria has been entangled in a civil war since 2011, and the infrastructure in many major cities was destroyed, leading to a humanitarian and economic crisis. Millions of Syrians have fled Syria for other countries, resulting in one of the worst refugee crises in the world. It is expected that there has not been any fisheries monitoring and/or control since the start of the civil war in Syria in 2011.

Country specific implementation

Following the so-called 'Arab Spring' in 2011, an uprising began in Syria, slowly evolving into an armed conflict. Reported marine fisheries catches were available from the FAO Fishstat database for the 2011-2015 by taxa and year. The FAO taxonomic breakdown was improved following the methods applied by Ulman *et al.* (2015). The four taxonomic groups 'demersal percomorphs nei', 'marine crustaceans nei', 'marine molluscs nei', and 'sharks, rays, skates, etc. nei' were broken down into more detailed taxa.

Reported catch

Ulman *et al.* (2015) assumed that the reported industrial component of the total reported catch was 1000 t. $year^{-1}$ between 2005 and 2010. Due to the start of the turmoil in Syria, it is likely that industrial trawling was reduced for security reasons. It was then assumed that industrial reported catch were around 500 t·year^{-1} for 2011-2015. The reported artisanal catch was obtained by subtraction of the reported industrial catch from the total FAO reported catch. The improved taxonomic disaggregation of the FAO catch was applied here to each of the reported industrial and artisanal catch.

Unreported catch

<u>*Unreported industrial*</u>

To estimate the unreported industrial catch, Ulman *et al.* (2015) reconstructed the total industrial catch using different anchor points of the number of industrial vessels and catch in Syria. The number of trawlers of 2010 was assumed to have decreased by 50% in 2011-2015 while keeping the same CPUE of 2010. To estimate the unreported industrial catch, the industrial reported catch was subtracted from the total industrial reconstructed catch. The taxonomic breakdown applied for 'demersal percomorphs nei' was applied to disaggregate the unreported industrial catch.

<u>*Unreported artisanal commercial*</u>

According to Ulman *et al.* (2015), total unreported catch was around 98% of reported landings in 2010. Due to the war, unreported catch has likely increased. However, to remain conservative, it was assumed that unreported catch for 2011-2015 was also equivalent to 98% of total reported landings. The unreported artisanal commercial catch is obtained by subtraction of the unreported industrial catch from the total unreported catch. The taxonomic disaggregation applied to the reported FAO catch is applied to the artisanal unreported catch.

Recreational and subsistence

In a state of war food security is affected negatively. In this case, fish becomes a substitute of other unavailable food. According to Faour and Fayad (2014) the number of people living within the main Syrian coastal cities increased by 1.5 million.

To estimate subsistence catches, the per capita subsistence rate for 2010 was assumed and applied to the coastal population for 2011-2015. The coastal population was obtained from Faour and Fayad (2014) for the years 2011 and 2014. An interpolation and extrapolation were performed to obtain the coastal population for the years 2012, 2013 and 2015.

Due to the war, recreational catch has likely drastically decreased but not completely stopped[1]. Recreational catch was thus assumed to have decreased by 80% in 2011-2015, compared to 2010.

The taxonomic disaggregation applied to the subsistence and recreational catch by Ulman *et al.* (2015) was also applied here.

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[1] Marine fishing… Artisanal and Spiritual sport (translated from Arabic)

http://www.esyria.sy/etartus/?p=stories&category=community&filename=201209220855011 (Last access January 26th, 2018)

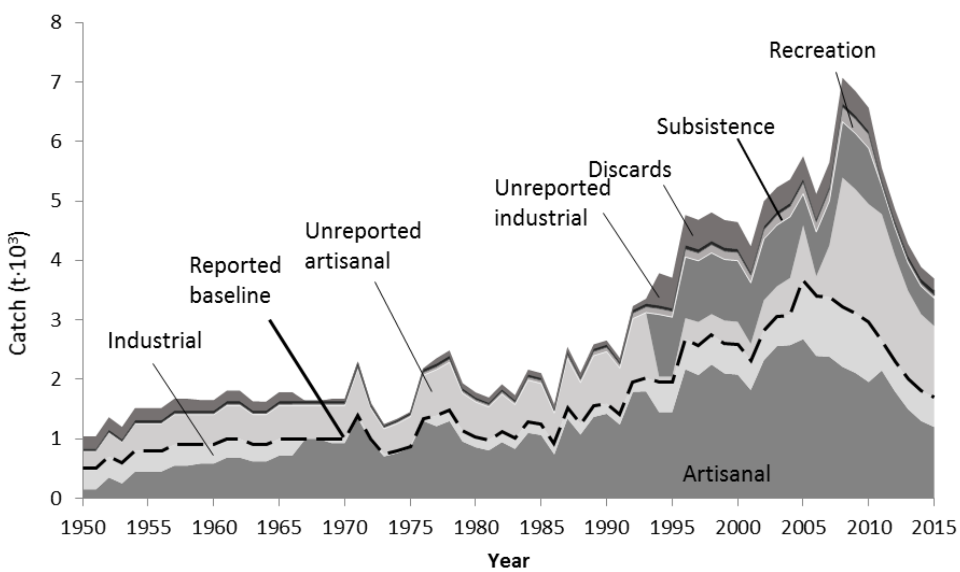
Discards

Discards were estimated to be around 20% of total industrial catch by Ulman *et al.* (2015). The same was assumed for 2011-2015, to which was applied the same taxonomic disaggregation.

Country specific results

Reconstructed marine fisheries catches for Syria for 2011-2015 amounted to twice the landings reported by the FAO on behalf of Syria, including reported artisanal (~36%), reported industrial (~11%), unreported artisanal (~35%), unreported industrial (~11%), industrial discards (~4%), subsistence (~2%) and recreational catches (~1%) (Figure 32a). The most caught families by the Syrian fishing industry for 2011-2015 are Scombridae, Sparidae, Clupeidae, Mullidae, and Carangidae (Figure 32b).

a)



b)

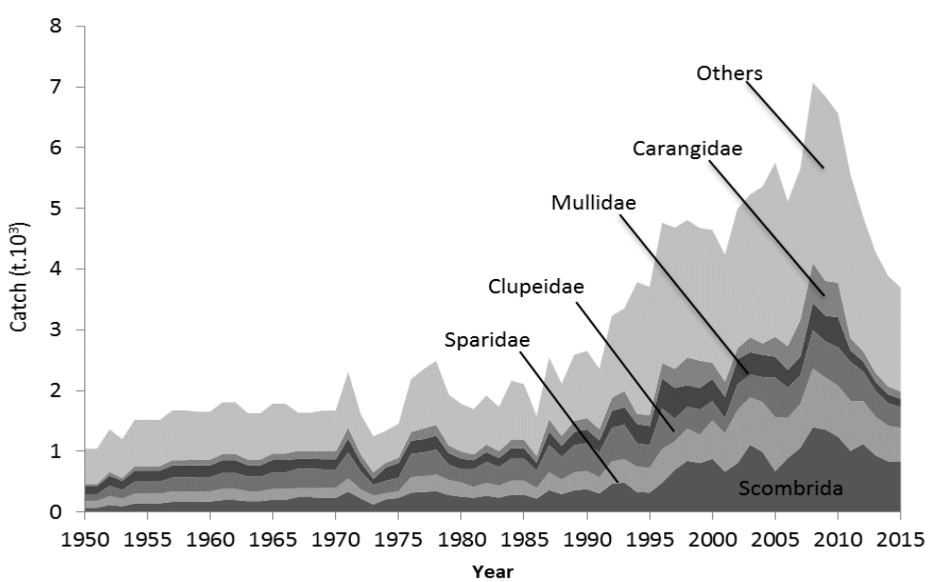


Figure 32. Reconstructed marine fisheries catches for Syria by a) fisheries sectors plus discards for 1950-2015. Landings as deemed reported by the FAO on behalf of Syria are overlaid as a dotted line; and b) by major taxa. Note the 'others' category includes over 30 additional taxonomic groups. Marine fisheries for 1950-2010 were reconstructed by Ulman *et al.* (2015).

2.3.1.14 Tunisia

Background

Tunisia is a North African country bordered by the Mediterranean Sea in the north and the east. Tunisia's coastline regroups three important embayments: the Gulf of Tunis in the north, the Gulf of Hammamet near the centre, and the Gulf of Gabes in the south. Tunisia has a large continental shelf of over 66,000 km^2, and in 2005, it claimed an Exclusive Economic Zone (EEZ) of 102,300 km^2 (Official journal of the Tunisian Republic 2005; www.seaaroundus.org) (Figure 33).

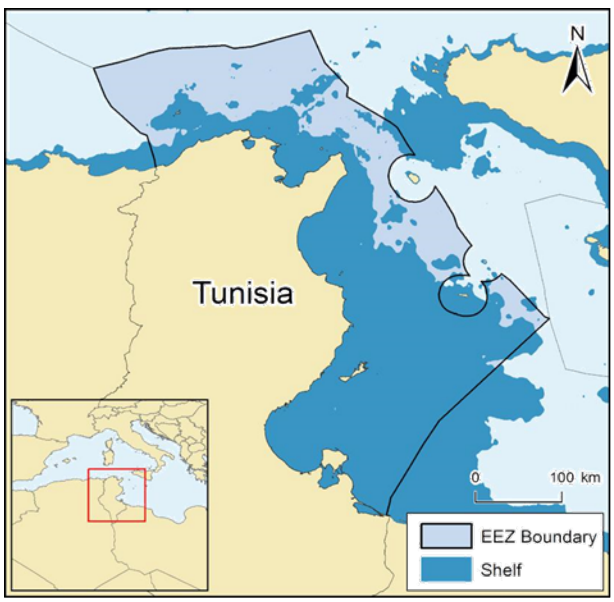


Figure 33. The EEZ and shelf area of Tunisia.

Overall the Tunisian artisanal fishery is well developed and mostly performed by motorized boats. The industrial fishery is gaining in importance, mainly through pelagic trawlers and seiners. Tunisia has a relatively good fisheries statistics collection system. Commercial landings are monitored and collected daily in each fishing port. The authorities do account for the subsistence, unreported artisanal and industrial commercial catches, as well as discards by applying, since the early 1970s, correction coefficients to each of the trawl, seine, and artisanal landings. Annual national statistical reports are made available publicly by the fisheries national department (DGPA).

In 2011, a revolution took place in Tunisia, starting the so-called "Arab Spring", which affected the fishing industry for the following few years with an increase in IUU fishing activities. The country has regained a general political and socio-economic stability and is now one of the only democracies in the SMAP region[1]. The Gulf of Gabes is the second largest continental shelf in the Mediterranean and is characterized by the presence of the largest seagrass (*Posedonia oceanica*) meadow making it one of the most important nursery habitats in the Mediterranean (Moullec et al. 2016). This has led to the development of intensive artisanal and industrial fisheries in the Gulf of Gabes (Najar *et al.* 2010).

In the most important fishing area in Tunisia, the Gulf of Gabes, heavy pollution, combined with overfishing and the use of illegal fishing gears has been leading to stocks decline. The population of that region is not only affected by pollution, but also by increasing unemployment.

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[1] The Economist Intelligence Unit's Democracy Index (2017) available online at https://infographics.economist.com/2017/DemocracyIndex/ [accessed on 20/12/2019]

Marine fisheries catch reconstruction for Tunisia was completed for 1950-2010 by Halouani *et al.* (2015). This study is an improvement and an update of the previously completed reconstruction to 2016.

Country specific implementation

Domestic marine fisheries data for Tunisia were available by year and taxa for 1950-2016from the FAO Fishstat database. Official landings were also assembled by sector, year and taxa for 1950-1976 and 1977-2016 from national Statistical Bulletins and the Tunisian Department of Fisheries and Aquaculture (DGPA), respectively (Halouani *et al.* 2015). There is a negligible discrepancy between the national and the FAO data. The FAO data were thus used here as the reported baseline given their better taxonomic disaggregation for 1950-2016.

Large- and small-scale commercial marine fisheries

A clear international or regional definition of the large-scale (industrial) and small- scale (artisanal) fisheries is nonexistent. In this study, the national definitions of the different fisheries components are adopted. However, trawlers are always considered industrial regardless of the country's definition as per Martín (2012b).

The Tunisian fishing industry can be categorized into four main fisheries sectors based on the main fishing gears: the trawl fishery, the longline fishery, the purse seine fishery (that includes the "*lampara*" fishery), and the artisanal "coastal" fishery (WWF 2014). The trawl fishery involves bottom trawlers and pelagic trawlers and targets fish and shrimps. The longline fishery targets both demersal and pelagic species. The *lampara* fishery consists in purse seines that use lights at night to attract fish. Similarly to the regular purse seine fishery, it targets small pelagics, mainly sardines. The small-scale or coastal fishery is multi-species and multi-gear. It includes non-motorized and motorized boats and land-based fishing (Romdhane 1998).

As for most world maritime countries, only small- and large-scale commercial catches are monitored. Nonetheless, in an effort to account for unreported and unmonitored commercial and subsistence catches, the DGPA has applied, since the late 1970s, correction factors to the official catch data. The unreported commercial catches are usually defined as fish sold directly to hotels, restaurants, in local markets, and to individuals without being accounted for by the statistical system. Subsistence catches accounted for by these factors are defined as catches consumed by the fishers on boats. These correction factors differ between sectors and are equivalent to 1.42 for the artisanal fishery, 1.17 for the trawl fishery, and 1.15 for the *lampara* fishery (Khalfallah 2013).

The National data for 1999-2014 were available for the following taxonomic groups by gears: Large Pelagic, shrimps, lobsters, cuttlefishes, and squids. The different gears were: pelagic trawls, benthic trawls, purse seines and *lamparas*, multi-gear artisanal, and longlines. Total catches of each of the taxa were matched to FAO reported catches of certain species part of the same taxonomic group as summarized in Table 30. This allowed the split catches of the matched species into artisanal and industrial. The large-scale fishery englobes catches by both pelagic and benthic trawlers, purse seines and *lamparas,* and longlines.

Table 30. Reported national taxonomic groups matched to FAO reported species for Tunisia.

National categories	Correspondent FAO taxonomic group
Large pelagics	Frigate and bullet tunas Little tunny(=Atl.black skipj) Leerfish Plain bonito Atlantic bonito Atlantic mackerel Tuna-like fishes nei Greater amberjack Atlantic bluefin tuna Jack and horse mackerels nei Swordfish
Shrimps	Blue and red shrimp Caramote prawn Speckled shrimp Deep-water rose shrimp
Lobsters	European lobster Norway lobster Palinurid spiny lobsters nei Mediterranean slipper lobster
Octopuses	Cephalopods nei Horned and musky octopuses Common octopus
Cuttlefishes	Common cuttlefish
Squids	Common squids nei

The taxonomic disaggregation per gear was available by gear for 1999-2014 (Tables 31 and 32). To account for 1950-1998 and 2015-2016, the percentage catch contributions of the small-scale sector to the landings of large pelagics and shrimps were extrapolated back to 1950 and to 2016. For the remaining groups the percentage catch contributions of the small-scale sector to total landings of 1999 were applied to 1950-1998 and those of 2014 were applied to 2015 and 2016.

The percentage contribution of small-scale was applied to each matched FAO species of which catches by the large-scale sector were obtained by subtraction of the estimated catches by small-scale sector from the total FAO reported catch. For the remaining species reported by the FAO it was assumed that they were caught equally by both large- and small-scale sectors. The equivalent of 10% of artisanal and industrial landings was deemed unreported, a conservative estimate. The same taxonomic compositions applied to the each of the artisanal and industrial fisheries were applied to disaggregate the unreported catch.

Table 31. Percentage catch contribution of the different sectors to catches of large pelagics and squids for 1999-2014 for Tunisia (in %).

Taxonomic group	Year	Small-scale	Large-scale			
			Benthic trawl	Pelagic trawl	Purse seines	Longlines
Large pelagics	1999	32.75	0.13	0.01	6.97	60.13
	2000	31.30	0.22	-	3.80	64.68
	2001	26.48	0.13	0.01	4.68	68.70
	2002	33.43	0.02	0.02	7.76	58.77
	2003	43.15	0.07	1.10	12.68	43.00
	2004	32.82	7.31	0.06	9.40	50.41
	2005	32.66	0.01	0.04	4.91	62.40
	2006	39.20	0.18	0.05	10.04	50.53
	2007	35.02	0.03	0.16	17.48	47.32
	2008	30.21	2.51	0.01	19.86	47.42
	2009	33.11	0.15	0.00	26.62	40.11
	2010	33.22	-	0.13	32.79	33.87
	2011	33.28	0.24	0.04	33.42	33.03
	2012	31.11	0.14	-	46.75	21.99
	2013	29.09	0.12	-	44.51	26.28
	2014	23.39	1.00	0.01	60.45	15.15
Squids	1999	18.03	47.61	0.00	34.35	-
	2000	25.09	54.00	0.22	20.69	-
	2001	20.81	65.30	0.04	13.85	-
	2002	11.30	58.49	0.13	30.09	-
	2003	15.72	64.81	0.00	19.46	-
	2004	13.21	66.90	-	19.89	-
	2005	14.50	70.72	0.00	14.78	-
	2006	19.50	73.84	-	6.66	-
	2007	27.10	65.81	0.00	7.09	-
	2008	26.96	49.93	0.08	23.03	-
	2009	17.53	69.74	-	12.73	-
	2010	17.61	63.58	0.01	18.81	-
	2011	18.14	60.35	-	21.51	-
	2012	10.84	69.50	-	19.65	-
	2013	14.90	70.49	-	14.61	-
	2014	18.18	72.58	-	9.24	-

Table 32. Percentage catch contribution of the different sectors to catches of cuttlefishes, shrimps, lobsters and octopuses for 1999-2014 for Tunisia (in %).

Taxonomic group	Year	Small-scale	Large-scale		Taxonomic group	Year	Small-Scale	Large-Scale (Benthic trawling)
			Benthic trawling	Pelagic trawling				
Cuttlefishes	1999	37.01	62.99	0.00	Lobsters	1999	88.88	11.12
	2000	43.42	56.56	0.02		2000	96.38	3.62
	2001	33.68	66.32	0.00		2001	95.59	4.41
	2002	35.91	64.09	-		2002	98.75	1.25
	2003	32.95	67.04	0.00		2003	99.00	1.00
	2004	40.01	59.99	-		2004	99.96	0.04
	2005	43.03	56.95	0.02		2005	98.08	1.92
	2006	38.92	61.08	0.00		2006	100.00	-
	2007	48.14	51.85	0.01		2007	99.59	0.41
	2008	61.38	38.62	0.00		2008	98.49	1.51
	2009	67.25	32.75	-		2009	97.32	2.68
	2010	68.06	31.94	-		2010	97.80	2.20
	2011	52.53	47.47	-		2011	97.42	2.58
	2012	50.50	49.50	-		2012	97.57	2.43
	2013	59.92	40.08	-		2013	99.27	0.73
	2014	69.61	30.39	-		2014	94.81	5.19
Shrimps	1999	22.72	77.28	-	Octopuses	1999	74.64	25.36
	2000	17.45	82.55	-		2000	82.12	17.88
	2001	21.41	78.59	-		2001	84.37	15.63
	2002	16.62	83.38	-		2002	85.09	14.91
	2003	22.16	77.84	-		2003	72.02	27.98
	2004	20.31	79.69	-		2004	74.19	25.81
	2005	29.11	70.89	-		2005	77.84	22.16
	2006	26.65	73.35	-		2006	88.11	11.89
	2007	35.71	64.29	-		2007	92.18	7.82
	2008	26.11	73.89	-		2008	87.52	12.48
	2009	29.34	70.66	-		2009	86.33	13.67
	2010	24.17	75.83	-		2010	92.31	7.69
	2011	15.56	84.44	-		2011	86.59	13.41
	2012	21.33	78.67	-		2012	86.55	13.45
	2013	12.13	87.87	-		2013	88.96	11.04
	2014	17.29	82.71	-		2014	90.48	9.52

Recreational fishery

Khalfallah (2013) estimated the recreational catch for the year 2013, for the Gulf of Tunis using the number of recreational fishers members of the different Tunisian recreational fishing clubs, 3000 members, and the recreational fishing effort, i.e., number of trips per season and average catch amount per trip, To estimate recreational catches for Tunisia, Halouani *et al.* (2015) performed an interpolation between 1960 and 2013 to estimate recreational catch for earlier years, assuming that recreational fishing started in the early 1960s, and thus that recreational catch was equivalent to 0 in 1960. It was assumed that recreational catches remained constant during 2014-2016. The same taxonomic disaggregation applied for recreational catches in the previous reconstruction was applied here.

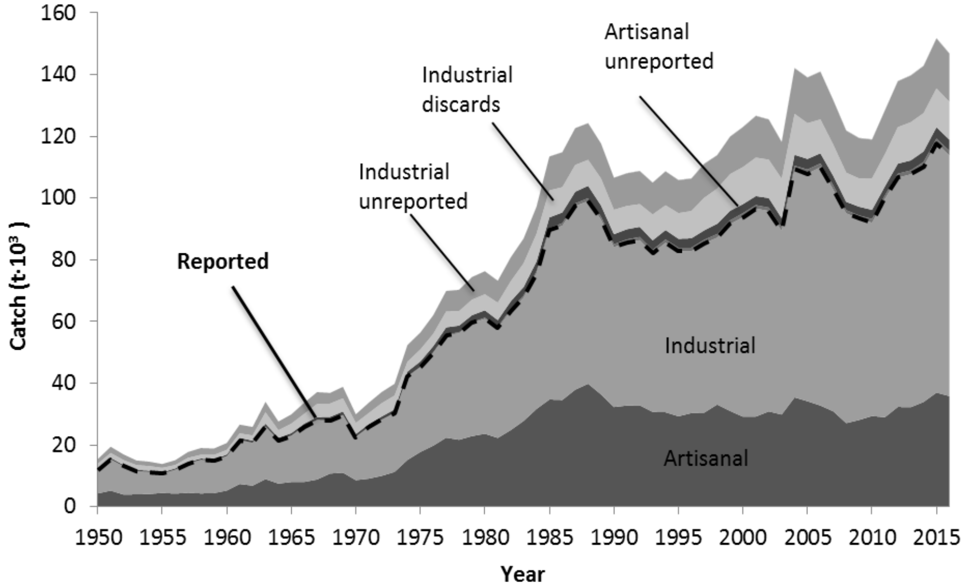
Discards

The percentage of artisanal and industrial discarded catch to total artisanal and total landings, respectively, were estimated from the previous reconstruction for 2010. The estimated percentages were applied to the total artisanal and industrial catch for 2011-2016. The same taxonomic disaggregation applied for discards in the previous reconstruction by Halouani *et al.* (2015) was applied here.

Country specific results

Reconstructed marine fisheries catches were estimated for Tunisia for 2011-2016. Previously completed catch reconstruction by Halouani *et al.* (2015) for Tunisia for 1950-2010 was improved. This reconstruction covers for 1950-2016 the following sectors: reported artisanal catch (~27%), reported industrial catch (~51%), unreported artisanal catch (~2.7%), unreported industrial catch (~10.2), industrial discards (~8%), artisanal discards (~1%), and recreational catch (~0.1%) (Figure 34a). The families contributing most to the catches in Tunisian waters for 1950-2016 are: Clupeidae (~23%), Sparidae (~12%), Scombridae (~10%), and Sciaenidae (~5%) (Figure 34b).

a)



b)

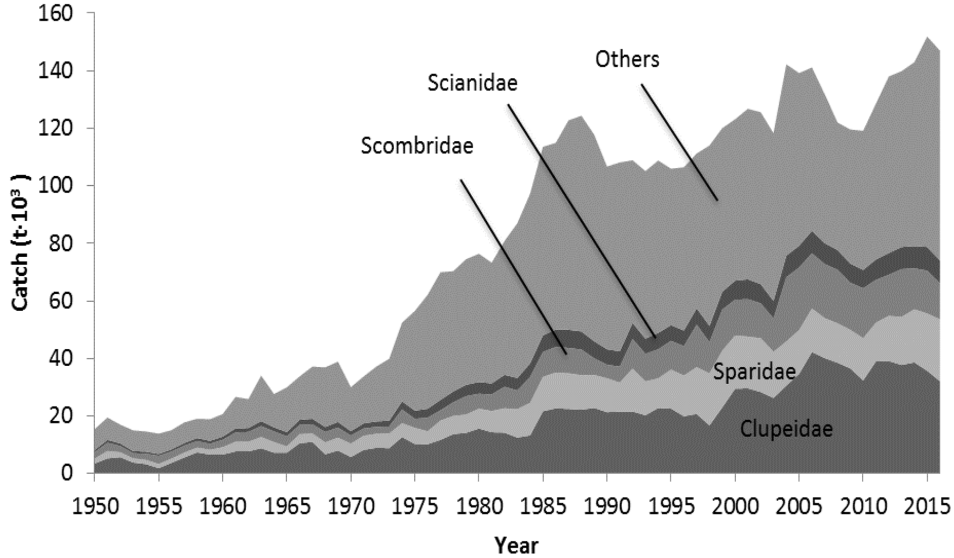


Figure 34. Reconstructed marine fisheries catches for Tunisia for 1950-2016, by a) fisheries sectors, plus discards shown separately, with FAO data overlaid as a dotted line (note that the recreational catches are too small to be visible); and b) by main taxonomic group. Note the 'others' category includes 56+ additional taxonomic groups, family level or higher taxa.

2.3.1.15 United Arab Emirates (UAE) (Excluding Fujairah)

Background

The United Arab Emirates (UAE) is situated in the southeastern of the Arabian Peninsula, covering an area of 83,600 km^2. The Emirati population was estimated at around 9 million in 2014 (www.worldbank.org), of which a high percentage is composed of immigrants[2]. The UAE have their main coast on the Persian Gulf and a shorter (Fujairahan) coast on the Gulf of Oman. The UAE's EEZ in the Persian Gulf is about 52,500 km^2 (www.seaaroundus.org, Figure 35). The Persian Gulf fisheries of the UAE are entirely small-scale, multi-gear and multi-species (Grandcourt *et al.* 2010). The recreational and subsistence fisheries are of a minor importance.

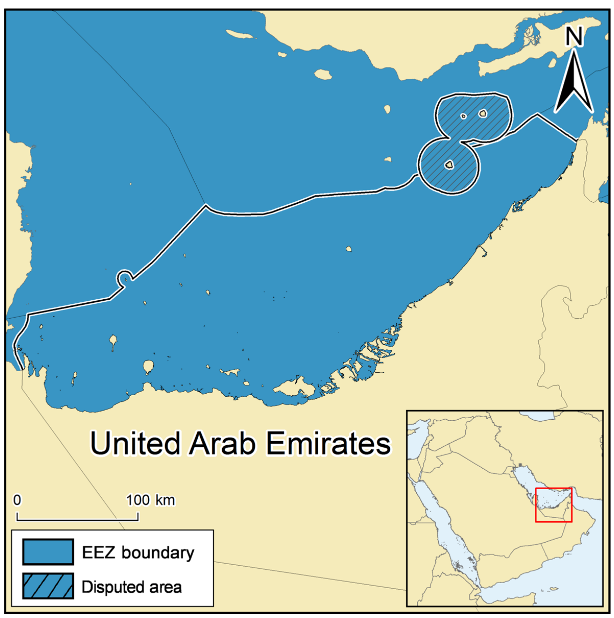


Figure 35. The EEZ and shelf area of the UAE (excluding Fujairah).

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[2] http://www.bq-magazine.com/economy/socioeconomics/2015/04/uae-population-by-nationality [accessed on the 25th of March 2016]

Country specific implementation

Reported catch

Official reported data were made available by the FAO for the UAE as a whole (including Fujairah). Given that the catch reconstructions for the UAE and the Fujairahan EEZs are completed here separately, their reported catch had to be separated. Reported landings for Fujairah were made available by the Fujairah Statistics Centre (FSC) (www.fscfuj.gov.ae) for 2011-2015. Reported catch for UAE excluding Fujairah were then obtained by subtracting the reported catch for Fujairah from the total reported FAO catch for the UAE.

According to Al-Abdulrazzak (2013a), the UAE have been over-estimating their catches because of the inclusion of imported fish to the national fisheries statistics. Thus, reported catches were adjusted by decreasing them by 40% as per Al-Abdulrazzak (2013a). Finally, all reported catch for UAE were deemed artisanal.

Unreported catch

Unreported catches by the *hadrahs* were estimated to be 692t per year for the UAE for 1950-2010 by Al-Abdulrazzak (2013a) and thus the was assumed for 2011-2015. According to Al-Abdulrazzak (2013a) illegal driftnetting started after the ban of driftnetting in 1989. It was assumed that participating vessels in illegal driftnetting were equivalent to 10% of the total fishing boats and were catching 20% more than what was reported. To estimate the illegal catches by driftnets, the following was applied:

Let A = Total number of boats (The number of boats was obtained from governmental sources). However, the number of boats previously used by Al-Abdulrazzak (2013a) and available for the 1997-2011, included boats in Fujairah. This was corrected by subtracting the number of boats operating in Fujairah, obtained from governmental reports for the same time period from the total UAE boats. The number of boats for 2012-2015 were assumed to be the same as for 2011 and those for 1989-1996 were assumed to be the same as for 1997.

B= Total illegal catch = FAO reported adjusted catch for UAE (excluding Fujairah) * 1.2;

Then: C= Illegal CPUE = B/A;

Let D= Vessels involved in illegal activities= 10% * (A);

Then, Illegal driftnet catches = C * D;

Total unreported artisanal catch was equivalent to the sum of the unreported *hadrah* catch and the illegal driftnet catch.

Recreational catch

As per Al-Abdulrazzak (2013a) recreational fishers were estimated to be 0.12% of the UAE population (excluding the Fujairahan population) and were assumed to catch 1 kg of fish per trip and to effectuate 104 trips per year. Recreational catches were estimated using this method for 2011-2015.

Subsistence catch

As explained by Al-Abdulrazzak (2013a), the population that fishes for their personal consumption and that of their families was estimated to be 0.0046 % of the total UAE population. It was also assumed that they fished 5 kg per week.

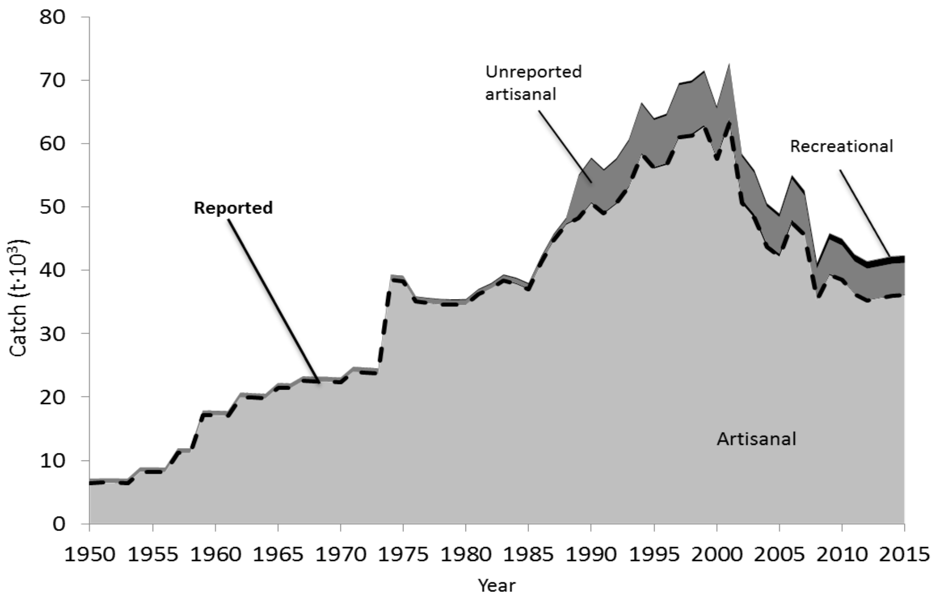
Discards

Discards were estimated following Al-Abdulrazzak (2013a) method, according to which artisanal discards were equivalent to 2.56% of the *gargoor* catches for the UAE.

Country specific results

Marine fisheries catches were reconstructed for the UAE in the Persian Gulf for 2011-2015. The previously completed reconstruction by Al-Abdulrazzak for 1950-2010 was also improved. Reconstructed marine fisheries catches amounted to the landings reported by the FAO on behalf of the UAE for 1950-2015 (excluding Fujairah). This reconstruction includes reported artisanal, unreported artisanal, subsistence, recreational and discards (Figure 36a). The families that contributed the most to the reconstructed catch were Scombridae, Clupeidae, Carangidae, and Lethrinidae (Figure 36b).

a)



b)

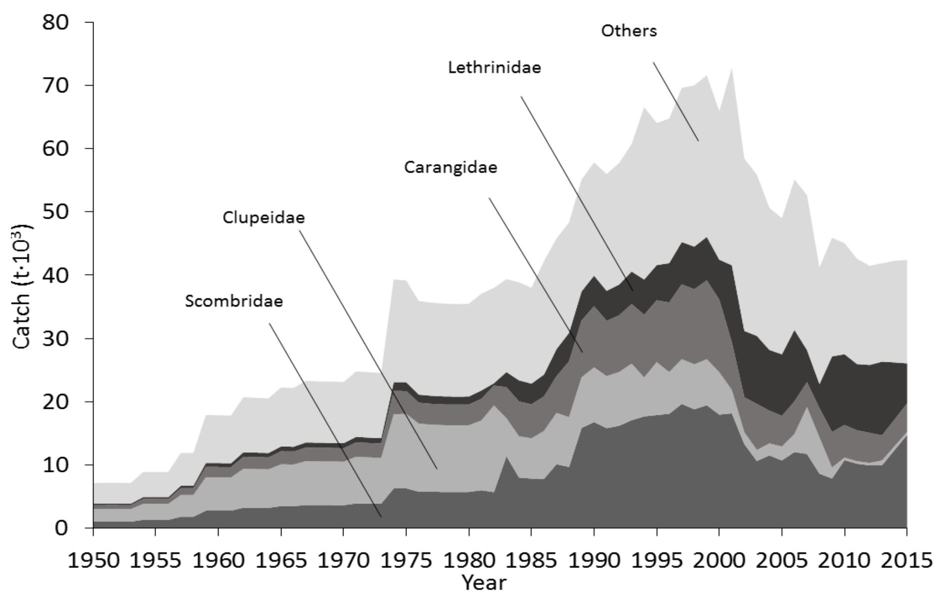


Figure 36. Reconstructed marine fisheries catches for the UAE (excluding Fujairah) for 1950-2015 with reported data overlaid as a dotted line, by a) sectors plus discards; and b) by major taxa.

2.3.1.16 Fujairah (UAE)

Background

Fujairah is part of the United Arab Emirates (UAE) but is located on the eastern coast of the country (Figure 37). Unlike the rest of the Emirates with a coastline on the Persian Gulf, Fujairah is the only of the seven emirates with a coast on the Gulf of Oman (www.fujmun.gov.ae[1]). Fujairah has an area of 1,300 km^2 (www.citypopulation.de[2]) and is mostly mountainous, with plains allowing farming while other Emirates are mostly desert-like. It is warm most of the year, with rainy winters. Fujairah had a population of 200,000[24] in 2014.

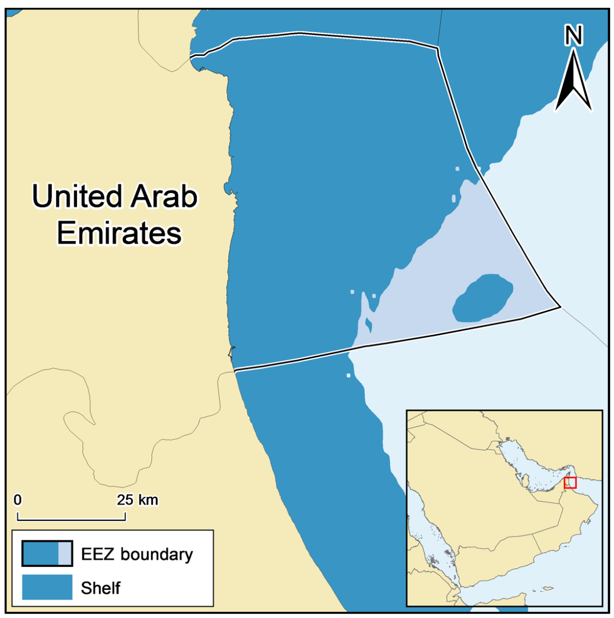


Figure 37. The EEZ and shelf area for Fujairah (UAE).

[24] www.government.ae/en/about-the-uae/the-seven-emirates/fujairah

Fujairah's economy is heavily based on government grants from Abu Dhabi. Thus, a decade ago, in order to develop its economy, Fujairah created a free trade zone, similar to that of Dubai, allowing for full foreign ownership of facilities (www.robinsonlibrary.com[3]).
The Gulf of Oman is located to the south of the Strait of Hormuz, and water from both the Arabian Sea to the south and the Persian Gulf to the north circulates past it (Pous *et al.* 2004).

The waters off Fujairah (Figure37) within an EEZ of 4,370 km^2, are part of the Gulf of Oman, and are characterized by a rich fish fauna, some of which reef-associated, as well as abundant large pelagic species and small schooling species (Sheppard *et al.* 1992). Several fishing villages dot the coast of Fujairah, whose Ministry of Agriculture and Fisheries (MAF) is responsible for the management and monitoring of fishing activities (Pearson *et al.* 1998).

Fujairah's fisheries are artisanal, with fishers deploying diverse types of gears (Table 33) that change according to the target species and seasonally (Pearson *et al.* 1998). *Tarrads* use mainly traps, some nets and hook and lines to catch pelagic and demersal species. In the winter and early spring, *tarrads* are also employed in beach seine fishing for sardines, which are sun-dried and transformed into fertilizer, which is then exported. *Launshs* usually fish in deeper waters than *tarrads* (Pearson *et al.* 1998).

Table 33. Types of vessels, their gears and their targeted species in Fujairah, UAE.

Gear	Targeted species	Type of vessel
Nets (drifts and set)	Pelagic and demersal fish	Small outboard-powered (*tarrads*)
Traps (*gargurs*)		
Hook and lines		
Beach seine		
Lanshs (seines)	Pelagic fish, mostly sardines	Large diesel-powered (*dhows*)

While demersal fish species account for approximately 40% of the landings along the east coast of the UAE, migratory pelagic fish are the most valuable fish targeted along the Fujairahan coast. Fishing occurs all year, with most landings in winter and spring, and the lowest landings in summer (Pearson *et al.* 1998).

Country specific implementation

Reported catches

Reported data for landings were available for 1995-2015 from the Fujairah Statistics Centre (FSC) (www.fscfuj.gov.ae) and from the Federal Competitiveness and Statistics Authority (FCSA) (www.fcsa.gov.ae). However, the catch amounts reported therein were reduced by 40%, based on the Emirates catch reconstruction by Al-Abdulrazzak (2013c) showing an over-reporting of the fisheries catches in the UAE. In order to determine the reported catches for 1950-1994, the reduced reported catch for 1950-2015 was converted to a per capita catch amount applied to the regional population for the same period. The per capita catch rate for 1995-2015 was extrapolated to 1950 and then applied to the corresponding population of 1950-1994. The resulting approximate reported landings estimates were then used as the 'reported baseline', to which were added unreported artisanal, subsistence, and recreational catches as well as major discards. Information from independent and government studies of the UAE (www.fcsa.gov.ae) and Oman (Omani Fisheries Statistic Department 2014) and the catch reconstruction of the UAE (Al-Abdulrazzak 2013c) was used here to estimate unreported catches

Unreported artisanal catches

To reconstruct unreported small-scale commercial catches, catch per unit effort (CPUE) in the Omani regions immediately adjoining Fujairah were used from the official statistical reports of the Omani Ministry of Agriculture and Fisheries (Omani Fisheries Statistic Department 2014). Thus, similar effectiveness and efficiencies between these two neighboring fleets was assumed. The fishing effort in Fujairah, i.e., number of boats, for the 1995-2015 was identified from national fishing statistical reports of the FSC (www.fscfuj.gov.ae) and from the FCSA (www.fcsa.gov.ae).

Fujairah is bordered by two coastal regions that are part of Oman, i.e., Musandam in the north and El-Batina in the south, of which the fisheries are similar to Fujairah. The CPUEs for the artisanal fishery in each of these two regions were identified and converted from the catch per boat per trip to catch per boat per year, and then averaged. This average CPUE was decreased from 54 $t \cdot boat^{-1} \cdot year^{-1}$ to 40 $t \cdot boat^{-1} \cdot year^{-1}$ in order to remain conservative. This revised CPUE was applied to the fishing effort of 1995-2015 in Fujairah (Table 34). The resulting estimated total catch for 1995-2015 was converted into a per capita rate that was applied to the local Fujairah's population for 1950-1994. The unreported artisanal catches were then obtained through subtraction of the reported landings from the estimated total artisanal catches.

Table 34. Key data used to estimate the unreported artisanal fishery of Fujairah, UAE.

Key data	**Value**
CPUE in Musandam ($t.boat^{-1}$)	64.75
CPUE in Al Batina ($t.boat^{-1}$)	43.64
Mean CPUE applied to Fujairah ($t.boat^{-1}$)	40.00
Boat in Fujairah in 2010	685.00

Recreational catches

Two types of recreational fishing were considered in this study, i.e., domestic recreational fishing, and recreational fishing by foreign tourists. Their catch was estimated separately then both estimates were added up to obtain the total recreational catch.

To estimate the domestic recreational catches, i.e., recreational catches by UAE citizens, total recreational catches for the UAE estimated by Al-Abdulrazzak (2013c) were converted to a per capita catch applied to the whole population of the country for each year, beginning from 1960 (i.e., it was assumed that UAE citizen began fishing recreationally in 1960). This per capita was then multiplied by the regional population for each year for the years 1960-2015.

To estimate the recreational catches by foreign tourists, the number of recreational fishing licenses obtained by tourists from 2006 to 2010 was identified from the national official reports (www.fcsa.gov.ae), which are assumed to be 'fishing tourists'. The number of tourist fishing licenses was held constant between 2006 and 2015 at 1,311. It was assumed that prior to 1960, there was no tourist fishing, and that the increase in foreign tourism was linear from 1961 to 2006. Then, it was assumed that each fishing tourist stays an average of two weeks in Fujairah, corresponding to 5 days of fishing with a catch rate of 5 kg·fishing-day^{-1}.

Subsistence catches

UAE citizens own domestic fishing vessels, but do not work on these boats. Foreign workers brought into the UAE to work as commercial fishers represent 0.0046% of the country's total population, according to Al-Abdulrazzak (2013c). This percentage was applied to estimate (foreign) fishers in Fujairah back to 1960 when this pattern of importing labour began. It was then assumed that each fisher has been taking home an average of 5 kg of fish, per week for self- and family consumption.

Discards

According to Kelleher (2005a), discard rates for Oman are about 1%. This was used to estimate discards of commercial fishing in Fujairah by applying it to the reconstructed artisanal catch of each year from 1950-2015.

Taxonomic disaggregation

The taxonomic disaggregation for both reported and estimated unreported catches was based on the official reports of the Omani government for the neighboring regions to Fujairah (Omani Fisheries Statistic Department 2014). The average proportions of each taxon caught in

Musandam and El-Batina was then calculated (Table 35) and then multiplied the proportions by the annual catch of Fujairah. For subsistence catches and discards the same source as for the artisanal fishery were used. However, taxa were aggregated to the family level for both subsistence catches and for discards. The most commonly targeted fishes by the recreational fishery in Fujairah were identified from Fishfishme Inc., which has one of the biggest online platforms allowing finding and booking charter trips around the world (www.fishfishme.com). Percentages by taxa were assumed according to their importance and popularity in the region (Table 36).

Table 35. Composition of fisheries catches from Musandam and Al Batina, Oman (%) based on statistical reports of the Omani Fisheries Statistic Department (2014).

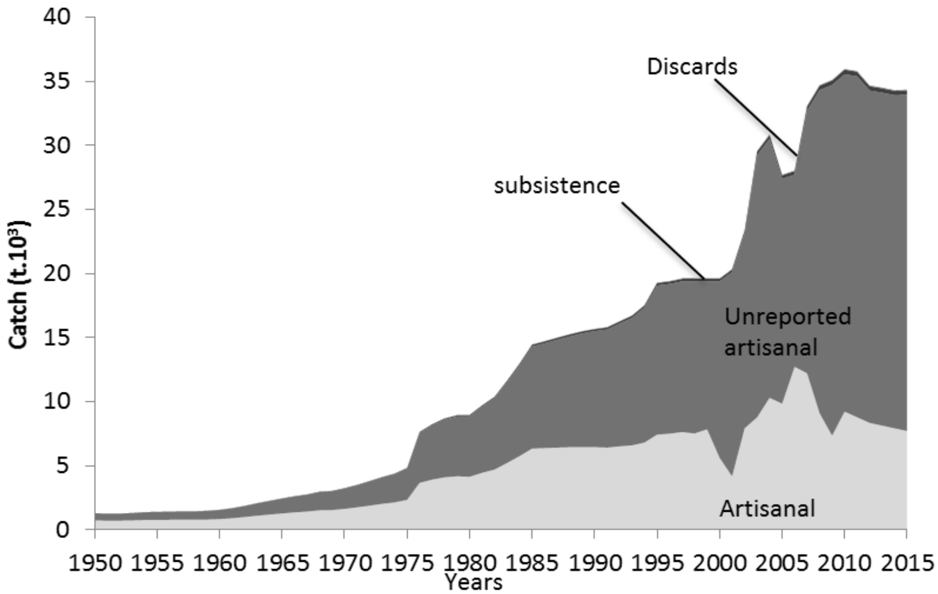
Species	Musandam	Al Batina	Mean	Species	Musandam	Al Batina	Mean
Large pelagics				**Demersal**			
Yellowfin tuna	0.7	3.3	4.0	Emperor	5.5	3.3	8.8
Longtail tuna	20.0	9.6	29.6	Seabream	1.9	1.5	3.5
Kawakawa	3.8	2.7	6.5	Grouper	4.0	2.4	6.4
Striped bonitto	0.0	0.1	0.1	Crocker	0.0	0.2	0.2
Frigate tuna	0.7	0.2	0.9	Sweetlips	1.2	0.8	1.9
Skipjack	0.0	0.1	0.1	Snapper	2.5	0.9	3.4
Other tuna	0.5	0.1	0.6	Jobfish	0.1	1.0	1.1
Kingfish	3.5	3.4	6.9	Rabbitfish	0.3	0.3	0.5
Queenfish	4.5	1.7	6.2	Catfish	0.4	0.4	0.8
Barracuda	3.4	5.1	8.4	Ribbonfish	0.3	0.3	0.7
Cobia	0.1	0.3	0.3	Other	3.6	3.5	7.1
Sailfish	0.1	0.8	0.9	**Sharks & Rays**			
Large Jacks	6.0	3.2	9.2	Sharks	4.0	2.8	6.8
Other	0.6	0.3	0.9	Rays	0.4	1.8	2.2
Small Pelagics				**Crustaceans**			
Sardine	5.4	25.4	30.8	Cuttlefish	0.3	3.7	4.1
Indian mackerel	6.8	7.3	14.1	**Other**	0.8	2.5	3.2
Anchovy	11.8	6.3	18.0				
Small jacks	4.5	3.0	7.4				
Mullets	0.6	0.3	0.9				
Needlefish	1.4	0.4	1.8				
Other	0.5	1.2	1.6				

Table 36. Assumed catch composition of the recreational fishery of Fujairah.		
Scientific name	**Common name**	**%**
Istiompax indica	Black marlin	5
Kajikia audax	Striped marlin	5
Istiophorus platypterus	Sailfish	5
Coryphaena hippurus	Dorado	20
Thunnus albacares	Yellowfin tuna	20
Seriola dumerili	Amberjack	10
Sphyraena barracuda	Baracuda	10
Lutjanidae	Red snapper	10
Istiophoridae	Other marlins	5
Others	Marine fishes nei	10

Country specific results

Total marine fisheries catches in Fujairah increased from around 1,500 t·year^{-1} in the 1950s to approximately 33,000 t·year^{-1} in the 2000s (Figure 38a). The reconstructed catches are 3.3 times the reported landings by the UAE authorities on behalf of Fujairah for 1995-2015, i.e., the only period with available fisheries reports for Fujairah. Until the late 1990s, unreported catches were lower than the reported catches. This has since changed, mainly due to the increase of unreported artisanal fishing. Despite the importance of recreational fishing as an attraction for local and international tourists, recreational catch seem to remain relatively low, and so have discards. The catch composition suggests that Scombridae followed by Engraulidae, Carangidae, Clupeidae, and Serranidae contribute most to the catches in Fujairah (Figure 38b).

a)



b)

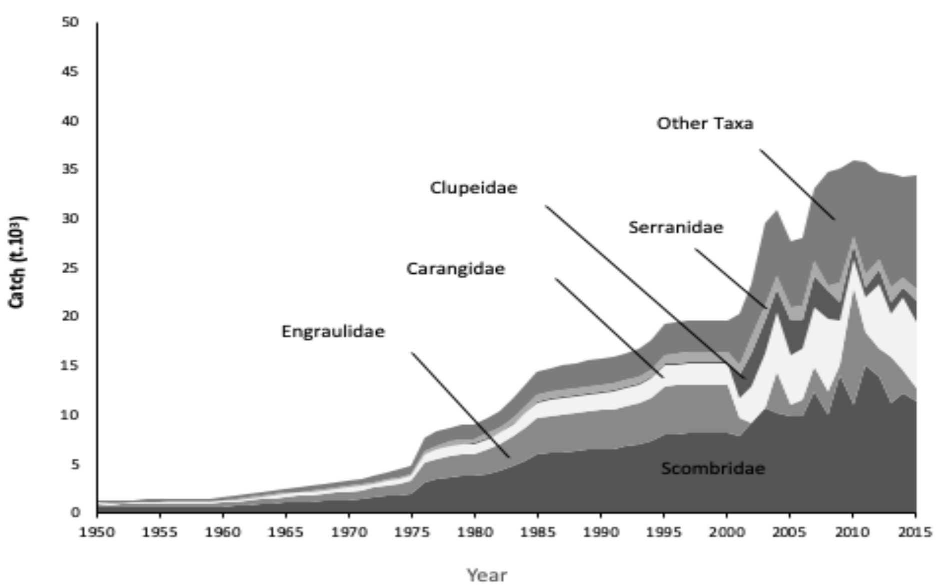


Figure 38. Reconstructed marine fisheries catches for Fujairah (UAE) for 1950-2015, by a) fisheries sectors plus discards. Top dark line represents the discards. Recreational catches are included in the figure, but are too small to be visible and b) by major taxa. Note the 'others' category includes 22 additional taxonomic groups.

2.3.1.17 Yemen

Background

Yemen is located in the southwestern region of the Arabian Peninsula and is bordered by Saudi Arabia in the North, Oman in the East, the Red Sea in the west and the Arabian Sea (mainly the Gulf of Aden) in the south. Yemen's Red Sea EEZ of 35,861 km^2 has a continental shelf of about 26,000 km^2 (Figure 39) The Arabian Sea EEZ is considerably larger with an area of 509,240 km^2 and a continental shelf of about 28,600 km^2. Overall, the Yemeni EEZs are characterized by important coral reefs, some of which are in a state of degradation (www.seaaroundus.org ; Hassan *et al.* 2002; Kotb *et al.* 2008).

Prior to the start of the 2015 Yemeni civil war, the fishing industry in Yemen contributed with 3% to the country's GDP and represented the third most important economic sector in the country (Anon. 2012b; Al-Fareh 2018). As per 2003 around 3% of the Yemeni population depended directly or indirectly on fishing (Morgan 2006d).

The Yemeni fishing industry was considered to be the most important source of livelihood and food security for the Yemeni coastal communities (Anon. 2017), of which at least 18% heavily depended on fishing to survive (Al-Fareh 2018). The Yemeni government at the time often invested in the fishing sector with the help of international organizations, e.g., World Bank, and bilateral agreements with several countries (Morgan 2006d). Despite the socio-economic importance of the fishing industry and the efforts invested by the government to develop it, IUU fishing activities, mainly by industrial vessels, have been common practice within the Yemeni

EEZs. This is due to inefficient monitoring and surveillance of the fishing activities (Morgan 2006d; Tesfamichael *et al.* 2012b; Pramod 2018). This situation has most likely worsened given the 2015 war (Al-Fareh 2018).

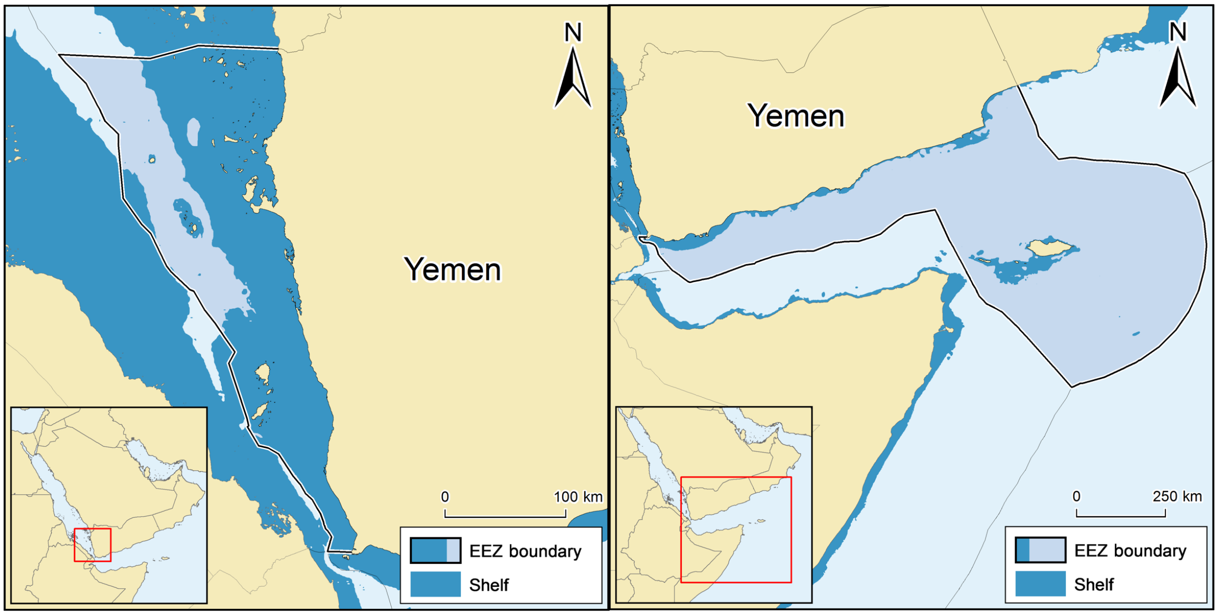


Figure 39. The EEZs and shelf areas of Yemen in the Red Sea (on the left) and in the Gulf of Aden (on the right).

The Saudi-led coalition launched extensive attacks on fishing boats and fish markets along the Yemeni Red Sea coast (Al-Fareh 2018). For instance 50 fishers out of 86 were killed by Saudi air strikes in August and September 2018. They were on a fishing trip and most of their boats were destroyed (Walsh 2018). In August 2018 the Saudi-led coalition also bombarded one of the main fish markets and a hospital, killing at least 30 civilians and injuring many more (Kalfood and Coker 2018).

It was estimated that over 65% of fishers and other people employed in the fish processing industry have lost their livelihood source (UNOCHA 2015; Lopour 2016). According to Al-Fareh (2018) about 50% of fishers on the Yemeni Red Sea coast are unable to fish due to safety reasons as well as to a lack of financial resources (i.e., to pay for fuel and boat maintenance).

Here marine fisheries catch reconstructions were updated to 2011-2017, for both Yemeni EEZs, i.e., Red Sea EEZ and Arabian Sea EEZ.

Country specific implementation

Reported data

Official marine landings were available by year and taxa for 2011-2017 via the FAO Fishstat database on behalf of Yemen. However, reported landings combined catches from both EEZs. Red Sea landings were available for 2011-2014 from Al-Fareh (2018). Gulf of Aden landings were obtained by subtraction of the Red Sea landings from the reported ones for 2011-2014. Reported catches from the Red Sea EEZ represented 10% of the total reported catches in 2014 compared to 18 % in 2010 and 25% in 2011. Given that fishing activities in the North of Yemen have most likely decreased from 2015 on, due to the war, it was assumed that the Red Sea landings represented 10% of total Yemeni marine fisheries landings for 2015-2017.

According to Tesfamichael *et al.* (2012b) the domestic Yemeni fishery along the Red Sea was fully artisanal during the 2000s. The same was applied here.

According to Tesfamichael *et al.* (2012a) the fishing industry in the Gulf of Aden was almost fully artisanal. Artisanal catch represented 99% of the total reported catch. The same assumption was carried here.

Unreported data

<u>*Unreported commercial fisheries*</u>

According to the previous catch reconstruction for the Yemeni Red Sea EEZ, unreported artisanal catches for 2010 were equivalent to 10% of the reported artisanal landings. The turmoil in the country has likely led to a lack of proper data collection and monitoring, and to an increase in unreported fishing activities. Al-Fareh (2018) reports zero landings in the Red Sea cities of Hajjah and Taiz in 2015 and 2016. It is, however, unlikely that commercial fishing ceased during these years and it is more likely that fishing activities decreased and that commercial fishing was not monitored. To remain conservative it was assumed that unreported catches have likely doubled between 2014 and 2015, i.e., from 10% in 2014 to 20% in 2015, assuming 10% in 2010-2013 and 20% in 2015-2017.

According to the previous reconstruction, unreported artisanal catch in the Yemeni Arabian Sea EEZ increased from 1.1 in 2000 to 1.8 times the reported artisanal catch in 2010. It was conservatively assumed that unreported artisanal catch were equivalent to 1.5 times the total artisanal reported catch. Unreported industrial catch were negligible and were equivalent to about 4.5% the reported industrial catch in 2010 (an average of 5% for 2005-2010). Given the instability in the country, the unreported industrial catch was conservatively increased to 10% for 2015-2017, while keeping the same percentage of 5% for 2011-2014.

The same taxonomic compositions applied for unreported catch in the previous Yemeni reconstructions were applied here.

Subsistence and recreational catch

For the Red Sea, subsistence catches were defined as the fish consumption by the crew, assumed to be 10% of total artisanal reconstructed catch in 2010, and as the per capita consumption by the coastal population estimated at 750t in 2010. The same was applied for 2011-2014.

Given the start of the war in 2015 and the inability of most fishers and people to fish for safety reasons, it was assumed that subsistence catch by the coastal population decreased by 50% to 375t per year for 2015-2017. This is a very uncertain estimate due to the lack of data. The same taxonomic disaggregation as in the previous reconstruction was applied here.

Subsistence catch in the Arabian Sea and the Gulf of Aden was estimated to be 10% of artisanal catch in 2010. The same was applied here.

Discards

Discards for the foreign fishery in the Red Sea Yemeni EEZs and for the industrial domestic fishery in the Gulf of Aden EEZ were estimated to be twice the industrial catch in the previous reconstructions. The same was also applied here. The same taxonomic compositions applied in the previous reconstructions were applied here.

Foreign industrial landings

According to Tesfamichael *et al.* (2012b) industrial landings in the Red Sea EEZ consisted mainly of foreign catch. The catch amount by foreign industrial boats of 5,486 t in 2010 was retained for 2011-2014 and halved for 2015-2017 as it is unsafe to fish in the Yemeni Red Sea EEZ because of the war.

Country specific results

Marine fisheries catches were reconstructed for Yemen for 2011-2017 for both its EEZs, the Red Sea and the Gulf of Aden. The reconstructed catches for the Yemeni Red Sea EEZ amounted to 1.9 the landings reported by the FAO on behalf of the region. This reconstruction includes reported artisanal (~54%), unreported artisanal (~7%), subsistence (~8%), foreign industrial (~11) and discards (~21%) (Figure 40a). The following taxonomic dominate the catches within the Yemeni Red Sea are Scombridae (~32%), Clupeidae (~18%), Percomorpha (~9%) and Elasmobranchii (~4%) (Figure 40b).

The reconstructed catches for the Yemeni Gulf of Aden EEZ amounted to 2.8 times the data reported by the FAO on behalf of the region. This reconstruction includes reported artisanal (~36%), reported industrial (~<1%), unreported artisanal (~54%), unreported industrial (~<1%), industrial discards (~<1%), and subsistence (~9%) (Figure 41a). The following taxonomic groups dominate the catches within the Gulf of Aden EEZ of Yemen are Clupeiformes (~52%), Scombridae (~37%), Percomorpha (~6%), and Carcharhinidae (~4%) (Figure 41b).

a)

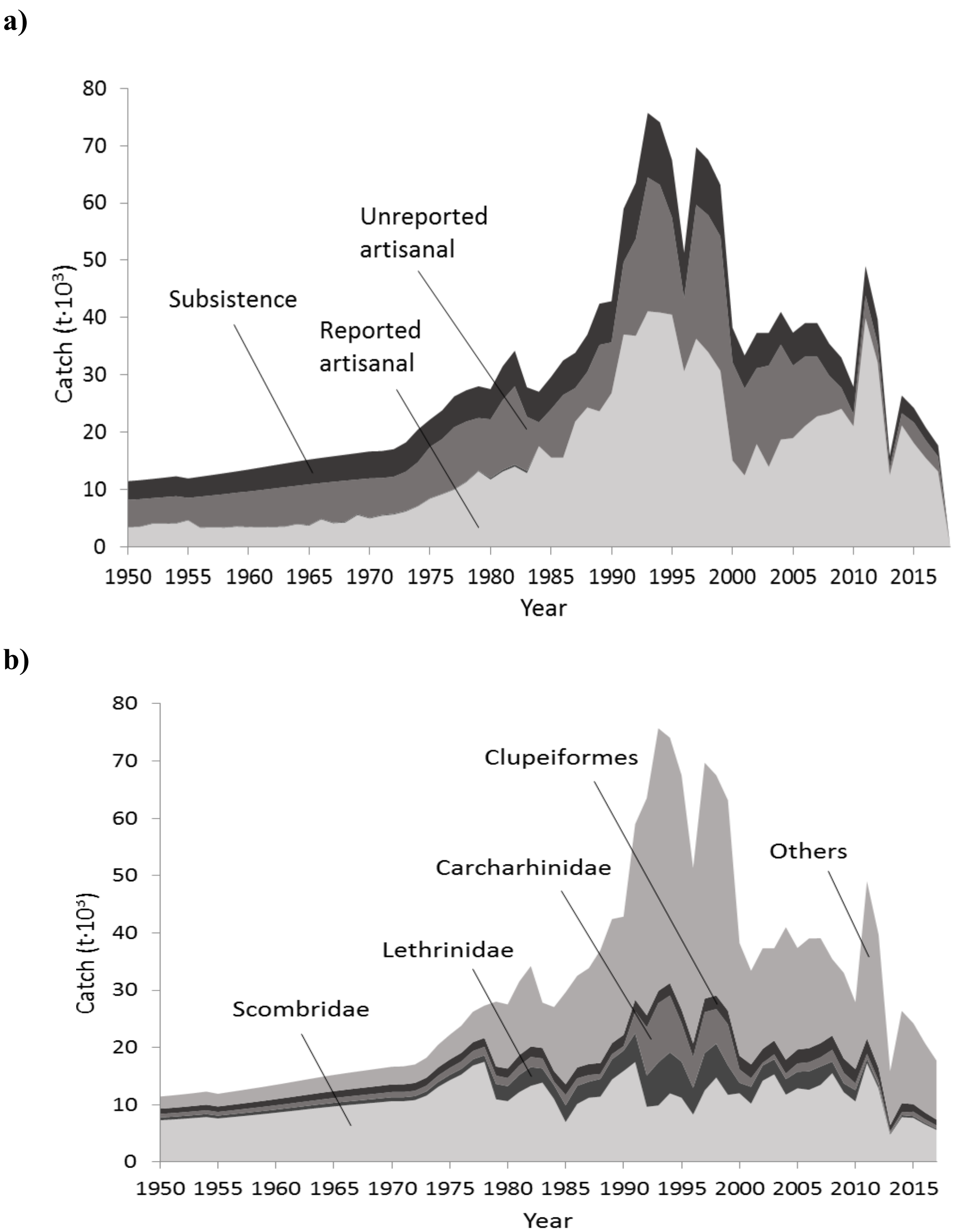
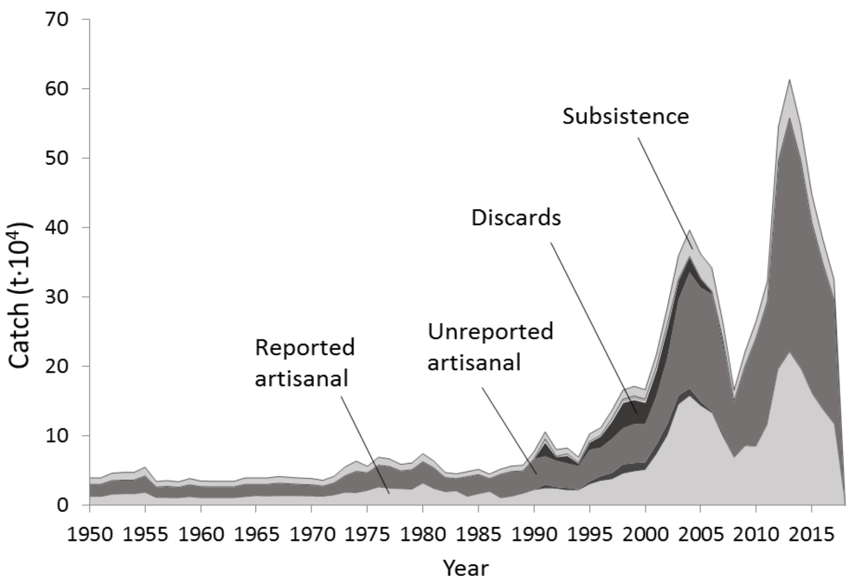


Figure 40. Reconstructed marine fisheries catches for Yemen (Red Sea) for 1950-2015, by a) fisheries sectors plus discards; and b) by major taxa.

a)



b)

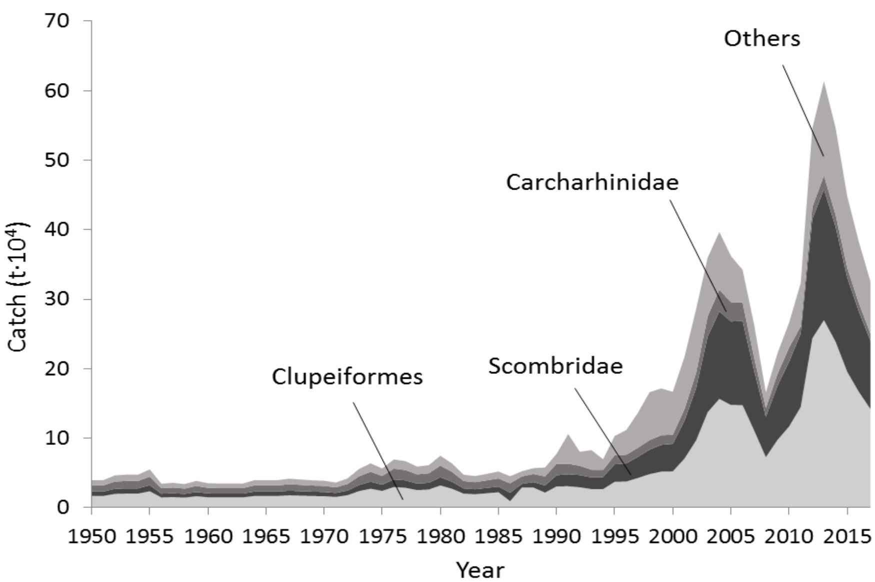


Figure 41. Re Reconstructed marine fisheries catches for Yemen (Gulf of Aden) for 1950-2015, by a) fisheries sectors plus discards; and b) by major taxa.

2.3.2 Results on the SMAP regions level

Marine fisheries catches were reconstructed for 17 countries of the Southern Mediterranean and the Arabian Peninsula regions for 1950-2015 (Figure 42). Results here are presented for the FAO Areas 51 and 37 separately.

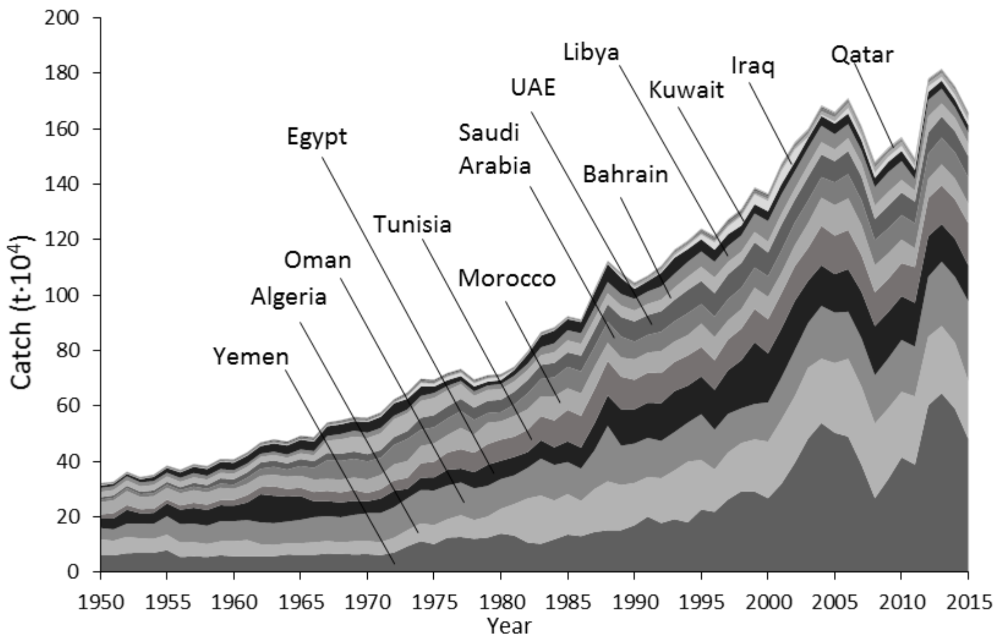


Figure 42. Reconstructed marine fisheries catches for 17 countries of the 'Southern Mediterranean and the Arabian Peninsula' regions. Note that catches by Jordan, Lebanon, Palestine, and Syria are included in this graph but are relatively low compared to the remaining countries and do not show. Note that Egypt includes Mediterranean and Red Sea EEZ catches and the Mediterranean catch is from the results of Chapter 3 of this thesis. For Morocco, only the Mediterranean catches are included.

Marine fisheries catches by the SMAP countries have increased considerably since the 1950s, but have been relatively stable in the 2000s. Yemen has the highest catch (~ 21% of total SMAP catch), followed by Algeria (14%), Oman (~13%) and Egypt (11%). These four countries have caught the equivalent of 60% of the total catch of marine living resources by the SMAP.

The Southern Mediterranean countries have caught around 24 million tonnes of marine living resources between 1950 and 2015. This is around 1.7 times the catch amount reported by the FAO on behalf of Morocco, Algeria, Tunisia, Libya, Mediterranean Egypt, Lebanon, Palestine, and Syria (Figure 43). It should be noted that these results include the reconstructed catch for Egypt for 1950-2015 that are not part of this chapter, but are part of Chapter 3.

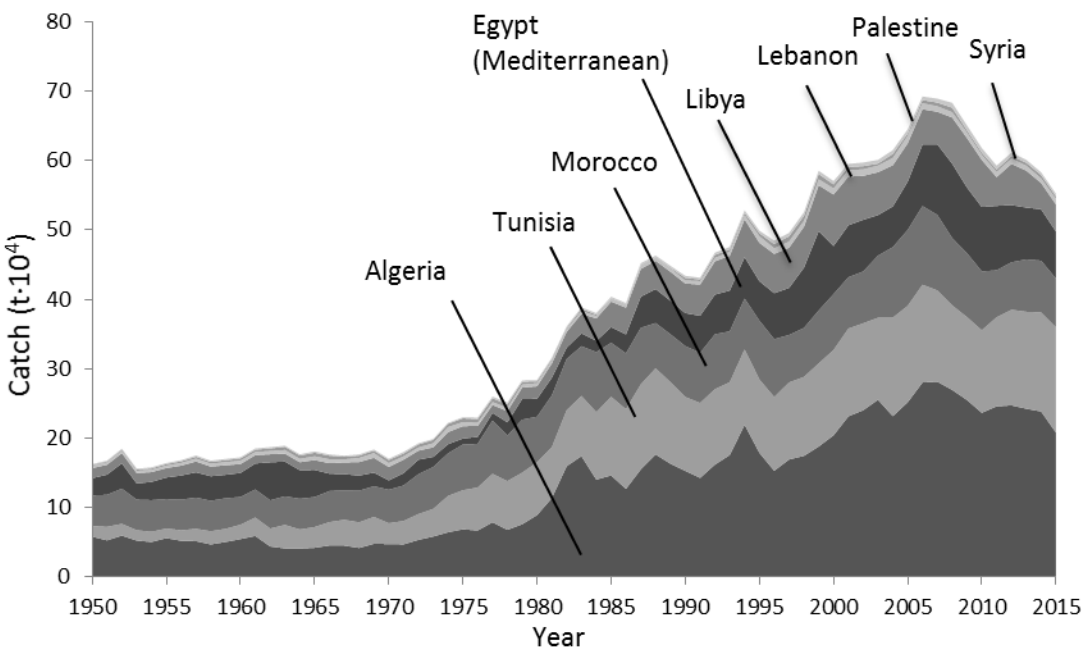


Figure 43. Reconstructed marine fisheries catches for 8 countries of the southern Mediterranean for 1950-2015. Note that the Mediterranean catch for Egypt is from the results of Chapter 3 of this thesis.

Reconstructed catches for the Southern Mediterranean include reported artisanal (~ 20%), reported industrial (~38%), unreported artisanal (~16%), unreported industrial (~10%), subsistence (~4%), recreational (~2%), artisanal discards (~2%), and industrial discards (8%) (Figure 44).

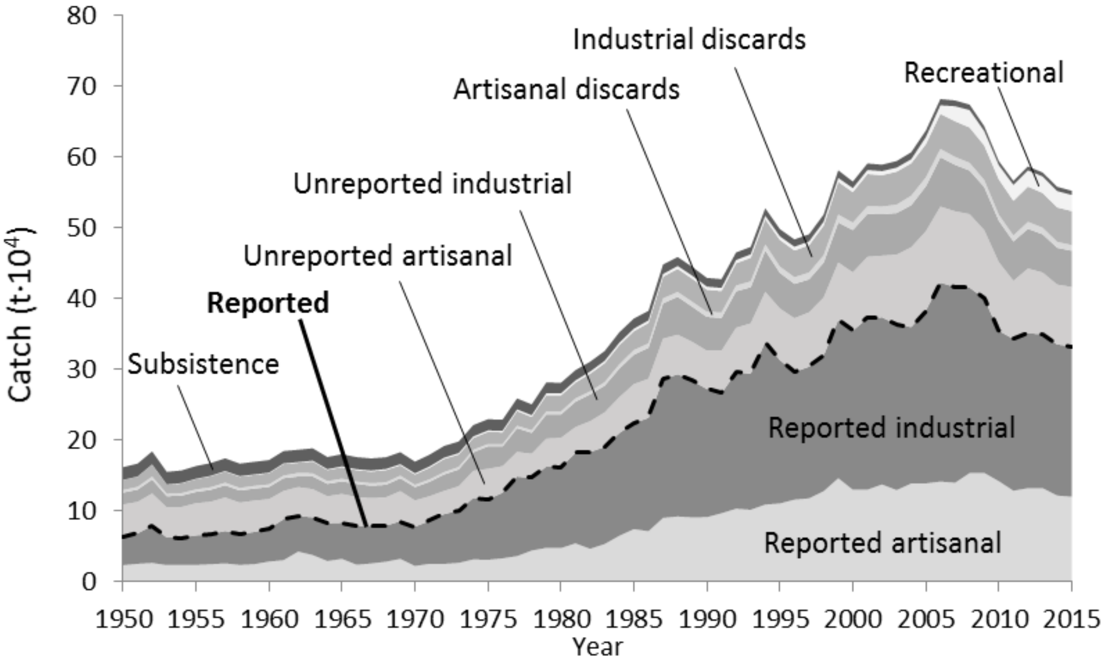
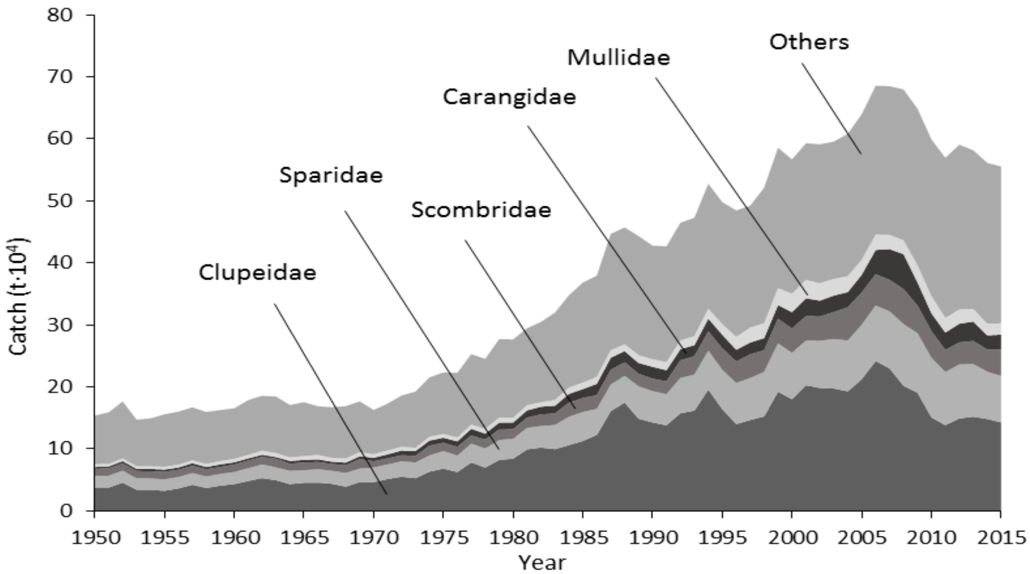


Figure 44. Reconstructed marine fisheries catches by sector for the southern Mediterranean countries for 1950-2015. The reported baseline is overlaid as a dotted line.

Major caught families within the Southern Mediterranean are Clupeidae (~30%) and Sparidae (~13%), which represent almost 50% of total catch by the Southern Mediterranean countries within their Mediterranean EEZs. The following major taxa caught are Scombridae (~7%), Carangidae (~4%), and Penaeidae (~3%) (Figure 45a). The European pilchard (*Sardinella pilchardus*) represents 20% of catch by the Southern Mediterranean countries from their EEZs (Figure 45b).

Marine fisheries catches by the Southern Mediterranean countries within their EEZs steadily increased from the early 1970s until the mid- 2000s. Since then catches have been slowly decreasing.

a)



b)

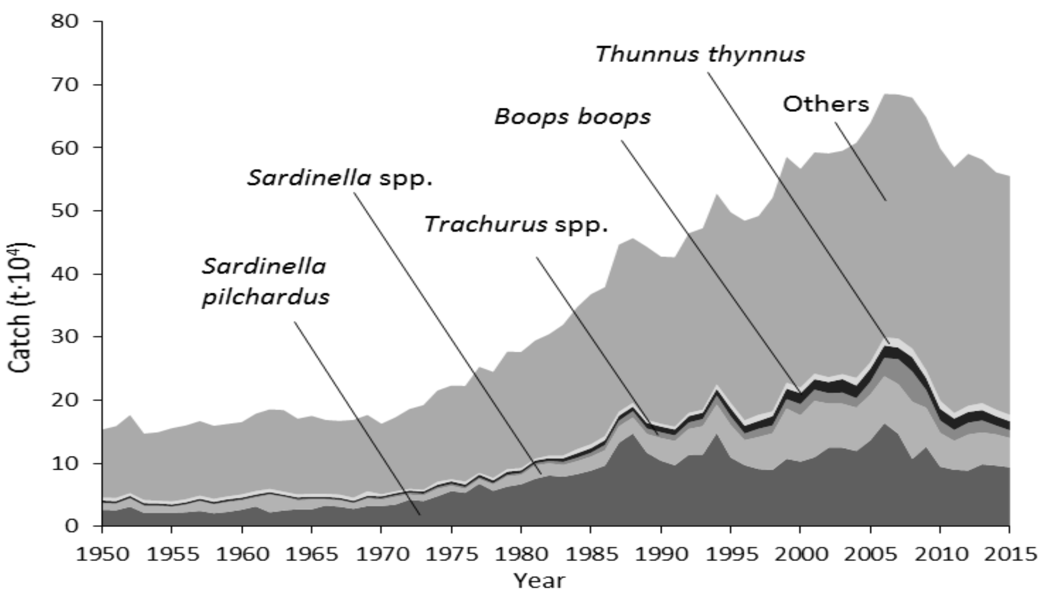


Figure 45. Reconstructed marine fisheries catches for the southern Mediterranean countries, i.e., Morocco, Algeria, Tunisia, Libya, Egypt, Palestine, Lebanon, and Syria, by a) families; and b) species.

Marine fisheries catches by the countries of the Arabian Peninsula and Egypt in the Red Sea amounted to 38 million tonnes between 1950 and 2015. This is about 1.8 times the landings reported by the FAO on behalf of Jordan, Saudi Arabia, Yemen, Oman, Qatar, Bahrain, Kuwait, UAE, Iraq, and the Red Sea EEZ of Egypt (Figure 46).

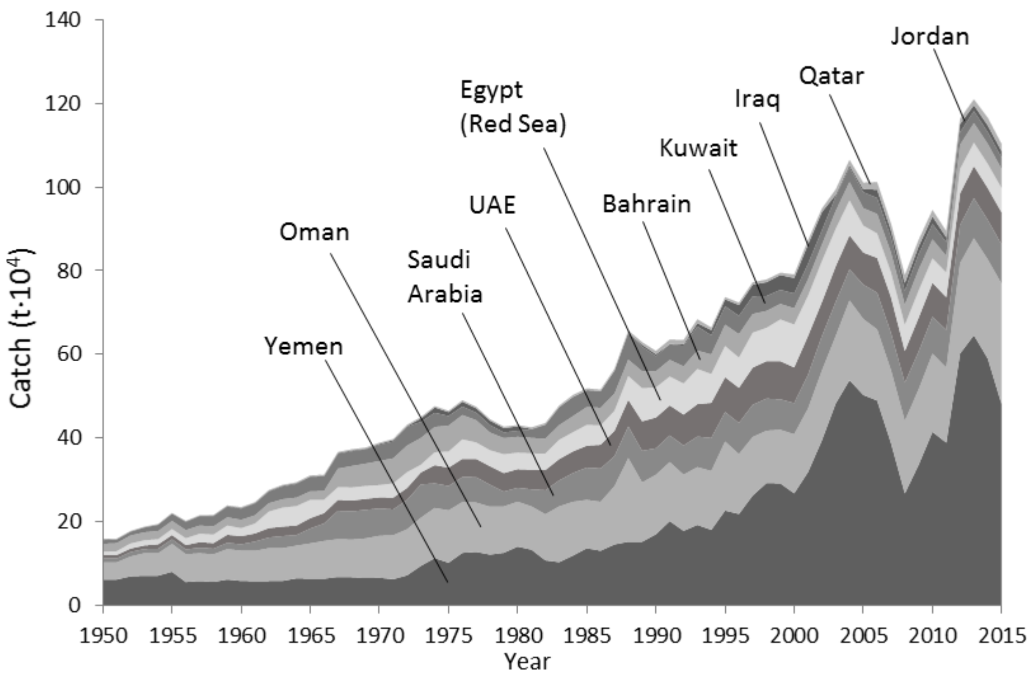


Figure 46. Reconstructed marine fisheries catches for the countries of the Arabian Peninsula and the Red Sea EEZ of Egypt.

Reconstructed catches for the Arabian Peninsula countries and Red Sea Egypt include reported artisanal (~48%), reported industrial (~7%), unreported artisanal (~24%), unreported industrial (~3%), recreational (>1%), subsistence (~5%), artisanal discards (~3%), and industrial discards (~10) (Figure 47). Major caught families from area 51 by the countries of the Arabian Peninsula and the Egyptian Red Sea EEZ are Clupeidae and Engraulidae (~23%), Scombridae (~18), Carangidae (~5%), Lethrinidae (~5%), Serranidae (~3%), and Carcharhinidae (~3%) (Figure

48a). The most caught species is the Indian oil sardine (*Sardinella longiceps*), which represents 8% of total catch by the Arabian Peninsula countries and Egypt in area 51 (Figure 48b).

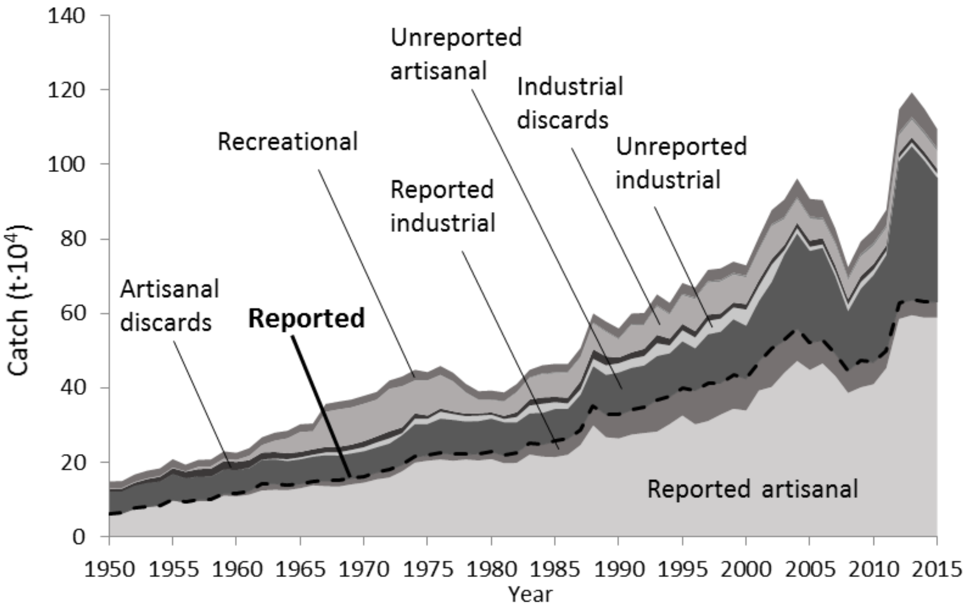
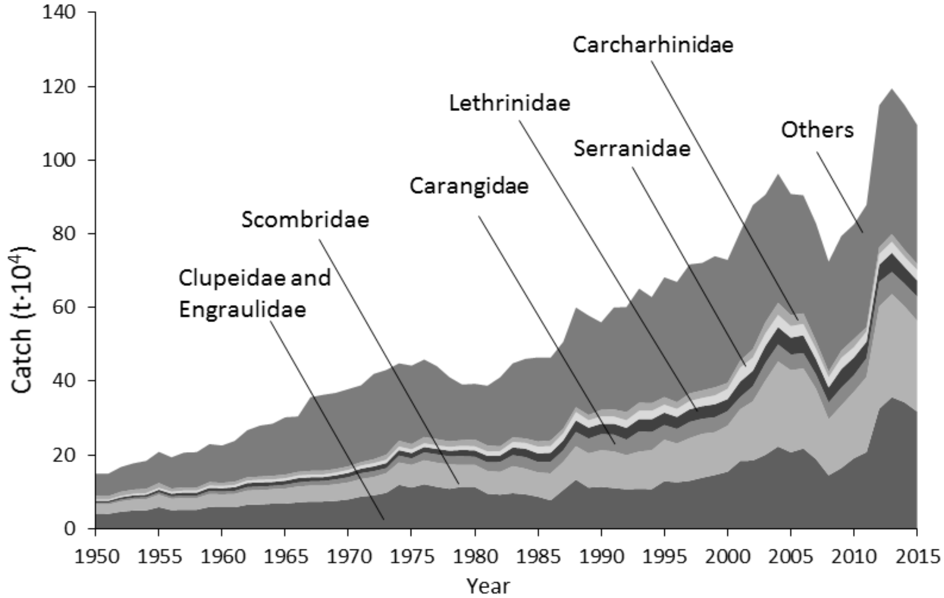


Figure 47. Reconstructed marine fisheries catches by sector for the countries of the Arabian Peninsula and Egyptian Red Sea EEZ for 1950-2015. The reported baseline is overlaid as a dotted line.

Marine fisheries catches by the countries of the Arabian Peninsula and Egypt within the Area 51 increased almost linearly from the 1950s until the late 2000s. Catches have decreased in recent years, even though reported catches show a certain stability.

Confidence intervals for the marine fisheries catch reconstructions for the areas 37 and 51 were higher for the early years, given the limited information sources, and decreased over time (Figure 49). However, uncertainty levels have increased since 2011 due to the lack of information in many countries of the SMAP as a result of the post-2011 events. However, these reconstructions remain conservative overall.

a)



b)

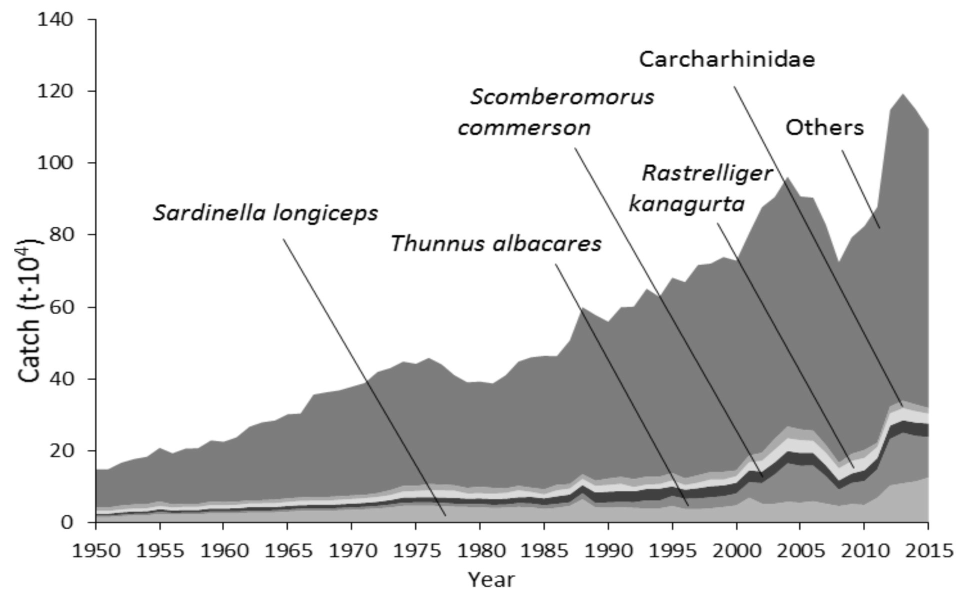
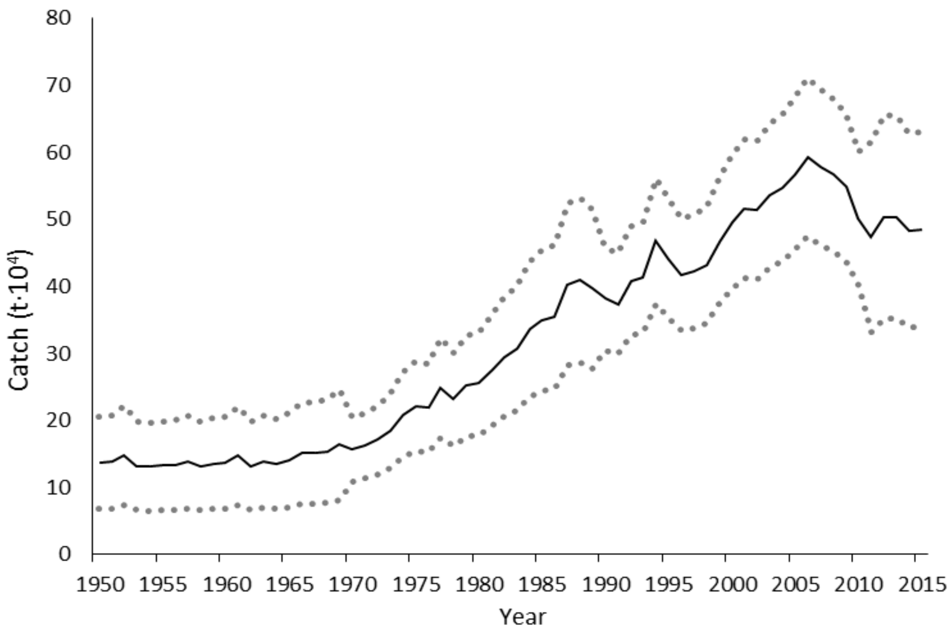


Figure 48. Reconstructed marine fisheries catches from the area 51 including Egypt and the countries of the Arabian Peninsula, i.e., Jordan, Saudi Arabia, Yemen, Oman, UAE, Qatar, Bahrain, Kuwait, and Iraq by a) families; and b) species. The category 'others' includes a) 108 additional families; and b) almost 350 species.

a)



b)

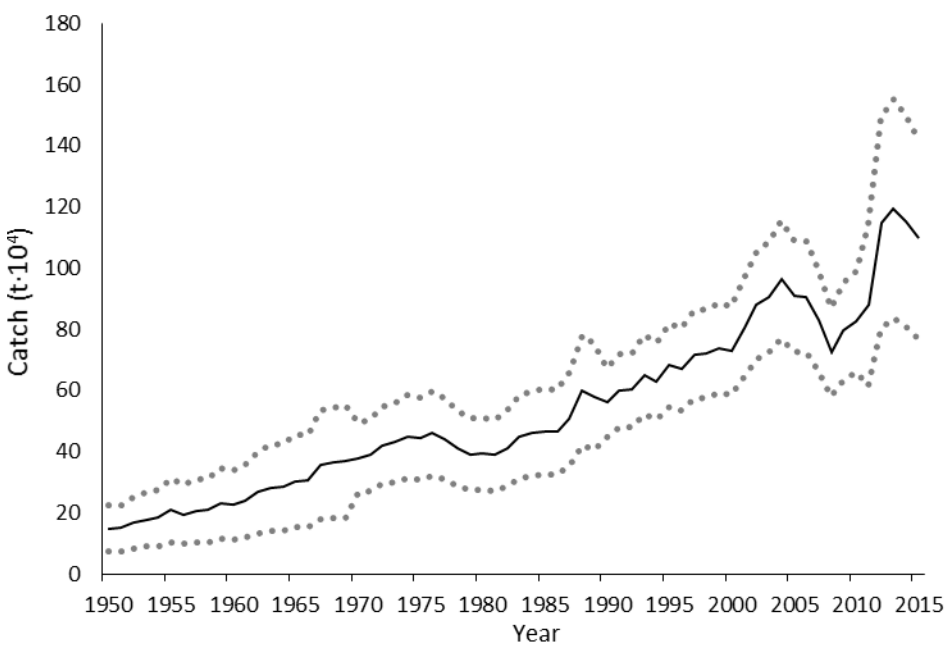


Figure 49. Uncertainty estimates for total reconstructed marine fisheries catches for: a) area 37; and b) area 51. The dotted lines represent the upper and lower confidence interval.

2.4 Discussion

Total reconstructed marine fisheries for FAO Areas 37 and 51 by the countries of the Southern Mediterranean and the Arabian Peninsula were 70 % and 80% higher than their reported catch data, respectively. For some of these countries reconstructed catches were even higher, e.g., reconstructed catches for Bahrain were 5.6 times the reported data. These considerable discrepancies between reconstructed and reported catch data for the SMAP regions were mainly due to important unreported artisanal landings and to sizable industrial discards, but also to unreported industrial landings for the southern Mediterranean countries. Total reconstructed artisanal and industrial landings by the southern Mediterranean countries in their EEZs within FAO Area 37 were similar, representing 36% and 48% of the total reconstructed catch, respectively. Reconstructed artisanal landings by the Arabian Peninsula countries and Egypt within their EEZs in FAO Area 51 represented over 70% of the total reconstructed catch.

Notwithstanding that the estimates of unreported artisanal catch were conservative, the artisanal fishery seems to yield the majority of fish and seafood for the SMAP countries. That said, similarly to many economically developing countries, SMAP governments have not attached as much of an importance to their artisanal fisheries as they have done to the industrial sector (Feidi 1997; Mahon 1997; Ruddle and Hickey 2008; Al-Abdulrazzak *et al.* 2015). Not only are artisanal fisheries in the SMAP often rural and difficult to monitor, but in most of these countries fisheries management is intertwined with stock assessments (see Chapter 1) and the investment in the fishing industry, e.g., fuel subsidies, infrastructure improvements, etc., is often focused on or limited to the industrial fisheries (Feidi 1997; Mahon 1997; Pinello and Dimech 2013; Carbonetti *et al.* 2014; EastMed 2014).

The consequential intensification of certain industrial fisheries, such as the trawl fisheries does not only spoil the marine living resources, e.g., through low selectivity and high discards, but often enters in conflict with the artisanal and traditional fisheries by competing over fish. This has often led to tremendous socio-economic impacts given that the artisanal fisheries often represent a significant source of food security and livelihood (see Chapter 1). Within some SMAP countries, with relatively corrupt governmental institutions, industrial fisheries are often able to get away more easily with breaking the law; for instance by illegally fishing in shallow waters, damaging the nets of the artisanal fishers, not reporting all of their catch or simply fishing beyond the allocated quotas (personal observations; Carbonetti *et al.* 2014).

Furthermore, the artisanal fisheries had been viewed for the longest time as a 'rudimentary' fisheries from which economically developing countries have tried to move away as a way of becoming more industrialized, as discussed in Ratner and Allison (2012). Although this view has been slowly changing over the past few years and increasing attention is being attached to the importance of artisanal fisheries (FAO 2018; Smith and Basurto 2019), erroneous underestimates of the artisanal landings within the SMAP countries has caused their marginalization (Pauly 2006; Mills *et al.* 2011). It should be noted that in some Persian Gulf countries, trawling was recently banned (see Results section).

One of the other main findings of this study consists of the significant contribution of the sardines (*Sardinella* spp.) and anchovies (Engraulidae) to the total catch of the SMAP region. The intensification of aquaculture in some Southern Mediterranean countries, i.e., Tunisia, Egypt, and Morocco, a considerable part of sardines, anchovies, and other forage fishes has been oriented to fishmeal production for aquaculture of the European seabass (*Dicentrachus labrax*) and gilthead seabream (*Sparus aurata*) (Monfort 2007; Bjørndal and Guillen 2018).

Aquaculture production is consumed locally in some regions, but also exported to Europe (Monfort 2007). Tremendous amounts of sardines and other forage fish are also used for the fattening of Atlantic Bluefin (*Thunnus thynnus*) within offshore cages in the Mediterranean, including in some of the SMAP countries such as Tunisia (personal observations; Monfort 2007). This tuna is usually destined for export to Japan and around 12-20 kg of mostly sardines are necessary for 1kg of Tuna (Monfort 2007). Given that sardines and other forage fishes represent a main protein source for the inhabitants of most Mediterranean countries the question of how much of this fish is actually still consumed by people instead of being transformed into fishmeal should be raised.

The process of transforming cheap fish of lower trophic level into commercially more valuable fish of higher trophic level was coined "farming up the food web" by Pauly *et al.* (2001). Stergiou *et al.* (2009) underlines the ecological and socio-economic risks related to this issue for the Mediterranean countries where the aquaculture of carnivorous fish largely exceeds that of herbivorous species. While several studies and mass media document the conflicts between fishmeal production for fish farms in Western African countries (see, e.g., Pauly 2019) and the small-scale sardine fisheries, e.g. Tacon and Metian (2009) and Green (2018), few studies have examined the role of aquaculture on the economy of forage fish in North Africa and other economically developing regions. It would be necessary to further study the uses of these fishes within the SMAP countries in order for aquaculture to be sustainable within the region.

Chapter 3: A Century of Mediterranean Fisheries Catches in Egypt (1917-2017)

3.1 Introduction

Synopsis: In this chapter, I apply the catch reconstruction approach to the Mediterranean fishery of Egypt for 1917-2017. Then I used the reconstructed catch data to compute two catch-based indicators: the Marine Trophic Index (MTI) and the Mean Temperature of Catch (MTC).

Situated in the Northeastern corner of the African continent, Egypt straddles North Africa and West Asia. It is delimited by two seas: the Mediterranean Sea in the North and the Red Sea in the East (Figure 50). The Nile, one of the longest rivers in the world, flows north through several East African countries until it reaches the Mediterranean Sea.

Figure 50. The EEZ and shelf area of Egypt (Mediterranean).

The Nile has been key to the development of Egypt, one of the cradles of human civilization (Maspero and Sayce 1894; Kuper and Kröpelin 2006). The Nile has supported fishing since at least the African humid period, about 15,000 years ago (Sahrhage 2008). By the end of this period, around 7,000 to 5,000 years ago, North Africa was progressively transforming into the Sahara desert (deMenocal and Tierney 2012). Food and water became scarce. Hunter-gatherers were then forced towards regions where a water source was available, including the Nile (Kuper and Kröpelin 2006). The flooding of the Nile also allowed for the land on both sides of the river to remain fertile. This permitted abundant crop production and animal husbandry, and thus economic stability and diplomatic relations through trade between the ancient Egyptians and other civilizations (Maspero and Sayce 1894; Bates 1917; Kuper and Kröpelin 2006).

As the Egyptian civilization thrived, fishing intensified, notably with fishing boats made of papyrus (Maspero and Sayce 1894; Bates 1917; Sahrhage 2008). According to Aleem (1972a), seine and beam-trawls were deployed between 2660-2180 B.C. and 2180-1640 B.C., respectively. Other fishing gears such as traps, harpoons and longlines were also commonly used (Brewer and Friedman 1990). Bates (1917) mentioned that during the rule of the 18th Egyptian dynasty, i.e., between 1550 and 1292 B.C., preserved fish used to be sent to Syria and Egyptian fishers had to pay taxes to the state. Fish was so important to the Egyptians that they were thought of as "fish-eaters" by neighboring civilizations (Bates 1917).

With an estimated population of around 100 million people, Egypt is now the 14th most populated country in the world (www.worldbank.com). The population is still mostly concentrated around the Nile River and delta, with lower densities along the remaining Mediterranean and the Red Sea coasts. By 1902, the Aswan low dam was built as an attempt to better control the Nile flooding and improve the irrigation system for British colonial interests (Mitchell 2011). This first dam did not succeed in stopping the flooding but was the drive behind the building of the second dam. The Aswan low dam had already reached its maximum capacity when the Aswan High Dam was constructed by the Egyptian government between 1960 and 1970 (Fahim 2015). The Aswan High Dam has since been generating a major part of the electricity for the country (Abu-Zeid and El-Shibini 1997). It has protected the country from droughts, e.g., between 1979 and 1987, stopped the flooding and allowed the intensification of agriculture (Abd-El Monsef *et al.* 2015).

Yet, one of the most documented negative effects of the Aswan High Dam had to do with the Mediterranean Egyptian fishery. The dam blocked the flow of nutrients to the Nile delta and the Mediterranean Sea, leading to a decrease in primary production and a decrease of fish catch (El-Hehiawy 1974; Al-Kholy and El-Wakeel 1975; Gerges 1976; Sharaf-El-Din 1977; Wadie 1981; Bebars *et al.* 1997; Nixon 2004). Paget (1921) and Wimpenny (1931) underlined the importance of the Nile flooding for the sardine fishery. In the early 20th century, temporary dams were built through the main Rosetta (west) and Damietta (east) arms of the Nile, which were annually broken by the floods. Every year, the sardine fishery would concentrate around the region where the dam would have broken first (Wimpenny 1931, 1934; Gorgy 1966) or in the words of Wimpenny (1932) "As a rule: A good flood is followed by a good fishery"(p. 1). The effect of the Aswan High Dam on the Mediterranean fisheries was therefore anticipated by some researchers, such as El-Zarka and Koura (1965). Some recent studies suggest that the return of the fisheries catch to pre-dam levels was a consequence of the urbanization of the Nile delta and to anthropogenic nutrients that replaced the nutrients sourced from the Nile (Nixon 2003; Oczkowski *et al.* 2009).

The Aswan High Dam was preceded by another project that has been equally consequential for the Egyptian fisheries. The Suez Canal was dug between 1859 and 1869. Prior to this the Mediterranean and the Red Sea had been connected only via the Isthmus of Suez. Yet even before the building of the Suez Canal, smaller, short lived and navigable canals and waterways were dug on several occasions to the Red Sea and parts of the Nile (Wilson 1939; Shea 1977). The building of the Suez Canal has provided the shortest and fastest route between the Indian Ocean and Europe, i.e., ships did not need to circumnavigate the African continent anymore, thus saving travel time and money. Yet, this facilitated the colonization of Africa by European countries. It also expedited transit to India, especially oil transport for Britain (Huber 2012; Perry 2019). The Suez Canal was controlled by Europeans until 1956, when the Egyptian government nationalized it following the historic 'Suez crisis'.

Since its construction, the Suez Canal has been a portal for an increasing number of Indo-Pacific marine species to the Mediterranean. This phenomenon is well documented and is known as Lessepsian migrations, named after the canal's architect, Ferdinand de Lesseps (Gorgy 1966; Por 1971; Golani 1998; Galil *et al.* 2015; Zakaria 2015). The rapid increase of the temperature of the Mediterranean has benefited the invasive Red Sea species over the Mediterranean species

(Bianchi and Morri 2003; Hiddink *et al.* 2012). Lessepsian species were sighted in the Mediterranean waters of Egypt soon after the opening of the Suez Canal; for example, the blue swimming crab (*Portunus pelagicus*) was found in the Mediterranean as early as 1889 and by 1924 it was common in fisheries landings (Fox 1924). A fish caught and preserved in Croatia in 1869, was later identified as the Indo-Pacific fish silver pomfret (*Pampus argenteus*) (Jakov *et al.* 2004), while the Indo-Pacific bluespot mullet (*Crenimugil seheli*) was caught off Alexandria in 1928 (Wimpenny 1930).

3.1.1 The Egyptian Mediterranean fishing industry (1917-2017)

Egypt's fisheries are freshwater and marine. Marine fishing activities take place mainly within the Mediterranean and the Red Sea. In 1983 Egypt claimed an Exclusive Economic Zone (EEZ) of 169,125 km^2 (see https://treaties.un.org). The Egyptian Mediterranean continental shelf is about 31,000 km^2 and an inshore fishing area of 29,160 km^2 (www.seaaroundus.org). Six Egyptian coastal lagoons open to the Mediterranean Sea: Maruit, Edku, Burollus, Manzala, Port Fouad and Bardawil lagoons (Aly *et al.* 2019).

Italian-owned trawlers were the first to lay the ground for the modern trawl industry in the Mediterranean Egyptian waters. Their catch can be considered domestic given that the Italian fishers and skippers involved in this fishery were most likely part of the Italian diaspora of Egypt (Paget 1921; Borsoi 2010). The Italian trawlers landed their catch in Egypt and fished in relatively shallow waters close to the coast. The trawl deployed was known as the "*Bragozzi*" type, which consists of two sailing trawlers carrying the trawl net in pair (Paget 1921; Faouzi

1933). In 1928, steam trawling trials were unsuccessful. During the 1920s, an increasing number of trawlers was being motorized reaching 31 motorized trawlers out of 85 trawlers in total in 1930 (Wimpenny 1932). In 1927, the "Société Misr pour les Pêcheries", i.e., translating into the "Egyptian Fisheries Company", was founded and deployed trawlers first in the Red Sea waters of Egypt and then within the Mediterranean waters of Egypt around the early 1930s. This was the first introduction of Egyptian owned trawling in Egypt's Mediterranean waters (Wimpenny 1932; Faouzi 1933, 1936; Davis 2014).

The number of trawlers increased from just over 40 in 1920 to over 100 in 1926, but decreased to 40 in 1935. However, by 1935 almost 70% of trawlers had been motorized, a rapid increase from the 1920s, when most were un-motorized (Paget 1921). The trawl fishery was, economically the most important of the Egyptian Mediterranean fishing industry since at least the mid-20th century (Alsayes *et al.* 2010). Most trawls currently deployed are bottom trawl targeting mostly shrimps, but are multi-species overall (Ibrahim *et al.* 2011; EastMed 2014; Aly *et al.* 2019).

Equally important to the trawl fishery within the Egyptian Mediterranean waters is the sardine fishery. Sardine has been exploited by different types of nets: driftnet, gillnets, beach seines, purse seines (Paget 1921, 1923; Wimpenny 1930; Wadie 1981; Wassef *et al.* 1985; Akel 2009). As mentioned earlier, the sardine fishery was drastically impacted by the construction of the Aswan High Dam.

The remaining artisanal fishery is locally known as 'shore' fishery. Through the country's history, it has functioned as a typical Mediterranean multi-species multi-gear fishery. Trammel nets, gillnets, throw nets and longlines are some of the most important gears deployed in this category. The ‘shore’ fishery employed mostly Egyptian men but also some women and children (Paget 1921). Conflicts between this fishery and the trawl fishery are common given that they share the same coastal fishing grounds (Aly *et al.* 2019).

3.1.2 Marketing and management of Egyptian Mediterranean fisheries

During the first decades of the 20th century, fish was sold in auction markets known as *halakas* (‘circle’ in Arabic). These markets were under the control of the market owners who are often the sole buyer of the fish in that market and who would be the ones to communicate statistics of commonly unweighted and unidentified fish to the authorities. The owners of the *halakas* would then send the purchased fish to the central markets. This system caused fishers to earn little money from their catch and people to be unable to afford fish (Faouzi 1933; Abou-Samra 1935). Many regions were unaccounted for by the statistics and the successive colonial and Egyptian governments in those years had little control over the marketing of fish (Faouzi 1933, 1936). In 1926, a law regarding the prohibition of certain fishing methods was issued and was one of the first laws to regulate Egyptian fisheries (El-Miralai 1926). In 1932, efforts were made by the authorities to better organize and control the fisheries and hence improve the accuracy of the statistics. However, this did not work as expected (Abou-Samra 1935; Faouzi 1938).

The Mediterranean fishery management for Egypt has come a long way since then. Since the law of 1926, the Fisheries Act of 1983 has been the most important fisheries-related legislation in Egypt. It has established the General Authority for Fish Resources Development (GAFRD) which governs fisheries and aquaculture (Morgan 2006b; Goulding 2013). The GAFRD has been responsible for licensing the fishers, overseeing fishers' cooperatives, as well as collecting and publishing the fisheries statistics (EastMed 2014). As the other maritime countries, Egypt has been sending since the 1950s its fisheries statistics to the Food and Agricultural Organization (FAO), which has made global fisheries statistics public in their FishStat database[25].

Different forms of colonization by the British existed in Egypt between 1882 and 1953. Nevertheless, the country achieved a relative autonomy in 1922, which brought to power the Sultan Fuad I. The revolution that occurred in 1952 brought about a republic presided by Gamal Abdel Nasser. In 2011, Egypt was the second country after Tunisia to witness several anti-regime movements known as the January 25th Revolution. These movements led to the overthrow of the government of Hosni Mubarak and to the organization of elections which were won by the *Muslim Brotherhood* (i.e., an Islamic party). The deterioration of the country's situation on many levels and the ongoing protests country wide, resulted in a military coup d'état in 2013. Since then, the military has been ruling the country. Such events have most affected the country politically, socially and economically (Abdou and Zaazou 2013), and fisheries were not spared (Viney 2011; Öztürk 2015).

Assessing the state of the Egyptian Mediterranean fisheries is key to better evaluating the health of the Mediterranean marine living resources, especially when one of the biggest threats to the

[25] FAO (online) available at http://www.fao.org/fishery/statistics/en [accessed 04/11/2019]

Mediterranean marine ecosystem—Lessepsian migration—passes through Egypt first. With the acceleration of global warming and the knowledge that the Mediterranean has been one of the first and most affected, it is vital to know how the ‘temperature of the catch’ connected to the warmer waters of the Red Sea has increased. All of this plays under the shadow of a rapidly increasing human population and fishing pressure.

This study aims (1) to document and quantify a century of Mediterranean marine catches for Egypt including unreported landings and discards; (2) evaluate the mean temperature of catch for the past 100 years; and (3) to assess the impact of a long-term fishing industry on the trophic level of catch.

3.2 Methods

3.2.1 The marine fisheries catch reconstruction

3.2.1.1 Official catch data

Reported marine fisheries catch data were available by year and taxa for the Mediterranean EEZ of Egypt for 1920-1935 and 1950-2017 from both Egyptian national sources, i.e., GARFD, National Institute for Oceanography & Fisheries (NIOF) and Central Agency for Public Mobilization and Statistics (CAPMAS), and from the FAO Fishstat database (Table 37).

National and FAO data were compared. National data had a better taxonomic disaggregation for the years 1962 and 1964-1969. Both datasets became taxonomically more similar starting in 1970. Overall, the FAO annual catches were higher than those reported nationally for most years, and were hence kept here as the reported baseline for 1950-2017. The national taxonomic disaggregation was then used to taxonomically improve the reported FAO baseline for 1962. National total catch data were higher than the FAO data for 10 years (i.e., 1958-1960, 1962-1963, 1966, 1968, 1970, 1975 and 1977). The difference was deemed to consist of unreported catches.

Table 37. Sources of reported catch data for the Mediterranean EEZ of Egypt (1917-2017).

Years	Sources
1920-1935	Paget (1921, 1922, 1923, 1925); Jenkins-Bey (1925); El-Miralai (1926, 1928); Wimpenny (1930, 1931, 1932, 1934); Abou-Samra (1935); Faouzi (1933, 1936, 1937, 1938).
1950-1957	FAO
1958-1960	FAO and El-Zarka and Koura (1965)
1961-1984*	FAO, NIOF and CAPMAS (1973- 2006)
1985-2017*	FAO, GAFRD and CAPMAS (1973- 2006, 2006, 2007, 2008-2019)

*Data for the years 1961, 1963, 1976, 1988 and 1990 were only available from the FAO.

Reported catch data were not available for 1917-1919 and 1936-1949. It is not clear whether data were collected for these years or not. Both time periods coincided with periods during and after major wars, i.e., WWI (1914-1918) and WWII (1939-1945). It is not clear whether fishing during WWII continued or was restricted to the artisanal fishery. Given the inshore nature of the trawlers in Egypt, of which many were not motorized, it was assumed here that the fisheries went on, but that their catch was not monitored, due to wartime restrictions. The same was applied for the years that coincided with WWI, i.e., 1917-1918.

To account for the missing reported data for 1917-1919 and 1936-1949, interpolations between total landings and catch by taxa were performed between 1935 and 1950. For some species, i.e., *Merluccius merluccius*, *Dicentrarchus labrax*, *Dicentrarchus punctatus*, *Pomatomus saltatrix*, *Solea solea* and *S. aegyptiaca* (as one group), *Boops boops*, *Trichiurus lepturus*, and *Eutrigla gurnardus* and *Chelidonichthys lastoviza* (as one group), the interpolations were performed between 1935 and 1962 in order to improve the FAO taxonomic disaggregation of 1950-1962. Furthermore, interpolations were performed between 1962 and 1964 to improve the taxonomic disaggregation of the 1963 FAO catch data.

3.2.1.2 Defining the commercial fishing sectors

The commercial fishing sectors are not clearly defined within the Mediterranean Egyptian fishing industry. EastMed (2014) completed a study where the Egyptian Mediterranean fishing fleet was classified into 6 groups according to the vessels' length. In the early years, the Egyptian Mediterranean fishing industry was divided in three sectors: the trawl fishery, the "shore" fishery (including purse seines and other types of nets and traps), and the artisanal sardines fishery (Paget 1921; Faouzi 1936). Currently, a broad definition of the Egyptian industrial fishing fleet exists and is in function of the vessel's length (>24m), the level of industrialization of onboard processing techniques and other technological features of the fleet, e.g., presence of freezing capacity (Hatem Hanafy Mahmoud, personal communication, November 24, 2019).

Most trawlers operating in the Egyptian Mediterranean waters answer the national criteria for the industrial category. According to EastMed (2014), trawlers are considered as the most sophisticated and important fleet within the Egyptian Mediterranean fishery in terms of vessels' size, tonnage, engine power, trip length, fuel consumption and employment. Most motorized fishing boats are, however, not advanced enough to be categorized as 'industrial'. Instead they are classified under the "semi-industrial" or "artisanal" category (Hatem Hanafy Mahmoud, personal communication, November 24, 2019). In 2012, longlines accounted for 40% of the deployed gears, followed by bottom trawls with 36%, trammel nets with 16% and purse seines with 8%. However, around 33% of longliners, 5% of netters and 4% of purse seiners deploy mainly trawl nets, in spite of their different categorization. This increases the percentage of fishing boats deploying trawl nets to 41% from the total Egyptian Mediterranean fleet (EastMed 2014).

In catch reconstruction studies, commercial fisheries must be classified as either industrial (i.e., large-scale) or artisanal (small-scale). Furthermore, trawl catches, whether by motorized or un-motorized boats and regardless of the type of trawl net, vessel length or national definitions, are always considered industrial in catch reconstructions studies, as *per* Martín (2012b). Hence in this study all trawl landings by the Mediterranean Egyptian fishing industry are considered industrial. The rest of the commercial catches by the nationally classified "semi-industrial" or "artisanal" fleet are classified here as or artisanal.

3.2.1.3 Sectors and taxonomic disaggregation of reported catch

Industrial (i.e., trawl) catch was obtained for 1920-1935, 1964 and 1967-1992 from national reports (Table 37) and for 1958-1960 and 1962-1963 from Aleem (1969).

The 1920 trawl catch for Alexandria was only reported from July to December 1920, but for the whole 12 months of 1920 for Port Said. The average catch contribution of trawl catch to total trawl catch for January to June of the years 1921 to 1934 was about 47% (as per the national reports in Table 37). To remain conservative, it was assumed that the catch contribution of trawlers for the missing months of January to June 1920 was about 30% of the total trawl catch of 1920.

When World War I ended in 1918, information on the Mediterranean industrial fishery of Egypt for 1917-1919 was scarce. In the national "*Report on the fisheries of Egypt in 1920*", Paget (1921) briefly mentioned that trawl catch data from Port Said were available from 1919, without providing these statistics. This was the only available information regarding the activities of trawlers before 1920. Given the longstanding and important Italian diaspora in Egypt, it is very likely that trawl fishing had existed for some years before that.

However, to remain conservative, trawlers were assumed to have started their operations in the Mediterranean waters in 1919. The number of trawlers represented about 3% of total fishing boats in 1920. It was assumed that the number of trawlers in 1919 was 2% of total fishing boats. By dividing the trawl catch by the number of trawlers of 1920, the trawler CPUE was estimated for 1920 to be 18.7 $t \cdot boat^{-1} \cdot year^{-1}$. To remain conservative a 15 $t \cdot boat^{-1} \cdot year^{-1}$ was assumed for 1919 and applied to the estimated number of boats of 1919.

Industrial and artisanal landings in 2017 were estimated to be 41% and 59%, respectively (Hatem Hanafy Mahmoud, personal communication, July 14, 2019). According to Alsayes *et al.* (2010), trawl catch represented 43.3% of total landed catch in 2008. EastMed (2014) reports that 42% of total catch in 2012 originated from trawls. Interpolations between these different anchor points, summarized in Table 38, were performed to estimate the percentage catch contribution of trawls to the total reported catch for the missing years of 1936-1957, 1961, 1993-2007, 2009-2011 and 2013-2016.

Table 38. Anchor points of estimated percentage catch contribution of trawl catch to the total reported catch for Egypt (Mediterranean).

Years	Percentages	Sources
1935	20	Faouzi (1938)
1958	57	Aleem (1969)
1960	64	Aleem (1969)
1962	79	Aleem (1969)
1964	71	Aleem (1969)
1992	44	CAPMAS (1994)
2008	43	Alsayes *et al.* (2010)
2012	42	EastMed (2014)
2017	41	Hatem Hanafy Mahmoud[26] (personal communication, July 14, 2019)

Egyptian artisanal (i.e., shore and sardine) Mediterranean landings were available from national reports (Table 37) for 1920-1935. However, the shore catch data were taxonomically disaggregated only for 1930-1933 and 1935. Some freshwater species were reported as part of the marine shore Mediterranean fishery and were then subtracted from the total catch. The taxonomic disaggregation for 1930 was applied to the reported shore catch of 1920-1929 and the taxonomic disaggregation for 1935 was applied to the reported shore catch of 1934.

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Sardine landings were also available from the FAO and national datasets for 1950-2017. To estimate sardine catches for 1936-1949, an interpolation was performed between sardine catches of 1935 and 1950. Shore catch for 1936-1949 and 1950-2017 was obtained by subtraction of trawl and sardine catch from total catch. Artisanal catch for the 1950-2017 was obtained by subtraction of trawl catch from total catch.

The sector distribution for some taxa was obtained for 2017 and was estimated for 1920-1935 from the national fisheries reports summarized in Table 37. According to both sources, certain species (other than sardines) were targeted by either trawls or other artisanal gears for all of 1920-2017 (Table 39). These species were assigned to their proper sectors for 1936-2017.

The total catch of these species was then subtracted from the total estimated landings for each of the industrial and artisanal sectors. The percentage of non-assigned catch by sector was then obtained and applied to the rest of the taxonomic groups.

Table 39. Species that contributed mostly to the catch of one sector for all of 1920-2017 for Egypt (Mediterranean).				
Year	**1920-1935**		**2017**	
	Industrial (trawl; %)	**Artisanal (%)**	**Industrial (trawl; %)**	**Artisanal (%)**
Penaeidae	74	26	80	20
Parapenaeus longirostris	100	0	100	0
Mugilidae	1	99	5	95
Clupeidae	0	100	2	98
Engraulidae	0	100	2	98
Dicentrarchus labrax	0	100	10	90
Dicentrarchus punctatus	0	100	10	90
Merluccius merluccius	100	0	100	0
Mullidae	98	2	70	30
Triglidae	100	0	90	10
Trichiurus lepturus	10	90	30	60
Pomatomus saltatrix	2	98	0	100

In 1920, the sardine catch was 2,350 t and it fluctuated during the following years, with an average of 3,762 t·year^{-1} from 1920-1935 (sources in Table 37). To remain conservative, it was assumed that the annual sardine catch was 1,500 t for 1917-1920.

The numbers of artisanal fishing boats in the Mediterranean governorate of Egypt were available for 1917-1935 (sources in Table 37). The catch per unit of effort (CPUE) of shore catch was estimated to be 1,260 t·boat^{-1}·year^{-1} for 1920 and an average of 1,015 t·year^{-1} for 1920-1935. To remain conservative, it was assumed that the shore CPUE for 1919-1917 was about 1,000 t·year^{-1} and was multiplied by the available number of fishing boats for 1917-1919 from the Egyptian fisheries national report by Paget (1921).

3.2.1.4 Unreported commercial catch

Unreported commercial landings include any commercialized catch that was not accounted for by the official statistics. Earlier reports described a larger percentage contribution of unreported catch to the total landings. Paget (1921), Wimpenny (1930), and Faouzi (1936, 1937) insisted on the unreliability of fisheries statistics and the reporting quality. As *per* El-Miralai (1928) “the majority of the fishermen sell their catch of fish outside of the *halaqas*; those quantities are therefore not included in our records” (p. 5). Furthermore statistics were rarely collected from regions far from the official ports and trawlers and shore catch oftentimes do not report their landings. Fish was often sold in private markets, without any governmental control (Faouzi 1933). In 1929, the methods for the estimation of sardine catch were changed due to statistics unreliability (Wimpenny 1931).

According to Aleem (1961, 1969), unreported catch was estimated to be equivalent to 20-30% of reported catch. This was mainly due to the channeling of fish landings outside of the traditional official markets, unlicensed fishers, under-estimation of landings weight by fishers, and the exclusion of several coastal landings cites from the national statistics. During the seventeenth and nineteenth sessions of the General Fisheries Council for the Mediterranean, the Egyptian representatives mentioned the unreliability of fisheries statistics in their country during the 1970s and the 1980s (GFCM 1984, 1989).

Currently, unreported commercial catch within the Egyptian Mediterranean coast is mostly defined as fish directly sold to consumers and retail markets without passing through the official channels, i.e., wholesale and auction markets. According to EastMed (2014), on average of 96% of all landings pass through the official market chain. Up to 5% and 3% of total artisanal and industrial landings, respectively, are sold directly to restaurants, consumers, and fishmongers, and are thus not reported. Based on this, it was assumed that unreported industrial catch decreased from 30% of trawl catch in 1919 to 3% in 2017. It was also assumed that artisanal catch decreased from 30% in 1920 to 5% in 2017. The taxonomic disaggregation of artisanal and industrial reported catch was applied to the unreported catch.

3.2.1.5 Recreational fishery

Although recreational fishing in Egypt has been a popular activity, since at least the time of the Pharaohs (Pitcher and Hollingworth 2002), it is still poorly regulated (Gaudin and Young 2007). Along the Egyptian Red Sea coast, the recreational fishing licenses are better monitored than in the Mediterranean coast. A category of "amateur" fishing licenses, however, exists and was considered here representative of the number of recreational fishers. The annual number of recreational licenses in the Mediterranean was obtained for 1996-2000 and 2002-2012 from Hatem Hanafy Mahmoud (personal communication, November 24, 2019.). Total fishing licenses were available for 1917, 1928-1935, 1969-1970, 1972-1973, 1976- 2017 from national reports (Table 37) Interpolations were performed to account for the missing years.

The percentages of recreational licenses compared to total fishing licenses for 1996-2000 and 2002-2012 were estimated in order to estimate the number of recreational licenses for 1920-1995 and 2013-2017. Recreational fishing licenses were equivalent to 9%, 31%, 19% and 39% of total fishing licenses in 2009, 2010, 2011 and 2012. To remain conservative, a constant percentage of 15% was assumed for 2013-2017 and was applied to the total number of fishing licenses.

Recreational boats in the marine Mediterranean waters of Egypt were mentioned in several national fisheries reports as not making any money. This is a confirmation of the existence of fishing boats in the region back in the 1920s (Jenkins-Bey 1925). It was assumed that recreational fishing started in 1920. Recreational licenses represented 3% of total fishing licenses in 1996. An interpolation was performed between 1919 and 1996, assuming 0 recreational fishers in 1919, to obtain the percentages of recreational licenses for 1920-1995. These percentages were applied to the total number of fishing licenses for 1920-1995 to obtain the number of recreational licenses for 1920-1995. A conservative 5 $kg \cdot year^{-1}$ was applied to the number of fishers for 1920-2017.

Taxa commonly targeted by the Egyptian Mediterranean recreational fishery were obtained from Gaudin and Young (2007). They consist of the species *Pagellus erythrinus*, *Scomber colias*, *Pomatomus saltatrix*, *Serranus cabrilla*, and *Sparus aurata* and the families Serranidae, Synodontidae, Sparidae and Moronidae. In the absence of data, it was assumed that these taxa had an equal contribution to the recreational landings.

3.2.1.6 Subsistence fishery

Subsistence catch is defined in this study as fish caught for household and crew consumption (for each of the industrial and artisanal fisheries). This kind of catch is not sold and is not fished for leisure. It is considered as a necessary source of food security, especially in rural areas where other animal protein sources could be inaccessible (Béné 2006).

CAPMAS (2019d) estimated crew consumption to be around 10% of the commercial catch in Egypt in 2017. This percentage involves all Egyptian fisheries, including the freshwater, and the marine Mediterranean and Red Sea fisheries. It is also unclear whether this crew consumption is for either one or both of the industrial and artisanal fisheries. According to EastMed (2014), the crew consumption ranges between 1% of total yields of trawlers and smaller artisanal boats, and 4% of total yield of longliners and purse seiners (considered artisanal in this study). To remain conservative, crew consumption for the artisanal sector within the Mediterranean Egyptian EEZ was assumed to have decreased from 10% in 1917 to 2% in 2017 of the total artisanal commercial catch. It was also assumed that crew consumption within the trawl fishery decreased from 5% in 1919 to 1% in 2017 of the total industrial commercial catch.

Subsistence catch for household consumption is defined here as fish caught by people living within a 5 km range from the Mediterranean coast in Egypt's rural areas, and likely without easy access to urban markets. A *per* capita subsistence catch rate was applied to half of this population to estimate the household fish consumption within the Egyptian Mediterranean coast. Assessment of the total rural population living within a 5 km range from the Egyptian coast was made available by the 'Socioeconomic Data and Applications Center' for the years 1990, 2000 and 2010 (CIESIN 2012b). This population estimate, however, applies to both the Egyptian Red Sea and Mediterranean coasts. The coastal rural population living within a 5 km range from the

Mediterranean Egyptian coast was estimated in a first step for 1990, 2000 and 2010, then for a second step for the rest of the years, as follows:

Let A_i: total rural population of the Egyptian Mediterranean costal governorates for year i;

F_i: total rural population of the Egyptian coastal governorates (including both the Mediterranean and the Red Sea governorates) for year i;

G_i: rural population living within 5 km from the whole Egyptian coast (including the Mediterranean and the Red Sea coast) for year i = (1990, 2000 or 2010) from CIESIN (2012b) ;

X_i: Rural population living within a 5 km range from the Mediterranean coast for year i;

B_i: proportion of the rural population living within 5km from the Egyptian Mediterranean coast from the total rural population of the Mediterranean coastal governorates for year i:

For i = (1990, 2000 or 2010)

$$X_i = \frac{A_i}{F_i} \times G_i$$

Then,

$$B_i = \frac{X_i}{A_i}$$

The obtained B_i is only for the years 1990, 2000 and 2010. An extrapolation is performed to obtain B_i for the years 1910, 1920, 1930, 1940, 1950, 1960, 1970, 1980 and 2020. Interpolations are then performed between the latter anchor points to obtain the B_i for the whole period of 1917-2017.

For i ∑ [1917, 1918,   ..2017] /(1990, 2000, 2010):

$$X_i = A_i \times B_i$$

This estimate is based on the assumption that the percentage of the rural population of the Mediterranean coastal governorates from the rural population of all Egyptian coastal governorates is equal to the percentage of the rural population living within a 5 km range from the Egyptian Mediterranean coast from the total rural population living within a 5 km range from the whole Egyptian coast.

Methods and sources according to which the variables A_i and F_i were estimated are summarized in Appendix C. Methods and sources according to which the *per* capita subsistence catch rate for 1917-2017 were estimated are summarized in Appendix C. The *per* capita subsistence catch rate within the Egyptian Mediterranean coastal rural areas was estimated to be 0.96 $kg \cdot year^{-1}$ in 1917 decreasing to 0.62 $kg \cdot year^{-1}$in 2017. This catch rate was applied to the estimated rural population living within 5km off the Mediterranean Egyptian coast to obtain the household subsistence catch for 1917-2017. The family disaggregation of the artisanal commercial landings was applied to the household subsistence catch and to the crew subsistence catch of the artisanal commercial fishery. The family disaggregation of the industrial commercial landings was applied to the correspondent crew consumption.

3.2.1.7 Discards

The portion of non-targeted catch that is undersized or/and non-commercially valuable is often discarded at sea. For trawlers, and especially shrimp trawlers, discards often represent a major and unavoidable part of the total catch (Alverson *et al.* 1996; Pérez-Roda *et al.* 2019). Several authors have studied discards of the trawl and other artisanal gears within the Egyptian Mediterranean fishery.

One of the early studies on bycatch of non-commercial fish in the Mediterranean Egyptian trawl fishery dates back to 1970-1971 during the Soviet-Egyptian expedition. Al-Kholy and El-Wakeel (1975) estimated non-commercial fish caught by trawlers to be 34% of the total catch. Rizkalla (1995) estimated trawl discards in 1993-1994 to be 26.6% of which 90% were undersized fish. A study on trawl discards by Faltas *et al.* (1998) estimated trawl discards in Abu-Qir, east of Alexandria, in 1996-1997 to be 17.9% of total catch. Half of these discards were made of undersized fish and the other half of low to non-commercially valuable species. Bottom trawl discards within the waters off Port Said in 1997 was estimated by El-Mor *et al.* (2002a) to be around 15-20% of total landings (averaged to 17.5%). Juvenile species, and low and non–commercial species constituted 86.5% and 5.5% of total discards, respectively. Alsayes *et al.* (2009) estimated trawl discards within the Mediterranean Egyptian waters to be 7.86-21.52% of total landings in 2008 (averaged to 14.69%). Rizkalla *et al.* (2016) estimated the catch of non-commercial species to be 48.8% of total landings by bottom trawlers in 2014 within the waters off Alexandria. Ragheb *et al.* (2019) completed a study on the species composition of non-target catch of the trawl fishery in 2017-2018 within the waters off Port Said. According to an ongoing study by Reda M. Fahim (personal communication, March 3, 2018), trawl discards are 33% and 21% in the eastern and western parts of the Egyptian Mediterranean coast, respectively.

These anchor points were used to estimate discards of the Egyptian Mediterranean trawl fishery for 1971, 1994, and 2008. To remain conservative, the 2014 estimate was not used in this study. Interpolations were performed to account for the missing years. For 1917-1949, it was assumed that discards represented 20% of total trawl catch. An interpolation between 1949 and 1975 was performed. It was assumed that discards represented 15% of total trawl catch in 2009-2017, similarly to 2008.

The species composition of low-valued and undersized fish was made available for 1920 by Paget (1921). These fishes were assumed to represent the species composition of discards for 1919-1980 with an equal catch contribution (Table 40). Species composition of discards were available from some of the studies on discards cited above (Tables 40, 41, 42 and 43).

Table 40. Catch composition of trawl discards for 1919-1980 for Egypt (Mediterranean) based on Paget (1921).

Species	Catch contribution (%)	Species	Catch contribution (%)
Argyrosomus regius	8.33	*Labridae*	8.33
Bothus	8.33	*Mullus barbatus barbatus* and *M. surmuletus*	8.33
Centriscus scutatus	8.33	*Spicara maena*	8.33
Cepola macrophthalma	8.33	*Spicara smaris*	8.33
Conger conger	8.33	*Squilla mantis*	8.33
Gobiidae	8.33	*Trachinus draco*	8.33

Table 41. Catch composition of trawl discards for 1981-2000 for Egypt (Mediterranean) based on Rizkalla (1995).

Species	**Catch contribution (%)**	**Species**	**Catch contribution (%)**
Spicara maena and *S. smaris*	71.31	*Boops boops*	0.44
Chelidonichthys lucerna and *C. lastoviza*	7.30	*Stephanolepis hispidus*	0.33
Serranus cabrilla and *S. hepatus*	7.27	*Mullus* spp.	0.30
Pagellus erythrinus and *P. acarne*	2.42	*Ariosoma balearicum*	0.28
Chondrichthyes	2.04	*Iniistius bimaculatus*	0.23
Bothus podas	1.85	*Microchirus ocellatus*	0.21
Uranoscopus scaber	1.82	*Conger conger*	0.15
Trachinus spp.	0.77	*Pagrus pagrus*	0.14
Citharus linguatula	0.65	*Echelus myrus*	0.12
Marine fishes nei	0.61	*Merluccius merluccius*	0.08
Argyrosomus regius	0.59	*Solea aegyptiaca*	0.08
Gobius niger	0.51	*Trichiurus lepturus*	0.05
Balistes punctatus	0.45	--	--

Table 42. Catch composition of trawl discards for 2000-2010 for Egypt (Mediterranean) based on Alsayes *et al.* (2009).

Species	**Catch contribution (%)**	**Species**	**Catch contribution (%)**
Pagellus erythrinus	53.74	*Xyrichthys novacula*	0.46
Octopus	13.29	*Solea solea* and *S. aegyptica*	0.44
Trachysalambria curvirostris	8.75	Brachurya (crabs)	0.33
Pagellus acane	5.17	*Ophichthus* spp.	0.33
Boops boops	3.48	*Serranus hepatus*	0.32
Lithognathus mormyrus	2.60	*Mullus surmuletus*	0.27
Callionymus filamentosus	2.08	Sepiidae	0.27
Ariosoma balearicum	2.05	*Apogon imberbis*	0.14
Stephanolepis hispidus	1.67	*Sparisoma certense*	0.11
Gobius paganellus	1.06	*Apogon lineatus*	0.06
Spicara maena	0.95	*Spicara smaris*	0.06
Bothus podas	0.70	*Uranoscopus scaber*	0.06
Gobius niger	0.51	*Trachinus radiatus*	0.05
Trachurus mediterraneus	0.51	*Mullus barbatus*	0.04
Erugosquilla massavensis	0.50	--	--

Table 43. Catch composition of trawl discards for 2011-2015 for Egypt (Mediterranean) based Rizkalla *et al.* (2016).

Species	Catch contribution (%)	Species	Catch contribution (%)
Trachinus draco	35.88	*Stephanolepis hispidus*	0.50
Lepidotrigla cavillone	35.23	*Echelus myrus*	0.45
Callionymus filamentosus	7.16	*Apogonichthyoides taeniat us*	0.31
Ariosoma balearicum	3.48	*Remora remora*	0.31
Xyrichthys novacula	1.89	*Gobius paganellus*	0.27
Erugosquilla massavensis	1.81	*Zeus faber*	0.21
Gobius niger	1.68	*Microchirus ocellatus*	0.14
Pempheris vanicolensis	1.35	*Squilla mantis*	0.13
Scorpaena scrofa	1.20	*Peristedion cataphractum*	0.11
Bothus podas	1.19	*Terapon puta*	0.11
Lagocephalus sceleratus	1.00	*Scorpaena notata*	0.08
Equulites klunzingeri	0.99	*Echeneis naucrates*	0.05
Phycis phycis	0.87	*Myra fugax*	0.05
Ophidion barbatum	0.83	*Conger conger*	0.04
Uranoscopus scaber	0.73	*Apogon imberbis*	0.03
Microchirus variegatus	0.72	*Engraulis encrasicolus*	0.03
Citharus linguatula	0.62	*Palaemon elegans*	0.02
Charybdis hellerii	0.51	*Ixa monodi*	0.01

Table 44. Catch composition of trawl discards for 2016-2017 for Egypt (Mediterranean) based on Ragheb *et al.* (2019).

Species	**Catch contribution (%)**	**Species**	**Catch contribution (%)**
Terapon puta	19.91	*Synodus saurus*	0.15
Herklotsichthys punctatus	15.42	*Sardina pilchardus*	0.14
Engraulis encrasicolus	11.54	*Plotosus lineatus*	0.14
Argyrosomus regius	9.63	*Sphyraena chrysotaenia*	0.13
Equulites klunzingeri	5.96	*Atherina boyeri*	0.11
Alepes djedaba	5.20	*Callionymus filamentosus*	0.10
Gobius niger	4.11	*Pomatomus saltatrix*	0.09
Trichiurus lepturus	4.07	*Pegusa impar*	0.09
Sardinella aurita	3.90	*Sphoeroides pachygaster*	0.08
Caranx crysos	3.23	*Apogonichthyoides pharaonis*	0.08
Gobius paganellus	3.18	*Upeneus asymmetricus*	0.07
Ariosoma balearicum	2.66	*Dussumieria elopsoides*	0.07
Solea solea	1.69	*Dactylopterus volitans*	0.06
Sardinella maderensis	1.24	*Ostorhinchus fasciatus*	0.06
Diplodus annularis	1.18	*Nemipterus randalli*	0.05
Chelon auratus	1.02	*Dicentrarchus punctatus*	0.04
Platycephalus indicus	0.97	*Trachinotus ovatus*	0.03
Solea aegyptiaca	0.82	*Mullus surmuletus*	0.03
Cepola macrophthalma	0.48	*Balistes capriscus*	0.03
Oblada melanura	0.43	*Pelates quadrilineatus*	0.03
Cynoglossus sinusarabici	0.42	*Jaydia smithi*	0.02
Muraena helena	0.37	*Stephanolepis hispidus*	0.01
Ophichthus rufus	0.31	*Conger conger*	0.01
Siganus rivulatus	0.26	*Raja miraletus*	0.01
Stephanolepis hispidus	0.23	*Epinephelus fasciatus*	0.00
Scomberomorus tritor	0.15	--	--

Discards by the artisanal fisheries occur but vary based on the gear. Faltas (1997) and Faltas and Akel (2003) estimated discards by the beach seines in Abu-Qir bay (east of Alexandria) to be 80% for 1994-1995 and 70% for 2000-2001, respectively, of which a majority was made of juvenile commercial fish. El-Mor *et al.* (2002b) and Ahmed and El-Mor (2006) estimated the discards of beach seines to be much lower within the waters off Port Said, i.e., 20-25% and 30% of total catch for 1997 and for 2003-2004, respectively. For 1975, Al-Sayes *et al.* (1981) estimated discards by beach seines to be 12.3% of total catch in the waters off Alexandria.

Discards by the Egyptian purse seine fishery were estimated by an ongoing study by Reda M. Fahim (personal communication, March 3, 2018) to be around 2% of total purse seine catch within the eastern part of the Egyptian Mediterranean coast and nonexistent in the Western part for both daytime and *lampara* type purse seines. El-Haweet (2001) estimated the non-targeted catch (including both landed and discarded bycatch) to be around 8% of total daytime purse seine catch in 1997-1998 in Abu-Qir Bay. Gabr and El-Haweet (2012) estimated the bycatch of the Mediterranean Egyptian longline fishery to be around 6.5% of total catch. Most of this bycatch was composed of valuable species and thus the amount of discarded fish is likely to be low. Based on all of the information above and to remain conservative, it was assumed that artisanal discards were 10% in 1917 and decreased to 5% in 2017. An interpolation was performed to account for the missing years.

3.2.1.8 Estimation of uncertainty

This catch reconstruction is based on different methods and information sources with different levels of certainty. The approach summarized in Chapter 2 (see Table 4 in Section "Quantifying uncertainty") was used here to evaluate the confidence intervals of this reconstruction. This approach is modified from criteria used by the Intergovernmental Panel on Climate Change to assess the uncertainty of information sources (Mastrandrea *et al.* 2010). Uncertainty ranges were computed and scaled based on Monte-Carlo simulations in (Ainsworth and Pitcher 2005) and (Tesfamichael and Pitcher 2007). The confidence intervals in Table 4 of Chapter 2 were applied to the Mediterranean marine fisheries catch reconstruction for Egypt for 1917-2017 by sector, as summarized in Table 45.

Table 45. Confidence intervals applied to the different sectors of the Mediterranean marine fisheries catch reconstruction for Egypt for 1917-2017.

Sector	Time period	Confidence interval
Reported artisanal	1917-1920, 1936-1957, 1961, 1965-1966, 1993-2007, 2009-2011 and 2013-2016	(AH) ±30%
	1921-1935, 1958-1960, 1962-1964, 1967-1992, 2008 and 2012	(AE) ±10%
	2017	(CE) ±20%
Reported industrial	1919, 1936-1957, 1961, 1965-1966, 1993-2007, 2009-2011 and 2013-2016	(AH) ±30%
	1920-1935, 1958-1960, 1962-1964, 1967-1992, 2008 and 2012	(AE) ±10%
	2017	(CE) ±20%
Unreported artisanal and industrial	1917-2017	(AH) ±30%
Subsistence	1917-2017	(AG) ±20%
	1917-2017	(AH) ±30%
Recreational	1917-2017	(AH) ±30%
Industrial discards	1919-1970, 1972-1993, 1995-2007 and 2009-2017	(AH) ±30%
	1971, 1994 and 2008	(AE) ±10%
Artisanal discards	1917-2017	DE) ±30%

3.2.2 'Marine Trophic Index' and 'Mean Temperature of Catch'

When estimating the mean trophic level of global fisheries landings for 1950-1994, Pauly *et al.* (1998) found that landings of large long-lived high-trophic level predator-type fish were gradually being replaced by low-trophic smaller short lived fish. This phenomena is known as "fishing down the food web" and has since that first publication been a major indicator of the expansion of fisheries, now known as the "Marine Trophic Index" (Pauly and Watson 2005b; Shannon *et al.* 2014). This indicator was applied to the fisheries of some Mediterranean countries, e.g., Greece (Stergiou and Tsikliras 2008), Turkey (Keskin and Pauly 2018) and Algeria (Babouri *et al.* 2014).

The Mean Temperature of Catch (MTC) is a catch-based indicator first introduced by Cheung *et al.* (2013). When oceans are warmer, marine fishes and invertebrate tend to migrate to waters where temperature is more suitable. By using the preferred temperature of exploited species weighed by their annual catch, it was possible for Cheung *et al.* (2013) to estimate an increase of the global ocean temperature by 0.19 degrees Celsius per decade between 1970 and 2006. The MTC was estimated for the Mediterranean as a whole using FAO data by Tsikliras and Stergiou (2014) and Stergiou *et al.* (2016) but also for some Mediterranean countries individually, e.g., Greece (Sauzade and Rousset 2013) and Turkey (Keskin and Pauly 2018).

The 1917-2017 reconstructed Egyptian Mediterranean industrial and artisanal landings and discards in the herein study were used to estimate the MTI and MTC for the commercial Egyptian fishery. Only subsistence and recreational catch were not included.

Reconstructed Mediterranean Egyptian marine catches consisted of 165 species and higher taxa. The trophic levels and average inferred temperature preference for these taxa were mainly obtained from FishBase (www.fishbase.org) for fish and SeaLifeBase (www.sealifebase.org) for invertebrates. The *Sea Around Us* website (www.seaaroundus.org) also provided information on the trophic levels of several species and higher taxonomic groups. Average inferred temperature preference by species were also available in the Supplementary Materials of Cheung *et al.* (2013), and in Aquamaps (www.aquamaps.org).

Both indexes were calculated following the same principle:

- Let $Y_{i,k}$ = catch of the n species I in year k, TL_i = trophic level of species I and T_i = temperature preference of species I :

$$MTI_i = \frac{\sum_i^n TL_i.Y_{i,k}}{\sum_i^n Y_{i,k}}, \ MTC_i = \frac{\sum_i^n T_i.Y_{i,k}}{\sum_i^n Y_{i,k}}$$

Segmented regression analysis was applied using the package "segmented" in "R Studio" [27] to the resulting MTI and MTI to identify 'breakpoints', i.e., years when the trend of mean temperature (for the MTC) and that of the mean trophic level of catch (for the MTI) increases or decreases.

[27] Package 'Segmented' (online) available at https://cran.r-project.org/web/packages/segmented/segmented.pdf [accessed 11/12/2019]

3.3 Results

3.3.1 Total catch

Total marine catches were reconstructed for the Mediterranean Egyptian EEZ for 1917-2017, including the following main components: reported industrial (~32%), reported artisanal (~42%), unreported commercial artisanal (~6%), unreported industrial (~4%), subsistence (~3%), recreational (~<1%), and discards (~12%) (Figures 51 and 52 and Appendix D. Table 1) Egypt's total reconstructed marine fisheries catches in the Mediterranean from 1950 to 2017 are about 1.3 times the landings reported by the FAO on behalf of Egypt for the same time period. A first peak catch of 54,954 t was reached in 1962, followed by a second peak of 114,500 t in 1999 and a third peak of 107,526 t in 2008. Catches decreased considerably in three separate occasions from 10,475 t in 1923 to 3,835 t in 1926, then from 54,954 t in 1963 to 8,634 t in 1975, and finally from 107,526 t in 2008 to 68,926 t in 2017.

Confidence intervals were estimated for each sector and applied to the reconstructed catch. As a result, this catch reconstruction has a confidence interval of ± 25% as illustrated in Figure 52. According to Chapter 2 this confidence interval is considered "high" and thus represents a relatively high certainty

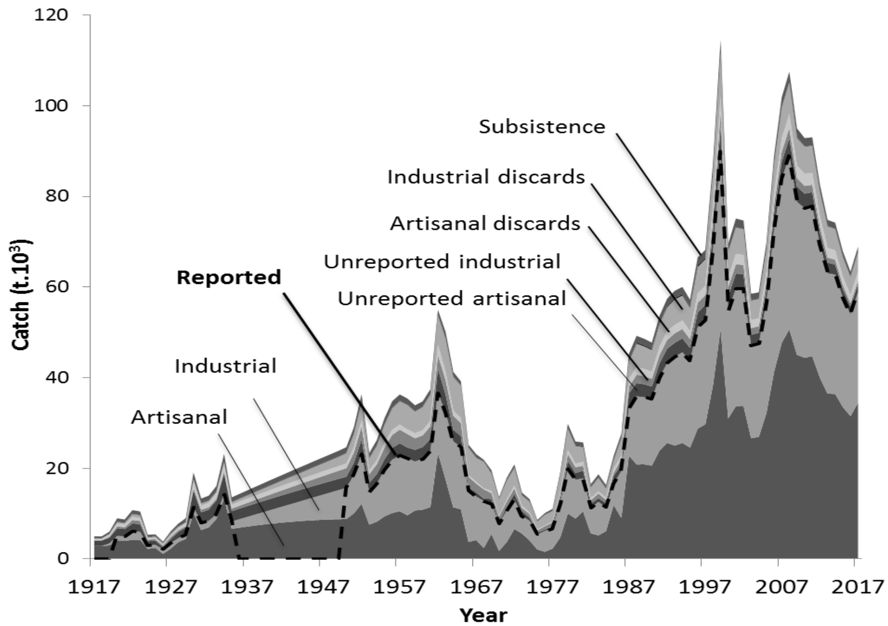


Figure 51. Reconstructed total catch for Egypt's Mediterranean EEZ for 1917-2017 by sector with reported data overlaid as interrupted line, recreational catches are too small to be visible in this graph.

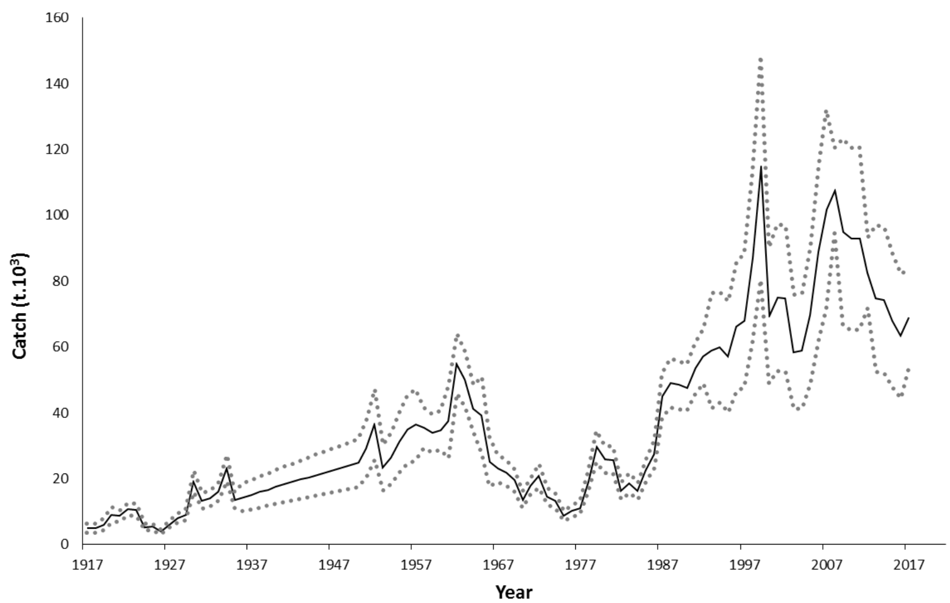


Figure 52. Uncertainty estimates for the marine fisheries catch reconstruction for Egypt (Mediterranean) for 1917-2017.

The catch composition of this reconstruction suggested that Clupeidae (~23% of total catch) and Sparidae (~11%) are the two most caught families in the Mediterranean waters of Egypt between 1917 and 2017. These two groups are followed by Penaeidae (~9%), Mugilidae (~ 4%), and Mullidae (4%) (Figure 53 and Appendix D. Table 2). The group 'others' include over 78 families. Sardines (*Sardinella* spp.) make up 95% of the Clupeidae family. Bogue (*Boops boops*), red porgy (*Pagrus pagrus)* and picarels (*Spicara* spp.) make up over 60% of the Sparidae catch. Catches of Clupeidae marked a sharp decrease between 1965 and 1979, from 9,679 t in 1965 to 1,864 t in 1966 to an all-time low of 590 t in 1968 and finally after back to 8,021 t in 1979.

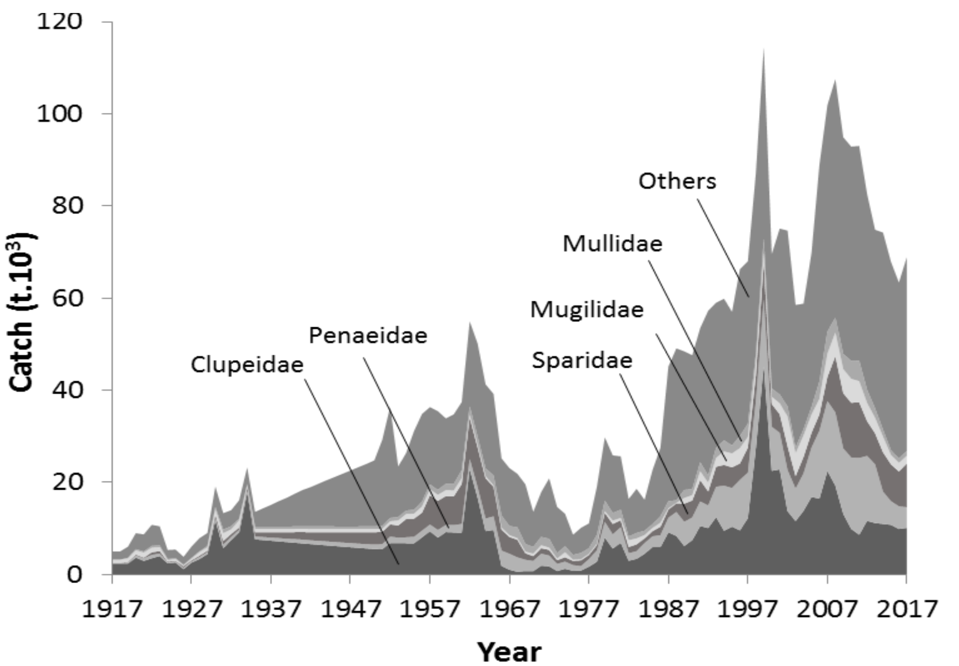


Figure 53. Reconstructed total catch for Egypt's Mediterranean EEZ for 1917-2017 by major family with 'others' made up of 78 families.

3.3.2 Unreported catch

Overall unreported catches represented 26% of total reconstructed catch and were equivalent to 36% of official landings for 1917-2017 (Figure 54). Industrial discards and unreported artisanal represent the bulk of the unreported catch, with around 36% and 24 % of unreported catch respectively. Industrial discards have decreased drastically since the 1917 from an average of 395 t·year^{-1} in 1919-1935 to an average of 5,331 t·year^{-1} in 2000-2017. Industrial discards were almost 3 times the amount of artisanal discards for 1917-2017 as illustrated in Figure 55. Subsistence catch decreased from 9 % to 2% of total reconstructed catch, i.e., from an average of 756 t·year^{-1} in 1919-1935 to 1,611 t·year^{-1} in 2000-2017. Recreational catch was estimated to be relatively stable from an average of 89 t·year^{-1} in 1919-1935 to 84 t·year^{-1} in 2000-2017.

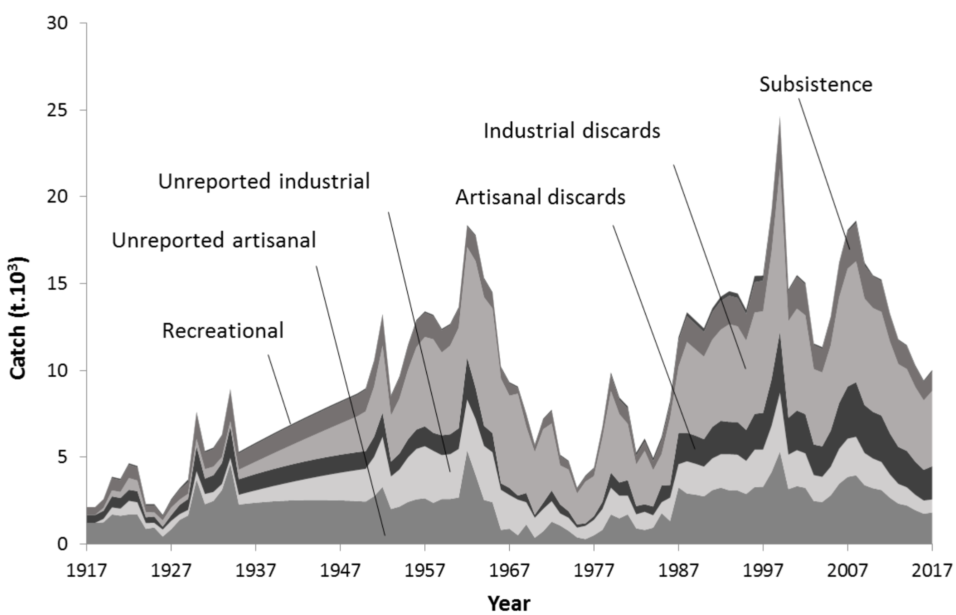


Figure 54. Unreported catch by sector for the Mediterranean EEZ of Egypt for 1917-2017

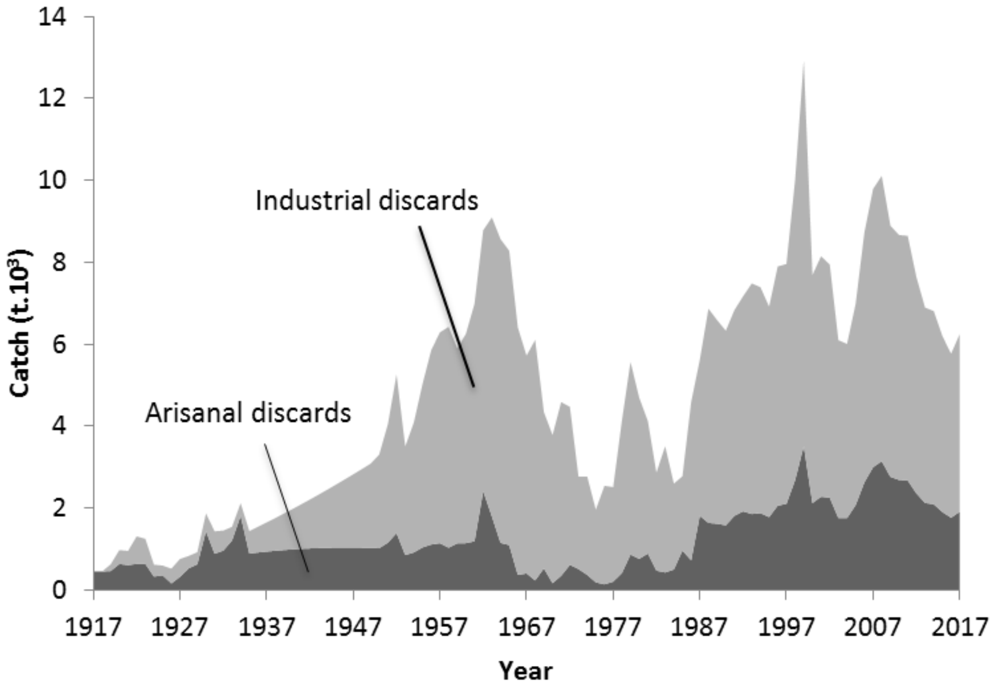


Figure 55. Reconstructed industrial and artisanal discards for Egypt's Mediterranean EEZ for 1917-2017.

3.3.3 Artisanal and industrial commercial landings

Commercial reported and unreported catch represented 84% of total reconstructed catches. Artisanal catch increased from an average of 6,794 t·year^{-1} in 1919-1935 to 130,747 t·year^{-1} in 2000-2017. Industrial catch increased from an average of 1,579 t·year^{-1} in 1919-1935 to 96,513 t·year^{-1} in 2000-2017.

Around 44% of the reported and unreported artisanal landings consisted of sardines (Figure 56); sardine landings represented over half of the catch in the first half of the century, which declined to 24% in 2017. The artisanal sardine catch reached low levels between 1967 and 1974, with 11% of catch in 1969 and 1973.

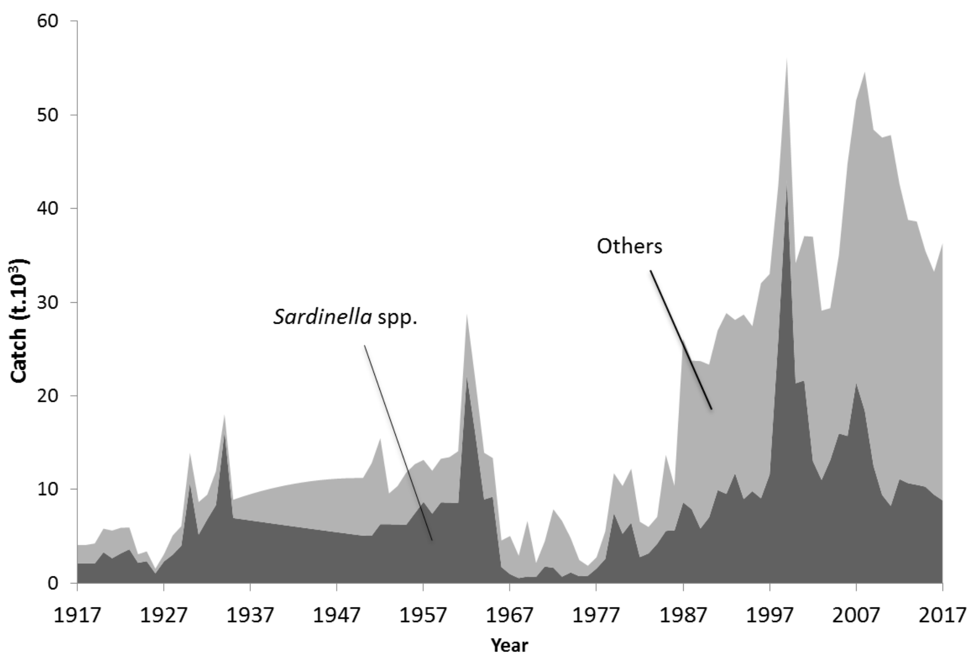


Figure 56. Reconstructed artisanal landings for Egypt's Mediterranean EEZ for 1917-2017 for sardines. The group 'others' includes over 55 species.

Reported and unreported industrial landings were made up mostly of shrimps (Penaeidae, ~20% of total industrial catch) followed by red mullets (*Mullus* spp., ~7%) (Figure 57). The catch contribution of shrimps to the industrial fishery has remained stable throughout the whole century, with an average of 18% in 1919-1935 and in 2000-2017.

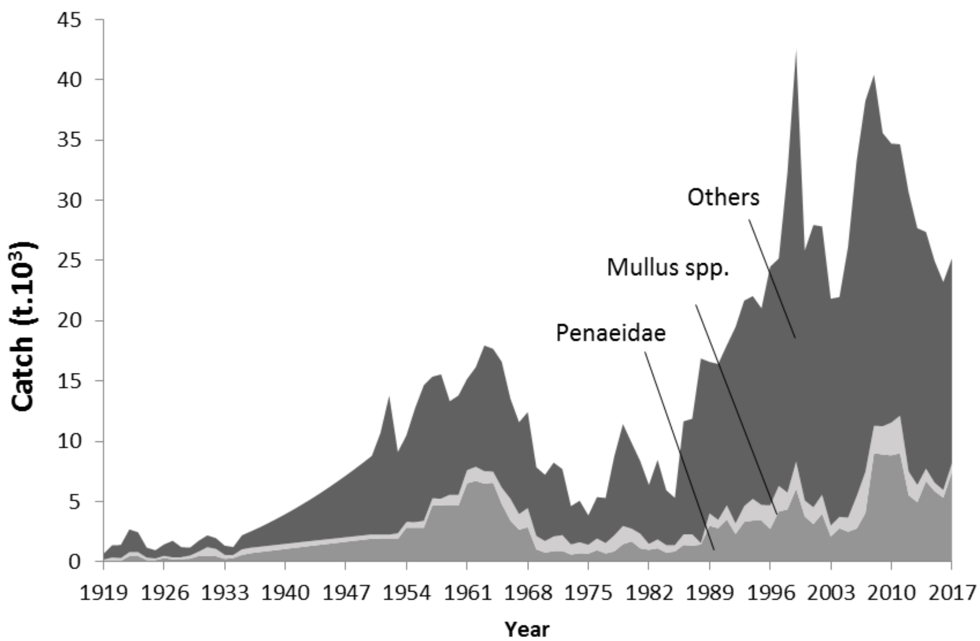
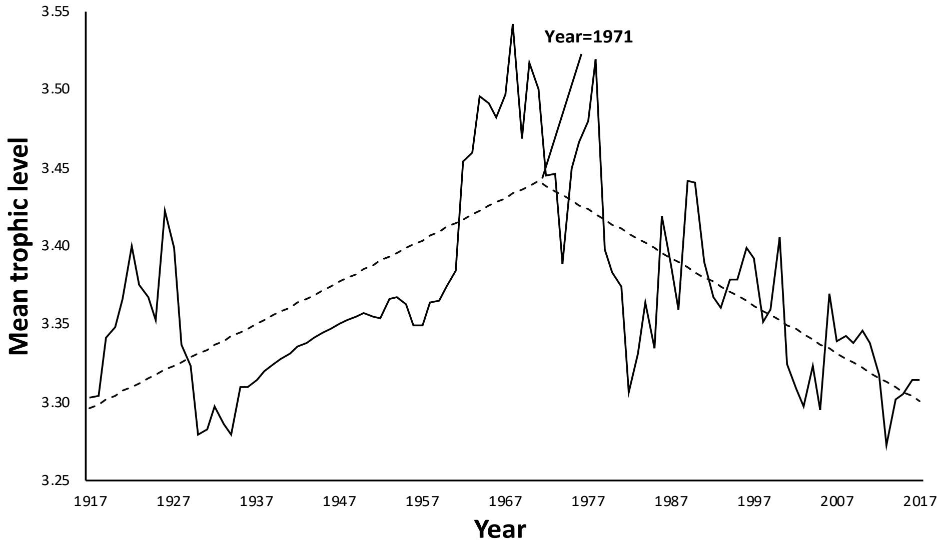


Figure 57. Reconstructed industrial landings for Egypt's Mediterranean EEZ for 1917-2017 for Penaeidae and *Mullus* spp.; the group 'others' includes over 60 species.

3.3.4 'Marine Trophic Index' and 'Mean Temperature of Catch'

The Marine Trophic Index and the Mean Temperature of Catch were evaluated for 1917-2017 for the Mediterranean waters of Egypt as illustrated in Figure 58. The mean trophic level of catch for the Mediterranean waters first increased up to 1971. Since then, the MTI has been decreasing (Figure 58a). The MTC started steadily increasing within the Mediterranean waters from 1934 to 2003 with an annual average of +0.01°C, after which the increase of temperature was more rapid with an average of +0.8°C per year (Figure 58b).

a)



b)

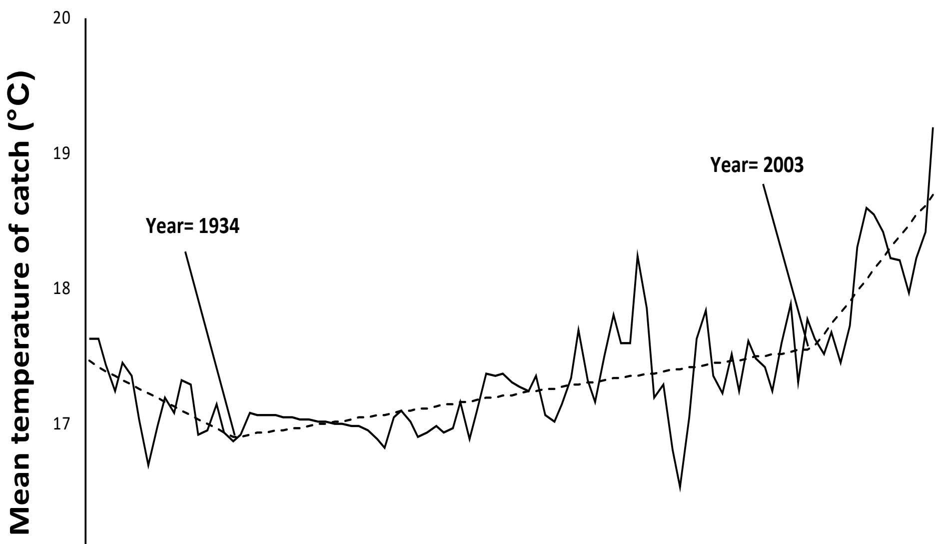


Figure 58. Catch-based indicators applied to the reconstructed catch data for the Mediterranean Egypt for 1917-2017: a) Marine Trophic Index (MTI); and b) Mean Temperature of Catch (MTC).

3.4 Discussion

This study re-estimates catches of marine fishes and invertebrates by Egypt from its Mediterranean waters to be around 3.7 million tonnes for 1917-2017. The majority of these catches were withdrawn from the Egyptian Mediterranean EEZ after WWII, amounting to about 3.2 million tonnes for 1950-2017. This compares to 2.4 million tonnes reported by the FAO on behalf of Egypt for 1950-2017. Despite the relatively high confidence interval of this reconstruction, it most likely provides very conservative estimates of unreported landings and discards within the Egyptian Mediterranean given that any assumptions made throughout this reconstruction are deemed very conservative.

Unreported catch is usually a factor that leads to overfishing. Signs of overfishing have occurred on several occasions between 1917 and 2017 in Mediterranean Egypt. In 1918 concerns were already expressed regarding the state of the Egyptian Mediterranean marine fishery (Faouzi 1933). According to Jenkins-Bey (1925) and El-Miralai (1926), despite the increase in the number of operating trawlers and fishing trips in 1924 and 1925, landings decreased considerably compared to earlier years, as this reconstruction illustrates it. In 1926, fishing of juvenile fish in shallow waters was highlighted by El-Miralai (1926). Hence, the first decrease of catch in the early 1920s could have been a sign of overfishing. “Bad weather” was also a suggested explanation to this decrease according to early studies (Jenkins-Bey 1925; El-Miralai 1928). Given the occurrence of WWII, reconstructed catches for 1936-1949 were based on interpolations and conservative assumptions.

After WWII, extensive research was being completed to develop the Egyptian marine fishing industry such as studies by Aleem (1961, 1969), El-Zarka and Koura (1965), and Gorgy (1966). Fisheries were expanding rapidly increasing landings by 55% between 1950 and 1962, just before drastically decreasing by half by 1966. Sardines were the most affected taxonomic group, decreasing from an average of 30% of commercial catch between 1950 and 1965 to almost 4% in 1968. A few years later, shrimp catch also decreased from an average of 17% of total commercial catch between 1950 and 1968 to 5% in 1973. The Aswan high dam has been considered as the main cause for this collapse, as documented by several studies (El-Hehiawy 1974; Gerges 1976; Sharaf-El-Din 1977; Wadie 1981; Bebars *et al.* 1997; Nixon 2004). However, some studies have also pointed out the contribution of the rapid increase of fishing pressure to this collapse and the concentration of bottom trawlers in shallow waters (El-Zarka and Koura 1965; Al-Kholy and El-Wakeel 1975; Bebars *et al.* 1997). For instance, the number of trawlers and purse seiners was multiplied by a factor of nearly 20 in only 10 years, i.e., from 30 to 574 units between 1952 and 1962 (Bebars *et al.* 1997). The Egyptian fisheries might not have suffered as much if only they were better managed.

The Mediterranean Egyptian fisheries started recovering from around the late 1980s. Landings have decreased again between 2008 and 2017, by 35%, while fishing pressure has been increasing. Overexploitation was confirmed by several stock assessments of commercially important species within the Mediterranean Egyptian waters, such as for Bogue (*Boops boops*) by Mehanna (2014), European hake (*Merluccius merluccius*) by Mehanna (2009b) and red mullets (*Mullus barbatus* and *M. surmuletus*) by Mehanna (2009a); (Mehanna 2009b). Some invasive species that have been exploited within the Egyptian Mediterranean waters were also found to be overfished, such as the peregrine shrimp (*Metapenaeus stebbingi*), assessed by Mahmoud *et al.* (2014a) and the Brushtooth lizardfish (*Saurida undosquamis*), assessed by Mahmoud *et al.* (2014b). Mehanna and Haggag (2010) recommend a decrease of fishing effort by 40-60% in Port Said in order to achieve Maximum Sustainable Yield.

The results of the MTI approach applied to the reconstructed catch data herein corroborate the hypothesis that the Egyptian Mediterranean marine fish stocks are overexploited. Indeed, the mean trophic level of catch has been decreasing since 1971. This was around the time when the Egyptian fishery experience a collapse. Although it may seem that the fisheries recovered, all they had actually did is reaching further down the food web.

Trawlers were considered as the main factor behind the overfished state of the Mediterranean Egyptian fisheries. According to EastMed (2014), this is due to the domination of the Egyptian Mediterranean fishing industry by trawlers, which is itself incentivized by high fuel subsidies. These trawlers have also been generating large amounts of discards, which are estimated here to be 3 times the discards generated by the artisanal fisheries.

The Mediterranean has been one of the first and most affected regions by climate change (Lionello *et al.* 2012; Lionello and Scarascia 2018). This has led to its 'tropicalization' and thus to a distribution shift of marine species (Cheung *et al.* 2013). This is illustrated by the results obtained by applying the MTC concept to the reconstructed catch. The MTC started increasing in 1934, an increase which seems to have intensified since 2003, due to the now rapid replacement of Mediterranean species by Lessepsian species, as projected by several studies, such as Lasram *et al.* (2010). Combined with overexploitation of the Mediterranean Egyptian fish resources, it is likely that the Mediterranean endemic species will disappear faster.

This study shows that the Egyptian Mediterranean fishery is in urgent need of a better management that should consist not only of limiting the activities of the trawlers, but also of improving the monitoring of other fisheries. For instance, recreational catch was here estimated at less than 1% for 1917-2017 in the Egyptian Mediterranean. This is most likely a considerable under-estimation given that recreational fishing is a long-established activity for the Egyptian people but one that has been lightly regulated (Gaudin and Young 2007; Hatem Hanafy Mahmoud, personal Communication, November 24, 2019). Alexandria seems to be the favourite spot for local recreational fishers (Ikeam 2018). Fishing tours within the Egyptian Mediterranean waters are offered to tourists via various online tour services for as low as 10 USD per hour[28][29]. With 8 million tourists in Egypt in 2017 (www.worldbank.org), recreational landings are probably higher than what this reconstruction estimates.

Given the overfished state of many Egyptian fish populations, some Mediterranean Egyptian fishers have been fishing in other neighboring countries as Cyprus (Anonymous 2018) and

[28] Fishing in the white Med (online) available at http://www.egypt.travel/attractions/fishing-in-the-white-med/ [accessed 20/11/2019]

[29] Fishing booker (online) available at https://fishingbooker.com/destinations/country/eg [accessed 20/11/2019]

Tunisia (Anonymous 2012a, 2012b, 2016). A better management of the Mediterranean Egyptian is necessary for a better management of Mediterranean fisheries as a whole. This study has shown that using catch data, it was possible to assess the state of the Egyptian Mediterranean marine fishing industry. Thus, by simply improving the monitoring of fisheries catches, and including the monitoring of unreported catch and discards, it is possible for Egypt to have a better and affordable assessment of the state of its Mediterranean fisheries for better management strategies.

Chapter 4: Assessments of 10 Fish Stocks from the SMAP Regions

4.1 Introduction

Synopsis: In this chapter, I applied the CMSY method to assess 10 stocks from the Southern Mediterranean and the Arabian Peninsula and for which catch data was reconstructed in the previous chapters.

The industrialization of fishing around the world, but mostly by economically developed countries, has led, since the 1950s, to increasing catches, but also to the spatial and bathymetric expansion of fisheries (Morato *et al.* 2006; Swartz *et al.* 2010), to the intensification of the global fishing effort (Anticamara *et al.* 2011) as well as to the continuous development of fishing technologies (Palomares and Pauly 2019). This has led to the depletion of fish stocks around the world (Tremblay-Boyer *et al.* 2011; Watson *et al.* 2013) and, since the mid-1990s, to a declining trend of world catches (Pauly and Zeller 2016a). In the meantime, fish stock assessments have become the basis of most fisheries management systems, which have become 'stock assessment driven' rather than 'management objective driven', to use terms suggested by Mahon (1997).

Stock assessments are mainly of two types: fisheries-independent and fisheries-dependent. Fisheries-independent stock assessment requires scientific cruises or research surveys to gather data on the biology and abundance of fish stocks (Pennino *et al.* 2016). Such surveys are expensive to carry out and require experience in collecting the most useful data and analysing them (Pauly 1996; Palomares *et al.* 2018). This kind of stock assessments is rarely implemented in economically developing countries due to their unaffordability. According to Pauly *et al.* (2013), stock assessments based on fisheries-independent data can cost from around 50,000 USD to millions of dollars per stock.

Fisheries-dependent stock assessments are carried out based on data and samples derived from fisheries, consisting of catch data, size composition data of the species caught, fishing locations, fishing effort, catch per unit of effort (CPUE), etc. While being more suitable for use in economically developing countries, these assessments \ still often require fisheries-independent data; also, they are easier to apply to industrial fisheries. However, the fisheries of economically developing countries are often dominated by the artisanal sector (see Chapters 1 and 2).

As a result, while globally, a majority of exploited fish stocks lack formal stock assessments, this problem is worse in economically developing countries, where over 80% of stocks lack stock assessments (Costello *et al.* 2012), and little information is available on their status.

It was within this framework that Martell and Froese (2013) introduced the 'Catch Maximum Sustainable Yield' (Catch-MSY) method, which was subsequently improved by Froese *et al.* (2017), and given a new acronym (CMSY). This catch-based model is data-light and computation-heavy and can assess the state of a stock while estimating fisheries reference points such as B/B_{MSY} and F/F_{MSY}, i.e., the biomass and fishing mortality relative to the biomass and fishing mortality associated with MSY. Froese *et al.* (2017) applied the CMSY method to 128 'formally' assessed European fish stocks which provided, for the overwhelming majority of them, close predictions to those estimated by classical stock assessment methods.

The large majority of exploited fish stocks within the Southern Mediterranean and the Arabian Peninsula regions (SMAP) regions lack formal stock assessments. For instance, very few stocks from the southern Mediterranean were assessed compared to the Northern Mediterranean (Lleonart and Maynou 2003). Here, an illustrative set of 10 stocks from the Mediterranean Sea, the Persian Gulf and the Arabian Sea is assessed using the CMSY method.

4.2 Methods

When a fish population within an ecosystem is reduced (e.g., by fishing), it will tend to increase as a function of its current biomass and its intrinsic growth rate (r) until it stabilizes at a maximum biomass it can reach in that ecosystem, i.e., its carrying capacity (k). Following Schaefer (1954, 1957), if fishing is adjusted such that the biomass is maintained at half the carrying capacity (k/2), a maximum growth increment can theoretically be sustainably removed from the population forever. This growth increment is called Maximum Sustainable Yield (MSY). The Schaefer model is also known as 'surplus-production model' (Figure 59), where the 'surplus' refers to the biomass that could be safely withdrawn from a given fish population while leaving enough individuals to reproduce and grow.

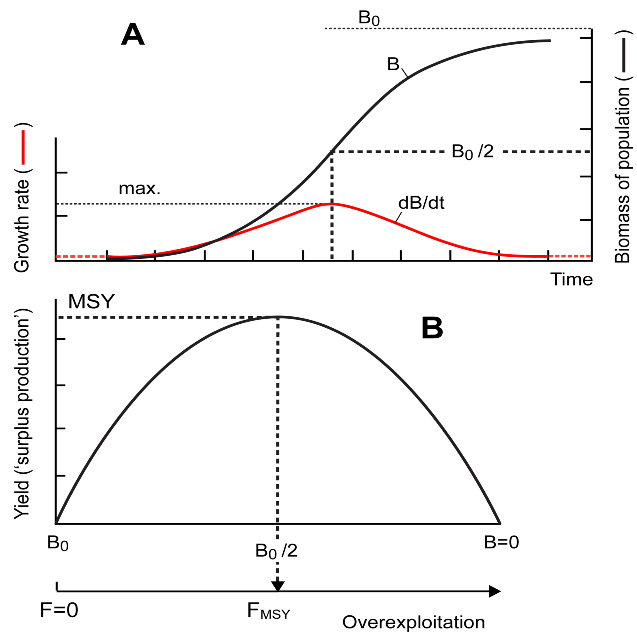


Figure 59. Basic principles behind (Schaefer-type) surplus-production models (figure from Palomares *et al.* (2018); reproduced with permission).

This model is based on the principle that the intrinsic growth rate (r) and the abundance, or 'biomass' (B), of a given population are the main factors behind its expansion. Or in mathematical terms:

$$B_{t+1}=B_t+r\cdot(1-B_t/k)\cdot B_t-C_t \qquad (1)$$

where B_t is the biomass in a given year, B_{t+1} is the exploited biomass in the subsequent year $t+1$, r is the intrinsic rate of population increase, k is the carrying capacity (assumed equivalent to the unexploited population size) and C_t is the catch in year t (Froese et al., 2017).

Note that in the term $r \cdot (1-B_t/k)$, the growth rate of the population (of biomass B_t-C_t), is dependent on how close B is to k, with the entire term becoming = 0 when $B_t = k$, while r itself does not change.

When a population is small, it is not able to increase much despite what may be a high intrinsic growth rate. As well, when a population is near carrying capacity, its growth is close to zero, again even when its intrinsic growth rate is high. However, at intermediate level, e.g., when population's biomass is at half of its carrying capacity, its growth is maximized (see Figure 59). Therefore, in theory, a fishery whose catch consists of the growth increment generated by a fish population at half its carrying capacity has a yield that is both maximal and sustainable; thus, the name Maximum Sustainable Yield (MSY). Also note that $MSY = r \cdot k/4$.

The CMSY model is based on the above theoretical framework and is applied via a software in R. It requires at least catch time series as input and constraints or 'priors', i.e., likely k and r ranges (Froese *et al.* 2017; Palomares *et al.* 2018). Prior r-range for different fish species, defined as 'resilience' by Musick (1999), are available from FishBase (www.fishbase.org). The prior k-range is estimated by the CMSY method based on three assumptions as per Froese *et al.* (2017): (1) k is larger than the maximum catch of a time series, which is consequently used as the lower range limit of k; (2) the maximum 'sustainable' yield depends on the productivity of the stock and thus on r; and (3) the more depleted a stock is, the closer the upper bound of k will be to the maximum catch of a time series.

The CMSY method consists of generating many thousands of biomass trajectories through equation (1) by applying a Monte-Carlo method to test thousands of r-k data pairs, and selecting which of those trajectories are 'viable' (Froese *et al.* (2017). According to Froese *et al.* (2017) a viable r-k parameter pair allows the model to provide a biomass trajectory compatible with the available time series, without the biomass crashing, i.e., reaching B≤0 (Figure 60).

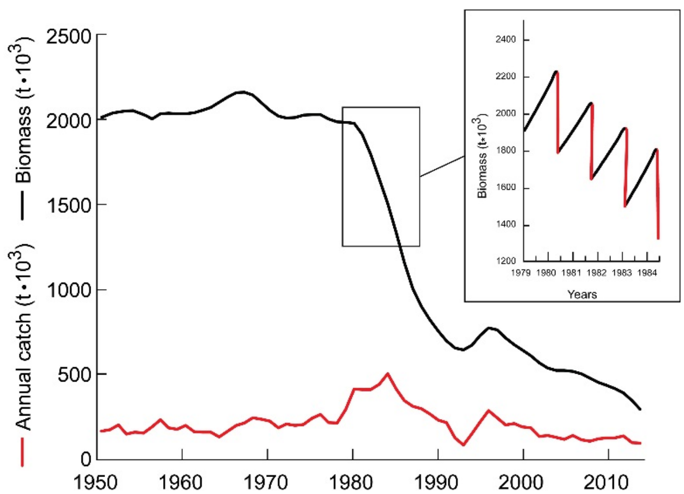


Figure 60. Basic principles behind the CMSY method: The initial population biomass (here in 1950) is assumed to be close to the carrying capacity (k) which increases in via annual growth increments and decreases as a result of fishing and thus the catch removals (in red) (figure from Palomares *et al.* (2018); reproduced with permission).

When information is available in addition to catches, such as CPUE and/or rough estimates of initial and terminal biomasses, the identification of viable r-k pair is more precise (see Froese *et al.* (2017)). In this study, the fisheries are data-poor and information other than the reconstructed catch data for the studied stocks were scarce (see Chapters 2 and 3). However, when local studies were (occasionally) available (even when they were published in so-called 'predatory journals'; see Chapter 1), they were compared to the results presented below. Thus, this work can be seen as an exploration of cases in which catch data may be sufficient to assess data-poor stocks. When only catch data are used, which is the case here, the CMSY method still provides estimates of MSY (see above), fishing mortality at MSY (F_{MSY} = r/2) and biomass at MSY (B_{MSY} = k/2).

The stocks assessed in this chapter with their appropriate priors r and k range are summarized in Table 46.

Table 46. Assessed fish stocks by species, countries and marine ecoregions and their correspondent priors r-k .

Marine ecoregions	**Countries**	**Species**	**Prior r-range ($year^{-1}$)**	**Prior k-range (10^3t)**	**Range of catch series**
Mediterranean Sea	Algeria and Morocco	*Engraulis encrasicolus*	0.39 - 0.91	33 - 99	1950-2016
		Sardina pilchardus	0.40 - 0.90	377 - 1130	1950-2016
		Sparus aurata	0.37 - 0.85	34.3 - 103	1950-2016
	Egypt	*Argyrosomus regius*	0.16 - 0.49	15 - 44.9	1917-2017
		Boops boops	0.39 - 0.89	13 - 38.9	1917-2017
		Sparus aurata	0.37 - 0.85	4.61 - 13.8	1917-2017
	Tunisia	*Merluccius merluccius*	0.35 - 0.80	8.07 - 24.2	1950-2016
		Pagellus erythrinus	0.31 - 0.78	17.4 - 52.2	1950-2016
Persian Gulf	Iraq and Kuwait	*Tenualosa ilisha*	0.39 - 0.89	52 - 156	1950-2015
Arabian Sea	Oman and Fujairah	*Sardinella longiceps*	0.37 - 0.85	242 - 726	1950-2015

4.3 Results

In this chapter, 10 stocks from the EEZs of the SMAP regions, i.e., the southern Mediterranean, the Arabian Sea, and the Persian Gulf, were assessed, 9 of which were found to be overfished (Table 49). Tables 48 and 49 summarize the fisheries reference points estimated for each stock via the CMSY method. The resulting graphs for each stock are summarized in Figures 61 to 70.

Table 47. Information on the species assessed in this chapter from www.fishbase.org and information on their status from the International Union for Conservation of Nature (IUCN)[30].

Scientific name	Common name	General information
Argyrosomus regius	Meagre	Meagre are migratory, benthopelagic fish distributed in the Eastern Atlantic, Mediterranean, and Black Sea. They belong to the drum or croaker (Sciaenidae) family and live at depths ranging from 15-300 meters. They were listed as Least Concern by the IUCN Red List in 2007.
Boops boops	Bogue	Bogue is a demersal species found along the shelf or coastal pelagic zone of the Eastern Atlantic, as well as the Mediterranean and Black Sea. This species belongs to porgies family (Sparidae) and is usually found at depths ranging from 10-100 meters. Bogues are currently listed as Least Concern by the IUCN Red List.
Engraulis encrasicolus	European anchovy	European anchovy are widely distributed along the Eastern Atlantic, from Norway to South Africa, as well as in the Mediterranean, Black, and Azov Seas. They are small pelagic species that can be found at depths from 10-400 meters. As of 2013, the IUCN Red List has categorized this species as Least Concern.
Pagellus erythrinus	Common pandora	Common pandora is a benthopelagic species belonging to the porgy (Sparidae) family. They are found in the Eastern Atlantic from Norway to Guinea-Bissau and in the Mediterranean. They reside within inshore waters and winter in deeper waters at depths of about 100 meters. The IUCN last assessed common pandora as Least Concern in 2009.
Sardina pilchardus	European pilchard	The European pilchard is commonly found at depths ranging from 25-100 meters in the Northeast Atlantic, Mediterranean, and Black Sea. It exhibits strong migratory and schooling behaviours. They are currently listed as Least Concern by the IUCN Red List.

[30] IUCN (2019) available online at www.iucnredlist.org/ [Accessed on 10-01-2020]

Table 47. Information on the species assessed in this chapter from www.fishbase.org and information on their status from the International Union for Conservation of Nature (IUCN)[30].

Scientific name	Common name	General information
Sardinella longiceps	Indian oil sardine	Indian oil sardine are distributed in northern and western parts of the Indian Ocean with the exception of the Red Sea and Persian Gulf. They are found at depths from 20-200 meters. Assessed by the IUCN Red List in 2009: Least Concern.
Sparus aurata	Gilthead seabream	Gilthead seabream belong to the porgy (Sparidae) family and are commonly found at shallow depths (1-30 meters) in the Eastern Atlantic, as well as the Black Sea. They are demersal, sedentary fish which are usually solidary or form small aggregations. Assessed in IUCN Red List in 2009: Least Concern.
Tenualosa ilisha	Hilsa shad	Hilsa shad is an anadromous species in the Indian Ocean from the Persian Gulf to Vietnam. They exhibit schooling behaviour in coastal waters and usually travel 50-100 km upriver to spawn. IUCN assessed hilsa shad in 2013: Least Concern.
Umbrina cirrosa	Shi drum	Shi drum is a medium-sized (common length is 40 cm), demersal species found in the coastal waters in the Eastern Atlantic, Mediterranean and Black Sea. As of 2007, their declining population are assessed as Vulnerable in the IUCN Red List.

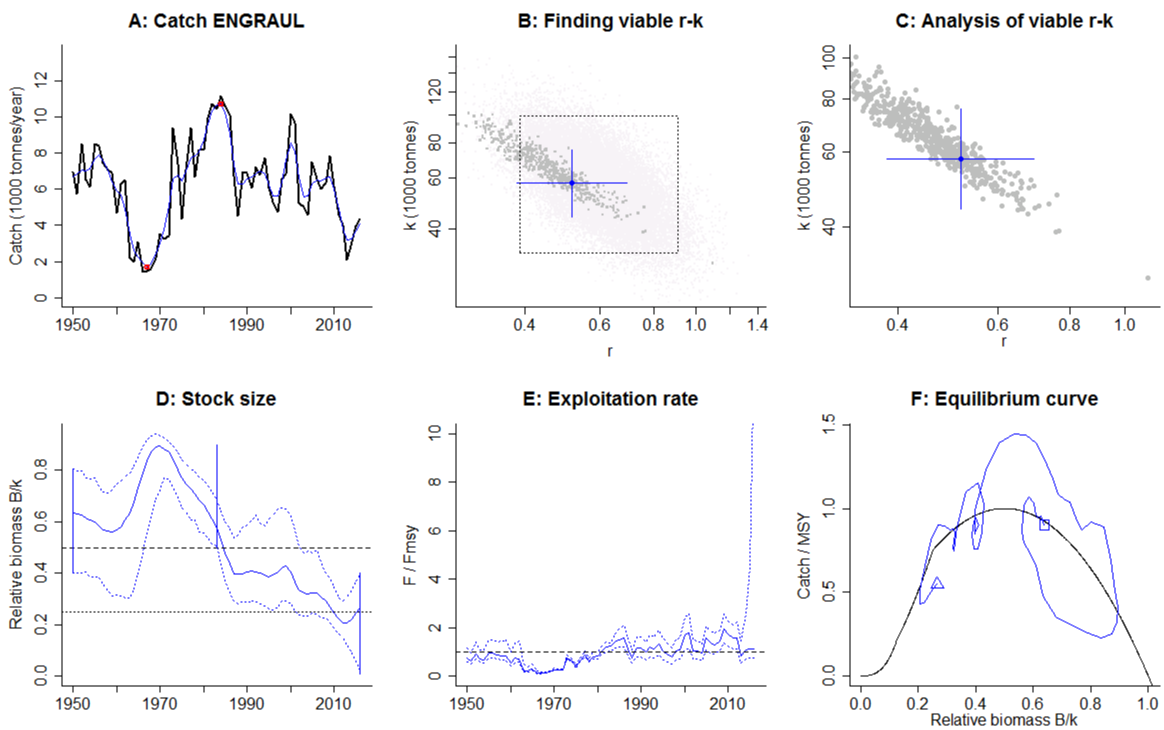
Table 48. Fisheries reference points predicted by the CMSY method for the stocks of the SMAP regions (MSY, k and B_{MSY} in 10^3t and CI= 95% confidence interval).

Countries	**Stock**	**Prior r (CI)**	**Prior k (CI)**	**MSY (CI)**	**Bmsy (CI)**	**Fmsy (CI)**	**Graphs**
Algeria and Morocco (Mediterranean)	*Engraulis encrasicolus*	0.51 (0.36 - 0.721)	59.4 (43.6 - 80.9)	7.46 (6.68 - 8.38)	29.7 (21.8 - 40.5)	0.255 (0.18 - 0.361)	Figure 61
	Sardina pilchardus	0.666 (0.497 - 0.894)	605 (453 - 808)	100 (86.8 - 118)	302 (226 - 404)	0.333 (0.248 - 0.447)	Figure 62
	Sparus aurata	0.645 (0.465 - 0.895)	53.4 (39.5 - 72.3)	8.54 (7.04 - 10.6)	26.7 (19.8 - 36.1)	0.323 (0.233 - 0.448)	Figure 63
Egypt (Mediterranean)	*Argyrosomus regius*	0.303 (0.205 - 0.45)	15.8 (11.5 - 21.7)	1.18 (0.961 - 1.4)	7.89 (5.74 - 10.8)	0.152 (0.102 - 0.225)	Figure 64
	Boops boops	0.671 (0.488 - 0.922)	19 (14.1 - 25.5)	3.18 (2.55 - 3.98)	9.48 (7.06 - 12.7)	0.336 (0.244 - 0.461)	Figure 65
	Sparus aurata	0.618 (0.456 - 0.839)	7.01 (5.34 - 9.22)	1.08 (0.892 - 1.3)	3.51 (2.67 - 4.61)	0.309 (0.228 - 0.419)	Figure 66
Tunisia	*Merluccius merluccius*	0.604 (0.438 - 0.832)	10.5 (7.61 - 14.5)	1.6 (1.25 - 1.97)	5.25 (3.8 - 7.24)	0.302 (0.219 - 0.416)	Figure 67
	Pagellus erythrinus	0.574 (0.398 - 0.827)	25.8 (18.5 - 36.1)	3.67 (3.02 - 4.63)	12.9 (9.23 - 18)	0.287 (0.199 - 0.414)	Figure 68
Iraq and Kuwait	*Tenualosa ilisha*	0.599 (0.448 - 0.802)	71.3 (56.8 - 89.4)	10.5 (8.49 - 13.2)	35.6 (28.4 - 44.7)	0.3 (0.224 - 0.401)	Figure 69
Oman and Fujairah	*Sardinella longiceps*	0.628 (0.45 - 0.878)	277 (200 - 382)	43.7 (36.2 - 51.3)	138 (100 - 191)	0.314 (0.225 - 0.439)	Figure 70

Table 49. Fisheries reference points predicted by the CMSY method for the stocks of the SMAP regions for the last year of the catch data time series (MSY, k and B_{MSY} in 10^3t and CI= 95% confidence interval).

Countries	**Stock**	**Year**	**F Year^{-1}**	**Relative biomass**	**B/B_{MSY}**	**Exploitation (F/F_{MSY})**	**Graphs**
Algeria and Morocco (Mediterranean)	*Engraulis encrasicolus*	2016	0.291	0.253	0.506	1.14	Figure 61
	Sardina pilchardus	2016	0.225	0.495	0.990	0.675	Figure 62
	Sparus aurata	2016	0.419	0.394	0.789	1.30	Figure 63
Egypt (Mediterranean	*Argyrosomus regius*	2017	0.213	0.328	0.655	1.40	Figure 64
	Boops boops	2017	0.371	0.271	0.543	1.10	Figure 65
	Sparus aurata	2017	0.358	0.157	0.314	1.85	Figure 66
Tunisia	*Merluccius merluccius*	2016	0.57	0.354	0.707	1.89	Figure 67
	Pagellus erythrinus	2016	0.485	0.400	0.800	1.69	Figure 68
Iraq and Kuwait	*Tenualosa ilisha*	2015	0.222	0.0496	0.099	3.47	Figure 69
Oman and Fujairah	*Sardinella longiceps*	2015	0.707	0.434	0.868	2.25	Figure 70

a)



b)

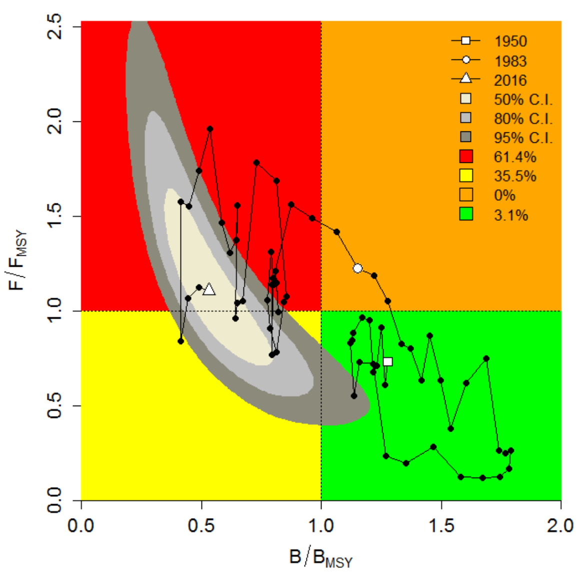
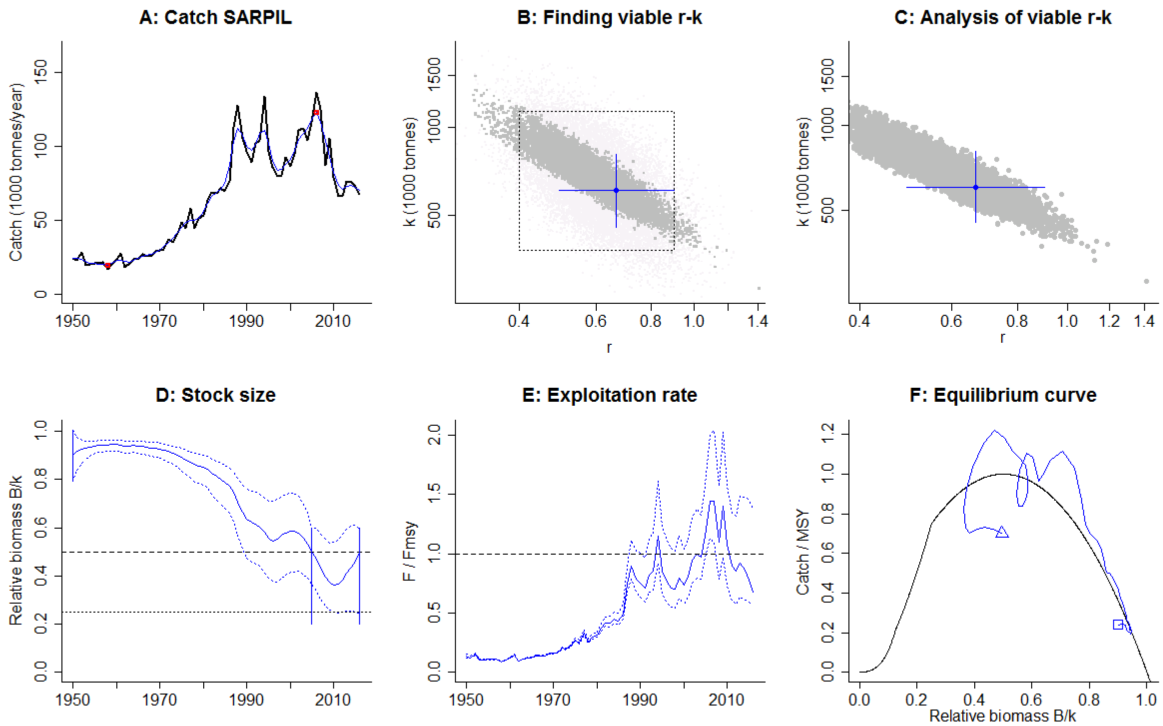


Figure 61. CMSY results for the stock of *Engraulis encrasicolus* for Algeria and Morocco (Mediterranean).

a)



b)

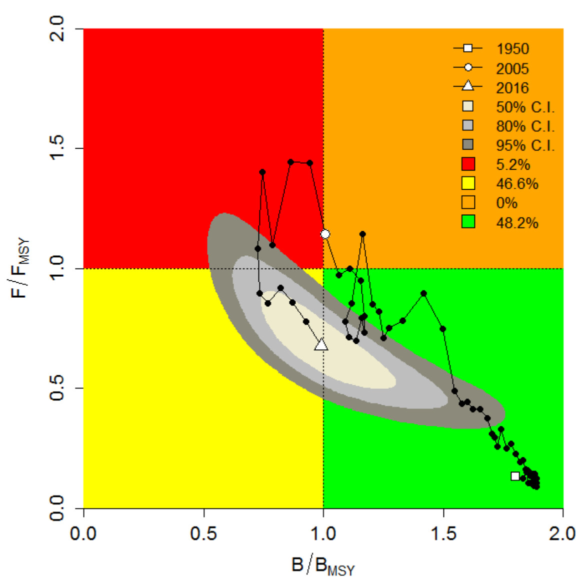
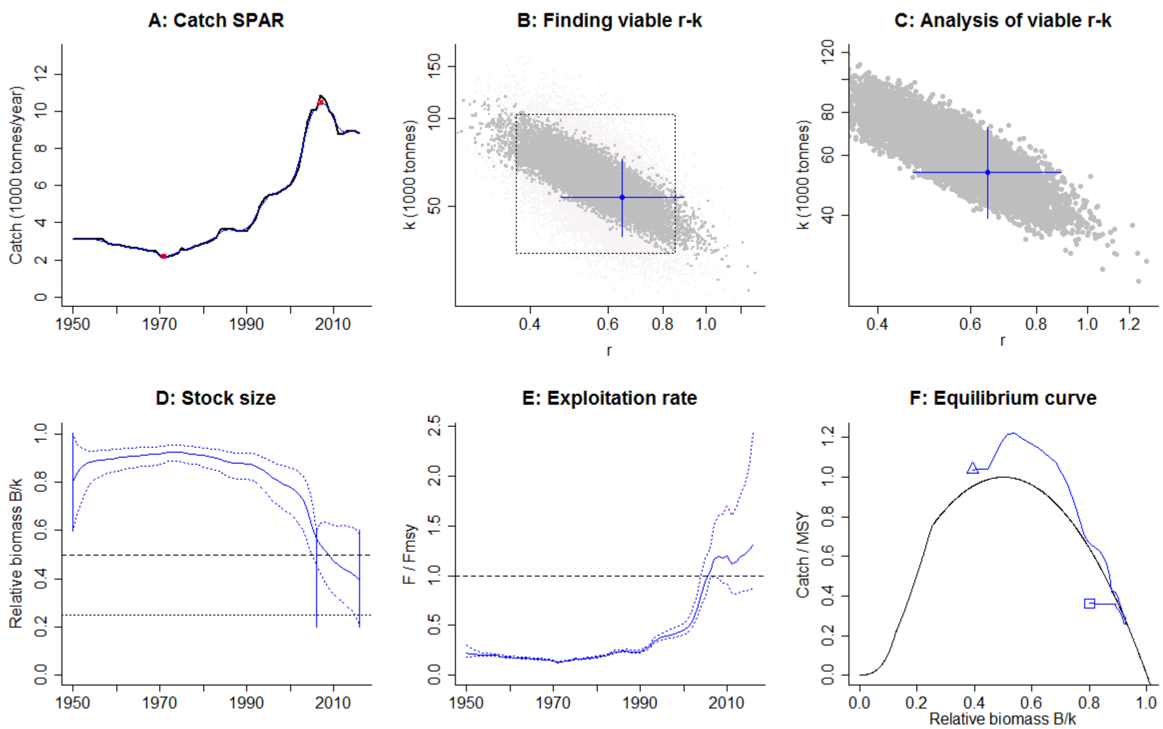


Figure 62. CMSY results for the stock of *Sardina pilchardus* for Algeria and Morocco (Mediterranean).

a)



b)

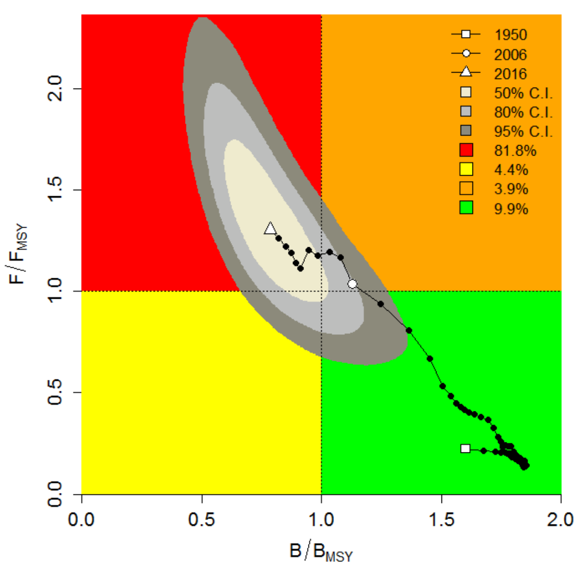
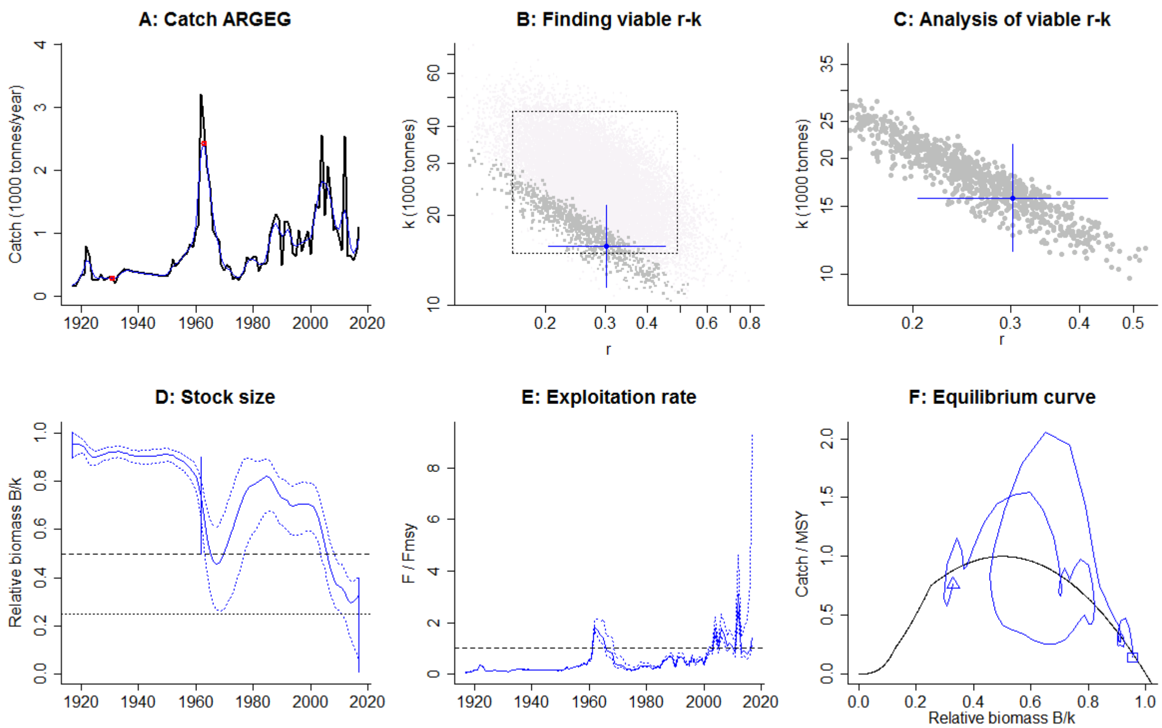


Figure 63. CMSY results for the stock of *Sparus aurata* for Algeria and Morocco (Mediterranean).

a)



b)

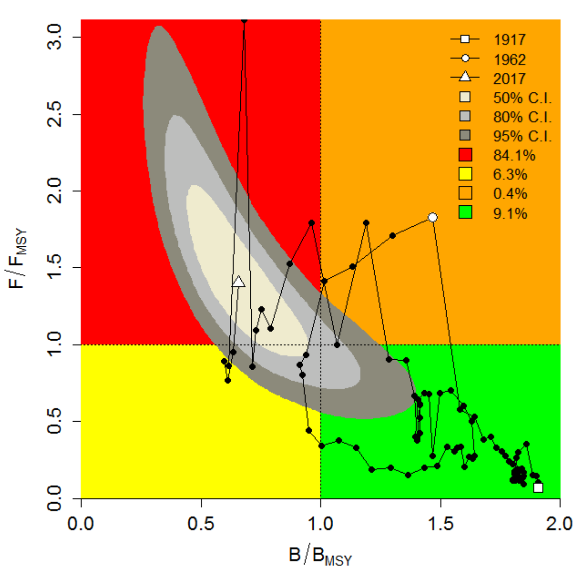
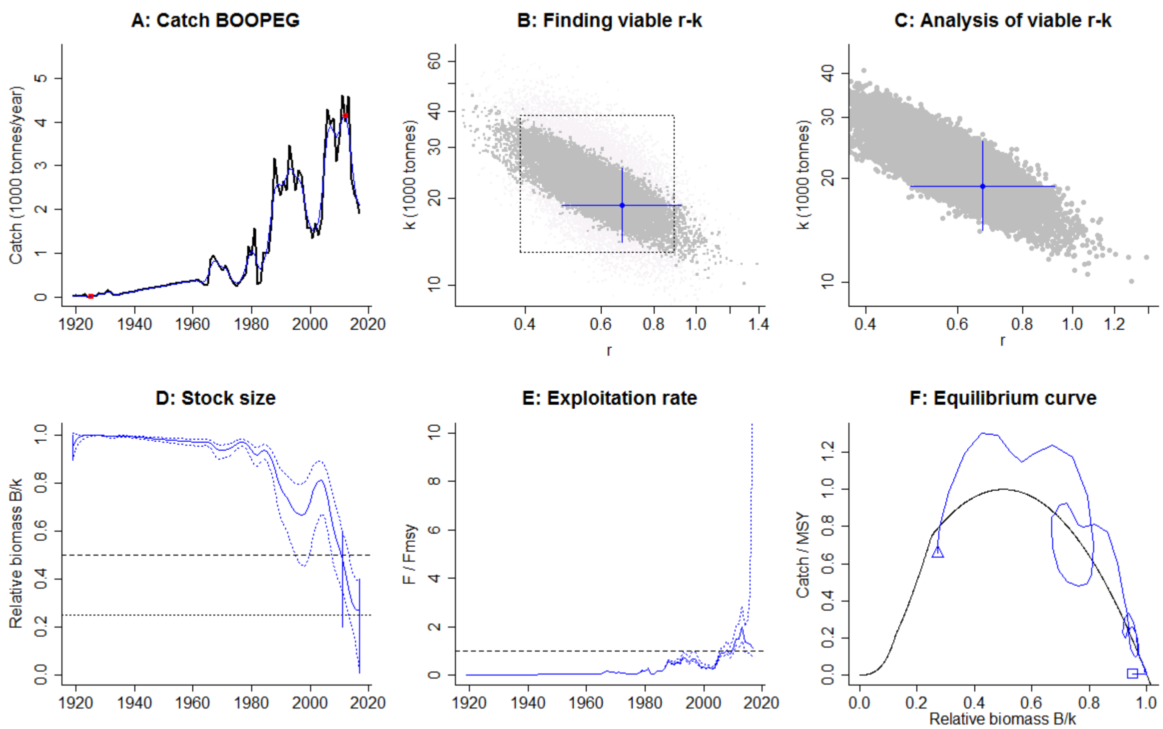


Figure 64. CMSY results for the stock of *Argyrosomus regius* for Egypt (Mediterranean).

a)



b)

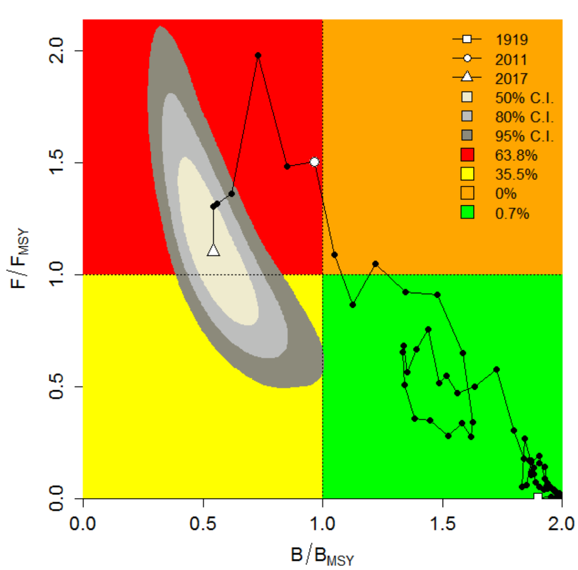
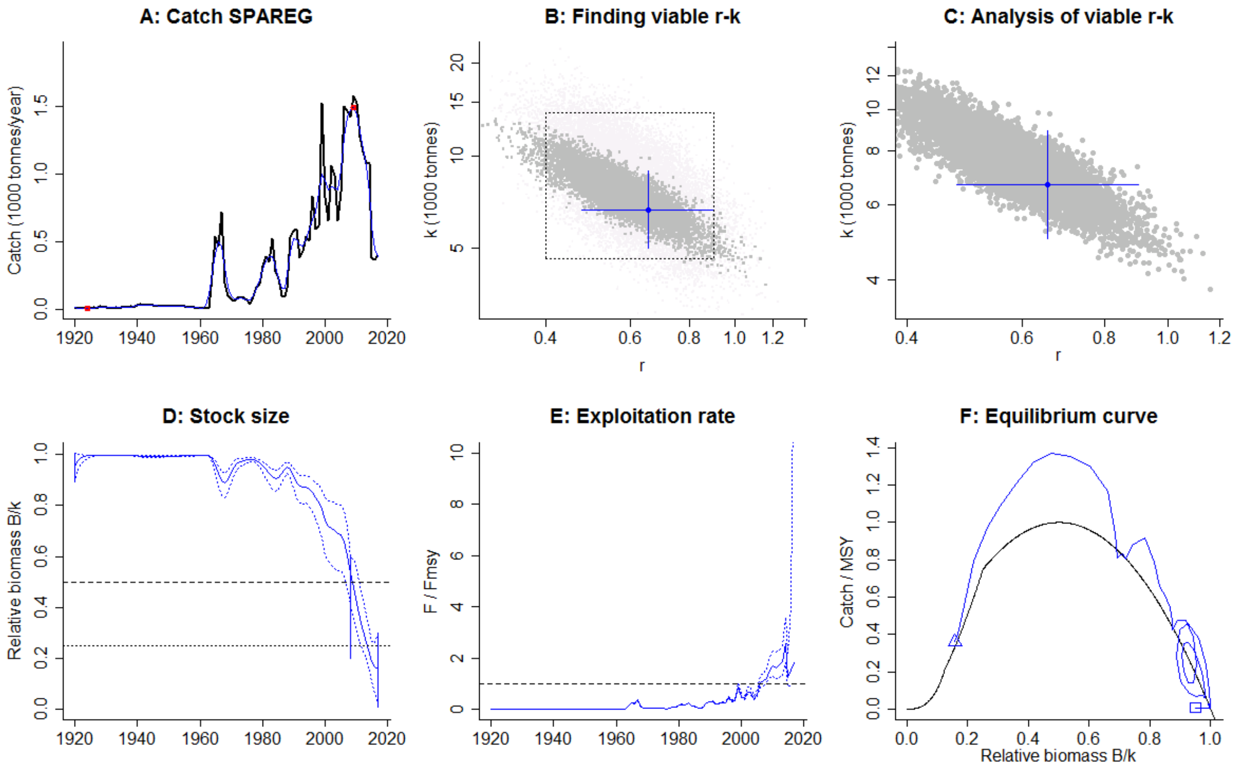


Figure 65. CMSY results for the stock of *Boops boops* for Egypt (Mediterranean).

a)



b)

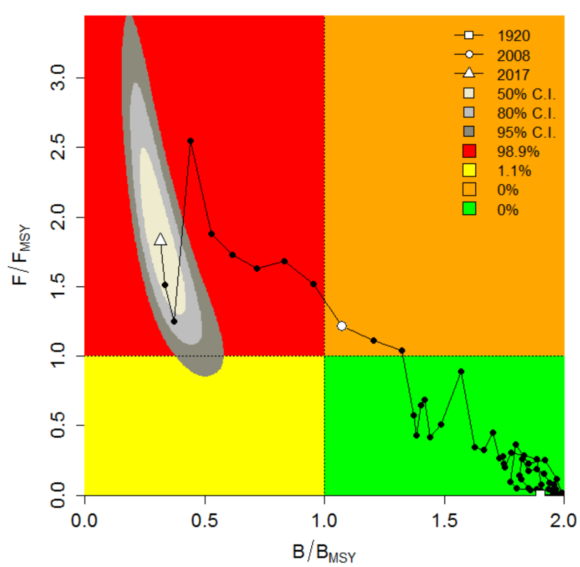
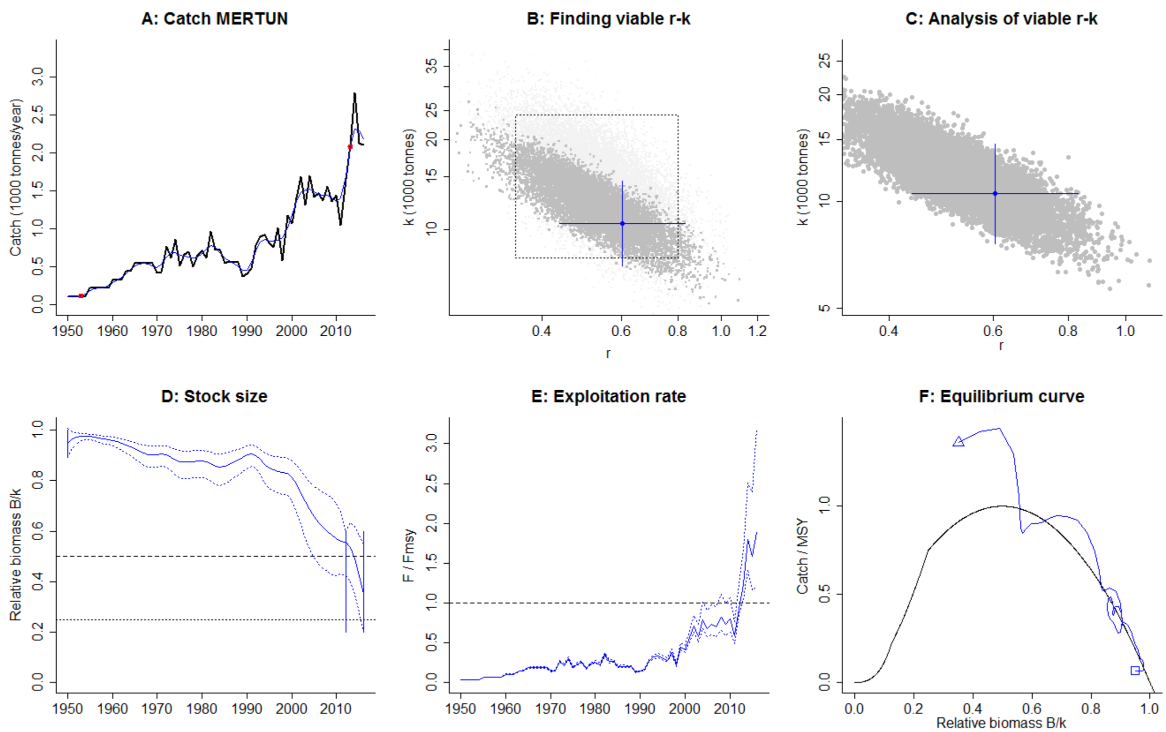


Figure 66. CMSY results for the stock of *Sparus aurata* for Egypt (Mediterranean).

a)
b)



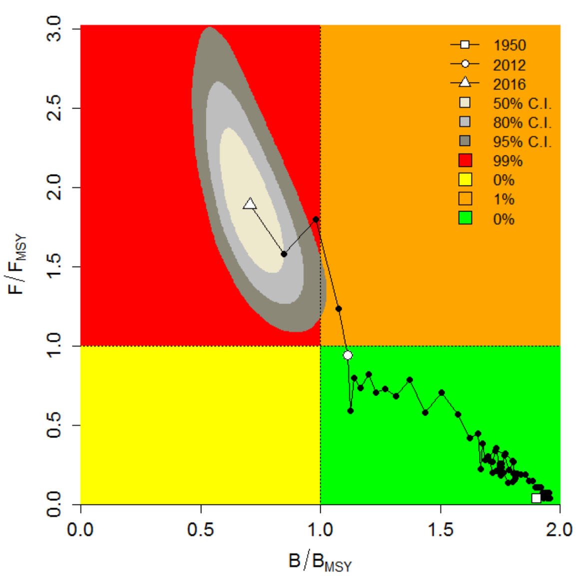
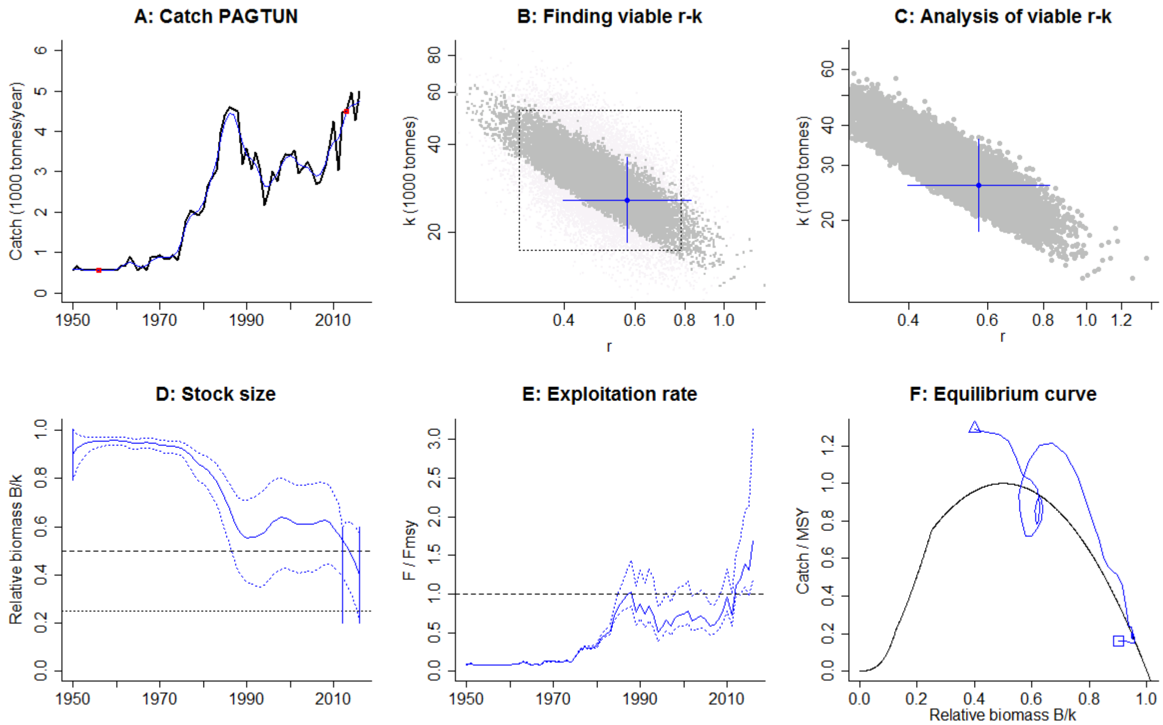


Figure 67. CMSY results for the stock of *Merluccius merluccius* for Tunisia.

a)



b)

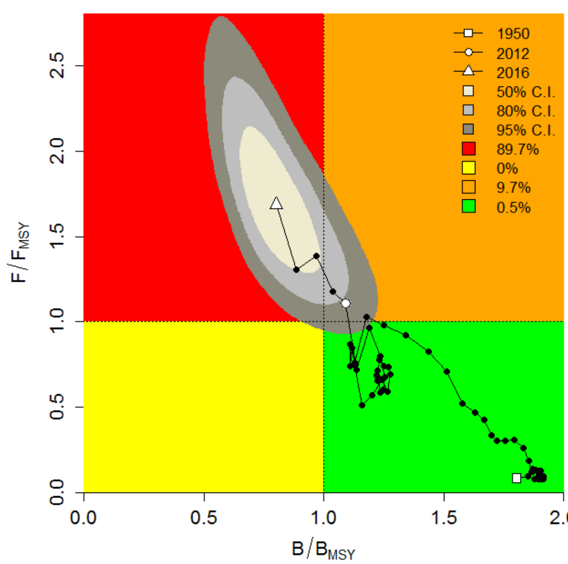
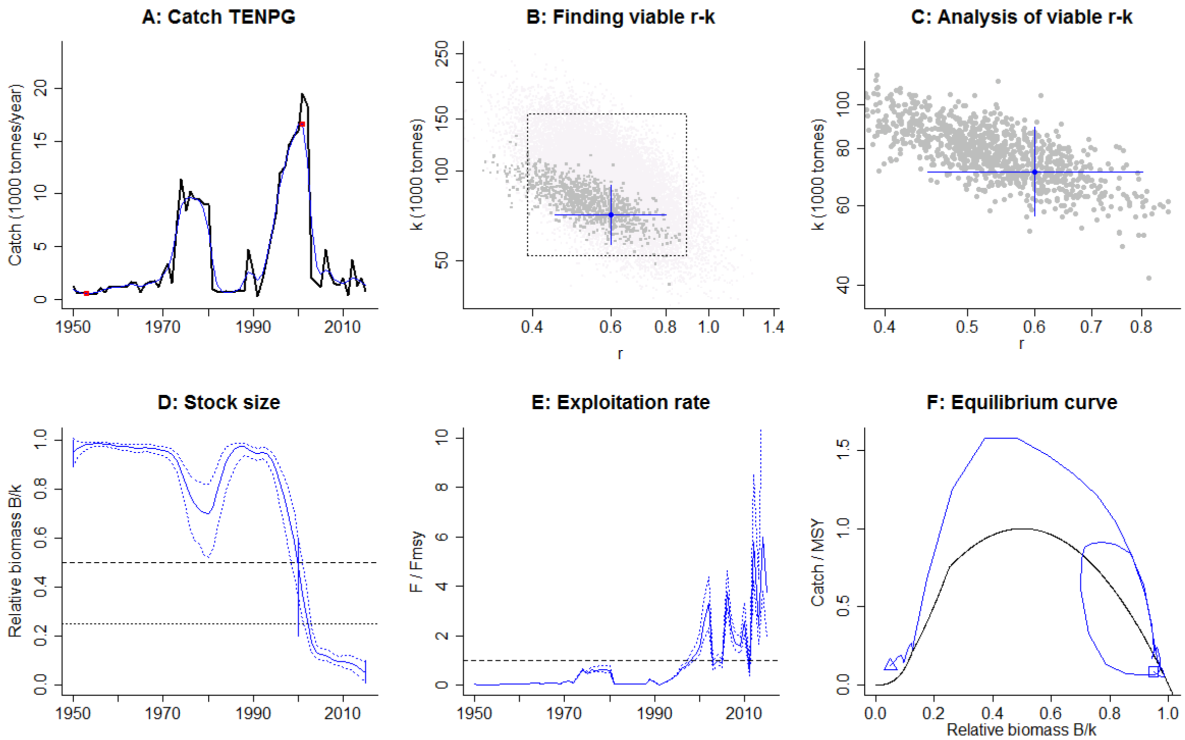


Figure 68. CMSY results for the stock of *Pagellus erythrinus* for Tunisia.

a)



b)

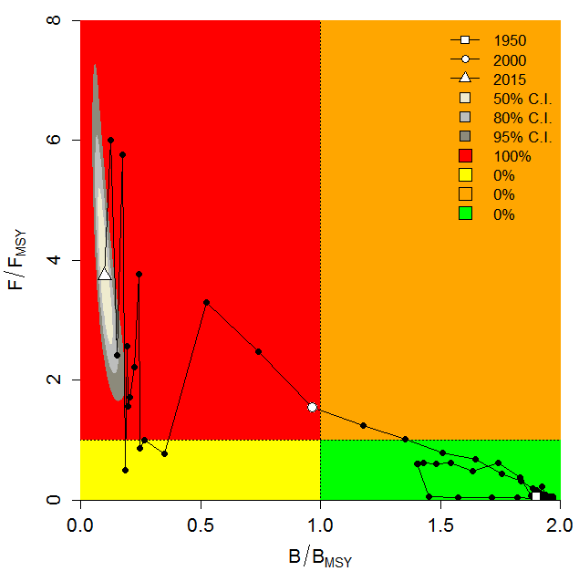
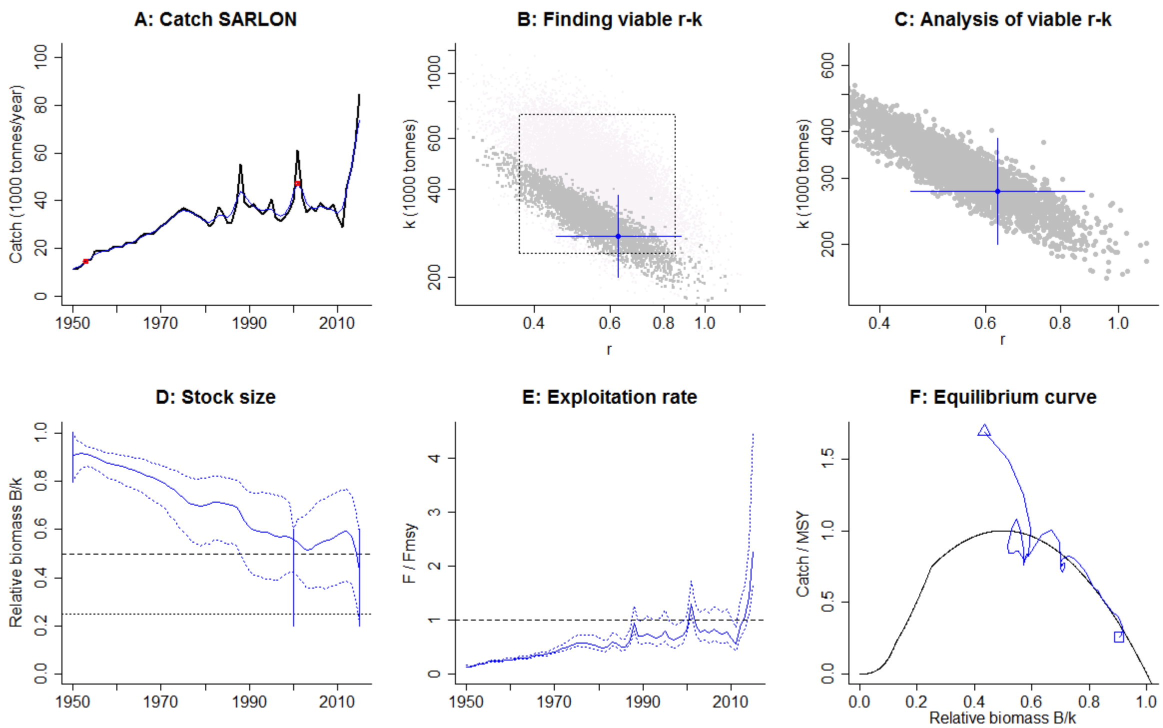


Figure 69. CMSY results for the stock of *Tenualosa ilisha* for Iraq and Kuwait.

a)



b)

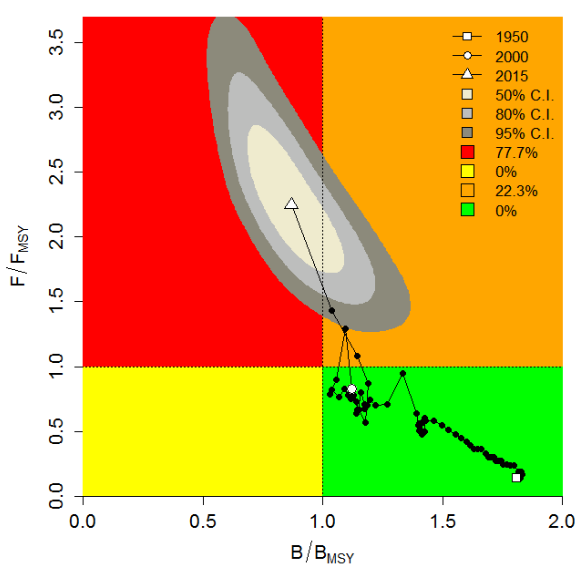


Figure 70. CMSY results for the stock of *Sardinella longiceps* for Oman and Fujairah.

4.4 Discussion

The results of the CMSY analysis completed herein suggest that 9 out of the 10 assessed fish stocks are currently overfished. The stock of *Engraulis encrasicolus* within the Mediterranean EEZs of Algeria and Morocco has been fished beyond MSY levels since the 1980s leading to a strong decrease of biomass (Figure 61a). The results suggest that due to an increase in fishing pressure in the mid-1980s, the stock size of *Engraulis encrasicolus* within the Mediterranean waters of Algeria and Morocco decreased relative to B_{MSY} and is currently overfished (Figure 61b; Table 49). These results are corroborated by local stock assessments for this species such as in the bay of Algiers for 2000 by Bouaziz and Bennoui (2004) and in Eastern Algeria for 2016 by Benchikh *et al.* (2018). Both of these studies found the stock of *Engraulis encrasicolus* to be overfished in Algerian waters.

The catch of *Sardina pilchardus* within the Mediterranean EEZs of Algeria and Morocco has been mostly below MSY levels with occasional overfishing, e.g., late 2000s (Figure 62). The overall decrease in landings after 2010 was translated by the CMSY method as a decrease of exploitation rate and a light increase in stock biomass, but this is highly uncertain (see 'E: Exploitation rate' in Figure 62a). If CPUE data were available for these years it would probably improve the stock assessment post-2010. The state of this stock worsened around the mid-2000s due to an increase in fishing pressure. By 2016 the situation improved with a decrease in fishing mortality (Figure 62b; Table 49). However any increase of fishing pressure would reduce the size of the exploited to below B_{MSY} (i.e., in 2016 $B \approx B_{MSY}$); so unless preventive measures are taken, this stock could be overfished. A stock assessment of the *Sardina pilchardus* by Bouaziz *et al.* (2014) along the central coast waters of Algeria concluded that the state of the stock changed from being healthy in 2001 to being overfished in 2011, which corresponds to the results of our stock assessment. Bedairia and Djebar (2009) assessed the stock of *Sardina pilchardus* in the eastern coast of Algeria in 2006-2007 and found that the stock was 'moderately exploited' but that fishing effort should not increase. So the state of the different sub-stocks along the Algerian and the Moroccan coasts could be different, but overall it seems like fishing pressure should be decreased.

The stock of *Sparus aurata* within the Mediterranean EEZs of Algeria and Morocco was healthy between 1950 and 2005, after which an increase in fishing pressure (in 2006-2016) reduced the size of the exploited stock to below B_{MSY} (Figure 63; Tables 48 and 49). A stock assessment of the *Sparus aurata* within the lagoon of the Mellah in eastern Algeria revealed that overfishing was occurring during the beginning of the 2000s (see Chaoui and Kara (2011).

The stock of the *Argyrosomus regius* within the Mediterranean EEZ of Egypt was assessed for 1917-2017 using the CMSY method. This stock was intensively overfished during the early 1960s due to a tremendous increase in fishing pressure within the Mediterranean marine fisheries of Egypt at the time (see Chapter 3). After a significant reduction of biomass, likely worsened by the construction of the Aswan high Dam (see Chapter 3), the stock recovered. However, it has been fished beyond MSY levels since the early 2000s leading to a significant decline of the exploited biomass to below B_{MSY} (Figure 64; Table 49). As per 2017, this stock seems to be overfished. It should be noted that juveniles of this species have been fished from the Egyptian Nile delta, a natural spawning area for this fish, and farmed in brackish-water ponds (Haffray *et al.* 2012; Arechavala-Lopez *et al.* 2015). The farming of this fish seems to have intensified since the late 2000s (see El-Shebly *et al.* (2007), Sadek *et al.* (2009) and Arechavala-Lopez *et al.* (2017)) . Hence, the overfishing of the *Argyrosomus regius* could be also a result of recruitment overfishing.

The stock of *Boops boops* within the Mediterranean waters of Egypt was assessed for 1917-2017 using the CMSY method. This stock seemed healthy until the increase of fishing effort in the late 2000s reduced the stock, leading to overfishing starting 2010. Despite the decrease of the exploitation rate since 2011 due to the Egyptian revolution of 2011, and consequently the temporary decrease in fishing effort, the exploited biomass seems to have slightly increased but is still below B_{MSY} (Figure 65; Tables 48 and 49). Studies regarding the state of the Egyptian Mediterranean *Boops boops* stock by Allam (2003) and by El-Haweet *et al.* (2005) for 1999 and 2003-2004 , respectively, found the stock to be ‘moderately exploited’ and fished at MSY levels, which validates our results for the years in question. A more recent stock assessments by Azab *et al.* (2019) for 2018 found the stock to be overfished, which validates our results for 2017. A stock assessment by Mehanna (2014) for 2007-2009 also found the stock of *Boops boops* along the Egyptian Mediterranean coast to be overfished. These results are slightly different from those presented here. If other data such as CPUE or initial abundance were available, these results would likely have been closer to those of Mehanna (2014).

The stocks of *Sparus aurata* was assessed for the Mediterranean waters of Egypt for 1917-2017. Catches from these stocks decreased by over 50% in 2015. This might have been a result of increased fishing pressure (Figures 66; Table 48), resulting in a significant reduction in the size of these stocks since 2008. A stock assessment for *Sparus aurata* by Mehanna (2007) for 2004-2005 in Port Said, eastern Mediterranean coast of Egypt, revealed the stock to be overfished due to high fishing pressure. However, our results suggest a healthy stock of *Sparus aurata* in those years. If CPUE data information for instance were available, they could have probably generated results closer to those of Mehanna (2007).

Merluccius merluccius and *Pagellus erythrinus* within the EEZ of Tunisia were assessed using the CMSY method. These stocks seemed healthy until 2012 when fishing pressure reduced the exploited biomasses for each of these stocks to below B_{MSY} (Figures 67 and 68, respectively; Tables 48 and 49). A stock assessment for *Merluccius merluccius* within the waters of Tunisia, Italy and Malta (GFCM (2018) and within Tunisian waters only (Khoufi 2015) concluded that the stock was strongly overfished, which validates our results. Moreover, a study by Jarboui *et al.* (1998) on the state of *Pagellus erythrinus* in the Golf of Gabes, southern Tunisia, in the early 1990s suggested that recruitment overfishing was already occurring then. It is not clear whether this situation extended to the remaining Tunisian waters, as most fishing in Tunisia does occur in the Golf of Gabes. Additional data (priors) would help improve the results of our analysis. The stock of *Tenualosa ilisha* within Iraq and Kuwait was assessed for 1950-2015. This stock started being intensively fished in the 1970s. Due to the 1980-1988 Iran-Iraq War, followed few years later by the Iraq-Kuwait War, the coastal waters became unsafe for fishers to operate in (see

Chapter 2), which allowed for the stock to recover (Figure 69). However, the increase of the fishing pressure in the 1990s led in 2000 to a considerable reduction of the stock of *Tenualosa ilisha* (Figure 69; Tables 48 and 49). The occasional reduction of fishing pressure due to wars in Iraq in the 2000s did not really help mitigate the effects of the intensive fishing during the 1990s. The stock size was very low as per 2015. Other factors such as climate change and pollution might have contributed to the state of this stock (see Chapter 2). According to Al-Dubakel (2011) and Mohamed and Qasim (2014) *Tenualosa ilisha* within Iraqi waters is overfished. Iranian sources also reported that in the late 2000s that *Tenualosa ilisha* within the Iranian waters (adjacent to Iraq's) was overfished; see Hashemi *et al.* (2010) and Roomiani and Jamili (2011).

The stock of *Sardinella longiceps* within the EEZs of Oman (including the province of Musandam) and Fujairah (an Emirate of the UAE) was assessed using the CMSY method. This stock was healthy until the early 2000s, after which an increase in fishing pressure caused the stock size to decline (Figure 70). CPUE data are badly needed to reduce of this assessment.
In this chapter 10 stocks from the Southern Mediterranean and the Arabian Peninsula regions were assessed, 9 of which were found to be overfished with *Sardina pilchardus* as the only exception. This analysis was completed using only catch data as a basis. It could be much improved if other data were introduced as priors to the model. Nonetheless, the results regarding the current state of the stocks were confirmed by external sources for most of these assessments.

Chapter 5: Conclusion

Synopsis: This chapter presents the conclusions derived from the previous four chapters, as well as some general recommendations.

Self-proclaimed 'global studies' and 'regional studies' in fisheries science have more often underrepresented and even excluded the marine fisheries of economically developing countries (Pauly *et al.* 2015). In the meantime, most economically developing countries have been struggling with the management of their own fisheries due to the lack of 'mainstream' fisheries data, i.e., formal stock assessments and fisheries reference points, and the inability to properly manage fisheries without such data (Mahon 1997; Pauly 1997; Alabsi and Komatsu 2014). The goal of this thesis is to describe approaches to help deal with these shortcomings.

Chapter 1 expands upon the combination of factors that make most fisheries in economically developing countries truly data-poor in opposition to data-poor fisheries in the economically developed countries. The 17 countries that constitute the Southern Mediterranean and the Arabian Peninsula regions, i.e., Algeria, Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco (Mediterranean), Oman, Palestine, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates, and Yemen, are economically developing countries (some of which are low to medium income and others are high income countries[31]), and for which fishing is a several-millennia old

[31] The World Bank (Online) World Bank Country and Lending Groups available at https://datahelpdesk.worldbank.org/knowledgebase/articles/906519 [accessed on 04/02/2020]

activity. That said, fisheries of the SMAP regions are relatively data-poor. Besides dealing with similar issues as the remaining economically developing countries most of the SMAP countries have had at least one major turmoil event since the 1950s, e.g., the civil war in Algeria in the 1990s (see Belhabib *et al.* (2012) and Chapter 2 subsection 2.4.1.1.), the decennial wars in Iraq (Chapter 2 subsection 2.4.1.4), the Libyan turmoil since 2011 and the consequential people-smuggling issue (Chapter 2 subsection 2.4.1.8), the ongoing Palestinian crisis (see Abudaya *et al.* (2013a) and Chapter subsection 2.4.1.10.), the war in Syria and the refugee crisis (see Chapter 2 subsection 2.4.1.13.), the current war and humanitarian crisis in Yemen (Chapter 2 2.4.1.17), and the so-called 'Arab Spring" in the entire region.

In Chapter 2, I explored the impacts of political and socio-economic instabilities on the fisheries catches and management of each of these countries individually. As previously stated by Hendrix and Glaser (2011), McClanahan *et al.* (2015), Belhabib *et al.* (2018), and Belhabib *et al.* (2019), political and socio-economic crisis significantly affects fisheries and depending on the conflict's epicentre, could lead to an increase in the demand for fish and thus in subsistence and commercial fishing, e.g., Algeria, or to a decrease of fishing overall mostly due to safety reasons, as was the case in west Yemen and Libya.

Fisheries catch data is one of the few available information on fisheries in the SMAP regions, as is the case in other economically developing regions. (Pauly and Zeller 2016a). However, such data are often incomplete as discussed in Chapter 1 and Chapter 2; see also Jerven (2013). Hence, in Chapter 2, marine fisheries catches for the SMAP countries were reconstructed, including reported and unreported, small- and large- scale, and commercial and non-commercial landings, and discards. The uncertainty quantification of the catch reconstructions were also updated based on a two criteria approach that provides a simplified summary of the methods and information sources used in catch reconstructions in general.

In Chapter 3, the marine fisheries for the Mediterranean EEZ of Egypt were reconstructed for 1917 to 2017. This study showed that major events in Egyptian history have had significant impact on its Mediterranean fisheries. Case in point, the building of the Aswan High Dam combined with intensification of fishing effort in the region caused the near collapse of the fisheries in the Nile delta until anthropogenic nutrients replaced the missing nutrients from the Nile (Nixon 2003). The Suez Canal also led to the phenomenon of invasive species in the Mediterranean that has been threatening several endemic species and fisheries in the Mediterranean overall (Por 1971; Hiddink *et al.* 2012).

The Marine Trophic Index (MTI; Pauly and Watson 2005a) was applied to the reconstructed catch for Egypt and showed that 'fishing down' has been occurring since 1971 around the same time the Mediterranean fisheries of Egypt were close to depletion. Until the late 1960s the marine trophic level was increasing, most likely as a result of a modernization of the fishery that allowed catch of higher trophic level. The Mean Temperature (MTC; Cheung *et al.* 2013) of the reconstructed catch was also computed for Egypt and showed a slow increase since the mid-1930s that intensified since 2003, likely as a result of the acceleration of climate change.

The reconstructed catch for the 17 SMAP countries in Chapter 2 and Chapter 3 showed that unreported catch consisted mostly of unreported artisanal landings and industrial discards in both SMAP regions in addition to important unreported industrial landings in the Southern Mediterranean. While discards are virtually never reported in most countries around the world and are mostly generated in the industrial sector, by trawlers (Kelleher 2005b; Pauly and Zeller 2016a), the under-estimation of artisanal landings is a result of the isolated rural nature of most artisanal fisheries in the SMAP regions. Besides, most governments within the SMAP countries have not invested in the artisanal fishing industry but rather in the industrial fisheries as discussed in Chapter 2 (also see Schuhbauer *et al.* 2017).

The overall trend of the reconstructed catch for the 17 countries showed a decrease that may be a result of the combination of the post-2011 events in some countries and a sign of overfishing in most, which was the main focus of Chapter 4.

In Chapter 4 the recently developed CMSY catch-based stock assessment method of Froese *et al.* (2017) was applied to the reconstructed catch of 10 stocks from around the SMAP regions consisting of 3 stocks from Algeria/Morocco, 2 stocks from Tunisia, 3 stocks from Egypt, 1 stock from the Omani waters (including the waters of Fujairah), and one stock from the EEZs of Iraq and Kuwait. The results, which were corroborated by several local articles showed that 9 out of 10 of these assessed stocks are overfished.

Several recommendations could be deduced from the results in the aforementioned chapters. The first one is that artisanal fisheries are crucial to the society and economy of most of the SMAP regions and that they deserve more attention and credit from their government. Industrial-fisheries-centered assessments are not appropriate to manage fisheries that are dominated by the small-scale sector (Mahon 1997; Pauly 1997).

Furthermore, scientists and managers should be better trained to better adapt their fisheries evaluations and management strategies to the data-poor fisheries in economically developing countries instead of trying to unsuccessfully impose inadequate costly methods requiring fisheries-independent data.

This thesis shows that with simple recently developed tools it is possible to assess the state of data-poor fisheries within economically developing countries even of those where turmoil has occurred. Fisheries scientists from economically developed countries should try to better understand the complexities of data-poor fisheries within economically developing countries and accept the differences between the fisheries in their own regions and those in the rest (and majority) of the world. Instead of assuming that their fisheries are 'globally' representative they should collaborate with scientists from economically developing countries. This should not come from a neo-colonial and/or savior perspective as previously highlighted by Aprieto *et al.* (1986) but rather from a collaborative and learning perspective because local scientists and managers know their own fisheries better than foreign scientists. This collaboration can be as simple as publishing in open access journals, which are accessible to all at no cost, to transforming fisheries science in accordance with the principles of global studies.

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Appendices

Appendix A

Appendix A. Table 1. Population, Land area, EEZ and Continental Shelf of the SMAP countries in 2017.

Country	Population[32] (Thousands)	Land area[1] (km^2)	LME	EEZ[33] (km^2)	Shelf (km^2)
Algeria	41,318	2,381,741	Mediterranean Sea	126,353	9,985
Bahrain	1,493	771	Arabian Sea	10,225	10,225
Egypt	97,553	995,450	Mediterranean Sea	169,125	31,017
			Red Sea	91,279	23,180
Iraq	38,275	434,320	Arabian Sea	771	771
Jordan	9,702	88,780	Red Sea	166	59
Kuwait	4,137	17,820	Arabian Sea	11,026	11,026
Lebanon	6,082	10,230	Mediterranean Sea	19,516	1,067
Libya	6,375	1,759,540	Mediterranean Sea	351,589	64,763
Morocco[34]	35,740	446,300	Mediterranean Sea	18,302	4,933
Oman	4,636	309,500	Arabian Sea	533,180	59,071
Palestine[35]	4,674	6,020	Mediterranean Sea	256	256
Qatar	2,639	11,610	Arabian Sea	31,590	31,590
Saudi Arabia	32,938	2,149,690	Arabian Sea	33,792	33,791
			Red Sea	186,392	69,756
Syria	18,270	183,630	Mediterranean Sea	10,503	1,085
Tunisia	11,532	155,360	Mediterranean Sea	101,857	67,126
UAE	9,400	83,600	Arabian Sea	58,218	57,474
Yemen	28,250	527,970	Arabian Sea	509,240	28,566
			Red Sea	35,861	25,923

32 www.WorldBank.org
33 www.SeaAroundUs.org
34 Morroco shares an EEZ with the Atlantic Ocean that is not included in this work
35 West Bank and Gaza

Appendix B

Appendix B. Table 1. Different catch reconstruction (CR) work completed the 17 SMAP countries.

Country	CR update	CR improvement	Fully completed CR	Time Period
Algeria	X			2011-2016
Bahrain		X		1950-2015
Egypt (Med)*			X	1917-2017
Egypt (Red Sea)	X			2011-2017
Fujairah (UAE)			X	1950-2015
Iraq			X	1950-2016
Jordan		X		1950-2015
Kuwait	X			2011-2015
Lebanon		X		2007-2016
Libya			X	1950-2017
Morocco (area 37)		X		2010-2016
Oman (x2) **			X	1950-2015
Palestine	X			2011-2015
Qatar	X			2011-2015
Saudi Arabia (x2)**	X			2011-2016
Syria	X			2011-2015
Tunisia		X		1950-2016
UAE (Persian Gulf)	X			2011-2015
Yemen (x2)**	X			2011-2017

*Completed as chapter 3 of this thesis;

** Two fisheries, and hence two catch reconstructions for one country.

Appendix B. Table 2. References for previously completed reconstructions that were updated herein.

Country	Reference
Algeria	Belhabib D, Pauly D, Harper S and Zeller D (2012) Reconstruction of Marine Fisheries Catches for Algeria, Marine Fisheries Catches in West Africa Part I. Fisheries Centre Research Reports 20(3): 1-22.
Egypt (Red Sea)	Tesfamichael D and Mehanna SF (2012) Reconstructing Red Sea fisheries of Egypt: Heavy investment and fisheries. pp. 23-50 *In* Tesfamichael D and Pauly D (eds.), Catch reconstruction for the Red Sea large marine ecosysytem by countries (1950-2010). Fisheries Centre Research Reports 20(1). Fisheries Centre, University of British Columbia.
Kuwait	Al-Abdulrazzak D (2013c) Reconstructing Kuwait's marine fishery catches: 1950-2010. pp. 23-29 *In* Al-Abdulrazzak D and Pauly D (eds.), From dhows to trawlers: a recent history of fisheries in the Gulf countries, 1950 to 2010. Fisheries Centre Research Reports 21(2). Fisheries Centre, University of British Columbia.
Lebanon	Nader MR, Indary S and Moniri NR (2014) Historical Fisheries Catch Reconstruction for Lebanon (GSA 27), 1950-2010. Fisheries centre Working Paper Series 11: 19.
Morocco	Belhabib D, Harper S, Zeller D and Pauly D (2013) Reconstruction of marine fisheries catches from Morocco (north, central and south), 1950-2010. Fisheries Centre Research Reports 20(3). pp. 23-40 *In* Belhabib D, Zeller D, Harper S and Pauly D (eds.), Marine fisheries catches in West Africa, 1950-2010, part I. Fisheries Centre, University of British Columbia.
Palestine	Abudaya M, Harper S, ulman A and Zeller D (2013) Correcting mis - and under-reported marine fisheries catches for the Gaza Strip: 1950-2010. ACTA ADRIAT 54(2): 241-252.
Qatar	Al-Abdulrazzak D (2013d) Total fishery extractions for Qatar: 1950-2010. pp. 31-37 *In* Al-Abdulrazzak D and Pauly D (eds.), From dhows to trawlers: a recent history of fisheries in the Gulf countries, 1950 to 2010. Fisheries Centre Research Reports 21(2). Fisheries Centre, University of British Columbia.
Saudi Arabia (Red Sea)	Tesfamichael D and Rossing P (2012) Reconstructing Red Sea fisheries catches of Saudi Arabia: National wealth and fisheries transformation. pp. 153-178 *In* Tesfamichael D and Pauly D (eds.), Catch reconstruction for the Red Sea large marine ecosysytem by countries (1950-2010). Fisheries Centre Research Reports 20(1). Fisheries Centre, University of British Columbia.

Appendix B. Table 2. References for previously completed reconstructions that were updated herein.

Saudi Arabia (Persian Gulf)	Tesfamichael D and Pauly D (2013) Catch reconstruction of the fisheries of Saudi Arabia in the Gulf, 1950-2010. pp. 39-52 *In* Abdulrazzak DA and Pauly D (eds.), From dhows to trawlers: a recent history of fisheries in the Gulf countries, 1950 to 2010. Fisheries Centre Research Reports 21(2). Fisheries Centre, University of British Columbia.
Syria	Ulman A, Saad A, Zylich K, Pauly D and Zeller D (2015) Reconstruction of Syria's Fisheries Catches from 1950-2010: Signs Of Overexploitation. Acta Ichthyologica et Piscatoria 15: 259.
UAE (excluding Fujairah)	Al-Abdulrazzak D (2013a) Estimating total fish extractions in the United Arab Emirates: 1950-2010. pp. 53-59 *In* Al-Abdulrazzak D and Pauly D (eds.), From dhows to trawlers: a recent history of fisheries in the Gulf countries, 1950 to 2010. Fisheries Centre Research Reports 21(2). Fisheries Centre, University of British Columbia.
Yemen (Red Sea)	Tesfamichael D, Rossing P and Saeed H (2012) The marine fisheries of Yemen with emphasis on the Red sea and cooperatives. pp. 105-134 *In* Tesfamichael D and Pauly D (eds.), Catch reconstruction for the Red Sea large marine ecosystem by countries (1950-2010). Fisheries Centre Research Reports 20(1). 20, Fisheries Centre, University of British Columbia.
Yemen (Arabian Sea)	Tesfamichael D, Rossing P and Saeed H (2012) Reconstruction of Yemen's catches in the Gulf of Aden, 1950–2010. pp. 135-152 *In* Tesfamichael D and Pauly D (eds.), Catch reconstruction for the Red Sea large marine ecosystem by countries (1950-2010). Fisheries Centre Research Reports 20(1). 20, Fisheries Centre, University of British Columbia.

Appendix C

C.1. Estimation the Egyptian rural Mediterranean coastal population

C.1.1. Total rural population of the Egyptian Mediterranean costal governorates

This population represents people living within the rural areas of the 8 Egyptian Mediterranean coastal governorates, i.e., Alexandria, Port Said, Matruh, North Sinai, Damietta, Dakahlia, Kafr el-Sheikh and Beheira. This information was only available for certain years, i.e., 1966, 1976, 1986, 1996, 2014 and 2017, as summarized in Table C.1.1.1.

Table C.1.1.1 Total and rural population within the Mediterranean coastal governorates in Egypt and information sources.

Year	Total Population	Rural population	Sources
1917	2,549,893	-	CAPMAS (1921)
1937	3,227,384	-	Law (2015)
1947	3,981,962	-	Law (2015)
1957	6,204,000	-	Law (2015)
1966	6,990,148	3,857,296	CAPMAS (1976)
1976	9,878,249	5,559,767	CAPMAS (1987b)
1986	12,942,546	7,155,646	CAPMAS (n.d.)
1996	15,641,002	8,707,572	CAPMAS (1998)
2007	19,325,000	-	CAPMAS (2019c)
2008	19,782,000	-	CAPMAS (2019a)
2009	20,289,000	-	CAPMAS (2019a)
2010	20,771,000	-	CAPMAS (2019a)
2011	21,245,000	-	CAPMAS (2019a)
2012	21,710,000	-	CAPMAS (2019a)
2013	22,261,000	-	CAPMAS (2019a)
2014	22,618,571	12,563,898	CAPMAS (2015)
2015	23,263,000	-	CAPMAS (2019a)
2016	23,804,000	-	CAPMAS (2019a)
2017	24,312,017	13,565,878	CAPMAS (2019a)

The following describes how the rural population of the Egyptian Mediterranean costal governorates A_i was estimated in the years with data, i.e., 1917-1965, 1967-1975, 1977-1985, 1987-1995, 1997-2013 and 2015-2016:

i. The total and rural populations of all of Egypt (i.e., not only the Mediterranean governorates) were available for the years 1917, 1927, 1937, 1947 and 1960 from Khalifa *et al.* (1973) (Table C.1.1.2). The annual percentage of the rural from the total population of all of Egypt was then estimated for each of these years and for the missing years (i.e., 1918-1926, 1928-1936, 1938-1946, and 1948-1959) by interpolation.

Table C.1.1.2 Total and rural population of all of Egypt for earlier years from Khalifa *et al.* (1973).

Year	Total Population	Rural population
1917	12,718,255	10,029,700
1927	14,083,276	10,367,436
1937	15,920,694	11,429,001
1947	18,805,926	12,603,610
1960	25,771,465	16,120,368

ii. The percentage of urban from total population of all of Egypt was available by year for 1960-2017 through the World Bank (www.WorldBank.com), the annual percentages of the rural Egyptian population were obtained from these.

iii. The total population of the coastal Mediterranean governorates was also available for certain years as summarized in Table C.1.1.2. To estimate this population for the missing years, linear interpolations were performed.

It was assumed that the percentage of the rural from the total population within the coastal Mediterranean Egyptian governorates was equal to the percentage of the rural from the total population of all of Egypt. The previously obtained annual percentages of rural from total populations of all of Egypt for 1917-2017 were applied to the total population of the Egyptian Mediterranean coastal governorates to obtain the rural population of the Egyptian Mediterranean coastal governorates A_i for the missing years.

C.1.2. Estimation of Fi: total rural population of the Egyptian coastal governorates

The rural population of the Egyptian Mediterranean coastal governorates was already estimated for each year of the study period in the step C.1.1. The rural population of the Egyptian Red Sea coastal governorates was available for 1986, 1996 and 2014 as summarized in Table C.1.2.1 . Interpolations were performed to obtain the rural population of the Egyptian Red Sea coastal governorates for 1990, 2000 and 2010.

Table C.1.2.1 Rural population of the Egyptian Red Sea coastal governorates and information sources.

Year	Rural population	Source
1986	309,687	CAPMAS (n.d.)
1996	422,425	CAPMAS (1998)
2014	742,761	CAPMAS (2015)

C.2. Estimation of the per capita subsistence catch rate

The *per* capita fish consumption rate in Egypt has increased over the years as summarized in Table C.2.1. These rates are for all of Egypt including consumption of both marine (Mediterranean and Red Sea) and freshwater fish.

Table C.2.1. Apparent *per* capita consumption rate in Egypt over the years and information source.

Year	*Per* capita consumption (kg·year^{-1})	Source
1920	3.20	Paget (1921)
1968	4.00	Aleem (1969)
1986	6.50	Dawoud (2005)
1991	8.30	EastMed (2014)
1995	8.40	Dawoud (2005)
1998	11.00	Lucchetti *et al.* (2016)
2000	13.68	Dawoud (2005)
2001	15.30	Dawoud (2005)
2009	17.60	EastMed (2014)
2012	20.55	Lucchetti *et al.* (2016)

To account for the missing years, interpolations and extrapolations were performed based on the above anchor points.

The contribution of aquaculture to the fish supply was made available for 1969-2017 by the national CAPMAS reports (CAPMAS 1973- 2006, 2006, 2007, 2008-2019, 2015). This contribution has increased drastically since the late 1970s from less than 1% to 20.5% of total Egyptian fish supply in 1984 to 10% in 1993 to 45% in 2000 to 79% in 2017 (CAPMAS 1979, 1987a, 1995, 2002, 2019d). According to Dawoud (2005) and EastMed (2014), the continuous increase of the *per* capita fish consumption rate in Egypt since the 1990s was due to the increase of the aquaculture fish supply. Available percentage contribution of aquaculture to the total fish supply were used to estimate the *per* capita fish consumption rate that excludes fish originating from aquaculture.

The *per* capita fish consumption rates in the rural regions of 6 Mediterranean coastal governorates (i.e., Damietta, Dakahlia, Kafr El-sheikh, Behera, Matruh and North Sinai) were averaged to be 11.14 $kg \cdot year^{-1}$ (Dawoud 2005). This is equivalent to 80% of the nationwide *per* capita fish consumption rate of 13.68 for the year 2000. It is then possible to assume that the *per* capita fish consumption rate along the Mediterranean coastal rural areas is similar to the rest of Egypt. The Egyptian Mediterranean coastal rural population has most likely gained increased access to markets and other food sources over the years. Furthermore, wild fish consumed within a 5 km range off the coast is likely originating from the Mediterranean shore waters. Based on all of this, the *per* capita subsistence catch rate for the rural population of the Mediterranean coast was assumed to be equivalent to around 30% of the estimated *per* capita consumption rate for wild fish in 1917 decreasing to only 3% in 2017. Interpolations were performed to account for the years between 1918 and 2016.

Appendix D

Appendix D. Table 1. Reported landings versus total reconstructed catch (in tonnes) by sector for the Egyptian Mediterranean, 1917-2017.

Year	Reported	Reconstructed	Industrial	Artisanal	Subsistence	Recreational	Discards
1917	-	4,532	-	3,308	458	-	453
1918	-	4,548	-	3,330	455	-	453
1919	-	5,540	655	3,466	503	-	631
1920	5,083	8,171	1,362	4,763	708	101	978
1921	4,972	7,969	1,387	4,604	681	75	958
1922	6,123	9,922	2,686	4,861	773	81	1,311
1923	6,001	9,659	2,447	4,901	757	59	1,252
1924	3,053	4,884	1,166	2,552	387	55	622
1925	3,129	4,949	953	2,807	404	68	599
1926	2,156	3,514	1,437	1,287	236	85	523
1927	3,506	5,604	1,740	2,576	405	65	761
1928	4,584	7,139	1,207	4,241	576	169	834
1929	5,300	8,189	1,169	5,082	667	148	925
1930	11,471	17,537	1,739	11,637	1,461	96	1,871
1931	7,972	12,288	2,185	7,259	955	77	1,435
1932	8,421	12,876	1,957	7,945	1,012	80	1,454
1933	9,837	14,841	1,333	10,064	1,212	92	1,545
1934	14,295	21,377	1,222	15,206	1,768	82	2,122
1935	8,280	12,559	2,196	7,539	942	93	1,442
1936	-	13,287	2,509	7,820	975	105	1,546
1937	-	14,012	2,840	8,082	1,006	105	1,652
1938	-	14,736	3,190	8,326	1,035	162	1,760
1939	-	15,457	3,559	8,551	1,063	145	1,870
1940	-	16,176	3,947	8,757	1,090	287	1,982
1941	-	16,892	4,352	8,945	1,113	356	2,096
1942	-	17,607	4,776	9,115	1,134	240	2,212
1943	-	18,320	5,217	9,267	1,154	253	2,331
1944	-	19,030	5,676	9,400	1,171	258	2,451
1945	-	19,739	6,153	9,515	1,187	241	2,574
1946	-	20,445	6,647	9,612	1,201	223	2,699
1947	-	21,150	7,157	9,691	1,214	215	2,827

Appendix D. Table 1. Reported landings versus total reconstructed catch (in tonnes) by sector for the Egyptian Mediterranean, 1917-2017.

Year	Reported	Reconstructed	Industrial	Artisanal	Subsistence	Recreational	Discards
1948	-	21,853	7,685	9,752	1,225	216	2,956
1949	-	22,554	8,230	9,795	1,235	222	3,088
1950	15,700	23,341	8,791	9,820	1,246	192	3,310
1951	18,500	27,576	10,701	11,226	1,429	197	4,052
1952	23,100	34,534	13,788	13,587	1,737	174	5,261
1953	14,800	22,198	9,104	8,430	1,089	173	3,506
1954	16,600	24,988	10,513	9,148	1,188	170	4,094
1955	19,600	29,620	12,767	10,439	1,364	160	5,033
1956	21,900	33,238	14,657	11,260	1,483	137	5,858
1957	22,900	34,826	15,366	11,681	1,395	123	6,292
1958	22,200	33,995	15,558	10,676	1,330	125	6,426
1959	21,500	32,533	13,327	11,843	1,286	71	5,912
1960	22,100	33,529	13,806	12,024	1,173	56	6,254
1961	23,800	36,263	15,174	12,616	1,107	56	6,988
1962	36,600	53,710	16,149	25,801	1,183	61	8,783
1963	32,300	48,594	17,955	19,352	1,433	65	9,098
1964	26,000	40,175	17,676	12,545	1,033	69	8,567
1965	24,700	38,268	16,613	12,065	859	77	8,282
1966	15,000	24,535	13,555	4,129	605	72	6,411
1967	13,800	22,349	11,580	4,572	700	67	5,723
1968	12,800	21,462	12,423	2,663	334	72	6,107
1969	12,100	18,854	7,846	6,059	668	73	4,349
1970	7,858	13,153	7,215	1,964	369	73	3,784
1971	10,657	17,271	8,229	4,068	533	73	4,590
1972	13,129	20,073	7,693	7,239	715	74	4,475
1973	9,508	14,037	4,613	6,110	544	74	2,766
1974	8,379	12,666	5,066	4,436	444	74	2,775
1975	5,380	8,288	3,846	2,284	271	75	1,963
1976	6,177	9,774	5,362	1,723	298	75	2,546
1977	6,677	10,588	5,292	2,487	432	75	2,515
1978	12,260	18,393	8,747	5,129	557	76	4,115
1979	19,937	28,749	11,429	10,919	949	76	5,569
1980	17,470	24,955	9,875	9,661	828	76	4,703

Appendix D. Table 1. Reported landings versus total reconstructed catch (in tonnes) by sector for the Egyptian Mediterranean, 1917-2017.

Year	Reported	Reconstructed	Industrial	Artisanal	Subsistence	Recreational	Discards
1981	17,788	24,707	8,358	11,401	871	77	4,128
1982	11,232	15,810	6,374	6,139	523	77	2,869
1983	12,613	17,982	8,456	5,635	539	77	3,511
1984	11,365	15,621	5,936	6,652	522	78	2,600
1985	16,591	21,777	5,297	12,888	815	78	2,779
1986	19,384	26,642	11,659	9,799	796	78	4,588
1987	33,351	43,564	11,872	24,629	1,508	79	5,616
1988	35,883	47,518	16,878	22,499	1,490	79	6,868
1989	35,695	46,911	16,595	22,500	1,455	79	6,591
1990	35,310	46,101	16,423	22,184	1,417	80	6,333
1991	40,062	51,834	17,987	25,719	1,581	80	6,838
1992	43,169	55,515	19,493	27,526	1,658	80	7,173
1993	44,617	57,279	21,678	26,880	1,640	81	7,486
1994	45,601	58,138	22,058	27,482	1,637	81	7,394
1995	43,700	55,409	21,046	26,344	1,535	81	6,920
1996	51,100	64,437	24,501	30,815	1,747	82	7,900
1997	52,749	66,153	25,180	31,819	1,766	82	7,961
1998	68,000	84,819	32,317	41,032	2,207	82	10,015
1999	89,943	111,585	42,558	54,290	2,832	83	12,925
2000	54,872	67,711	25,850	33,132	1,724	83	7,692
2001	59,624	73,182	27,965	36,013	1,828	83	8,151
2002	59,619	72,788	27,841	36,021	1,782	84	7,946
2003	46,973	57,046	21,840	28,390	1,390	77	6,102
2004	47,481	57,361	21,980	28,707	1,368	66	6,010
2005	56,721	68,166	26,143	34,305	1,570	84	6,994
2006	72,666	86,875	33,346	43,963	1,926	83	8,725
2007	83,762	99,623	38,271	50,694	2,138	90	9,791
2008	88,882	105,169	40,435	53,811	2,195	162	10,111
2009	78,790	92,928	35,597	47,810	1,900	78	8,894
2010	77,388	90,981	34,723	47,067	1,817	78	8,669
2011	77,799	91,170	34,666	47,424	1,777	78	8,648
2012	69,332	80,988	30,680	42,359	1,549	78	7,647
2013	63,027	73,389	27,698	38,594	1,371	78	6,897

Appendix D. Table 1. Reported landings versus total reconstructed catch (in tonnes) by sector for the Egyptian Mediterranean, 1917-2017.

Year	Reported	Reconstructed	Industrial	Artisanal	Subsistence	Recreational	Discards
2014	62,746	72,829	27,383	38,509	1,312	78	6,813
2015	57,602	66,645	24,964	35,431	1,173	78	6,205
2016	53,964	62,237	23,225	33,268	1,064	78	5,767
2017	58,926	67,745	25,184	36,409	1,103	78	6,248

Appendix D. Table 2. Total reconstructed catch by family (in tonnes) the Egyptian Mediterranean, 1917-2017, 'others' contain 78 additional taxonomic groups.

Year	Clupeidae	Sparidae	Penaeidae	Mugilidae	Mullidae	Others
1917	2,383	122	49	709	0	1,726
1918	2,373	123	49	718	0	1,740
1919	2,362	269	108	777	138	2,388
1920	3,684	472	176	917	286	3,443
1921	2,966	560	157	1,076	260	3,705
1922	3,537	738	554	996	400	4,550
1923	4,023	520	555	847	395	4,137
1924	2,417	242	164	332	240	1,931
1925	2,609	239	162	377	169	1,866
1926	1,179	288	326	178	224	1,641
1927	2,587	292	233	327	200	2,436
1928	3,361	451	279	764	193	2,836
1929	4,428	421	322	752	288	2,792
1930	11,803	487	743	1,150	490	4,422
1931	5,717	780	769	1,716	801	3,537
1932	7,501	692	609	1,018	680	3,468
1933	9,169	544	502	1,562	380	3,988
1934	17,777	391	782	408	296	3,572
1935	7,631	645	885	723	534	3,175
1936	7,482	670	1,009	721	534	3,950
1937	7,335	685	1,135	718	535	4,716
1938	7,188	719	1,259	716	536	5,514
1939	7,043	730	1,383	714	537	6,258
1940	6,900	794	1,505	712	539	7,103
1941	6,757	834	1,626	709	541	7,893
1942	6,615	813	1,746	707	544	8,555
1943	6,475	837	1,866	705	547	9,297
1944	6,335	858	1,984	703	551	10,029
1945	6,197	872	2,101	701	555	10,741
1946	6,059	887	2,218	698	559	11,448
1947	5,923	906	2,333	696	564	12,157
1948	5,788	929	2,448	694	570	12,867
1949	5,654	953	2,561	692	575	13,575
1950	5,522	982	2,674	690	588	14,322

Appendix D. Table 2. Total reconstructed catch by family (in tonnes) the Egyptian Mediterranean, 1917-2017, 'others' contain 78 additional taxonomic groups.

Year	Clupeidae	Sparidae	Penaeidae	Mugilidae	Mullidae	Others
1951	5,500	1,096	2,664	687	637	18,619
1952	6,846	1,395	2,653	684	717	24,149
1953	6,821	1,192	2,643	1,091	746	10,968
1954	6,793	1,290	3,948	1,086	787	12,441
1955	6,765	1,437	3,933	1,082	853	17,074
1956	8,085	1,433	3,917	1,347	1,044	19,032
1957	9,377	1,484	6,332	1,318	1,055	16,778
1958	8,018	1,660	6,312	1,314	1,074	17,071
1959	9,210	1,549	6,270	1,293	1,392	14,176
1960	9,125	1,610	6,239	1,280	1,417	15,088
1961	9,006	1,980	8,683	1,262	1,716	14,779
1962	22,892	2,229	8,909	641	1,847	18,435
1963	16,627	2,286	8,630	566	1,792	20,191
1964	9,420	2,736	8,736	478	1,666	18,240
1965	9,679	2,968	6,388	315	2,145	17,710
1966	1,864	3,339	4,567	445	2,597	12,399
1967	1,050	3,462	3,631	416	1,985	12,572
1968	590	3,152	3,810	370	2,328	11,618
1969	769	2,442	1,401	371	1,651	12,961
1970	739	2,212	1,033	563	1,458	7,591
1971	1,919	2,606	1,193	639	1,822	9,698
1972	1,778	2,343	1,208	521	1,919	13,094
1973	756	1,551	799	356	1,207	9,985
1974	1,244	1,561	956	1,096	1,312	7,016
1975	813	1,244	911	250	1,045	4,372
1976	870	949	1,262	256	1,370	5,440
1977	1,708	1,629	911	235	1,231	5,381
1978	2,785	2,460	1,156	272	1,957	10,396
1979	8,021	3,418	1,951	376	2,274	13,734
1980	5,634	3,073	2,268	752	1,645	12,488
1981	6,908	3,389	1,492	505	1,794	11,567
1982	2,987	1,643	1,329	1,496	810	8,145
1983	3,405	1,660	1,492	1,290	1,187	9,565
1984	4,503	2,340	1,016	697	949	6,717

Appendix D. Table 2. Total reconstructed catch by family (in tonnes) the Egyptian Mediterranean, 1917-2017, 'others' contain 78 additional taxonomic groups.

Year	Clupeidae	Sparidae	Penaeidae	Mugilidae	Mullidae	Others
1985	5,948	2,347	1,131	697	825	11,721
1986	5,948	2,604	1,815	879	1,415	14,856
1987	9,164	3,164	1,777	285	1,525	29,236
1988	8,386	5,186	1,888	93	594	32,939
1989	6,198	5,241	3,944	1,254	1,748	30,060
1990	7,463	4,931	3,668	1,165	1,306	29,064
1991	10,532	5,349	4,618	1,932	1,955	29,110
1992	10,095	4,908	3,033	1,887	1,582	35,749
1993	12,453	6,605	4,345	1,908	2,194	31,494
1994	9,505	9,783	4,490	2,962	2,396	30,720
1995	10,388	8,399	4,487	3,020	1,725	29,006
1996	9,575	10,975	3,563	3,351	2,624	36,177
1997	12,259	9,856	5,444	2,320	2,862	35,260
1998	27,502	10,103	5,670	2,647	1,903	39,284
1999	45,312	14,428	7,910	2,283	3,069	41,497
2000	22,495	9,610	4,896	1,593	1,808	29,116
2001	22,812	7,940	4,060	2,372	1,920	35,990
2002	13,734	8,920	5,168	6,456	2,179	38,198
2003	11,619	7,032	2,719	4,954	1,261	30,930
2004	13,830	8,117	3,592	4,676	1,330	27,250
2005	16,814	10,746	3,221	3,954	1,631	33,454
2006	16,507	14,697	3,560	3,364	3,755	47,000
2007	22,488	15,173	5,210	5,055	4,796	49,128
2008	19,298	15,875	12,220	5,167	3,204	51,763
2009	13,182	14,198	11,985	5,230	3,320	46,990
2010	9,890	15,533	11,860	5,191	3,867	46,535
2011	8,656	16,649	12,074	4,600	4,441	46,605
2012	11,648	14,110	7,537	3,960	2,821	42,540
2013	11,184	12,744	6,743	3,347	2,065	38,755
2014	10,992	6,994	8,537	3,403	1,505	42,788
2015	10,782	5,155	7,992	2,040	1,018	40,910
2016	9,885	4,921	7,558	1,908	930	38,178
2017	10,134	4,487	9,486	1,677	1,045	42,098