INVESTIGATIONS ON ECOSYSTEM BASED FISHERIES MANAGEMENT STRATEGIES FOR THE TURKISH SEAS

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

INVESTIGATIONS ON ECOSYSTEM BASED FISHERIES MANAGEMENT STRATEGIES FOR THE TURKISH SEAS

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Rising societal and economic needs of the increasing human population together with the growing size of fishing fleets, developing technology in the fishing and globalization of fish food market exerted a significant pressure on the marine ecosystems within the last decades. These pressures resulted in irreversible changes on the marine ecosystem structures and, in turn, limited the socio-economic benefits obtained from marine ecosystems. Ecosystem Based Fisheries Management aims to achieve a sustainable balance between the sociatial needs of the society and ecological health of the natural resources.

This study provides a base for Ecosystem Based Fisheries Management (EBFM) for Turkish Seas employing an interdisciplinary holistic approach in three steps; I) Evaluating the historical development of the Turkish fisheries sector with its diverse sub-sectoral (marine and inland capture and aquaculture), sub-regional (along seven discrete geographical areas) and species based production trends as well as defining its diverse societal objectives, II) Exploring the direction and magnitude of the historical changes in the Turkey's marine capture fisheries (in the Black Sea, the Marmara Sea, the Aegean Sea and the Mediterranean Sea) and the corresponding response of its supporting ecosystems in relation to concurrent management measures, III) elucidating and comparing the structure, function and fisheries impact of the regional EEZs and predicting the impact of different management options. The holistic approach included socioeconomic and ecological indicators as well as modelling studies with Ecopath with Ecosim (EwE).

Results quantified the level of human induced pressures driven by increasing societal and economic demands due to the human population increase, national economic crises and corresponded governmental subsidies. Since 1980s, per capita fish consumption decreased 1.5 kg/year with 14% increase in Turkey’s fisheries production capacity and 52% rise of the human population. Indicator trends and interrelations observed between the indicators in this study could be summarised as follows; i) regional fisheries fleets have developed an over-fishing capacity, too many fishers were exploiting the constrained amount of stocks with excessive number of vessels that have excessive engine power with very low efficiency, ii) this fishing over-capacity eradicated the long sized, vulnerable fish species from the ecosystem and the ecosystem became significantly dominated by small pelagic fish, iii) even though the numbers of fishers, vessels and fishing effort of the fleet have been decreasing within the last decade, ecological indicators continued to give warning signals for a possible more severe deterioration in the regional ecosystems. Scenario simulations (except the ecology weighted scenario in the Black Sea) indicated that if the histrorical management policies were based on the ecosystem characteristics, the current targeted fish species biomass, landing weight and value would be in a better condition. Similar to the past scenario simulations, future predictions showed that EBFM can contribute to the ecological health of the ecosystems as well as to their economic efficiency. For this reason, the achievement and sustainability of ecological and socio-economic targets can be possible with a successful implementation of ‘Ecosystem Based Fisheries Management’ to the regional seas. The produced information and assessed gaps within the thesis study can be taken as a step forward on this way.

Keywords: Fisheries management, EBFM, ecological and socio-economic assessment

ÖZ

TÜRKİYE DENİZLERİ İÇİN EKOSİSTEM TEMELLİ BALIKÇILIK YÖNETİM SEÇENEKLERİNİN GELİŞTİRİLMESİ ÜZERİNE ARAŞTIRMALAR

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Geçtiğimiz on yıllık süreçler içerisinde nüfusla birlikte artan sosyo-ekonomik ihtiyaçlar, balık avlama filolarındaki büyüme, balık avcılığındaki teknolojik gelişmeler ve su ürünleri pazarının küreselleşmesi deniz ekosistemleri üzerinde önemli bir baskı unsuru oluşturmaktadır. Bu baskılar deniz ekosistemlerinin yapısında geri dönüşü olmayan değişikliklere yol açmakta ve deniz ekosistemlerinden elde edilen sosyo-ekonomik faydaların azalması ile sonuçlanmaktadır. Ekosistem Temelli Balıkçılık Yönetimi (ETBY), balıkçılık yönetiminde, toplumsal ihtiyaçlar ile doğal kaynakların ekolojik sağlığı arasında sürdürülebilir bir denge sağlamayı hedeflemektedir.

Bu tez çalışması disiplinlerarası bütüncül bir yöntem uygulayarak ETBY kararları için üç aşamalı bilimsel bir temel oluşturmaktadır; I) Türkiye balıkçılık sektörünün tarihsel gelişimini alt sektörler (deniz ve iç sularda avcılık ve yetiştiricilik), alt bölgeler (ülkenin yedi coğrafi bölgesi) ve tür bazında değerlendirmek ve toplumsal önceliklerini belirlemek, II) Türkiye deniz balıkları avcılığında (ulusal düzeyde ve Karadeniz, Marmara Denizi, Ege Denizi ve Akdeniz'de) ve geçmişten günümüze gerçekleşen değişimlerin yönünü ve boyutlarını, bölgesel ekosistemler üzerindeki sonuçları ile birlikte süregelen yönetim uygulamaları ile ilişki içerisinde değerlendirmek, III) bölgesel denizlerdeki Münhasır Ekonomik Bölge (MEB) ekosistemlerinin yapı ve işleyişlerini açıklamak ve karşılaştırmak ve aynı zamanda farklı yönetimsel uygulamalarının etkilerini tahmin etmek. Bu amaç için kullanılan bütüncül yöntem sosyo-ekonomik ve ekolojik indikatörler ile birlikte Ecopath with Ecosim (EwE) ekosistem modeli ile yapılan modellemele çalışmalarından oluşmaktadır.

Sonuçlar insan nüfusu ile birlikte artan sosyal ve ekonomik ihtiyaçlar, ulusal ekonomik krizler ve eş zamanlı hükümet teşviklerinin seviyesini sayısal olarak ortaya koymuştur. Türkiye nüfusunun %52 artarken, toplam balıkçılık üretiminin sadece %14 artmasıyla ile Türkiye'de kişi başına düşen balık tüketimi 1980'lerden günümüze 1,5 kg azalmıştır. Türkiye deniz balıkçılığına uygulanan indikatör eğilimleri I) bölgesel balıkçılıkların yüksek seviyede motor gücüne sahip çok sayıda tekne ve çok sayıda balıkçı ile, düşük verimliliğe neden olan aşırı avcılık seviyesine ulaştığını, II) bu aşırı avcılık kapasitesi ile zaman içerisinde bölgesel ekosistemlerdeki uzun boylu, uzun ömürlü, balıkçılığa hassas türleri azalttığı ve ekosistemlerde küçük pelajik balıkların dominant olduğunu, III) son yıllarda balıkçı ve tekne sayısının ve balık avlama gücünün azalmasına ragmen ekolojik indikatörlerin daha ileri ekolojik zarara yönelik uyarı sinyalleri vermeye devam ettiğini göstermiştir. EwE ile yapılan senaryo simülasyonları (Karadeniz'deki ekoloji öncelikli senaryo dışında) geçmişteki balıkçılık yönetimi uygulamalarının ekosistem temelli yapılmış olmaları halinde avlanan türlerin biyokütle, av miktar ve değerlerinin günümüz değerlerinden daha iyi olacağını göstermiştir. Geçmişe dönük senaryolara benzer şekilde, geleceğe yönelik tahminler ETBY sonuçlarının ekosistem sağlığına olduğu kadar balıkçılığın ekonomik verimliliğine de katkı verebileceğini göstermektedir. Bu nedenle balıkçılıkta ekolojik ve sosyo-ekonomik hedeflere ulaşmanın ETBY'nin bölgesel denizlere uygulanması ile mümkün olabileceği ortaya çıkmaktadır. Tez çalışması kapsamında üretilen bilgiler ve belirlenen eksiklikler bu amaç için bir adım olarak kullanılabilir.

Anahtar Kelimeler: Balıkçılık yönetimi, ETBY, ekolojik ve sosyo-ekonomik değerlendirme

To my beloved mom, for everything she added to my life.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. CHAPTER: Thesis Introduction

1.1. The social importance of fisheries

Globally, fisheries has provided an important source of animal protein and 58 million people are employed directly through fisheries and aquaculture and around 200 million direct and indirect employement opportunities are created along the value chain (FAO, 2015). Fisheries contributed 17% of the global population's animal protein intake and 6.7% of all protein consumed in 2013 (FAO, 2016) and provided associated health benefits (Kris-Etherton et al., 2002; Silvers and Scott, 2002; Fernandez et al., 1999). As stated in its definition by Fletcher et al. (2002), it is a unit engaged in raising and/or harvesting fish that is defined in terms of people involved, fish species or type, water or seabed area, fishing methodolgy, boat classes and activity purpose. In 2014, 87% of the fisheries production was directly used for human consumption and the left was used for non-food products which was mainly utilized as a source for feeding cultured fish species. Fisheries economy is also important at international trade. Fish food was reported as one of the most traded global commodities with an export volume of 58 million tonnes with the corresponding economical value of US$148 billion in 2014 (FAO, 2014). Considering the projected further growth in global human population, food deficiency, unemployment and the need for further economical growth has been rising as a challenging issue which needs to be also considered in fisheries management.

1.2. History of marine capture fisheries and its management

Globally, fisheries production was mainly consisted of capture fisheries in the early times of fisheries whereas its contribution decreased down to 55.9% in 2014 (FAO, 2016). The history of capture fishing started with primitive fishing techniques and became industrialized with the use of steam trawlers and power winches in the early nineteenth century and with diesel engines after the First World War (Wing, 2001). Freezer trawlers, radar and acoustic fish finders were also used after Second World War and industrial fishing became widespread. The 1950s and 1960s were the period when the increased fishing effort resulted in higher catches and encouraged the managers and politicians to implement several subsidy programs to increase the fishing effort to land higher catches (Pauly et al., 2002; FAO, 2003). However, the globally known first collapse was occurred in 1971–1972 in Peruvian anchoveta stocks though it was related to an El Niño event. It was followed by declining total catches from the North Atlantic in the mid-1970s and the declining trend accelerated with the collapse of most of the cod stocks off New England and eastern Canada in the late 1980s and early 1990s (Myers et al., 1997). Globally, the proportion of the fully fished, overfished, depleted, or recovering stocks from overfishing was increased from 60% in the mid-1970s to almost 90% in 2013 leading to economic overfishing creating economic losses (World Bank, 2017).

The management of marine fisheries had an international legal basis with the U.N. Convention on the Law of the Sea (UNCLOS; United Nations 1982) which provides obligations on sectoral and spatial use of marine resources dealing with dependent species. It was followed with the Rio Declaration (1992) providing new guidelines for fisheries and marine conservation and the Convention on Biological Diversity (1992). Specific obligations for straddling and highly migratory fish stocks were further delineated by U.N. Fish Stocks Agreement (UNFSA; United Nations 1995) which also includes principles for ecosystem based fisheries management. The United Nations Food and Agriculture Organization (FAO) Code of Conduct on Responsible Fisheries (FAO 1995) further detailed a code of ethics for fishing all aquatic species and various FAO international action plans. The United Nations open-ended Informal Consultative process (UNICPOLOS or ICP) was established in 1999 and at the 2001 Iceland-FAO Conference on Responsible Fisheries in the Marine Ecosystems, Ecosystem Approach to Fisheries (EAF) was internationally adopted. In the period of 2003-2012, the focus of global debate was biodiversity which displayed a negative state in the 2005 Millennium Ecosystem Assessment. Following the Green Growth Concept (adopted in 2005 at the UN Economic Social Commission for Asia and the Pacific (ESCAP)) and green economy (by the Rio+20 Summit in 2012), FAO promoted Blue Growth which is based on the identified challenges in the Rio+20 outcome document and its post-2015 development agenda.

The ‘Ecosystem-based fisheries management’ (EBFM) has been proposed as a “*new paradigm of fisheries management that should consider not only fisheries, but also* *other biotic, abiotic, and human components of ecosystems and their interactions*" (FAO, 2003). EBFM uses cross-disciplinary evaluations with multiple variables to improve existing management frameworks (Chen et al., 2008; Garcia and Cochrane, 2005). Examining current fishery management practices, it proposes a better understanding and management of stock interactions, stock-prey relationships, and stock-habitat requirements (Pikitch et al, 2005). The overall aim is to avoid ecosystem degradation minimizing the risk of irreversible changes in natural species assemblages and ecosystem processes, achieving and sustaining the socio-economic benefits considering the ecosystem and producing information on ecosystem processes needed to understand the human impact (Pikitch et al, 2005).

1.3. Fisheries and fisheries management in Turkey

Turkey has 8,333 km coastline on four seas (20.4% on the Black Sea, 17.3% on the Marmara Sea, 41.8% on the Aegean Sea and 20.5% on the Mediterranean Sea) and 14,000 km^2 total inland surface area of dams and lakes. Thus Turkey appears to have a great potential for marine and inland capture and aquaculture production, and its contribution to food security, employment, domestic income and foreign trade. Turkey's fishery sector developed rapidly after the establishment of Republic of Turkey in 1923, in parallel to above mentioned global progressions and a population increase from 13 million up to 78.7 million in 2015. The legislative changes to support the development of Turkey's fisheries first started in 1938 with customs tax exemptions and continued with the imports of engine and fishing equipment and promotions for the fishing vessels in 1952 and facilitation of bank loan use in 1954. Afterwards, customs tax exemptions for fishing gear imports and easy facilitation of bank loan use in 1976 were provided. Tax free equipment purchases in 1982 and 25% government contribution to fixed investment in 1984 were implemented. Similar to the collapse of Peruvian anchovy stock collapse, the Black Sea anchovy stock was collapsed in 1989 and the driving mechanism behind the collapse was attributed to overfishing (Daskalov, 2002; Gucu, 2002) as well as invasion of *Mnemiopsis leidyi* and its predation on anchovy eggs and larvae (Kideys, 2002) and climatic changes (Oğuz et al., 2003). After this, the permits for the new fishing vessel licenses were restricted to control fishing pressure in an attempt to resurrect the fisheries in general though a limited number of vessel licenses were permitted at three specific occasions (1994, 1997 and 2002). However, in the following period, bank loan use was promoted in 1993 and 2005, and fuel subsidies were provided in 2004 (Üstündağ, 2010; Unal and Goncuoglu, 2010). Fisheries management in Turkey utilizes basic regulatory instruments such as minimum mesh and fish size, closed season and area, restricited gears, techniques and/or vessels, banned species and quota scheme for Bluefin tuna and venus clam (Ünal and Göncüoğlu, 2010).

In the meantime, Turkey had experienced several economic crises during its history. The most important of them can be stated as 1973-74 petroleum crises, 1977-78 crises, the 1994 economic crisis, the 1998 textile crisis, the November 2000 and February 2001 crises and the 2008-2009 global crisis (Aydın, 2013).

1.4. Methodolgy of the thesis

The key considerations within the thesis study was summarized as below;

- The scope of the PhD thesis was constructed as an approach to fisheries management and development specific to Turkey's fisheries sector as a whole and especially for the marine capture fisheries.
- The PhD research results were assessed aiming to balance diverse societal objectives of the Turkish fisheries which were defined as fisheries contribution to national diet, economy, employment, foreign trade, fish food supply to aquaculture sector and country's self-sufficiency for fish food in the thesis.
- Available data and knowledge on the biotic, abiotic and human components of the ecosystems and their interactions were gathered from the published literature and official statistics and utilized within the integrated approach of the thesis so as to generate further knowledge and determine the uncertainties about them.
- An integrated approach was adopted to the thesis including a set of complementary indicator and model based methodologies covering various social, economic and ecological aspects of fisheries and ecosystem.
- Turkey's Regional sea boundaries' were considered as ecologically meaningful as the regional seas bear quite different physical, chemical, ecological characteristics as well as different fisheries structures.

- The integrated approach was consisted from regional based socio-economic and ecological dimensions as well as national based societal dimensions with two way interactive deductions and inductions.
- The end products of the approach were delivered to stakeholders such as fishers, fish farmers, academicians, fisheries managers, civil associations and coast guards via regional workshops so as to ensure their prevalence.

1.5. Organization of the Chapters

Chapter 1 (Thesis introduction): An overall introduction to the fisheries management, EBFM, thesis methodology and thesis structure was provided in this chapter.

Chapter 2 (From past to present: An overall view on the production and societal value of the Turkish fisheries sector): Globally, fisheries is an important source for food, employment and economy. Fish food is also one of the most traded food commodities around the world. Sustainable fisheries management regarding sector's societal, economic and ecological standpoints has been rising as a challenging issue under the cumulative impact of multi-stressors such as human population rise, growing economy, technological developments, proliferation of fish food international trade and environmental constraints together with the global warming. From this aspect, Turkey's fisheries sector provides a good case study possessing all the above mentioned multi-stressors, consisting of marine and inland capture and aquaculture sub-sectors with a diverse species composition along a wide range of geography from the Mediterranean Sea to the Black Sea and from the Asia to the Europe. **2nd Chapter of the PhD thesis was dedicated to evaluate the historical development of the Turkish fisheries sector with its diverse sub-sectoral (marine and inland capture and aquaculture), sub-regional (along seven discrete geographical areas) and species based production trends as well as to define the diverse societal objectives of the Turkish fisheries which were selected as fisheries contribution to the national diet, economy, employment, foreign trade, fish food supply to aquaculture sector and country's self-sufficiency for fish food.**

Chapter 3 (Regional ecological and socio-economic consequences of the national fisheries management policies: Indicator approach): Marine capture fisheries has been an important contributor to the fisheries sector production, economy and employment. However, its contribution has become limited due to the overexploitation of marine fisheries resources as a result of growing size and development in technology of the fishing fleets together with the above mentioned multi-stressors. Indicators have been widely used for a real, wide-reaching evaluation of marine ecosystems and fisheries within there (Coll et al., 2016). They enable the understanding of the important processes occurring in the fisheries and their supporting ecosystems, determination and monitoring the achievability of future targets. Fisheries has been one of the rapidly growing sectors in Turkey occasionally financed by state subsidies for the development of its technological infrastructure in order to increase its production weight and value, and provide job opportunities. Fishing grounds in the surrounding seas have been exploited with different fishing intensities depending upon their productivity level and catch rates. Hence, the responses of these different ecosystems to overfishing have been realized differently. Turkish marine ecosystems have been heavily exposed to anthropogenic within the last decades which resulted in adverse impacts on the ecological and socio-economic structures of the regions. As a result, long term alterations occurred in the fishing pressures exerted on the surrounding marine ecosystems that had potentially resulted in changes in the regional fisheries and marine ecosystem structures. **3th Chapter of the thesis focused to understand the direction and magnitude of the historical changes in the Turkey's marine capture fisheries (in the Black Sea, the Marmara Sea, the Aegean Sea and the Mediterranean Sea) and the corresponding response of its supporting ecosystems in relation to concurrent management measures.**

Chapter 4 (Testing object oriented Ecosystem Based Fisheries Management Strategies in the Turkish seas: A modelling study): Ecosystem models have enabled to consider the whole ecosystem components in interaction and become a useful tool to guide fisheries policies. Ecopath with Ecosim (Christensen and Walters, 2004) has been used for the application of ecological and socio-economic analyses in a wide geographical area. **The fourth chapter is dedicated to elucidate the long term**

progressions in the Black Sea, Marmara Sea, Aegean Sea and Mediterranean Sea ecosystems and predict their future states from an ecological, social and economic perspective by using end to end ecosystem modelling tools. To examine the long term progressions observed in the regional seas, Ecopath with Ecosim (EwE) ecosystem model was set and validated for the years 1995-2014. The validated models were then used to carry out forecast simulations for the 2014-2033 period and EwE Policy Search Tool was utilized to predict the impact of different management options on the Turkish marine ecosystems.

Chapter 5 (Synthesis of the thesis): **5th Chapter of the thesis synthesize the outputs of the 2nd, 3rd and 4th chapters so as to inform the future decision making processes for Ecosystem Based Fisheries Management and achievement of the Good Environmental Status (GES) in the region in order to ensure sustainable utilization of the regional sea ecosystems for the needs of today's and future generations.**

2. CHAPTER: From past to present: An overall view on the production and socio-economical value of the Turkish fisheries sector

2.1. Introduction

Capacity of the capture fisheries fleets increased globally since 1950's and resulted in over-exploitation of natural stocks limiting todays' capture production capacity (Watson et al., 2013). Meantime, a rapid increase in the aquaculture production was observed as a reflection to the expansion of culture areas, higher experience gained in agriculture and developments in production technologies (Samuel-Fitwi et al., 2012). As a result, in the period of 1970 to 2010, an annual aquaculture growth rate of 8.2% (from 2.57 to 59.9 million tons) was recorded that is much higher than that of 1.5% for the captured production (from 38.2 to 68.4 million tons, Tacon and Metian, 2013). In 2012, 71.4 million tonnes of capture production and 86.6 million tonnes of aquaculture production contributed 45% and 55% of the world global fisheries production, respectively (FAO, 2014).

Fisheries production was utilized for food and non-food purposes (e.g. fish meal/oil). Almost 20% of the global fisheries production was used for the non-food purpose in 2012 (FAO, 2014). The quantity of fish food available for human consumption is determined by the proportion of its non-food usage (e.g. fish meal/oil) as well as the quantity of exported and imported fish food. The ratio of total domestic fish production to total fisheries consumption determines self-sufficiency rate for fish food, which is an important indicator showing the countries capability to meet their fish food demand. For example, in 2011 European Union was capable of supplying only 45% of its 24.5 kg per capita fish consumption demand from its own resources whereas the rest (8.38 million tons) was imported (EUMOFA, 2014).

In this chapter, the production and societal value of the fisheries was evaluated so as to provide an insight to the driving mechanisms and societal value of fisheries sector in which marine capture fisheries have a role together with inland capture and marine and inland aquaculture sectors. It was also explored whether the global state and trends described above are also applicable to the Turkish fisheries sector. Recent decreases in Turkish marine and inland capture fisheries suggest that they may be. To date, however, the potential role of Turkey's fisheries sector has not been evaluated in terms of both the national and global perspectives. This chapter examines (i) how the Turkey's fisheries sector performed in terms of its diverse sub-sectoral (marine and inland capture and aquaculture), sub-regional (along seven discrete geographical areas) and species based production trends, (ii) how the societal value of the fisheries sector changed in terms of its contribution to Turkey's food security, Gross National Production (GNP), international fish food trade and fish food supply to aquaculture sector, (iii) how the Turkey's fish food self-sufficiency rate and supply balance changed in relation to country's ever-increasing human population within the last decades. By providing a comprehensive understanding on the long term dynamics, this chapter will serve as a step towards reaping up the potential benefits from Turkey's fish food production units and provide insights for a better management of Turkey's fisheries sectors.

2.2. Materials and Methods

Data sources: Fisheries data were derived from the yearly Fishery Statistics booklets published by Turkish Statistical Institute (1970-2015, TurkStat, 1970-2015). In these booklets, marine capture fisheries data were collected by annual surveys applied during January and May whereas freshwater products and aquaculture production data were taken directly from Ministry of Food, Agriculture and Livestock (TurkStat, 2015). The other socio-economic parameters, i.e. human population and fisheries contribution to Gross National Production were obtained from the website of the Turkish Statistical Institute (TurkStat, 2015). The parameters used in this study and their temporal coverages were listed in Table 1.

Fisheries production data: They consisted of the Turkey's marine and inland, capture and aquaculture sectors. Production weight and economic value generated by these four fisheries sub-sectors were analyzed both at yearly and multi-decadal scales along seven discrete geographical areas. The most important species obtained from each sub-sector were also determined based on their yearly-averaged production weight.

International fish trade volume: It was analyzed using the weight and value time series of imports and exports as well as multi-decadal changes of their proportion. The most imported and exported species in 2013 were also stated based on their weight and value.

Table 1. List of the parameters and their temporal coverages.

Parameter	**Available since**
Marine capture production weight	1970
Marine capture production value	1998
Inland capture production weight	1970
Inland capture production value	1998
Marine aquaculture production weight	1996
Marine aquaculture production value	1998
Inland aquaculture production weight	1996
Inland aquaculture production value	1998
Fisheries import weight	1982
Fisheries import value	1982
Fisheries export weight	1982
Fisheries export value	1982
Amount of fish production for non-food use*	1982
Total domestic fish consumption*	1982
Per capita fish consumption*	1982
Fish food self-sufficiency rate	1982
Fisheries contribution to Gross National Production	1970

*****Calculated values

Total domestic fish consumption: It was computed by;

Total domestic fish consumption = (total marine and inland capture and aquaculture production + imports) – (exports + non-food usage (e.g. processed fish in fish meal/oil factories))

Per capita fish consumption: It was calculated by the ratio of total domestic fish consumption to human population size.

Fisheries contribution to GNP: It was calculated by the ratio of the total fisheries production value contributed by all the fisheries sub-sectors (marine and inland, capture and aquaculture fisheries) to the GNP.

Self-sufficiency rate of fish food: It was the ratio of total fisheries production to the total domestic fish consumption.

Fish food supply balance sheet: It documented the balance of production, imports, exports, non-food usage amounts as well as total fish supply (the sum of fisheries production and fish food import) and domestic fish consumption (EUMOFA, 2014). The sheet template was expanded with the human population size, fisheries contribution to GNP, per capita fish consumption and fish food self-sufficiency rate so as to display societal value of fisheries.

2.3. Results

Total fisheries production: Total fisheries production of Turkey was recorded as 184.2 ktonnes in 1970, it peaked in 2007 at 772.3 ktonnes then declined to 672.2 ktonnes in 2015 (Figure 1). The yearly averaged fisheries production weight was 184.6 ktonnes in 1970s, 544.4 ktonnes/year during 1980s, 524.0 ktonnes/year in 1990s, 628.6 ktonnes in 2000s and 636.4 in 2010-2015 period. The corresponding economical value was US$1.17 billion/year (1.56 billion TL/year nominal and 5,35 billion TL/year reel) in the 2000s, US$1.48 billion/year (2.89 billion TL/year nominal and 3.76 billion TL/year nominal) in 2010-2015 and US$1.40 billion/year (3.81 billion TL/year) in 2015.

Captured/cultured production: The relative contributions of Turkey's captured and cultured production in marine and inland waters has changed over the recent decades in both weight and value. During 1990s, Turkey's fisheries production started to receive contributions from the newly developing aquaculture sector (Figure 2). The share of the aquaculture sector in the total fisheries production increased from 5.2% (27.1 ktonnes/year) in the 1990s to 17.2% (107.9 ktonnes/year) in the 2000s and 33.5% (212,9 ktonnes/year) in 2010-2015 period (Figure 1). The growth of the aquaculture sector was more pronounced in economic value as accounted for 35.3% (US$413,1 million) in the 2000s and 58.6% (US$865,9 million) in 2010-2015. In

2015, Turkey's aquaculture production reached at the peak value of 240.3 ktons, with a value of US$ 944.6 million, contributing 35.8% of the total production weight and 67.3% of the total production value.

Sub-sectoral and sub-regional composition of the fisheries production: The biggest component of Turkey's fisheries production weight has been the marine capture fisheries, although its contribution decreased from 90.2% in 1970s to 60.4% in 2010-2015 period and found to be 59.2% in 2015 (Figure 1). Similarly, inland capture production contribution of 9.8% in 1970s was down to 5.8% in 2010-2015 and 5.1% in 2015. Meanwhile, 2.0% and 2.9% marine and inland aquaculture production share in the total in 1990s increased up to 17.4% and 16.5% in 2010-2015 period and were 20.7% and 15.1% in 2015, respectively. Economic value of the fisheries production was consisted of 59.8% marine capture, 6.2% inland capture, 22.5% marine aquaculture and 11.5% inland aquaculture sectors in 2000s. These values were 37.2%, 4.2%, 39.9% and 18.8% in 2010-2015 period and were 29.6%, 3.1%, 49.2% and 18.2% in 2015, respectively.

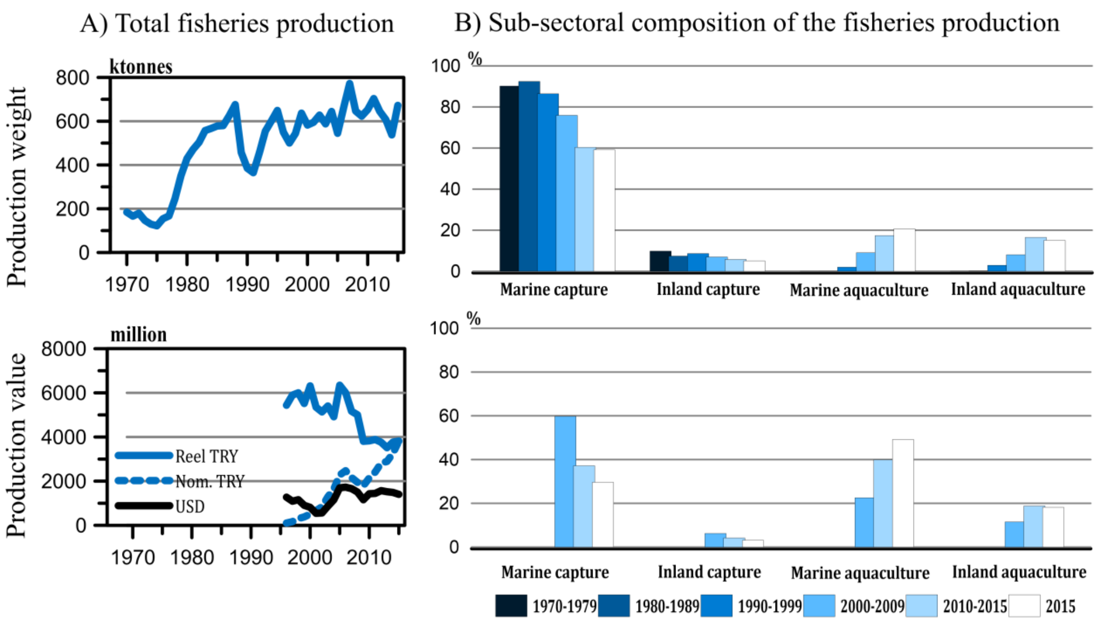

Figure 1. Weight and value of a) total fisheries production in Turkey from 1970 to 2015 and b) sub-sectoral percentage composition of the total fisheries production.

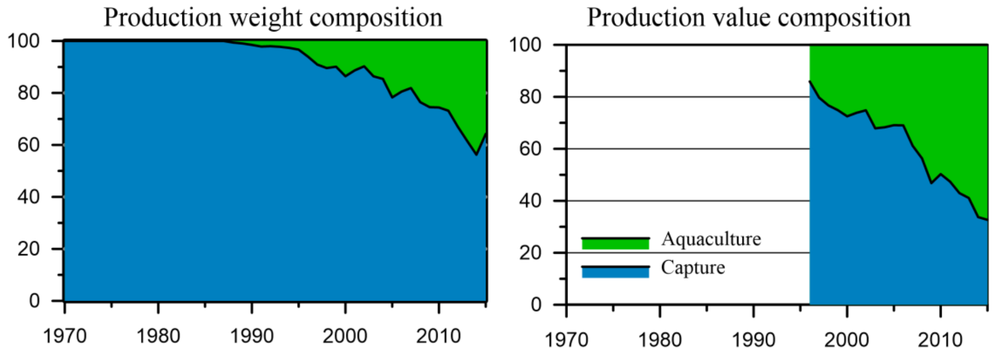

Figure 2. Percentage contribution of captured and cultured production to the total fisheries production in Turkey.

Marine capture production: The year of 1988 marked as the highest recorded landing amount (623.4 ktons) obtained by the marine capture fisheries (Figure 3). Afterwards, marine landings decreased noticeably down to 409.9 ktonnes in 1989, to 342 ktonnes in 1990 and to 317.4 ktonnes in 1991 mainly due to the collapse of the anchovy stocks in the Black Sea (Kideys, 2002), which comprises over 50% of total landings in most years (Table 2). Even though the anchovy stocks recovered in the succeeding years, total landings fluctuated around 460 ktons. Since then, a record low was 266 ktonnes in 2014. It was recorded as 167.6 ktonnes in 1970s, 503.4 ktonnes/year in 1980s, 452.6 ktonnes/year in 1990s, 477.3 ktonnes/year in 2000s and 387.1 ktonnes/year in 2010-2015 period (Figure 3, Table 2). The value of marine landings was US$993.5 million in 1996, oscillated around US$666.5 million during 1998-2015 with a maximum of US$1,103.1 million recorded in 2006 (Figure 4). In 2015, 397.7 ktonnes of marine landing was valued as US$415.3. The top ten landed species by each period and in 2015 were listed in Table 2.

Inland capture production: The share of inland capture fisheries in the total fisheries production (in terms of weight) varied between 5.1-9.3% since 1970s (Figure 3). The sector performed more than a two-fold growth from 1970s to 1990s with an increase from 17.1 ktonnes/year in the 1970s to 40.1 ktonnes/year in the 1980s and 44.2 ktonnes/year in the 1990s (Table 2). Its highest production level (54.5 ktons) was recorded in the 1998. Afterwards, a gradual decrease was observed down to 43.4 ktonnes/year in the 2000s, 36.5 ktonnes/year in 2010-2015 and 34.2 ktonnes in 2015.

Its contribution to the total production value also decreased from 6.2% (US$69.9 million/year) in the 2000s down to 4.2% (US$61.5 million/year) in 2010-2015 and 3.1% (US$43.1 million) in 2015 (Figure 4). The most important species landed from Turkey's inland waters were carp (*Cyprinus carpio*) and tarek (inci kefali in Turkish, *Chalcalburnus tarichi*), which together account for over 50% of the landed catch (Table 2).

Marine aquaculture production: First statistical records of the marine aquaculture fisheries dated back to 1988 with a production level of 19 tonnes (Figure 3). Production capacity of the marine aquaculture performed a rapid growth and reached the average values of 57.3 ktonnes/year (US$278 million/year) in the 2000s and 109.0 ktonnes (US$568 million/year) in the 2010-2015 (Figure 4, Table 2). The sector expanded its share in weight in the total fisheries production from 9.1% in the 2000s to 17.4% in the 2010-2015 (Figure 1). However its contribution in value to the total fisheries production expanded from 22.5% in the 2000s up to 39.9% in the 2010-2015 period. The overall highest weight and value produced by the marine aquaculture sector was recorded in 2015 as 139.0 ktonnes and US$689.6 million, respectively. Sea bass and sea bream were the two major cultivated species contributing more than 90% of the marine aquaculture production. Their yearly averaged production levels for the 2000s, 2010-2015 and 2015 were given in Table 2.

Inland aquaculture production: 587 tonnes of inland aquaculture production in 1988 increased up to its maximum production level of 123.0 ktonnes in 2013 (Figure 3). This level was decreased to 108.1 ktonnes in 2014 and 101.4 ktonnes in 2015 which corresponded to US$255.0 million in value (Figure 4). The sector's share in the total fisheries production in weight was 8.1% (50.7 ktonnes/year) in the 2000s, 16.5% (103.9 ktonnes/year) in 2010-2015 and 15.1% (101.4 ktons) in 2015. Even though inland capture fisheries production in weight was around at the same level with the marine aquaculture fisheries production, its value was less than half of the marine value. Inland aquaculture production contribution in value to the total fisheries production was 11.5% in the 2000s, 18.9% in 2010-2015 and 18.2% in 2015. Trout was the main cultivated species in inland waters constituting more than 97% of the inland aquaculture production since 1996 (Table 2).

Even though recreational fisheries consitutes an important socio-economic component of fisheries (Cooke and Schramm, 2007), it could not be included in the thesis as there are no official statistics.

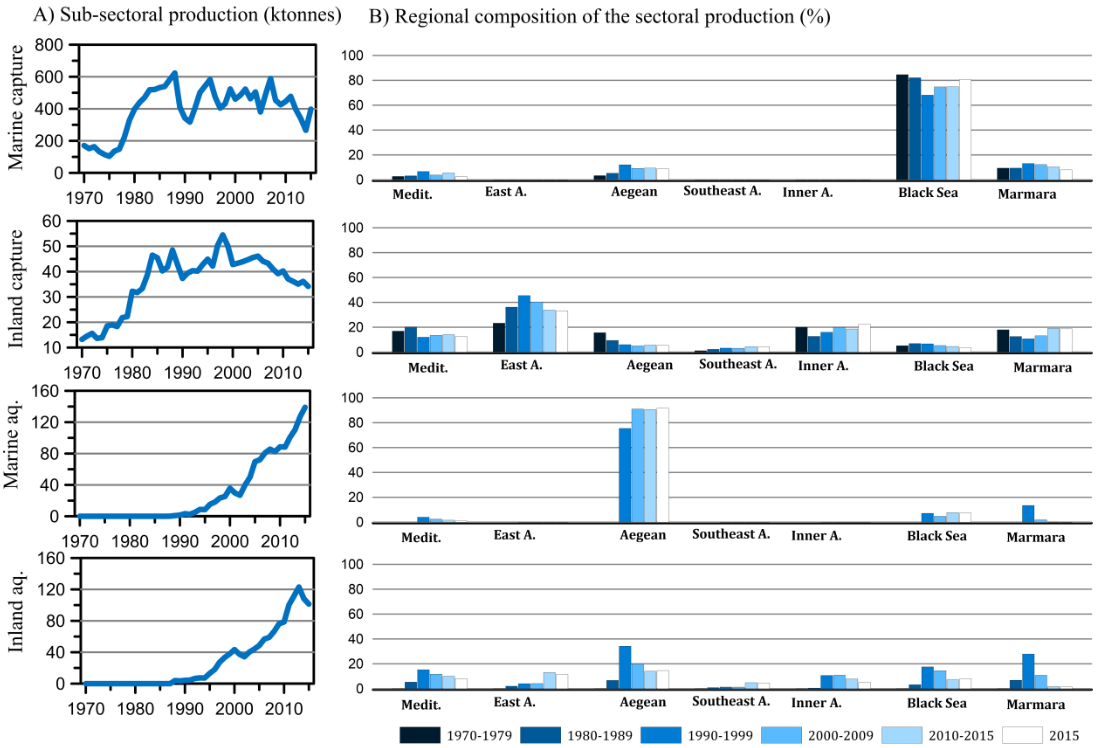

Figure 3. Long-term decadal changes in the fisheries sub-sectoral production weight and value composition of the Turkey's fisheries production with the contribution of marine and capture fisheries and aquaculture.

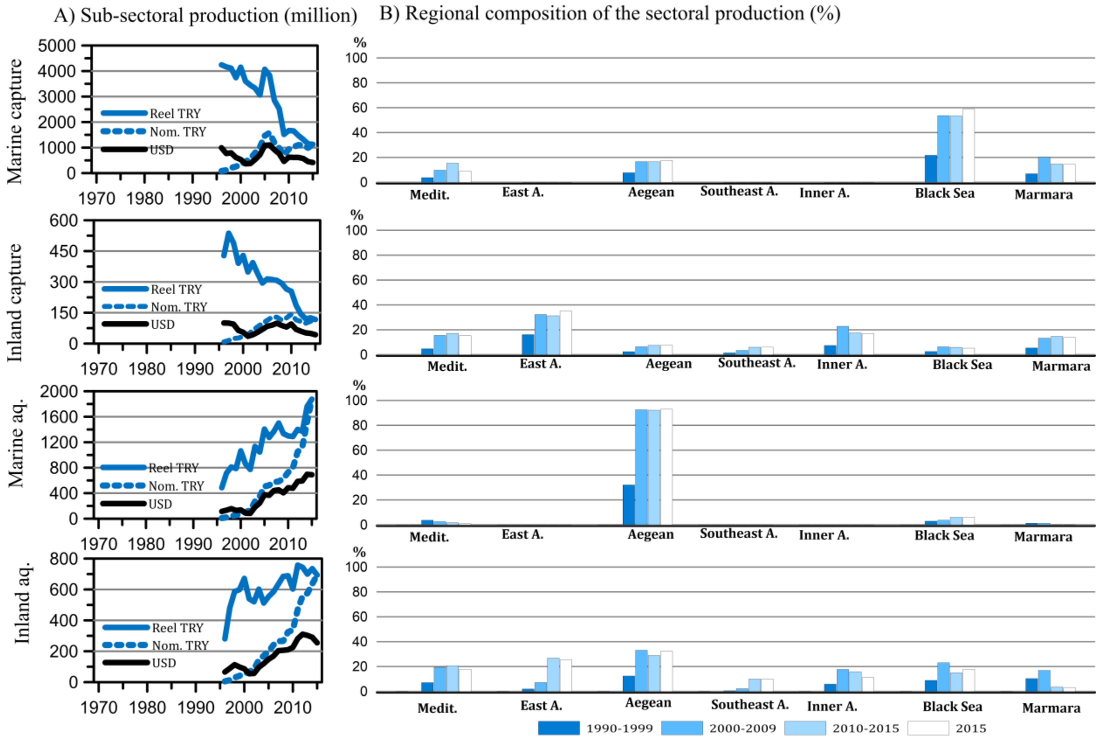

Figure 4. Sub-regional fisheries production as value along seven sub-geographical regions of Turkey.

***International fish trade volume*;** Total international fish trade, including both imports and exports, of Turkey grew from 11.5 ktonnes in 1981 up to 231.8 ktonnes which valued for US$943.2 million in 2015 (Figure 5). However, the relative contribution of imports and exports to Turkey's international fish trade volume changed markedly over time (Figure 6). In the 1980s, exports accounted for 88.8% (15.4 ktonnes/year) of international fish trade volume as weight. This declined to 33.0% (15.1 ktonnes/year) in the 1990s, then steadily increased to 42.9% (35.9 ktonnes/year) in 2000s and 53.3% (88.9 ktonnes/year) in 2010-2015. In terms of value, exports were accounted for 62.1% (US$51.7 million) in 1990s, 75.3%

Table 2. Long-term decadal changes in the produced species from marine and inland, capture and aquaculture production.

		1970-1979			1980-1989			1990-1999		
Marine Capture		Yearly average	167,539	(%)	Yearly average	503,418	(%)	Yearly average	452,595	(%)
	1	Anchovy	86,846	51.8	Anchovy	272,380	54.1	Anchovy	235,810	52.1
	2	Horse mackerel	20,677	12.3	Horse mackerel	81,443	16.2	Sardine	25,707	5.7
	3	Atlantic bonito	8,491	5.1	Spanish mackarel	16,561	3.3	Mussels	20,126	4.4
	4	Whiting	8,279	4.9	Atlantic bonito	15,941	3.2	Horse mackarel	18,964	4.2
	5	Jack mackerel	6,313	3.8	Whiting	15,895	3.2	Whiting	18,125	4.0
	6	Blue fish	5,740	3.4	Blue fish	15,789	3.1	Mullet	17,777	3.9
	7	Mullet	3,139	1.9	Sardine	13,868	2.8	Spanish mackerel	14,027	3.1
	8	Sardine	2,862	1.7	Jack mackarel	10,539	2.1	Atlantic bonito	13,807	3.1
	9	Dog fish	2,543	1.5	Dog fish	5,110	1.0	European hake	11,335	2.5
	10	Turbot	2,458	1.5	Mussels	5,082	1.0	Jack mackerel	10,836	2.4
		2000-2009			**2010-2015**			**2015**		
		Yearly average	477,228	(%)	Yearly average	387,086	(%)	Total	397,731	(%)
	1	Anchovy	285,794	59.9	Anchovy	181,841	47.0	Anchovy	193,492	48.6
	2	Mussels	28,721	6.0	Sprat	47,444	12.3	Sprat	76,996	19.4
	3	Horse mackerel	17,768	3.7	Mussels	34,266	8.9	Mussels	37,404	9.4
	4	Sardine	16,487	3.5	Sardine	24,881	6.4	Sardine	16,693	4.2
	5	Atlantic bonito	16,338	3.4	Horse mackerel	17,569	4.5	Horse mackerel	14,290	3.6
	6	Sprat	13,891	2.9	Atlantic bonito	15,324	4.0	Whiting	13,158	3.3
	7	Blue fish	12,787	2.7	Whiting	10,415	2.7	Sea snail	8,795	2.2
	8	Mullet	11,852	2.5	Sea snail	8,170	2.1	Atlantic bonito	4,573	1.1
	9	Whiting	10,675	2.2	Blue fish	5,500	1.4	Blue fish	4,136	1.0
	10	Jack mackerel	9,850	2.1	Jack mackarel	5,400	1.4	Shrimps	3,995	1.0
Inland Capture		**1970-1979**			**1980-1989**			**1990-1999**		
		Yearly average	17,068	(%)	Yearly average	40,167	(%)	Yearly average	44,359	(%)
	1	Carp	5,951	34.9	Carp	15,222	37.9	Carp	16,453	37.1
	2	Tarek	2,171	12.7	Tarek	8,795	21.9	Tarek	14,798	33.4
	3	Cray fish	1,498	8.8	Cray fish	4,534	11.3	Pike perch	2,269	5.1
	4	Wels	925	5.4	Snail	1,697	4.2	Snail	1,417	3.2
	5	Pike perch	852	5.0	Pike perch	1,675	4.2	Sand smelt	1,042	2.3
		2000-2009			**2010-2015**			**2015**		
		Yearly average	43,408	(%)	Yearly average	36,477	(%)	Total	34,176	(%)
	1	Tarek	13,505	31.1	Tarek	9,322	26.6	Tarek	8,850	25.9
	2	Carp	12,735	29.3	Carp	9,261	25.4	Carp	7,223	21.1
	3	Sand smelt	4,021	9.3	Sand smelt	5,194	14.2	Gibel carp	6,745	19.7
	4	Snail	1,683	3.9	Gibel carp	3,790	10.4	Sand smelt	4,930	14.4
	5	Pike perch	1,632	3.8	Snail	1,384	3.8	Grey mullet	1,161	3.4
Marine Aquacult.								**1996-1999**		
								Yearly average	20,508	(%)
	1							Sea bream	8,743	42.6
	2							Sea bass	8,043	39.2
	3							Trout	1,830	8.9
		2000-2009			**2010-2015**			**2015**		
		Yearly average	57,274	(%)	Yearly average	109,017	(%)	Total	138,962	(%)
	1	Sea bass	30,846	53.9	Sea bass	63,508	58.3	Sea bass	75,164	54.1
	2	Sea bream	22,688	39.6	Sea bream	36,751	33.7	Sea bream	51,844	37.3
	3	Trout	2,046	3.6	Trout	5,946	5.5	Trout	6,872	4.9
Inland Aquacult.								**1996-1999**		
								Yearly average	28,955	(%)
	1							Trout	28,098	97.0
	2							Carp	858	3.0
		2000-2009			**2010-2015**			**2015**		
		Yearly average	50,666	(%)	Yearly average	103,850	(%)	Total	101,372	(%)
	1	Trout	50,029	98.7	Trout	103,627	99.8	Trout	101,166	99.8
	2	Carp	638	1.3	Carp	223	0.2	Carp	206	0.2

(US$191.7 million) in 2000s, 73.2% (US$509.8 million) in 2010-2015 period. 121.1 ktonnes fish food export of Turkey valued for US$692.2 million in 2015. Controversially, the share of imports in weight increased from 11.2% (1.9 ktonnes/year) to 67.0% (30.7 ktonnes/year) from 1980s to 1990s. Even though the quantity of imports increased in weight up to 47.8 ktonnes/year in 2000s and 77.9 ktonnes in 2010-2015 period, its share decreased down to 57.1% and 46.7%, respectively. Fish food imports share in the total international value was 37.9% (US$31.5 million) in 1990s, 24.7% (US$62.8 million) in 2000s, 26.8% (US$186.9 million) in 2010-2015 period. In 2015, 110.8 ktonnes of fish food import valued for US$251 million. In 2013, imports were mainly composed of mackerel/chub mackerel, tuna fish, salmon fish, coal fish, herrings and squids, while the main components of exports were sea bream, trout, sea bass, carp and tuna fish (Figure 7).

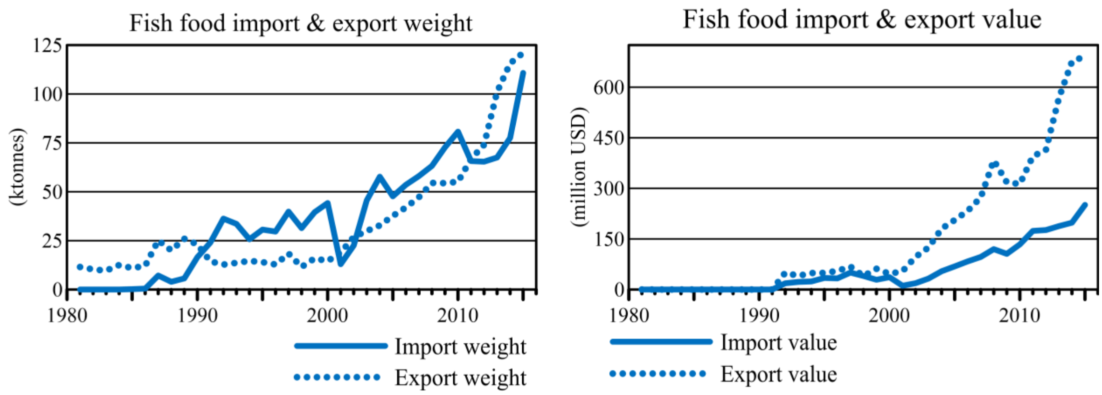

Figure 5. Long term changes in the fisheries import and export in weight and value (1982-2015)

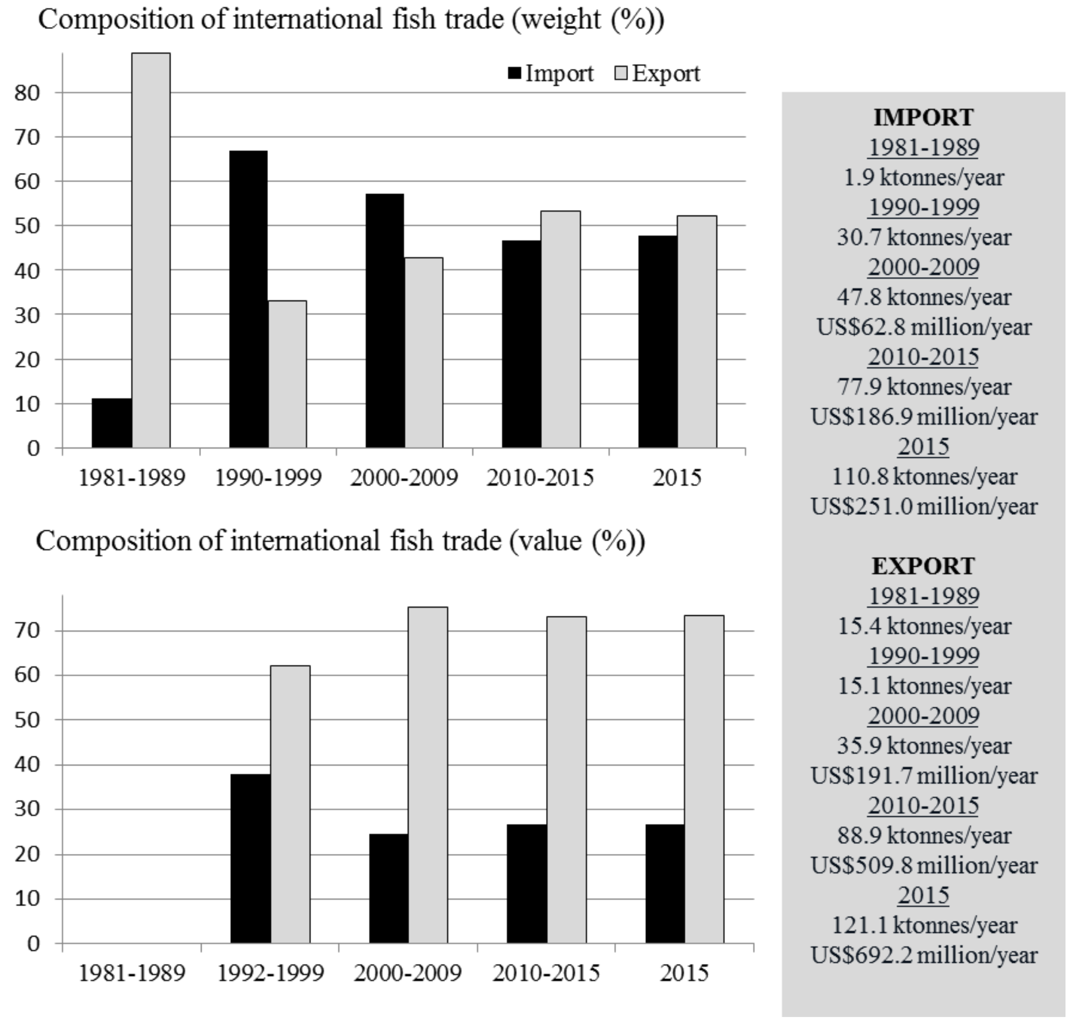

Figure 6. Decadal changes in the share of imports and exports in the international fish trade volume as weight and value.

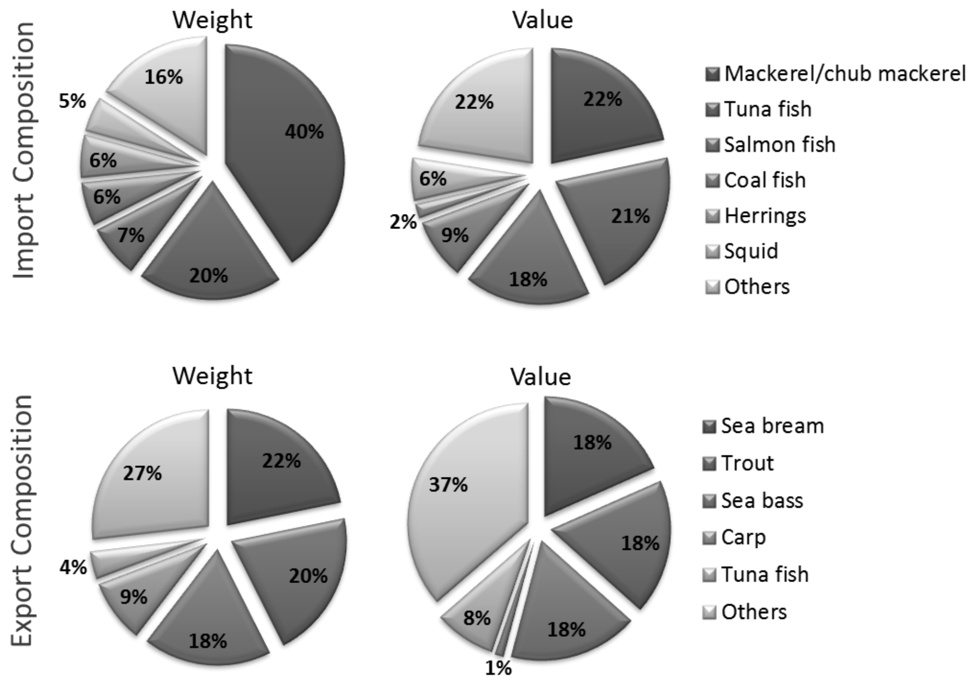

Figure 7. The percentage composition of Turkey's imports and exports in 2013.

Total domestic fish consumption; Amount of fisheries products used for the human consumption grew from 387.5 ktonnes/year in the 1980s up to 473.4 ktonnes/year in the 1990s and to 537.3 ktonnes/year in the 2000s (Figure 8). Following this increase, the annual average domestic consumption decreased to 481.9 ktonnes/yearin 2010-2015 and recorded as 485.8 ktonnes in 2015. Even though total fisheries production and imports displayed important growth within the last three decades, total domestic fish consumption remained limited due to the increasing amounts of exports and non-food usage.

Fish food self-sufficiency rate; Turkey's fish food self-sufficiency rate was observed always over 1 (Figure 8). The ratio of 1.45 in 1980s decreased to 1.11 in 1990s. The rate increased up to 1.17 in 2000s, 1.32 in 2010-2015 period and recorded as 1.38 in 2015.

Fisheries contribution to diet; Contribution of the fisheries sector to the diet (in terms of per capita domestic fish consumption) showed big variations during the last decades (Figures 8). Per capita fish consumption ranged between 5.4 kg/person/year and 9.9 kg/person/year with the mean of 7.4 kg/person/year person during 1981-2015. 7.7 kg/person/year per capita fish consumption in Turkey in 1980s and 1990s steadily declined to 7.6 kg/person/year in 2000s and 6.4 kg/person in 2010-2015 period and 6.2 kg/person/year in 2015.

Fisheries contribution to GNP; Fisheries contribution to the GNP decreased almost three-fold from 1970 to 1975 followed by a gradual increase to its highest level of 0.53% at 1983 (Figure 8). Since then, a gradual decrease has been observed and the fisheries sector contributed 0.27% of the country's Gross National Production in 2015. In terms of decadal averaged figures, 0.44%/year contribution to GNP was recorded in the 1980s, decreased to 0.32% in the 1990s, 0.30% in the 2000s, and 0.27 in 2010-2015.

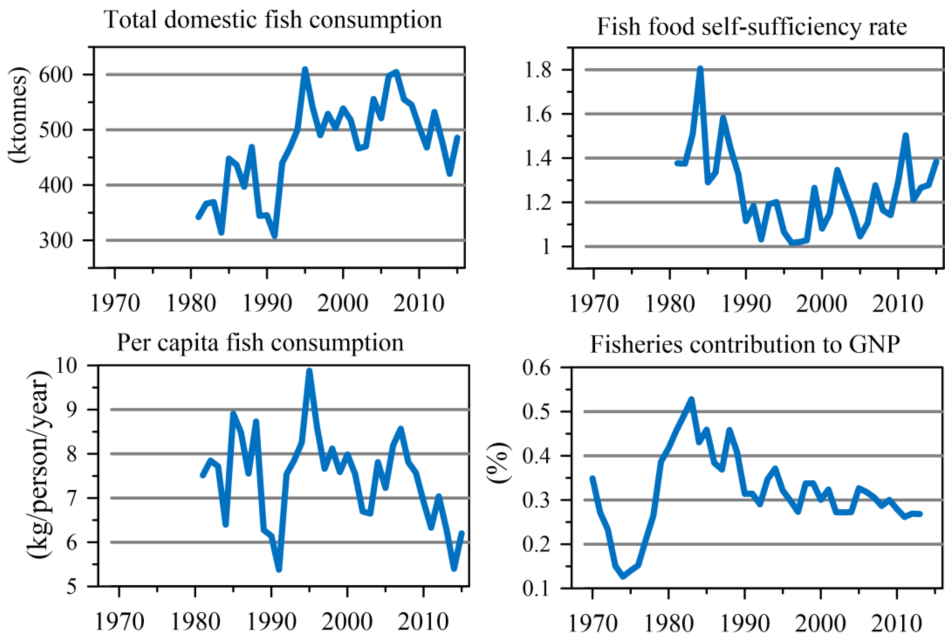

Figure 8. Long-term changes in the total domestic fish consumption, fish food self-sufficiency rate, per capita fish consumption and contribution of the Turkey's fisheries sector to GNP.

Fish food supply balance; In the 1980s, comparatively lower amount of total domestic consumption corresponded to a relatively higher per capita consumption rate (7.7 kg/person/year) due to the rapid increase in Turkey's population (50 million people) (Figure 9). In the 1990s, the amount of domestic consumption and human population size increased to 22% so as to keep the 7.7 kg/person/year consumption amount stable. The domestic consumption and human population size reached the levels of 537 ktonnes/year and 71 million in 2000s and this was resulted in a slight decrease in the per capita fish consumption to about 0.1 kg/person/year. Despite the increase in total fisheries production and amount of imports, an abrupt decrease in per capita fish consumption was recorded (6.4 kg/person/year) during 2010-2015 due to the losses by increasing export and non-food usage in addition to the continuously increasing population size. In 2015, 6.2 kg/person/year fish consumption rate was recorded for a total of 420 ktonnes of fish food consumed by 77.7 million population.

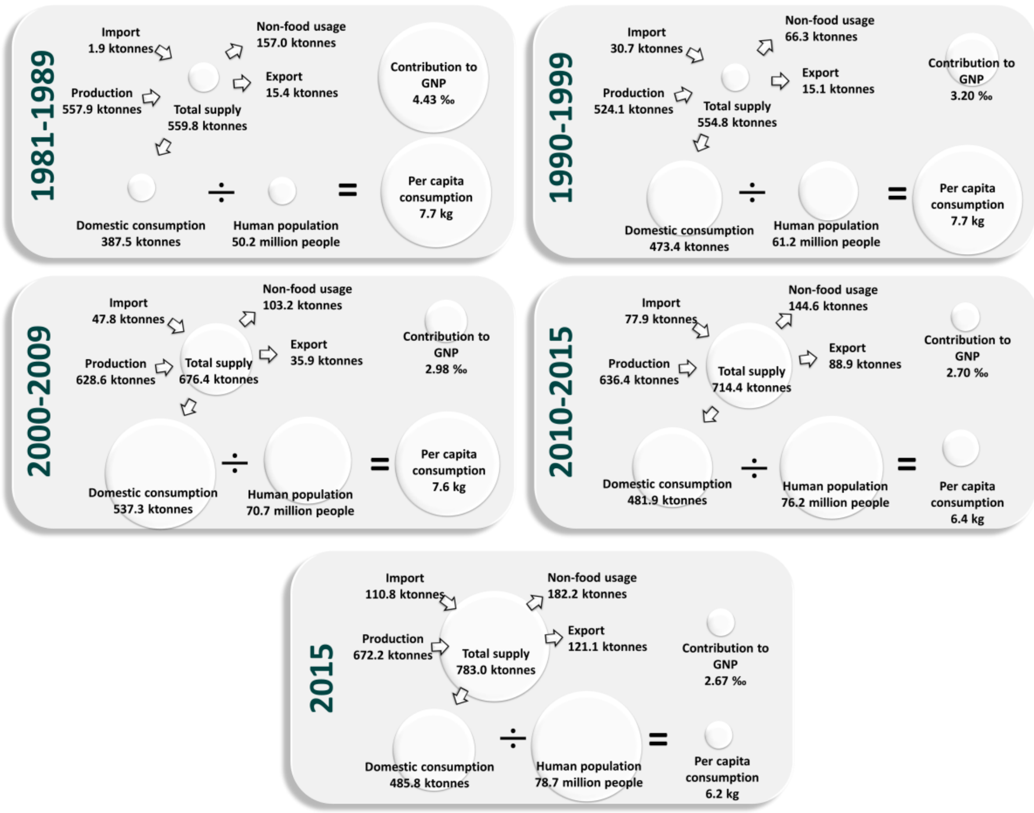

Figure 9. Yearly averages of decadal changes in the domestic consumption, fish contribution to diet and Gross National Production with their constituents (size of the

circles are proportional to the values, direction of the arrows indicates the flow of the fish).

2.4. Discussions and Conclusions

Turkey's total fisheries production performed more than a threefold growth from 1970s to 2010s. It was comprised solely of marine and inland capture fisheries in the 1970s, but by the 2010s, the contribution of capture fisheries to the total fisheries production had declined to 66.1% by weight and 41.4% by value. Decreasing landings from both marine and inland waters and increasing aquaculture production during the last decades were the main drivers of this change. The observed decrease in landings may threaten the sustainable compensation of the ever-increasing nutritive and socio-economic demands of the country in the years to come. On the other hand, the boosted aquaculture production acted as a balancing factor to compensate the shrinking landings from capture fisheries. The significance of rapidly growing aquaculture production was remarkable by means of economic value compared to the economic value obtained by the capture production. A standardized national plan for site selection, a better coordination for farming practices and legal instruments and a careful study of the pressures that adversely affect ecosystems were reported as basic requirements for aquaculture development in Turkey (Yücel-Gier et al., 2009). Meanwhile, improved fisheries management was found to reduce the growth of the potential global aquaculture growth (Jensen et al., 2014). Even though marine capture fisheries was losing its relative importance in terms of weight and value, this sector gained additional value due to its non-food usage for feeding cultivated fish in aquaculture sector. According to the trade openness analysis (Bayramoglu and Jacques, 2012), the indicator of openness to trade was found to possess a significant and positive impact on capturing fish and its further openness has a potential to increase the pressure on Turkey's declining fishery resources.

International fish trade volume of Turkey has significantly increased within time. The share of exports in the fish trade volume also increased within the last decades. Even though the value of exports was always higher than the imports, 1991-2000 and 2003-2010 were the two periods which the export weight exceeded the imports. Turkey had experienced a big economic crisis in 2001, which culminated in an unprecedented increase in the value of US Dollars compared to the Turkish Lira, and caused a threefold decrease in the weight and value of imports. Even though there are no big differences between import and export weight, three-fold higher value of exports demonstrated the importance of Turkey's fisheries sector for compensating the international trade deficit of Turkey.

In contrast to trends in global and European per capita fish consumption, which increased over recent decades (9.9 kg (1960s); 17.0 kg (2000s) and 19.2 kg (2012, FAO, 2014, global data)), Turkey's per capita fish consumption decreased from an average of 7.7 kg/person/fish in the 1980s down to 6.4 kg/person/year in 2010-2015, with a record low of 5.4 kg/person/year in 2014. Even though the total fish supply, the sum of fisheries production and imports, increased by 29% from the 1980s to the 2010s, the increasing use of fish products for processed food and export and the 50% population growth from 1980s to 2010s were the main factors responsible for the decrease of per capita consumption. This study showed that all the available fish for consumption, excluding the fish processed in the factory and exported and including imports can only supply 6.2 kg/person/year in 2015 which was much lower than the reported values for developing regions (17.8 kg/person/year in 2010) and low-income food deficit countries (10.9 kg/person/year) (FAO, 2014). Under the current circumstances, Turkey's fisheries sector was not capable of supporting higher per capita fish consumption as capture fisheries production was even declining. Major diet of the Turkish people consists of bread, other cereal crops, dairy products, vegetables and fruits. Compared to red-meat and chicken, fish food contribution to diet has been very limited over the last four decades (Turkish Healthy Nutrition and Mobile Life Program (2014 - 2017), 2013). If Turkey's per capita fish consumption increased up to world average of 19.2 kg/person/year in 2012 (FAO, 2014) or to European average of 24.5 kg/person/year in 2011 (EUMOFA, 2014), the current Turkey's self-sufficiency rate of 1.28 would decrease down to 0.43 and 0.29, respectively. In other words, if the residents of Turkey consumed fish at the same level of European people, Turkey's self-sufficiency rate of 0.33 would be lower than the Europe's 0.45. Increasing the aquaculture capacity, imports and decreasing the amount of fish processed in the factory would be the ways to meet the needs of the society if fish consumption increases. Considering the use of processed fish in the factories as fish food for the aquaculture, careful cost-benefit analyses should be done.

The period of greatest economic importance for the fishery sector in Turkey was the 1980s. Its share of the GNP gradually decreased within the following decades. However, Ulman *et al*. (2013), have reconstructed estimates of total fisheries removals in Turkey, including unreported landings, recreational landings and discards. Their estimate of fisheries production is 63% higher than the official statistics. Therefore per capita fish consumption and the economic value of the fisheries in Turkey may also be regarded higher than the values reported in this study.

From an holistic aspect, we could summarize that a total value of US$1.4 billion was obtained from 672.2 ktonnes of Turkey's fisheries production in 2015. The fisheries sector provided 6.2 kg/person/year fish consumption for 78.7 million people and contributed 0.27% of the GNP in 2014 and 0.22% of the total national employment in 2011. However, two critical points should be considered when evaluating the national importance of the Turkey's fisheries sector. First, the contribution of the sector to the GNP and to the national employment was assessed only by considering the primary sectors. When the secondary and tertiary sectors like all the machines, equipment, consumables used for fishing and fish farming activities, transportation, processing and marketing of the produced fish were taken into account, the national importance of the fisheries sector should be much higher. For example, 1.5% contribution of the fisheries sector to GNP represented 9.3% value added contribution in China (Li, 2015). Second, the illegal and unreported part of the fisheries production (also recreational fishing statistics), economy and employment were not known. If these secondary and tertiary activities, and the unknown illegal and unreported fisheries activities were included in this analysis, the real social and economic value generated by the Turkey's fisheries sectors will be better understood. Merino et al. (2012) investigated how the climate change and demand of incresing population drivers impacted marine fish and fisheries production using several numerical models. The results showed that meeting current and larger consumption rates feasible despite of above mentioned drivers when the resource management was sustainable and the dependency of animal feeds industry on wild fish was reduced. As the human population size is projected to be 94.6 million by 2050 (TurkStat, 2015), more research efforts including this kind of predictive modelling studies supplied by a comprehensive observation data sets are needed on the impact of the global warming together with the over-increasing human induced drivers on all of the fish food production systems of Turkey. The conventional fisheries management should also be extended to recognize the interdependency between human well-being and ecosystem health and the necessity to maintain ecosystem productivity (Ward et al., 2002) addressing the specific needs of each ecosystem more explicitly. Increased human population and growing demands for the food, employment and other related needs might be the main motivation for a more feasible fisheries development, in harmony with the economic growth and ecological sustainability. This is also necessary to be able to achieve Good Environmental Status (GES) in the seas and demands specific "integrated regional ecosystem management" approaches for each of the regional seas surrounding Turkey.

3. CHAPTER: Regional ecological and socio-economic consequences of the national marine capture fisheries management policies: Indicator approach

3.1. Introduction

Indicators have been widely used to understand the changes in the fisheries and its effect on the marine ecosystems, and transfer the scientific knowledge to the decision makers so as to inform and guide the fisheries management policies. From these aspects, use of indicators can result in a real, wide-reaching evaluation and provide guidance for EBFM implementation and Good Environmental Status (GES) achievement by enabling the understanding of the important processes occurring in the fisheries and their supporting ecosystems, determination and monitoring the achievability of future targets (Jennings, 2005; Shin et al., 2010).

Increasing human population size, technological improvements and globalization of the fish food market and neo-liberal business practices have fostered the rapid development of global fishing effort over the last decades (Anticamara et al., 2010). Since 1950s, global fishing effort has been expanded and fourfold enlargement of fishing area was resulted with a 2.4 times increase in landings (Swartz et al., 2010). The world's developing fishing fleets created a widespread overcapacity and excess fishing effort (Srinivasan, 2012; Watson et al., 2013) on the natural resources reaching their limits resulting in a decline of the global landings since late 1980s (FAO, 2014). As a result, in 2011, 61.3% of the world's marine fish stocks were found to be fully fished, 28.8% was over-fished and only 9.9% was under-fished (FAO, 2014). Due to the limited amount of landings, not only ecological but also socio-economic losses occurred in the marine capture fisheries threatening their sustainability (Allison et al., 2009). However, the expansion of global fishing effort continued despite a continuous decrease in landings even though the sector was sustained by national investment and subsidization policies that were known to be the important drivers of the excessive increase in the capacity and the exploitation (Sumaila et al., 2010; Anticamara et al., 2010). On the other hand, increasing unemployment rates driven by economic crises resulted an increase in the number of fishers because fisheries is regarded as the last resort of employment in many countries due to the fact that it does not require extensive a priori training (FAO, 2008).

Turkey's marine capture fisheries total landings collapsed down to a 36-year low of 266 ktonnes in 2014. Compared to 36 years ago, the same level of capture production was obtained by today's more than twofold larger, technologically well-equipped fishing fleet. This prioritised the necessity of investigation of the causality process of the collapse.

This chapter, firstly, examined the long term alterations occurred in Turkey's marine capture fisheries sector under the influence of two known factors, governmental subsidies and national economic crises. For this purpose, changes in the capacity of the fleet and its socio-economic efficacy were analysed for the period between 1970-2015 and interpreted under the influence of governmental subsidies implementation and economic crises based on the official data provided by Turkish Statistical Institute. The set of supportive governmental supports considered in this chapter (Üstündağ, 2010; Ünal and Goncüoğlu , 2010) were;

- 1976 Easy facilitation of bank loan use in
- 1982 Tax free equipment purchases in
- 1984 25% government contribution to fixed investment in
- 1994, 1997 and 2002 vessel licenses permittion at three specific occasions
- 1993 and 2005 bank loan use promotion
- 2004 fuel subsidies

Economic crises considered in this study (Aydın, 2013) were;

- 1973-74 petroleum crises
- 1977-78 crises
- the 1994 economic crisis
- the 1998 textile crisis
- the November 2000 and February 2001 crises
- the 2008-2009 global crisis

Secondly, a suit of fisheries indicators (landing weight, number of vessels and fishers in the fleet, fishing effort, catch per unit effort and catch per fisher) and landings based ecological indicators (mean trophic level of the catch, mean length, Intrinsic Vulnerability Index and proportion of small pelagic fish) were examined to communicate how the Turkey's regional marine capture fisheries changed in the period of 1970-2015 and how the ecosystem responded to fisheries. Time depended trends and interrelations between the indicators were analysed by means of statistical methods.

In summary, **this chapter focuses to understand the direction and magnitude of the historical changes in the Turkey's marine capture fisheries at national and regional scales and the corresponding response of the regional fishing efficiacy and marine ecosystems through the eyes of indicators.** Learning from the indicator-based assessments, it was aimed to inform the future decision making processes in order to ensure sustainable utilization of the regional ecosystems for the needs of today's and future generations.

3.2. Materials and Methods

Data source: In this study, the 1970-2015 fisheries landings and fleet data were directly taken from the DEKOYON Project database (dekoyon.ims.metu.edu.tr) which was constructed by the extraction of the data from the annual Fishery Statistics booklets published by the Turkish Statistical Institute. The official fisheries statistics were collected applying biannual surveys during January and May of each year by the Turkish Statistical Institute. Related socio-economic indicators were also based on Turkish Statistical Institute (TurkStat http://www.turkstat.gov.tr) and calculated based on the obtained data by the questionnaires.

Indicators: A set of fisheries and ecological indicators were selected depending upon the availability of data time-series (Table 3).

Fisheries indicators; Marine capture fisheries landings, number of vessels and fishers in the fleet, fleet's fishing effort in total engine power, Catch per Unit Effort (CPUE) and Catch per Fisher (CPF) were used as fisheries indicators in this study.

Estimated engine power of Turkey's marine capture fisheries fleet was calculated by giving average values to each HP class (9 HP for 1-9 HP class, 15 HP for 10-19

HP class, 45 HP for 20-49 HP class, 75 HP for 50-99 HP class, 200 HP for 100HP+ class). It was used as an indicator for increase or decrease in the fishing effort of the Turkey's marine capture fisheries fleet.

Estimated number of fishers in the sector was calculated by giving average values to each employment class (3 for 1-4 fishers class, 7 for 5-7 fishers class, 15 for 10-19 fishers class, 25 for 20-29 fishers class and 45 for 30 fishers+ class) and used as an indicator for the importance of the sector from the social domain.

Marine capture fisheries contribution to national employment refers to the ratio of employment created directly by the marine capture fisheries and indicates the national social importance of fisheries (FAO, 1999). This ratio was calculated by;

$$Employment_F = \frac{Number\ of\ fishers}{Total\ national\ employment} X\ 100 \quad (1)$$

Catch per Unit Effort was estimated by dividing Turkey's total marine capture fisheries landings by the estimated engine power of the fleet.

Catch per Fisher was estimated as the ratio of total marine capture fisheries landings to the estimated total employment in the marine capture fisheries and used as an indicator for the efficiency of fishing of the sector as well as the pressure exerted by each fisher (FAO, 2002).

Profitability (P) was calculated as the ratio of total income to expenses for marine capture fisheries. Low or negative profitability is an indicator for economically wasteful fish stock exploitation and excessive fishing capacity and effort on both economic and biological grounds (FAO, 1999). Profitability (P) was calculated as;

$$P = \frac{Total\ income}{(Fixed\ Capital\ Investments + Expenditures\ for\ activities)} \quad (2)$$

Ecological indicators; Depending upon the data availability, a set of landings-based ecological indicators were selected. Their calculation and interpretation with respect to fisheries were summarized below.

Mean Trophic Level of fish in the landings (mTL) is the weighted average trophic level of all fish species in the landings. Representing the trophic position of the whole catch, this indicator is used to assess the 'fishing down the food web' effect of the fisheries on the marine ecosystem as the fisheries tends to target species at higher TLs first (Pauly *et al.,* 1998). mTL decreases in response to overfishing.

Mean length of fish in the landings (mLength) is **t**he weighted average mean length of all fish species in the landings. It is used to track fishing effects on an ecosystem as the fishery removes larger fish first from the ecosystem (Shin *et al.,* 2005). mLength decreases in response to overfishing.

Intrinsic Vulnerability Index of the landings (IVI) is the weighted average intrinsic vulnerability of all fish species in the landings. It is used to track the overexploitation status of the more vulnerable species under fishing pressure (Cheung *et al.,* 2005). IVI decreases in response to overfishing.

Proportion of small pelagic fish in the landed fish weight (SmallP) is the ratio of small pelagic fish to all landed fish. It is used as supplementary indicator for mTL and MTI to detect the 'fishing down the food web' effect of the fisheries on the marine ecosystem. SmallP generally increases in response to overfishing.

Trophic level, small pelagic categorization, mean length and IVI values of the fish species were taken from FishBase library (http://www.fishbase.org) and given in Appendix I.

Statistical analyses: Nonparametric Mann-Kendall tests were used to test for significant long-term trends in the indicators and Spearman's rank correlation statistics were applied to detect the relationships between the indicators.

Table 3. List of the parameters used in the present study

Parameter	Available since
Marine landing weight	1970
Marine landing value	1996
Total vessel numbers	1970
Estimated HP power of the fleet*	1970
Estimated employment in fleet*	1970
Marine capture fisheries contribution to national employment*	1996
Catch per Unit Effort*	1970
Catch per Fisher*	1970
Profitability*	1999

*Calculated values

3.3. Results

3.3.1. Marine capture fisheries at national scale

The historical trend of the **Turkey's marine capture fisheries landings** was evaluated in session 2.3. Landings were found to be increasing during the year and the following year of the all economic crises except from the 1973-74 and 2008-9 crises (Figure 10) (Table 4).

Total vessel numbers in the Turkey's marine capture fisheries fleet displayed almost a threefold growth from 6,376 vessels in 1970 to its highest level of 18,542 vessels in 2003 (Figure 10). A gradual decrease has been observed since 2003 and the fleet size gradually decreased down to 14,340 vessels in 2015. Positive growth rates of the fleet size were recorded in the years and/or in the subsequent years of the supportive legislative measures implemented (Table 4).

Estimated engine power of the Turkey's marine capture fisheries fleet increased more than sevenfold from 1970 (184.7 thousand HP) to its maximum value (1,372.5 thousand HP) in 2006 (Figure 10). Afterwards, the values gradually declined down to 1,089.6 thousand HP in 2015. Similar to the vessel number, positive growth rates of estimated HP power of the fleet were recorded in the years and/or in the subsequent years of the supportive legislative measures implemented (Table 4).

Estimated employment provided by the marine capture fisheries was recorded as 46.7 thousand fishers in 1970 (Figure 10). This number drastically declined down to 16.4 thousand in 1976 and remained around 21 ±2 thousand fishers until the mid to late 1990s when employment increased to an average of 41.0 thousand fishers during the mid-2000s, which then gradually decreased down to 31.1 thousand fishers by 2015. Relatively higher unemployment rates driven by these three economic crises caused a three-step rise in the total number of fishers in the following years. Estimated number of fishers increased during the years of the economic crises in Turkey (rather than supportive legislations) except for the 1973-1974 crises (Table 4). Estimated fisher number and contribution of the employment in marine capture fisheries sector to the national employment were parallel to the unemployment rate of Turkey and its contribution to the total national employment ranged between 0.1-0.34%.

CPUE and CPF values were recorded higher within the period between the late 1970s and late 1980s indicating higher efficiency of the Turkey's marine capture fisheries (Figure 11). CPUE values were found to be decreasing from 1970 to 1976 because the reduction in the landing weight was higher than the estimated fishing effort in this period. Contrastingly, CPF increased from 3.7 tonnes/year to 8.3 tonnes/year due to the rapid decline in the number of fishers during the same period. Estimated engine power and employment of the fleet displayed continuous growth up to their over-all high values in 2006 and 2002, respectively. However, the amount of landings did not correspondingly increased and even collapsed occasionally. As a result, striking decreases were observed both in CPUE and CPF values. In 2015, CPUE was at its lowest level of 0.4 tonnes/year and CPF was 12.8 tonnes/year.

Profitability rate of Turkey's marine capture fisheries for the years between 1999 and 2015 were shown in Figure 11. The profitability rate of 4.3 in 1999 decreased down to 1.6 in 2015. Sudden decreases recorded in the profitability rate in 2001-2002 were due to the high employment costs in the sector during this period.

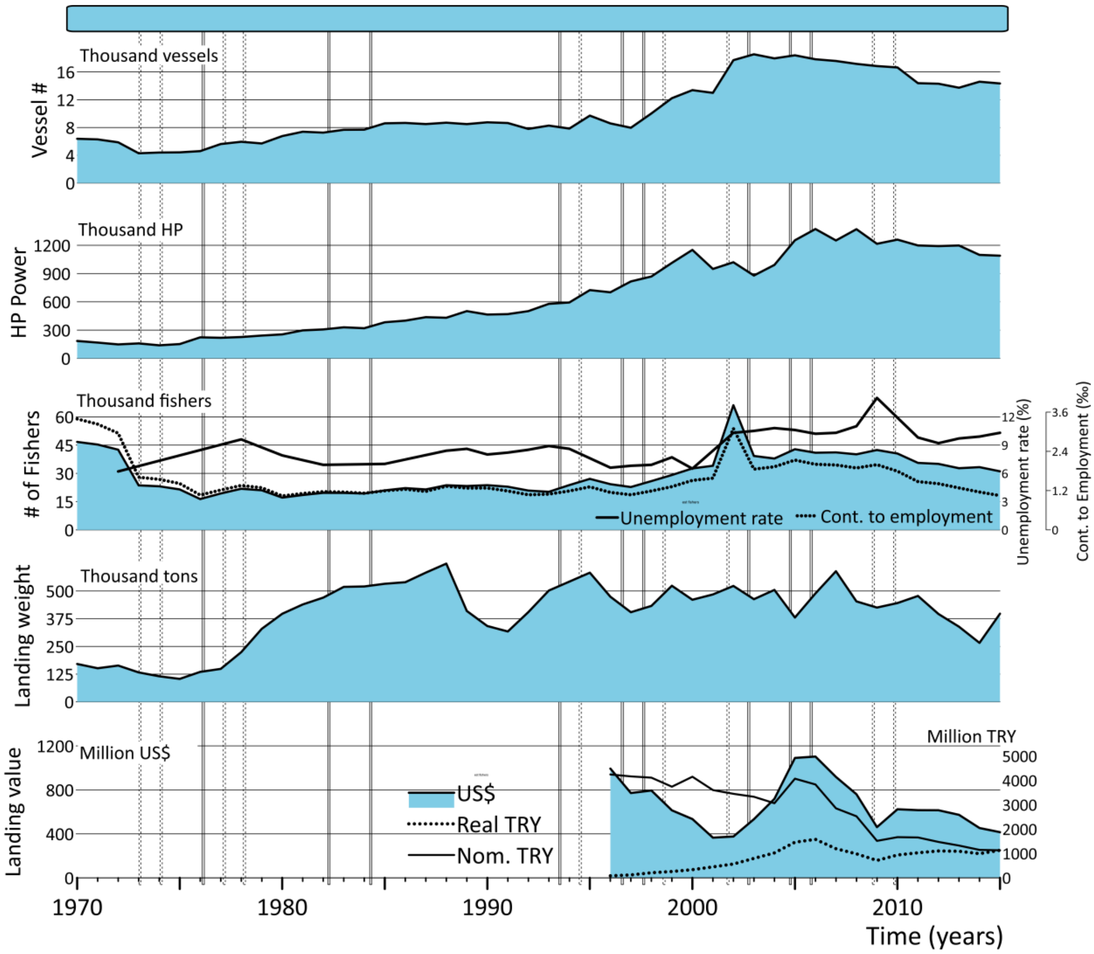

Figure 10. Changes in the vessel number, estimated engine power, fishers, landing weight and value of the Turkey's marine capture fisheries fleet during 1970-2015. The years when the governmental legislative supports (solid vertical lines) and the important economic crises (dashed vertical lines) were shown.

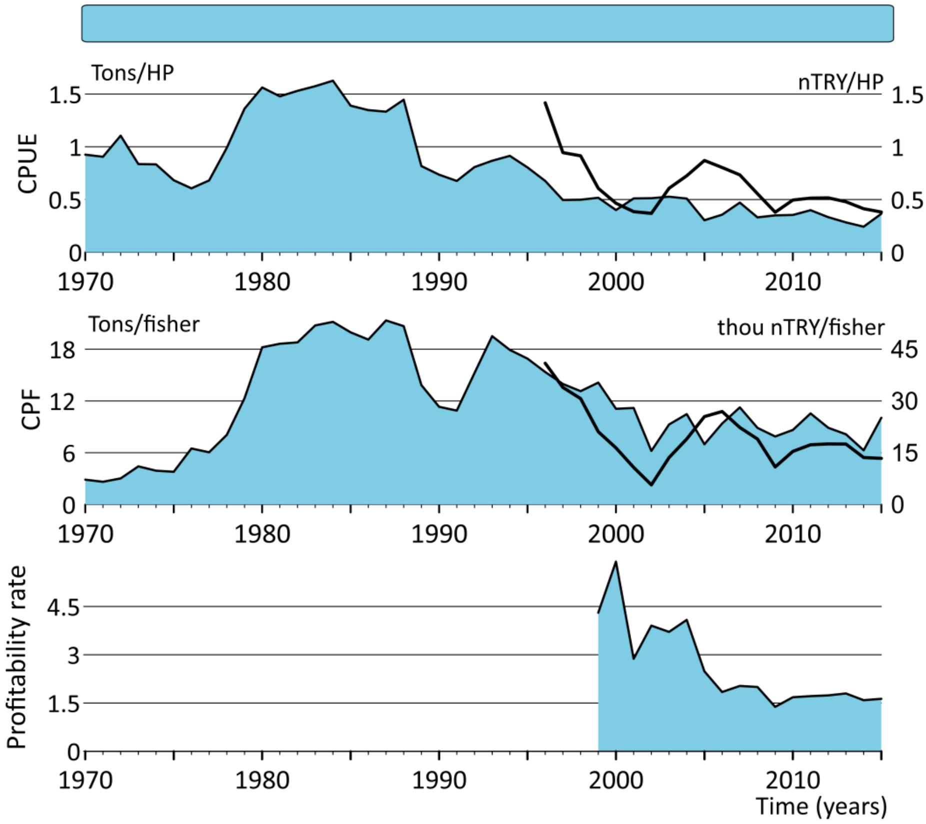

Figure 11. Changes in Catch per Unit Effort (CPUE) and Catch per Fisher (CPF) values in the Turkish marine capture fisheries fleet in 1970-2015 period.

Table 4. Relative growth rate of number of vessels, HP power of the fleet, number of fishers and landings in the years when the economic crises occurred and governmental subsidies were provided to the sector (t indicates the year of the event).

	Year(s)	# of vessels			HP power of the fleet			# of fishers			Landings		
		t	t+1	t+2	t	t+1	t+2	t	t+1	t+2	t	t+1	t+2
Years of crises	1973-1974	-13%↓	5%↑	2%↑	-3%↓	10%↑	47%↑	-17%↓	-7%↓	-24%↓	-16%↓	-10%↓	30%↑
	1977-1978	14%↑	-4%↓	19%↑	1%↑	7%↑	5%↑	16%↑	-4%↓	-18%↓	30%↑	47%↑	21%↑
	1994	7%↑	10%↑	-1%↓	5%↑	22%↑	-3%↓	18%↑	14%↑	-10%↓	8%↑	7%↑	-19%↓
	1998	3%↑	38%↑	-3%↓	6%↑	18%↑	14%↑	14%↑	13%↑	12%↑	7%↑	21%↑	-12%↓
	2001	-3%↓	36%↑	5%↑	-18%↓	7%↑	-14%↓	4%↑	94%↑	-41%↓	5%↑	8%↑	-11%↓
	2008-2009	-3%↓	-2%↓	-1%↓	-1%↓	4%↑	-5%↓	2%↑	-4%↓	-12%↓	-15%↓	5%↑	7%↑
Years of Subsidies	1976	2%↑	22%↑	6%↑	47%↑	-2%↓	4%↑	-24%↓	18%↑	13%↑	30%↑	10%↑	51%↑
	1982	-2%↓	6%↑	0%↑	3%↑	7%↑	-3%↓	6%↑	0%↑	-2%↓	7%↑	10%↑	0%↑
	1984	0%↑	12%↑	1%↑	-3%↓	20%↑	4%↑	-2%↓	9%↑	6%↑	0%↑	2%↑	1%↑
	1993	6%↑	7%↑	10%↑	12%↑	5%↑	22%↑	-3%↓	18%↑	14%↑	24%↑	8%↑	7%↑
	1996	-1%↓	2%↑	3%↑	-3%↓	16%↑	6%↑	-10%↓	-6%↓	14%↑	-19%↓	-15%↓	7%↑
	1997	2%↑	3%↑	38%↑	16%↑	6%↑	18%↑	-6%↓	14%↑	13%↑	-15%↓	7%↑	21%↑
	2002	36%↑	5%↑	-3%↓	7%↑	-14%↓	13%↑	94%↑	-41%↓	-3%↓	8%↑	-11%↓	9%↑
	2004	-3%↓	2%↑	-3%↓	13%↑	26%↑	10%↑	-3%↓	13%↑	-4%↓	9%↑	-25%↓	29%↑
	2005	2%↑	-3%↓	-1%↓	26%↑	10%↑	-9%↓	13%↑	-4%↓	0%↑	-25%↓	29%↑	20%↑

3.3.1. Marine capture fisheries at regional scale

The results from indicator based analyses were summarized below and Mann Kendall trend analyses and Spearman Rank Correlation analyses results were given in Appendixes II and III.

The Black Sea: The change of the Black Sea fisheries landings from 144.7 ktonnes in 1970 to 320.6 ktonnes in 2015 with a maximum of 494.1 ktonnes in 1988 was shown in Figure 12. The share of the Black Sea marine capture fisheries in the total marine landings was 85% (142.1 tonnes/year) in 1970s, 82.2% (413.9 tonnes/year) in 1980s, 69.2% (313.0 tonnes/year) in 1990s, 75% (357.8 tonnes/year) in 2000s, 75.3% in (291.5 tonnes/year) 2010-2015 and 80.6% (320.6 ton/year) in 2015 (Table 5). In terms of economic value, the region's contribution to the total was 54.4% (US$373 million/year) in 2000s, 53% (US$290.8 million/year) in 2010-2015 and 58.8% (US$244.3 million) in 2015. Anchovy landings contributed more than half of the Black Sea landings in all the times (Table 5).

The number of vessels and fishers in the Black Sea fishing fleet continued to increase until the mid-2000s though the maximum amount of landings was achieved in 1988. As a result, CPUE and CPF indicators displayed higher levels from the beginning to the end of 1980s and gradually declined towards 2015. Meanwhile mTL, mLength and IVI ecological indicators showed decreasing and SmallP indicator displayed increasing significant trends between the years of 1970 and 2015.

The Marmara Sea: Marmara Sea landings showed increasing decadal averages from 1970s to 2000s (14.7 ktonnes/year in 1970s, 47.6 ktonnes/year in 1980s, 57.0 ktonnes/year in 1990s and 58.1 ktonnes/year in 2000s) with a maximum of 83.3 ktonnes recorded in 1999 (Figure 13). Its share in the total marine landings was 8.8% in 1970s, 9.5% in 1980s, 12.6% in 1990s, 12.2% in 2000s. Marmara Sea landings decreased down to 38.9 ktonnes/year in the 2010-2015 period and 31.8 ktonnes in 2015 (Table 5). In terms of economic value, the region's contribution to the total was 19.3% (US$132.2 million/year) in 2000s, 14.6% (US$80.4 million/year) in 2010-2015 and 14.5% (US$60.1 million) in 2015. Similar to the Black Sea, anchovy was the most landed fish species in the Marmara Sea with an increasing contribution from 37% in 1970s to 57% in 2015.

Landing weight, the number of vessels and fishers in the fleet and fleet's engine power in the Marmara Sea increased towards the beginning of 1990s and decreased in the mid-1990s. Increasing values in 2000s had a decreasing trend towards 2015. The average CPUE level of 0.3 ton/HP until mid-2000s was recorded below 0.2 in the following years indicating a less efficient fishery in the period. Mean time mTL, mLength and IVI ecological indicators performed decreasing and SmallP indicator increasing significant trends in the whole time period.

The Aegean Sea: The Aegean Sea landings reached its maximum level of 72.7 ktonnes before 2000s, however, the growth of the vessel and fisher numbers and fishing power of the fleet continued up to their maximum values in the mid-2000s (Figure 14). For this reason, fisheries efficiency was higher during the 1980s and 1990s with higher CPUE and CPF values and rapidly decreased towards the late 1990s. 2000-2005 was the period when the fishing pressures continued to grow despite relatively low fishing efficiency. The regions contribution to the total landings was 3.7% (6.2 ktonnes/year) in 1970s, 5.2% (26.3 ktonnes/year) in 1980s, 11.7% (53.2 ktonnes/year) in 1990s, 9.1% (43.4 ktonnes/year) in 2000s, 9.1% (35.2 ktonnes/year) in 2010-2015 and 8.9% (35.4 ktons) in 2015. In economic terms, the region contributed to 16.8% (US$115.1 million) in 2000s, 16.4 (US$90.2 million) in 2010-2015 and 17.7% (US$73.3 million) in 2015. European pilchard was the most landed fish species from the Aegean Sea from 1970s to 1990s whereas anchovy was in the following period. Regarding the ecological indicators, significant positive trends in SmallP and negative trends in mLength and IVI were detected.

The Mediterranean Sea: Mediterranean Sea fisheries landings of 2.4 ktonnes/year in 1970 increased up to its maximum level of 43.7 ktonnes in 1992 (Figure 15). The values gradually decreased down to 12.2 ktonnes in 2001 and reached the second peak of 33.1 ktonnes in 2011. Afterwards, the amount of landings gradually decreased down to 10.0 ktonnes in 2015. The region's limited contribution to the total was 2.7% (4.6 ktonnes/year) in 1970s, 3.1% (15.6 ktonnes/year) in 1980s, 6.5% (29.4 ktonnes/year) in 1990s, 3.8% (17.9 ktonnes/year) in 2000s, 5.6% (21.6

ktonnes/year) in 2010-2015 and 2.5% (10.0 ktonnes/year) in 201. The region's economic contribution was 9.6% (US$65.8 million/year) in 2000s, 16% (US$87.8 million/year) in 2010-2015 and 9% (US$80.4 million) in 2015. European pilchard was the most landed fish species in the Mediterranean Sea since 1980s (Table 5).

Mediterranean Sea landings, the number of vessels and fisheries in the fleet and fishing power of the fleet performed significant positive growth in 1970-2015 period. Fishing pressure indicators continued to increase even though landings reached its maximum levels in the beginning of 1990s. For this reason fishing efficiency rapidly decreased towards the end of 1990s. IVI ecological indicator showed negative, SmallP indicator displayed positive significant trends in 1970-2015 period.

3.4. Discussions and Conclusions

At national level

The current study presented an insight for the development of excessive fishing capacity and its consequences in the Turkey's EEZs. Even though landings already attained its maximum value of 623 ktonnes in 1988, vessel number, engine power and employment of the fleet continuously grew up to their highest values in 2003, 2006 and 2005 respectively by performing correspondingly 4, 10 and 2 fold growths. Results of the study revealed that the continuous growth of the Turkey's marine capture fisheries, despite limited relative catch values and profitability rates, were due to;

I) Supportive management applications that resulted in the increase of the vessel numbers and engine power of the fleet in the year and/or in the following year of their implementation has led to relatively lower Catch per Unit effort (CPUE) and Catch per Fisher (CPF) values. This fostered the development of an economically unsustainable fisheries sector. This development further impaired by the decrease in the catches and even occasional stock collapses contrary to the increasing effort,

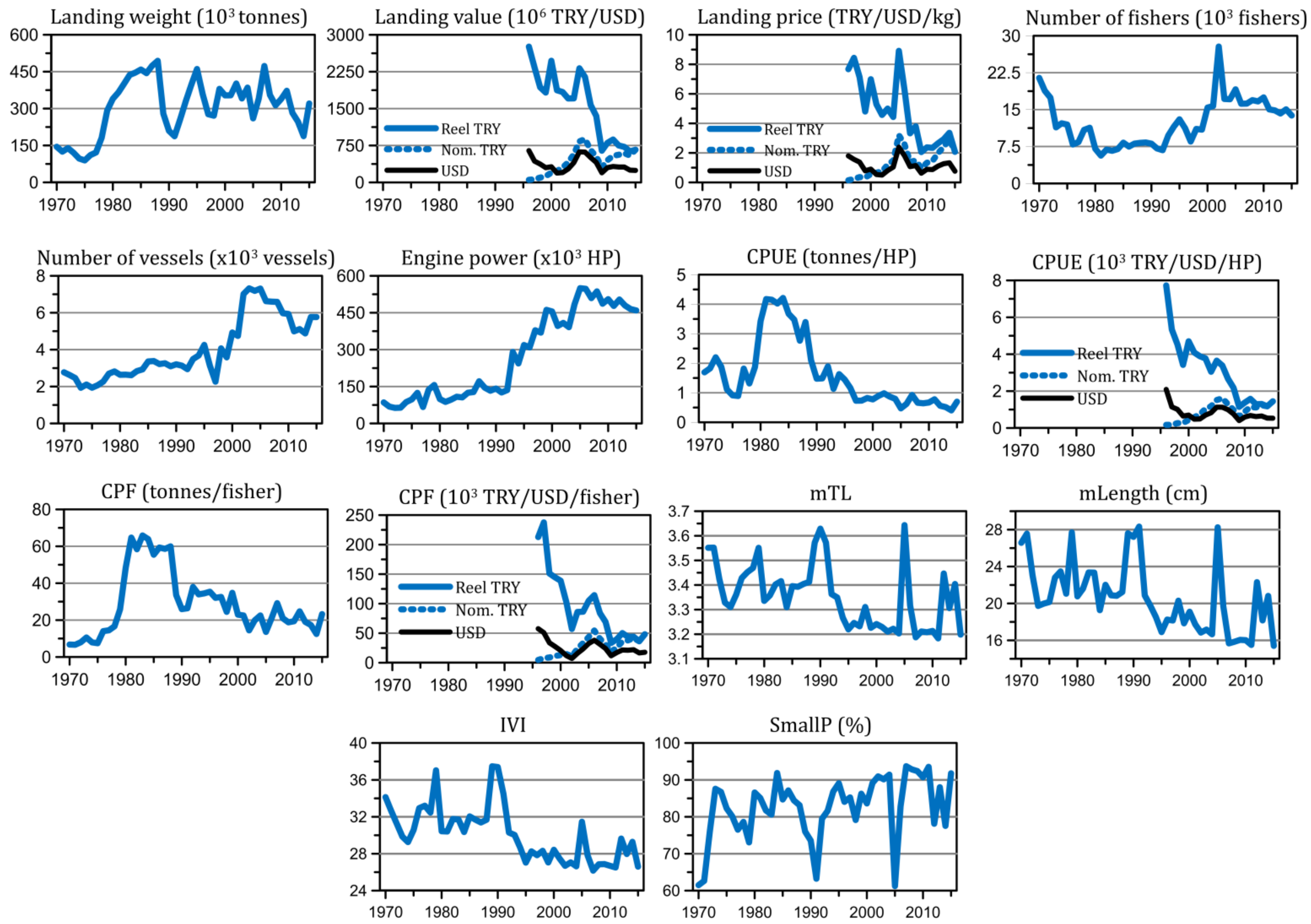

Figure 12. Time series of the selected fisheries and ecological indicators in the Black Sea.

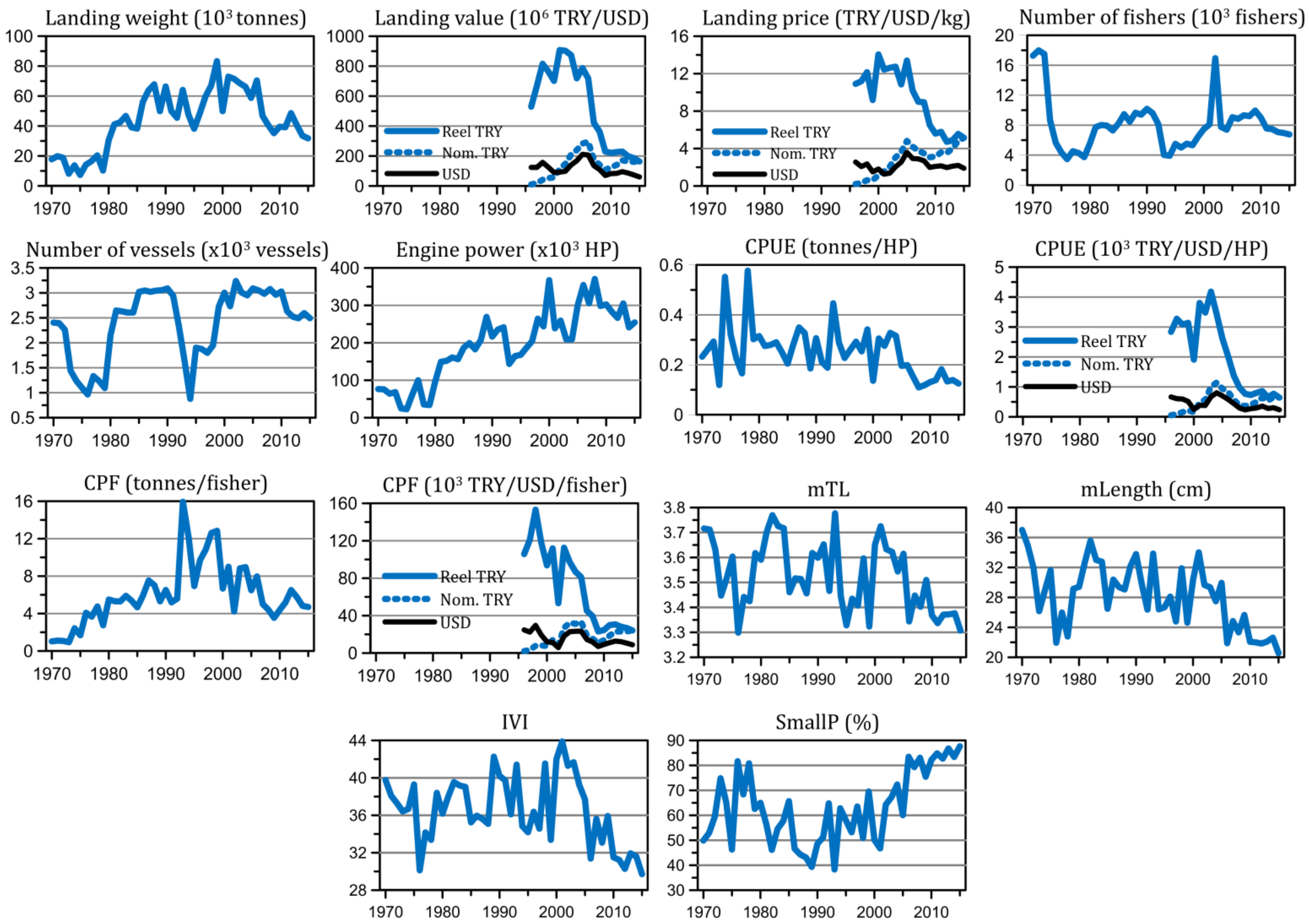

Figure 13. Time series of the selected fisheries and ecological indicators in the Marmara Sea.

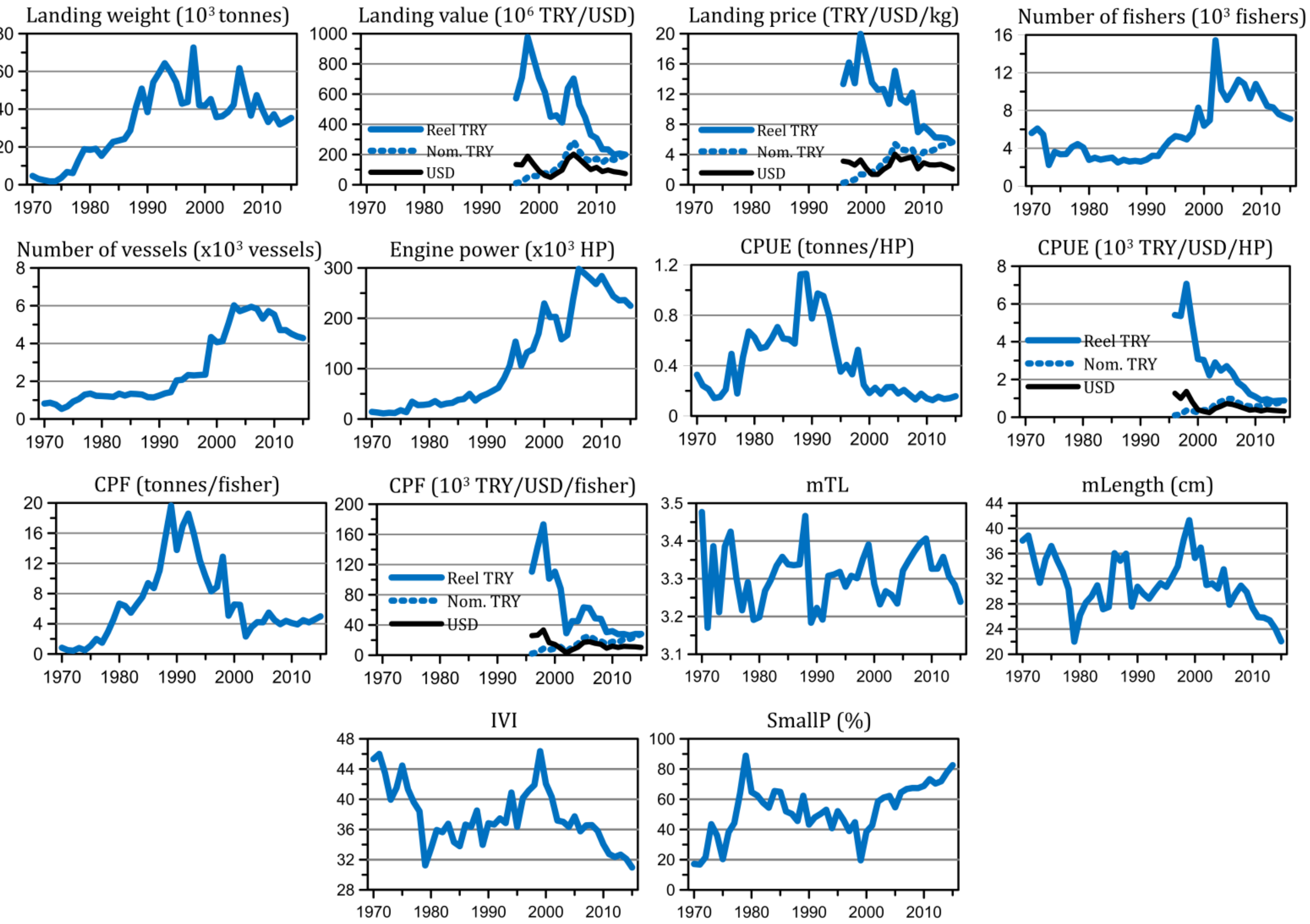

Figure 14. Time series of the selected fisheries and ecological indicators in the Aegean Sea.

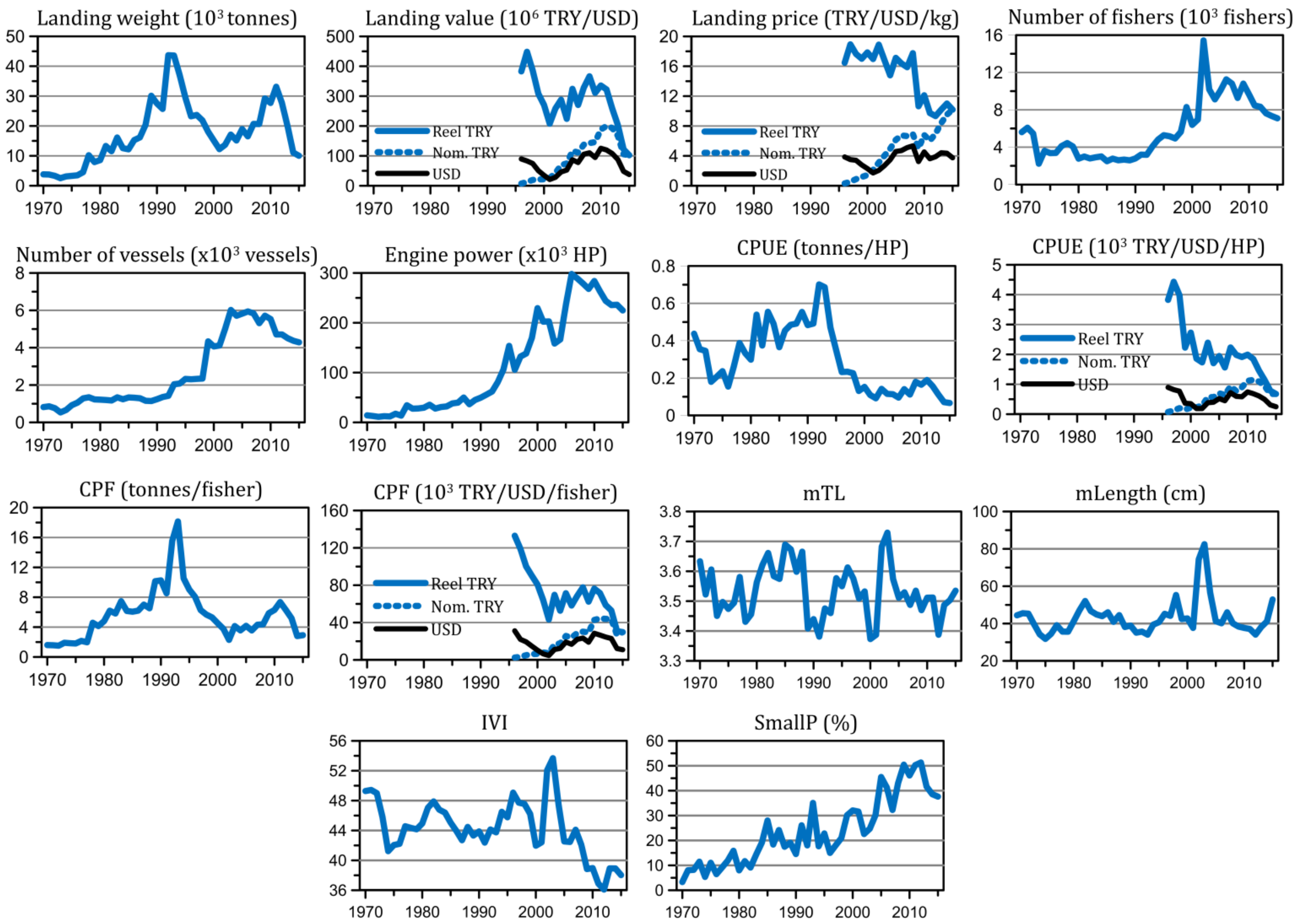

Figure 15. Time series of the selected fisheries and ecological indicators in the Mediterranean Sea.

Table 5. Contribution of the regions to the total marine landings weight and value.

Region	Sıra	1970-1979				1980-1989				1990-1999				2000-2009							
		Weight				Weight				Weight				Weight				Value			Price
		Tür	tons x103	Reg %	Tot %	Tür	tons x10	Reg %	Tot %	Tür	tons x10	Reg %	Tot %	Tür	tons x103	Reg %	Tot %	TL $x10^6$	Reg %	Tot %	TL/ Kg
Turkey	1	Anchovy	87		52	Anchovy	272		54	Anchovy	236		52	Anchovy	286		60	203		30	1
	2	Med. horse mack	21		12	Med. horse ma	81		16	European pilchard	26		6	Med. horse mackare	18		4	34		5	2
	3	Bonito	9		5	Bonito	17		3	Med. horse macka	19		4	European pilchard	16		3	30		4	2
	4	Whiting	8		5	Chub mackarel	17		3	Whiting	18		4	Bonito	16		3	56		8	3
	5	Atl. horse macker	6		4	Whiting	16		3	Grey mullet	18		4	Striped venus	16		3	13		2	1
	Turkey total		168		78		503		80		453		70		477		74	686		49	1
Black Sea	1	Anchovy	81	57	48	Anchovy	261	63	52	Anchovy	217	69	48	Anchovy	256	71	54	169	45	25	1
	2	Med. horse mack	18	13	11	Med. horse ma	74	18	15	Whiting	16	5	4	Striped venus	16	4	3	13	3	2	1
	3	Whiting	8	6	5	Whiting	15	4	3	Med. horse macka	16	5	3	Bonito	14	4	3	46	12	7	3
	4	Bonito	8	5	5	Bonito	13	3	3	Bonito	11	3	2	European sprat	14	4	3	3	1	1	0
	5	Atl. horse macker	6	4	3	Bluefish	11	3	2	Golden venus	9	3	2	Med. horse mackare	10	3	2	19	5	3	2
	Black Sea total		142	85	85		414	90	82		313	86	69		358	86	75	373	67	54	1
Marmara Sea	1	Anchovy	5	37	3	Anchovy	10	22	2	Anchovy	15	27	3	Anchovy	22	37	5	25	19	4	1
	2	Med. horse mack	2	14	1	Chub mackarel	8	17	2	European pilchard	6	11	1	Med. horse mackare	6	10	1	11	8	2	2
	3	Bonito	1	9	1	Med. horse ma	7	14	1	European hake	5	8	1	European hake	6	10	1	16	12	2	3
	4	Bluefish	1	8	1	Bluefish	4	8	1	Golden venus	4	8	1	Bluefish	4	7	1	23	17	3	5
	5	European pilchar	1	7	1	Shrimps	3	6	1	Chub mackarel	4	7	1	Atl. horse mackerel	4	7	1	9	7	1	2
	Marmara total		15	75	9		48	67	9		57	61	13		58	71	12	132	63	19	2
AAegean Seaan S	1	European pilchar	2	27	1	European pilch	9	36	2	European pilchard	14	27	3	European pilchard	10	22	2	17	15	3	2
	2	Grey mullet	1	11	0	Chub mackarel	1	5	0	Grey mullet	6	12	1	Anchovy	8	19	2	9	8	1	1
	3	Med. horse mack	1	9	0	Grey mullet	1	5	0	European hake	4	8	1	Grey mullet	4	10	1	10	9	1	2
	4	Anchovy	0	7	0	Anchovy	1	4	0	Chub mackarel	4	8	1	Bogue	2	4	0	4	3	1	2
	5	Bogue	0	7	0	Med. horse ma	1	4	0	Anchovy	4	7	1	European hake	2	4	0	7	6	1	4
	Aegean Sea total		6	61	4		26	53	5		53	63	12		43	59	9	115	41	17	3
Medit. Sea	1	Goby	1	12	0	European barra	2	12	0	European pilchard	3	10	1	European pilchard	3	16	1	5	8	1	2
	2	European barracu	1	11	0	European pilch	1	8	0	Grey mullet	2	8	1	Grey mullet	1	7	0	3	5	0	3
	3	Red Mullet	0	9	0	Shrimps	1	6	0	Chub mackarel	2	8	1	Bluefin tuna	1	6	0	4	6	1	4
	4	Grey mullet	0	7	0	Goby	1	6	0	European hake	2	6	0	Shrimps	1	6	0	7	11	1	7
	5	Common pandora	0	6	0	Red Mullet	1	5	0	Sand smelt	2	5	0	Med. horse mackare	1	4	0	2	3	0	2
	Medit. Sea total		5	45	3		16	37	3		29	39	6		18	39	4	66	32	10	4

Table 5 continued. Contribution of the regions to the total marine landings weight and value.

Region	Order	2010-2015								2015							
		Weight				Value			Price	Weight				Value			Price
		Tür	tons x103	Reg%	Tot %	TL $x10^6$	Reg%	Tot %	TL/ Kg	Tür	tons x103	Reg %	Tot %	TL $x10^6$	Reg %	Tot %	TL/ Kg
Turkey	1	Anchovy	182		47	136		25	1	Anchovy	193		49	151		36	1
	2	European sprat	47		12	15		3	0	European sprat	77		19	16		4	0
	3	Striped venus	34		9	12		2	0	Striped venus	37		9	4		1	0
	4	European pilchard	25		6	30		5	1	European pilchard	17		4	20		5	1
	5	Med. horse mackarel	18		5	39		7	2	Medit. horse mackare	14		4	31		7	2
		Turkey total	387		79	549		42	1		398		85	415		54	1
Black Sea	1	Anchovy	153	53	40	101	35	18	1	Anchovy	162	51	41	109	45	26	1
	2	European sprat	47	16	12	1	1	0	0	European sprat	77	24	19	16	7	4	0
	3	Striped venus	34	12	9	16	6	3	0	Striped venus	37	12	9	4	2	1	0
	4	Med. horse mackarel	14	5	4	23	8	4	2	Whiting	13	4	3	31	13	7	2
	5	Bonito	12	4	3	38	13	7	3	Med. horse mackarel	11	4	3	24	10	6	2
		Black Sea total	291	90	75	291	62	53	1		321	94	81	244	75	59	1
Marmara Sea	1	Anchovy	18	47	5	22	28	4	1	Anchovy	18	57	5	24	40	6	1
	2	European pilchard	7	19	2	9	11	2	1	European pilchard	5	14	1	5	9	1	1
	3	Med. horse mackarel	3	7	1	6	8	1	2	Med. horse mackarel	2	7	1	5	8	1	2
	4	Shrimps	2	5	1	9	12	2	4	Shrimps	2	6	0	6	10	1	3
	5	Atl. horse mackerel	2	5	1	5	6	1	3	Bluefish	1	4	0	10	16	2	7
		Marmara total	39	83	10	80	64	15	2		32	88	8	60	83	14	2
AAegean Sea	1	Anchovy	10	29	3	13	14	2	1	Anchovy	13	38	3	18	24	4	1
	2	European pilchard	10	28	3	12	13	2	1	European pilchard	9	27	2	11	15	3	1
	3	Bogue	2	5	0	3	4	1	2	Bogue	2	6	1	3	4	1	2
	4	Shad	1	4	0	2	2	0	1	Shad	1	4	0	2	2	0	1
	5	Shrimps	1	3	0	6	7	1	5	Shrimps	1	4	0	6	8	1	4
		Aegean Sea total	35	68	9	90	39	16	3		35	78	9	73	54	18	2
Medit. Sea	1	European pilchard	7	31	2	8	9	1	1	European pilchard	2	24	1	3	8	1	1
	2	Shrimps	1	6	0	12	14	2	10	Shrimps	1	11	0	9	23	2	8
	3	Red Mullet	1	5	0	11	12	2	10	Bonito	1	8	0	1	3	0	1
	4	Chub mackarel	1	4	0	3	3	0	3	Red Mullet	1	6	0	4	12	1	7
	5	Sand smelt	1	4	0	3	4	1	4	Chub mackarel	1	5	0	1	2	0	2
		Medit. Sea total	22	50	6	88	41	16	4		10	55	3	38	48	9	4

II) Economic crises culminated in the rise of the unemployment rate and caused growth of the fisher numbers. Further, the contribution of fisheries employment to the national employment in the years of economic crises (except for the 1973-74 crisis) and negative growth in the following years of the crises (except the 1998 crisis) resulted in haphazard expansions and contractions of the fishing effort creating detrimental ecological and economic consequences. This situation underlined that the fisheries sector was one of the last resorts of job with limited training and educational requirements (FAO, 1999).

The decreasing profitability ratio showed that even the fuel tax exemptions, which started in 2004 and increased from 84.422 million TRY in 2006 to 137.044 million TRY in 2011 (OECD, 2015), were not enough to make the marine capture fisheries economically profitable. It is the same with the retired 1,001 vessels with an approximate cost of US$ 45 million by the buyback program applied in 2012 by the Ministry of Food, Agriculture and Livestock (MoFAL) (Ünal et al., 2016). Very low profitability rates since 2006 may explain the recent decrease in the vessel numbers, engine power and employment in the succeeding period. Moreover, decreasing profitability values underlined the economic loss in the marine capture fisheries sector during these periods. Profitability rates reported to be different for different fishing gears such as trawlers, purse seiners, gillnets etc. in different regional fisheries (Reff regional Action plans). These differences could not be included in the thesis due to the lack of long term official data at this scale. High unemployment rates since 2006 did not increase the number of fishers, but kept fishermen carry out less efficient fisheries.

At regional levels

The implications of regional marine harvest fisheries on the long-term socio-economic changes developed differently due to peculiarities of the regional seas around Turkey. Even though some common properties could be noted, they occurred at different magnitudes and time scales.

All the fisheries indicators except the landing value and mean price have shown significant positive trends. Black Sea landing weight and values were always higher than the other regions whereas the mean price of the landing was lowest. Mediterranean Sea fisheries indicators were lower except from the mean price. Mean price of the landings was found to be gradually increasing from the Black Sea to the Aegean Sea, Marmara Sea and the Mediterranean Sea. CPUE and CPF values in the Black Sea were higher than the other regions in quantity, however, it was not true in terms of value.

The expansion of the fishing capacity of the regional fleets first resulted in increasing catches and then in many areas led to a transition phase linked to stagnating or declining regional catches due to the “fishing down the food web” (Pauly et al., 1998) phenomenon. Major changes in the CPUE led to a productive fishery between 1979 and 1988 in the Black Sea, 1974 and 1983 in the Marmara Sea, 1979 and 1994 in the Aegean Sea and 1978 and 1994 in the Mediterranean Sea. The current CPUE regimes are about three times lower than these productive periods except from the Marmara Sea. Globally the CPUE decreased by almost 50% from 1970 to 2006 (Watson et al., 2013). Similar productive regimes were also observed for CPF after 1980s other than the Marmara Sea, however, current CPF regimes are found to be about two times lower. In the Aegean Sea and the Mediterranean Sea, number of fishers has experienced continuously increasing regime shifts. In all the regional seas, the current CPF values were found to exceed the global average value of 2.3 tons/fisher in 2010 (FAO, 2012) that is, however, much lower than the European average value of 25.1 tons/fisher (FAO, 2012) and that of the Black Sea (24.1 tons/fisher).

Regarding the ecological indicators, long term trends of the landings based ecological indicators displayed the magnitute of the changes in the structure and functioning of the regional ecosystems. Further, the compositions and the sizes of regional fish stocks and regional fishing fleets displays greater variability between the regional seas surrounding Turkey due to large differences in their ecosystems; in agreement with Bilecenoğlu et al., 2002; Ünal and Göncüoğlu, 2010. Most importantly, the gradual increase in the proportion of short-lived small pelagic fish in landings 50% in the Black Sea, 35% in the Marmara Sea, 50% in the Aegean Sea and 30 % in the Mediterranean Sea over the last four decades indicating a ‘fishing down the food web’ effect in all of the Turkish regional sea ecosystems. Higher mLength and IVI, and lower SmallP values were observed from the Black Sea to the Marmara Sea, the Aegean Sea and the Mediterranean Sea. Negative significant trends detected for all of the sustainability indicators in the Black Sea showed the magnitude of the degradation of the Black Sea ecosystem during the last 40 years. Even though only one of the four indicators displayed a negative statistically significant trend, statistically insignificant decreases were experienced in the value of all the ecological indicators in the Marmara Sea, the Aegean Sea and the Mediterranean Sea. Compared to 1970, the mean trophic level of the landings decreased with a value of 0.3 in the Black Sea and the Marmara Sea, 0.07 in the Aegean Sea and 0.12 in the Mediterranean Sea. A shortening of the mean length of the fish community in the landings was also observed 10 cm in the Black Sea and Aegean Sea, 14 cm in the Marmara Sea and 6 cm in the Mediterranean Sea. Higher significant correlation values were observed between the regional fisheries pressure indicators whereas lower correlations were found between the ecological indicators.

The present study showed that very low relative catch values and economic profitability rates recorded in the recent years had already given the potential signals of a possible collapse as well as the existence of excessive fishing capacity and effort on both economic and ecological grounds. Recently implemented buy-back program retired a total of 1,001 vessels from the fleet (Ünal et al., 2016) but resulted in an inadequate decline in the engine power of the fleet. This study suggested that a further reduction in the fishing capacity of the fleet and provision of alternative employment options to the fishers are urgently needed to increase the efficiency and profitability of the Turkey's marine capture fisheries as well as to decrease the excessive fishing pressure on the fish stocks. Results presented here include uncertainies due to possible biases and uncertainties in the official data utilised in the analyses and the probability that they may not fully represent the real situation occurred over the analysis time frame. In addition to the uncertainities in the official data, the used indicators can be misleading such as the reported findings on mTL which states that it might not reliably predict changes in marine ecosystems and found to be decreased across increasing catch, survey and assessment mTL and recommends more efforts to measure true abundance trends for marine species (Branch et al., 2010). However, in the absence of more reliable data sources, current analyses is still useful to understand the long term trends in the fisheries and corresponding changes in the ecosystem and to show inconsistencies and gaps in knowledge. Future research should consider the ecological changes, especially human induced degradation, occurred in the fishing grounds of Turkey in the Black Sea, Marmara Sea, the Aegean Sea and the Mediterranean Sea. The degree of regional responses should be investigated and region specific policies should be developed considering the impact of invasive species, pollution, habitat loss and climate change which has a potential to affect temperature, salinity, windfields and seasonality, acidification, deoxygenation and sea level rise (Brander, 2013). The conventional fisheries management should consider these factors addressing the specific needs of each ecosystem more explicitly. Increased human population and growing demands for the food, employment and other related needs might be the main motivation for a more feasible fisheries development, in harmony with the economic growth and ecological sustainability. This is also necessary to be able to achieve Good Environmental Status (GES) in the seas and demands specific "integrated regional ecosystem management" approaches for each of the regional seas surrounding Turkey.

4. CHAPTER: Testing the Effect of Ecosystem Based Fisheries Management Strategies on Ecosystem and Fisheries of four Turkish seas: A modelling study

4.1. Introduction

Ecosystem-based fisheries management (EBFM) considers the complexity of the ecosystems, the relationships between the ecosystem components, major functional processes and human based/natural stressors upon them (Link, 2010). Due to these complexities, comprehensive ecosystem management has risen as a big challenge. The scientific community also recognizes the consideration of these complexities in the ecosystem management and several existing management frameworks were improved adapting EBFM with multivariate and interdisciplinary studies (Link, 2010; Garcia and Cochrane, 2005).

Ecosystem models are useful tools providing a better understanding and assessment of the above mentioned complexities that allow testing the impact of strategic scenarios (Christensen and Walters, 2004; Martell and Walters, 2008). Recent use of ecosystem models that provided an evaluation on the impact of fisheries and environmental changes on marine ecosystems has shown the value of ecosystem models in including policy optimization at ecosystem scale (Christensen and Walters, 2004). Hence, ecological forecasting has been a general goal for EBFM allowing the production of knowledge on the structure and function of marine ecosystems, future scenario testing, and assessment of the data gaps (Valette-Silver and Scavia, 2003).

In the scientific literature, an increasing appearance of trophic network models of aquatic ecosystems has been observed. Atlantis (Fulton et al., 2004), OSMOSE (Shin and Cury 2001, 2004; Travers et al., 2009) and Ecopath with Ecosim (EwE) (Christensen et al., 2005) have been prominent examples within the last few decades. EwE is the most used and tested ecosystem modelling tool globally with over 400 models published and also reported as capable for addressing a wide range of EBFM research questions (FAO, 2007). Trophic links among the ecosystem components were considered in the model structure so as to allow studying the impact of the fishing activities on ecosystem (Christensen and Walters, 2004). By using EwE, several important analyses can be summarized as: (1) exploration and comparison of ecosystem structure and functioning (Tomczak et al., 2009; Tecchio et al., 2015; Pranovi and Link, 2009; Coll et al., 2006; Corrales et al., 2015; Coll and Libralato, 2012; Tsagarakis et al., 2010) (2) evaluation of the impact of human activities (Albouy et al., 2010; Mackinson et al., 2009; Shannon et al., 2008); and (3) exploration of different options for marine ecosystem management (Araújo et al., 2008; Criales-Hernandez et al., 2006; Libralato et al., 2010; Heymans et al., 2009; Cisneros-Montemayor et al., 2012; Coll et al., 2013; Chen et al., 2009; Araujo et al., 2008; Cheung and Sumaila, 2008; Freire et al., 2007; Arreguin-Sanchez et al., 2004; Okey and Wright, 2004; Christensen and Walters, 2004; Ainsworth et al., 2008).

Research effort on the regional ecosystems of Turkey has focused more on single-species stock assessments (Gücü and Bingel, 1994) and lack of the consideration of species interactions, long term evaluations, impact of fisheries and scenario testings. To date, ecosystem model use for assessing the impacts of fishing policies and environmental change on the fisheries and ecosystems has been very limited in the Turkey's regional EEZs however there have been modelling studies at Large Marine Ecosystems (LMEs) level in the Black Sea (Akoğlu et al., 2014; Daskalov, 2002; Oguz et al., 2008), in the Aegean Sea (Tsagarakis et al., 2010) and in the Mediterranean Sea (Coll et al., 2008; Coll and Libralato, 2012). Limited by data, ecosystem modeling in the Turkey's EEZs stayed far behind compared to regions where time series data collection programs and investigations on food web interactions existed such as the western Europe (Coll et al., 2013) and northeastern United States (Link and Almeida, 2000).

Policy instruments in Turkey do not consider species interaction in relation to fisheries effect and socio-economic perspectives. For example, Total Allowable Catches (TACs) for anchovy and Venus clam were calculated based on the single species assessments. However, the seas surrounding Turkey bear very different ecological and socio-economic dynamics. As shown in Chapter 3, the regional sea ecosystems and fisheries therein experienced drastic changes over the last decades. Excessive fishing power exerted on the regional ecosystems resulted not only with decreasing landings but also with declining efficiency of the fishing activities and economic and social benefits from the fisheries. There is a lack of information on the different characteristics of the Turkey's regional ecosystems in a quantified way and the potential implications of different past and future management scenarios as required by EBFM.

The first aim of this chapter is to determine and compare the structure and functioning of Turkey's EEZs' ecosystems in the Black Sea, the Marmara Sea, the Aegean Sea and the Mediterranean Sea and assess the impacts of fishing upon them by using Ecopath mass-balance model within the period of 1995-2014. The second aim of this chapter is to capture the long-term time dynamic progressions (1995-2014) in the regional sea EEZs' by using Ecosim and investigate the potential impact of the different fishing policy applications on the previous and future status of the regional ecosystems and fisheries. This chapter serves as a scientific base for EBFM application in the Turkey's regional seas considering ecosystem health and its socio-economic services to the society synergistically and demonstrates how the ecosystem models can provide quantitative and predictive information that is useful for fisheries assessment and management.

4.2. Methodology

Ecopath with Ecosim (EwE) is built on a system of linear equations that describes the average mass and energy flows between the species groups in a certain period of time. Ecopath (a static model representing trophic web energy mass-balance) and Ecosim (a time-dynamic model that assessing the temporal dynamics of an ecosystem) are two main linked routins consisting EwE modelling approach (Christensen et al., 2005).

4.2.1. Mass balance ecosystem modelling with Ecopath

A mass-balance state of the food web was defined by a series of linear equations in the form of functional groups in Ecopath. Each functional group represents a species or groups of species linked by trophic interactions in the model. Gains (consumption, immigration) and losses (mortality, emigration) regulate the functional groups which are linked to each other by predator-prey relationships. Biomasses of the targeted and by-catch groups are extracted by fisheries. Flows of mass into and out of discrete biomass pools are described by each linear equation by using the formula;

$$B_i * \left(\frac{P}{B}\right)_i - \sum_{j=1}^{n} B_j * \left(\frac{Q}{B}\right)_j * DC_{ji} - B_i * \left(\frac{P}{B}\right)_i * (1 - EE_i) - Y_i - E_i - BA_i = 0 \quad (1)$$

where *B* stands for biomass, $(P/B)_i$ stands for the production to biomass ratio, $(Q/B)_j$ stands for the consumption to biomass ratio of predator *j*, DC_{ji} is the fraction of prey *i* in the average diet of predator *j*, *Y* is the landings, *E* is net migration rate, *BA* is the biomass accumulation rate, and *EE* is the proportion of the production utilised in the system for each functional group *i* (Christensen et al., 2005). An Ecopath model is expected to represent the main species and trophic levels that exist in the modelled ecosystem in the form of functional groups which perform a similar function in the ecosystem such as similar growth rates, consumption rates, diets, habitats, and predators. Functional groups, time frame and spatial extent of the model are selected depending on the addressed policy or research question and data availability.

Four mass-balance regional Ecopath models were setup to represent Exclusive Economiz Zones (EEZs) of the Turkey and fisheries in the Black Sea, Marmara Sea, Aegean Sea and Mediterranean Sea within the 1995-2014 period. 44 important species were defined according to the landings records of the Turkish Statistical Institute in the 1995-2014 period. Their English and local names together with the Latin names were given in Table 7. The general characteristics of these 44 species such as their main prey, habitat, diversity, trophic level, maximum and mean length, resilience, vulnerability and price category were summarized in Appendix I. Based on these characteristics, a total of 24 functional groups were defined to be used in the regional Ecopath models (Table 6).

The importance of the selected 24 functional groups for each ecosystem was evaluated by considering their contributions to the 20 year average landings (1995-2014) and included in the model structures defined for the each ecosystem. The selected functional groups for each ecosystem and their percentage contribution to 20 year average landings were given in Table 8. Considering also the importance of keeping the number of variables at a meaningful level to obtain maximum benefit from the ecosystem models, the number of functional groups was defined as 12 in the Black Sea, 13 in the Marmara Sea, 14 in the Aegean Sea and 16 in the Mediterranean Sea including phytoplankton, zooplankton and detritus.

Pleurobrachia, Noctiluca, Aurelia, Mnemiopsis and *Beroe* were also included in the Black Sea ecosystem as the historical changes occurred in this ecosystem were well known (Akoğlu et al., 2014). Number of the functional groups in the models increased from the Black Sea to the Mediterranean Sea because the lower number of species constructed higher proportion of the landings towards the Black Sea. The contribution of the selected species landings to the total landings in 1995-2014 was 96% in the Black Sea, 91% in the Marmara Sea, 78% in the Aegean Sea and 68% in the Mediterranean Sea (Table 7). For each functional group, input parameters and diet composition matrix for the four regional models were constructed by using available literature data (Akoğlu et al., 2014; Tsagarakis et al., 2010; Coll et al., 2009; Stergiou and Karpouzi, 2002) and given in Tables 8-15.

Indicators used to compare the regional ecosystems

Flow diagrams indicate the characteristics of network ecosystem models showing all the flows and biomasses in a single graph.

Ecosystem-wide statistics includes the sum of consumption, exports, respiratory flows, production, and all flows into detritus. The Total System Throughput (the sum of all fluxes in the system) and the System Omnivory Index (the average of the OIs of the consumer groups, weighted by the logarithm of their consumption) were the other descriptive indices.

The Mixed Trophic Impact (MTI) indicates the impact of the direct and indirect interactions in the food web. It displays the impact of a very small change in biomass of one group on the biomasses of all the other groups in the ecosystem (Ulanowicz and Puccia, 1990).

Table 6. The list of selected important fish species and their presence in the regional Ecopath models.

Latin names	English names	Local names	Functional Groups
Sarda sarda	Atlantic Bonito	Palamut, Torik	Atlantic bonito
Merluccius merluccius	Hake-Eurepean hake	Berlam, Bakalorya	Hake
Mullus barbatus	Red Mullet	Barbunya	Mullets
Upeneus molluccensis	Goldon banded	Barbunya (Paşa Barbunu)	
Mullus surmuletus	Surmullet	Tekir	
Trachurus trachurus	Horse Mackerel	İstavrit(kraça)	Mackerels
Trachurus mediterraneus	Jack Mackerel	İstavrit(karagöz)	
Sparus aurata	Gilt-head Bream	Çipura	Seabreams
Pagrus pagrus	Common Sea Bream	Fangri	
Diplodus annularis	Annular Bream	İsparoz	
Diplodus vulgaris	Two-Banded White Bream	Karagöz	
Oblada melanura	Sadlet Bream (Black-tai)	Melanurva	
Pagellus erythrinus	Pandora (SeaBream)	Mercan	
Dentex macrophthalmus	Large eye-dentex	Patlakgöz mercan	
Spondyliosoma cantharus	Black Bream	Sarıgöz	
Diplodus puntazzo	Sharp snout seabream	Sivriburun karagöz	
Pagrus caeruleostictus	Bluespotted seabream	Tranca	
Dentex dentex	Dog's Teeth	Sinağrit	
Scophthalmus maximus	Turbot	Kalkan	Flat fish
Platichthys flesus	Flounder	Pisi	
Solea solea	Common sole	Dil	
Squatina squatina	Angelshark	Keler	Sharks
Mustelus mustelus	Dog Fish (Smoroth-hound)	Köpek	
Trigla lyra	Piper gurnard	Kırlangıç	Gurnards
Trigloporus lastoviza	Streaked gurnard	Kırlangıç (mazak)	
Engraulis encrasicolus	Anchovy	Hamsi	Anchovy
Sprattus sprattus	Sprat	Çaça	Sprat
Lichia amia	Leer Fish	Akya	Leer Fish
Atherina boyeri	SandSmelt	Gümüş	SandSmelt
Sphyraena sphyraena	Barracuda	İskarmoz	Barracuda
Spicara smaris	Picarel	İzmarit	Picarel
Mugil cephalus	Mullet	Kefal	Mullet
Pomatomus saltator	Blue Fish	Lüfer	Blue Fish
Merlangius merlangus	Whiting	Mezgit	Whiting
Sardina pilchardus	Sardine	Sardalya	Sardine
Alosa fallax	Shad	Tirsi	Shad
Scomberesox saurus	Lizard Fish	Zurna	Lizard Fish
Shrimps	Shrimps	Karides	Shrimps
Bivalves	Bivalves	Midye	Bivalves
Octopus vulgaris	Octopus	Ahtapot	Cephalapods
Loligo vulgaris	Squid	Kalamar	
Sepia officinalis	Cuttle fish	Mürekkep balığı	
Rapana sp.	Sea snail	Deniz salyangozu	Gastropoda

Table 7. Selected groups for the regional models and their % proportions in the 20 year total landing of the respected region (grey areas refer the existence of the group in the regional ecosystem model).

Group names	Black Sea	Marmara Sea	Aegean Sea	Mediterranean Sea
Atlantic bonito	3.51	3.39	1.77	2.02
Hake		8.83	6.36	
Mullets	0.78	1.01	2.88	5.70
Horse mackerel	5.51	12.73	3.79	4.30
Seabreams			4.34	7.49
Flat fish	0.03	0.60	0.82	1.87
Sharks	0.29	0.24	0.13	
Gurnards				2.16
Anchovy	70.03	32.73	13.35	
Sprat	2.81			
Leer Fish				2.65
SandSmelt				5.00
Barracuda				2.40
Picarel			1.54	3.97
Mullet		3.24	11.34	7.71
Blue Fish	1.73	5.59		1.16
Whiting	3.75	2.42		
Sardine		9.27	26.01	13.52
Shad	0.29		1.52	
Lizard Fish				0.74
Shrimps		3.75	1.34	3.41
Bivalves	5.78	7.18		
Cephalapods			3.07	4.28
Gastropods	1.76			
Total %	96	91	78	68

Table 8. Black Sea Ecopath model input parameters (modified from Akoğlu et al. (2014)).

	Group name	Habitat area (fraction)	Biomass in habitat area (g/m²)	Production / biomass (/year)	Consumption / biomass (/year)	Ecotrophic efficiency	Unassimil. / consumption
1	Dolphins	1		0.436	5.77	0.9	0.2
2	Atlantic bonito	1		0.504	5.29	0.9	0.2
3	Bluefish	1		0.505	4.36	0.9	0.2
4	Atlantic mackerel	1	0.001	0.512	5.39		0.2
5	Whiting	1	0.1	0.706	2.13		0.2
6	Turbot	1	0.0142	0.614	1.64		0.2
7	Mullets	1		0.653	2.11	0.9	0.2
8	Sharks	1	0.084	0.552	1.90		0.2
9	Horse mackerel	1	0.101	2.739	9.16		0.2
10	Shad	1	0.003	2.284	9.60		0.2
11	Sprat	1	0.164	2.888	13.01		0.2
12	Anchovy	1	0.102	3	9.78		0.2
13	Gastropoda	1		1.02	3.13	0.9	0.2
14	Bivalves	1		8.05	52.12	0.9	0.2
15	Aurelia	1	0.064	12.39	34.51		0.2
16	Beroe	1	1.00E-06	9.64	27.56		0.2
17	Mnemiopsis	1	1.411	8.63	34.51		0.2
18	Pleurobrachia	1	0.191	7.3	37.18		0.2
19	Noctiluca	1	0.053	8.77	38.40		0.2
20	Zooplankton	1	1.392	43.81	268.71		0.2
21	Phytoplankton	1	1.213	291			0
22	Detritus	1	80			0	0

Table 9. Black Sea Ecopath model diet composition matrix (revised after Akoğlu et al. (2014)).

	Prey \ predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Dolphins	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	Atlantic bonito	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Bluefish	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	Atlantic mackerel	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	Whiting	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	Turbot	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	Mullets	0.00	0.00	0.00	0.00	0.12	0.13	0.10	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	Sharks	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	Horse mackerel	0.16	0.11	0.10	0.10	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	Shad	0.00	0.00	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	Sprat	0.32	0.34	0.30	0.30	0.43	0.00	0.00	0.14	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	Anchovy	0.35	0.34	0.30	0.30	0.43	0.00	0.00	0.14	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	Gastropoda	0.00	0.00	0.00	0.00	0.00	0.20	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	Bivalves	0.00	0.00	0.00	0.00	0.00	0.20	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	Aurelia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	Beroe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	Mnemiopsis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
18	Pleurobrachia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	Noctiluca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	Zooplankton	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	1.00	1.00	1.00	0.00	0.10	0.50	0.00	0.90	0.50	0.15	0.00
21	Phytoplankton	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.60	0.90
22	Detritus	0.00	0.00	0.00	0.00	0.00	0.48	0.30	0.00	0.00	0.00	0.00	0.00	1.00	0.50	0.50	0.00	0.10	0.50	0.25	0.10
23	Import	0.00	0.20	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
25	(1 - Sum)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 10. Marmara Sea Ecopath model input parameters (revised after Akoğlu et al. (2014) and Tsagarakis et al. (2010)).

	Group name	Habitat area (fraction)	Biomass in habitat area (g/m²)	Production / biomass (/year)	Consumption / biomass (/year)	Ecotrophic efficiency	Unassimil. / consumption	Detritus import (g/m²/year)
1	Dolphins	1		0.07	13.49	0.90	0.20	0.00
2	Atlantic bonito	1		0.35	4.36	0.90	0.20	0.00
3	Bluefish	1		0.51	4.36	0.90	0.20	0.00
4	Atlantic mackerel	1		0.46	4.88	0.90	0.20	0.00
5	Whiting	1		0.66	5.93	0.90	0.20	0.00
6	Hake	1		0.60	2.00	0.90	0.20	0.00
7	Sharks	1		0.55	1.90	0.90	0.20	0.00
8	Horse mackerel	1		0.39	5.13	0.90	0.20	0.00
9	Mullets	1		2.29	6.90	0.90	0.20	0.00
10	Sardine	1		0.52	7.39	0.90	0.20	0.00
11	Mullet	1		0.70	1.50	0.90	0.20	0.00
12	Anchovy	1		1.33	13.91	0.90	0.20	0.00
13	Shrimps	1		3.08	7.20	0.90	0.20	0.00
14	Bivalves	1		8.05	52.12	0.90	0.20	0.00
15	Zooplankton	1		20.00	50.00	0.90	0.20	0.00
16	Phytoplankton	1	0.33	291.00		0.90	0.00	0.00
17	Detritus	1	80.00			0.00	0.00	0.00

Table 11. The Marmara Sea Ecopath model diet composition matrix (revised after Akoğlu et al. (2014), Tsagarakis et al. (2010) and Stergiou and Karpouzi (2002)).

	Prey \ predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Dolphins	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	Atlantic bonito	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Bluefish	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	Atlantic mackerel	0.05	0.11	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	Whiting	0.20	0.00	0.00	0.00	0.02	0.00	0.10	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
6	Hake	0.00	0.00	0.00	0.00	0.05	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	Sharks	0.00	0.00	0.00	0.00	0.02	0.00	0.05	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
8	Horse mackerel	0.10	0.11	0.17	0.11	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	Mullets	0.04	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00
10	Sardine	0.10	0.21	0.17	0.11	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	Mullet	0.20	0.16	0.17	0.11	0.00	0.20	0.10	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00
12	Anchovy	0.20	0.16	0.17	0.11	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	Shrimps	0.01	0.00	0.00	0.00	0.08	0.10	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	Bivalves	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	Zooplankton	0.00	0.00	0.00	0.34	0.30	0.20	0.00	0.50	0.20	0.90	0.35	0.20	0.70	0.10	0.00
16	Phytoplankton	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.10	0.10	0.80	0.10	0.10	0.90
17	Detritus	0.00	0.00	0.00	0.00	0.48	0.30	0.40	0.00	0.48	0.00	0.40	0.00	0.20	0.80	0.10
18	Import	0.00	0.20	0.20	0.20	0.00	0.10	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00
19	Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	(1 - Sum)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 12. The Aegean Sea Ecopath model input parameters (revised after Tsagarakis et al. (2010)).

	Group name	Habitat area (fraction)	Biomass in habitat area (g/m²)	Production / biomass (/year)	Consumption / biomass (/year)	Ecotrophic efficiency	Unassimil. / consumption	Detritus import (g/m²/year)
1	Dolphins	1		0.07	13.49	0.90	0.20	0.00
2	Atlantic bonito	1		0.35	4.36	0.90	0.20	0.00
3	Horse mackerel	1		0.39	5.13	0.90	0.20	0.00
4	Mullets	1		2.29	6.90	0.90	0.20	0.00
5	Sardine	1		0.52	7.39	0.90	0.20	0.00
6	Hake	1		0.60	5.00	0.20	0.20	0.00
7	Picarel	1		0.80	1.70	0.90	0.20	0.00
8	Sharks	1		0.55	1.90	0.90	0.20	0.00
9	Seabreams	1		0.43	6.25	0.90	0.20	0.00
10	Mullet	1		0.70	1.50	0.90	0.20	0.00
11	Shad	1		2.28	9.60	0.98	0.20	0.00
12	Anchovy	1		1.33	13.91	0.90	0.20	0.00
13	Shrimps	1		3.08	7.20	0.90	0.20	0.00
14	Cephalapoda	1		2.34	5.30	0.90	0.20	0.00
15	Zooplankton	1		20.00	50.00	0.90	0.20	0.00
16	Phytoplankton	1	0.33	291.00		0.90	0.00	0.00
17	Detritus	1	80.00			0.00	0.00	0.00

Table 13. The Aegean Sea Ecopath model diet composition matrix (revised after Tsagarakis et al. (2010) and Stergiou and Karpouzi (2002)).

	Prey \ predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Dolphins	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	Atlantic bonito	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Horse mackerel	0.10	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	Mullets	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	Sardine	0.20	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	Hake	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	Picarel	0.20	0.15	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	Sharks	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	Seabreams	0.00	0.00	0.00	0.05	0.00	0.05	0.00	0.10	0.05	0.00	0.00	0.00	0.00	0.00	0.00
10	Mullet	0.10	0.15	0.00	0.05	0.00	0.05	0.00	0.10	0.05	0.00	0.00	0.00	0.00	0.00	0.00
11	Shad	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	Anchovy	0.20	0.15	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	Shrimps	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.10	0.10	0.03	0.13	0.00	0.00	0.10	0.00
14	Cephalapoda	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.20	0.05	0.03	0.13	0.00	0.00	0.05	0.00
15	Zooplankton	0.00	0.00	0.65	0.20	0.90	0.00	0.70	0.00	0.10	0.21	0.60	0.20	0.30	0.40	0.00
16	Phytoplankton	0.00	0.00	0.20	0.00	0.10	0.00	0.00	0.00	0.00	0.42	0.00	0.80	0.50	0.10	0.90
17	Detritus	0.00	0.00	0.00	0.45	0.00	0.65	0.30	0.20	0.65	0.32	0.13	0.00	0.20	0.35	0.10
18	Import	0.00	0.20	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	(1 - Sum)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 14. The Mediterranean Sea Ecopath model input parameters (revised after Coll et al. (2009)).

	Group name	Habitat area (fraction)	Biomass in habitat area (g/m²)	Production / biomass (/year)	Consumption / biomass (/year)	Ecotrophic efficiency	Unassimil. / consumption	Detritus import (g/m²/year)
1	Dolphins	1		0.07	13.49	0.90	0.20	0.00
2	Bluefish	1		0.51	4.36	0.90	0.20	0.00
3	Barracuda	1		0.43	4.00	0.90	0.20	0.00
4	Leer fish	1		0.40	5.00	0.90	0.20	0.00
5	Atlantic bonito	1		0.35	4.36	0.90	0.20	0.00
6	Lizard fish	1		0.40	5.00	0.90	0.20	0.00
7	Sharks	1		0.55	1.90	0.90	0.20	0.00
8	Mullets	1		2.29	6.90	0.90	0.20	0.00
9	Horse mackerel	1		1.50	7.00	0.90	0.20	0.00
10	Sardine	1		2.00	7.39	0.90	0.20	0.00
11	Gurnard	1		0.50	1.00	0.90	0.20	0.00
12	Sand smelt	1		0.60	2.00	0.90	0.20	0.00
13	Flat fish	1		2.10	7.53	0.90	0.20	0.00
14	Picarel	1		2.00	10.00	0.90	0.20	0.00
15	Seabreams	1		0.43	6.25	0.90	0.20	0.00
16	Mullet	1		0.70	1.50	0.90	0.20	0.00
17	Shrimps	1		3.08	7.20	0.90	0.20	0.00
18	Cephalapoda	1		2.34	5.30	0.90	0.20	0.00
19	Zooplankton	1		20.00	50.00	0.90	0.20	0.00
20	Phytoplankton	1		291.00		0.90	0.00	0.00
21	Detritus	1	80.00			0.00	0.00	0.00

Table 15. The Mediterranean Sea Ecopath model diet composition matrix (revised after Coll et al. (2009) and Stergiou and Karpouzi (2002)).

	Prey \ predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	Dolphins	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	Bluefish	0.10	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Barracuda	0.10	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	Leer fish	0.05	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	Atlantic bonito	0.15	0.03	0.05	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	Lizard fish	0.10	0.00	0.03	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	Sharks	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	Mullets	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.07	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
9	Horse mackerel	0.20	0.13	0.16	0.13	0.16	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	Sardine	0.10	0.27	0.21	0.20	0.16	0.17	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	Gurnard	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
12	Sand smelt	0.10	0.27	0.21	0.20	0.16	0.17	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	Flat fish	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
14	Picarel	0.10	0.27	0.21	0.20	0.16	0.17	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	Seabreams	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
16	Mullet	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.06	0.00	0.05	0.00	0.05	0.00	0.00	0.00	0.00
17	Shrimps	0.00	0.00	0.05	0.00	0.05	0.06	0.25	0.07	0.11	0.00	0.06	0.00	0.05	0.00	0.10	0.00	0.00	0.10	0.00
18	Cephalapoda	0.00	0.00	0.05	0.00	0.05	0.06	0.25	0.00	0.00	0.00	0.06	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
19	Zooplankton	0.00	0.00	0.00	0.00	0.05	0.22	0.00	0.07	0.53	0.90	0.22	0.40	0.31	0.90	0.36	0.40	0.50	0.40	0.00
20	Phytoplankton	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.10	0.00	0.10	0.00	0.00	0.20	0.10	0.80
21	Detritus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.56	0.50	0.51	0.00	0.36	0.60	0.30	0.40	0.20
22	Import	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
24	(1 - Sum)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The ‘‘keystoneness’’ index (KS) identifies the overall effect of the groups on the other groups compared to their biomass (Power et al., 1996, Piraino et al., 2002).

Lindeman spine plots break down flows and determine biomass transfer carried by trophic levels by using cumulative flows and biomasses by discrete trophic levels in ecosystem (Lindeman, 1942). The biomass fractions going to detritus from each trophic level and the transfer efficiency between the trophic levels are also evaluated.

Connectance index is the ratio of the number of actual links to the number of possible links in the food web. It includes feeding on detritus but disregards the opposite links like feeding of detritus on other groups.

System omnivory index is the average omnivory index of all consumers weighted by the each consumer’s food intake logarithm. It measures the feeding interactions distributed between trophic levels. Calculated for each consumer group, it also measures the variance of the trophic level estimate for the group.

4.2.2. Temporal dynamic modelling and scenario testing with Ecosim

Ecosim, the time dynamic version of Ecopath, generates dynamic biomass and catch rate estimates using the Ecopath’s initial parameters. Ecosim utilize a series of differential equations expressing the rate of biomass flux as a function of time dependent biomass and catch rates (Christensen and Walters, 2004). Biomass flux patterns can be either bottom-up or top down controlled as predator-prey interactions are moderated by prey behaviour.

Ecopath models have a baseline for a certain year and time series fitting is done by Ecosim incorporating density-dependence to elaborate the capacity of EwE model to simulate historical dynamics (Heymans et al., 2016). The constructed regional Ecopath models were set up to 1995 and the Ecosim module was run for 20 years. By doing repeated simulations Ecosim allows for the fitting of predicted biomasses to time series data. Regional EwE models were further fitted and compared with the available fisheries and satellite data (Figure 16).

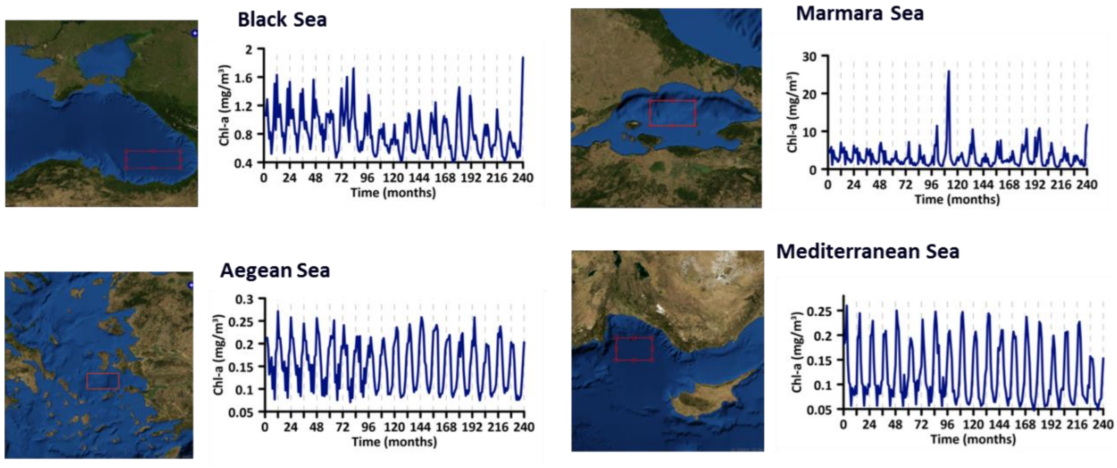

Figure 16. Time series of chl-a used for phytoplankton biomass derived from satellite used in the regional models (giovanni.gsfc.nasa.gov).

4.2.3. Scenarios for investigating possible fisheries management implications

'Fishing Policy Search' routine of the EwE software allows exploration of alternative fishery management policies under different policy objectives. It provides two ways: i) fishing rates can be set over time and results in terms of changes in catches, biomass and economic performance indicators can be examined encouraging to rapidly explore the options, and ii) formal optimization methods can be used to maximize a spesific management policy goal. These two approaches can be used together by carrying a formal optimization search and reshaping the fishing rate estimates from this search to meet other objectives together with the ones considered within the research. The policy optimization module utilizes the Davidson-Fletcher-Powell (DFP) optimization procedure, a nonlinear optimization procedure, for improvment an objective changing relative fishing rates. DFP uses 'conjugate-gradient' parameter variation scheme to test alternative parameter values. Hence, 'conjugate-gradient' approximates the objective function as a quadratic function of the parameter values and update the steps of the parameter.

After the regional Ecosim models were set, EwE 'Fishing Policy Search' module was utilized to simulate the potential implications of four management scenarios; i) reference scenario, ii) maximizing ecosystem health (ecology weighted), iii) maximizing fisheries rent (economy weighted) and iv) maximizing ecosystem health and fisheries rent (ecology and economy equally weighted) for the 1995-2014 and 2014-2020 periods.

Reference scenario; A 'business as usual' scenario. The target species were exploited as they were in the 1995-2014 period and 2014 fishing exploitation rates were kept constant for the period of 2014-2020.

Maximize fisheries rent; In this scenario, maximizing the net present value of profits from the ecosystem was the objective of management. It is often resulted in fishing by the most profitable fleets and decrease in ecosystems groups that are competing with or preying on the more valuable target species.

Maximize ecosystem structure or 'health'; Maximizing the 'ecosystem status' based on one of Odum's (1969) measures of ecosystem maturity is the objective of this scenario. It is generally resulted in decreasing fishing effort for the fleets targeting species that have high weighting factors.

Maximizing a weighted average of the two objective functions: Maximizing both fisheries rent and ecosystem structure or 'health' was the objective of this scenario. A weighting of 1 was given on either profit or ecosystem status in the previous scenarios and zero on the other objectives. A weight of 1 on each profit or ecosystem status objectives were put in this scenario. The same relative change is not expected for each objective as the model considers the profitability of fast growing species and ability of species to change their turnover rate.

4.3 Results

4.3.1 Mass balance regional models in 1995-2014 period

Schematic illustrations of the four regional ecosystem networks produced by Ecopath were shown in Figure 17. The **estimated trophic level of the functional groups** ranged from 1 (primary producers) to 4.20 in the Black Sea, 3.8 in the Marmara Sea, 4.02 in the Aegean Sea and 4.43 in the Mediterranean Sea. **Evaluated top predators** were dolphins and sharks in the Black Sea, Atlantic bonito and dolphins in the Marmara Sea, dolphins and Atlantic bonito in the Aegean Sea and Dolphins and leer fish in the Mediterranean Sea. **The average biomass distributions in the five trophic levels** in the regional ecosystems were depicted in Figure 18. According to the results, in the Black Sea, the highest total biomass proportion of 36.8% was in the first trophic level and decreased towards the 5^{th} trophic level (29.3% in the 2^{nd}, 28.8% in the 3^{th}, 4.8% in the 4^{th} and 0.3% in the 5^{th}). In the Marmara Sea, Aegean Sea and Mediterranean Sea, the highest biomass proportions were in the 2^{nd} and 3^{th} trophic levels and comparatively very low proportions were in the other trophic levels (2.3% in the 1^{st}, 44.3% in the 2^{nd}, 44.8% in the 3^{th}, 7.8% in the 4^{th} and 0.9% in the 5^{th} in the Marmara Sea, 1.5% in the 1^{st}, 48.7% in the 2^{nd}, 42.5% in the 3^{th}, 6.9% in the 4^{th} and 0.4% in the 5^{th} in the Aegean Sea and 2.0% in the 1^{st}, 39.3% in the 2^{nd}, 45.6% in the 3^{th}, 11.0% in the 4^{th} and 1.1% in the 5^{th} in the Mediterranean Sea).

Based on the regional Ecopath models, **general ecosystem statistics** were listed in Table 17. Sum of all production and Total System Throughput (the measure of total trophic flows within an ecosystem) were higher in the Black Sea (315.5 and 652.9 $g/m^2/year$) and it was followed by the Aegean Sea (169.8 and 396.4 $g/m^2/year$), the Marmara Sea (140.3 and 292.1 $g/m^2/year$) and the Mediterranean Sea (66.6 and 122.3 $g/m^2/year$). On the other hand, sum of all consumption was higher in the Aegean Sea (232.3 $g/m^2/year$) and it was followed by the Black Sea (159.4 $g/m^2/year$), the Marmara Sea (146.5 $g/m^2/year$) and the Mediterranean Sea (73.4 $g/m^2/year$). Total primary production/total respiration ratio was 2.90 in the Black Sea, 1.31 in the Marmara Sea, 0.86 in the Aegean Sea and 1.23 in the Mediterranean Sea.

Connectence Index and System Omnivory Index were higher in the Marmara Sea (0.28 and 0.30) and it was followed by the Aegean Sea (0.27 and 0.29), the Mediterranean Sea (0.25 and 0.24) and the Black Sea (0.14 and 0.15).

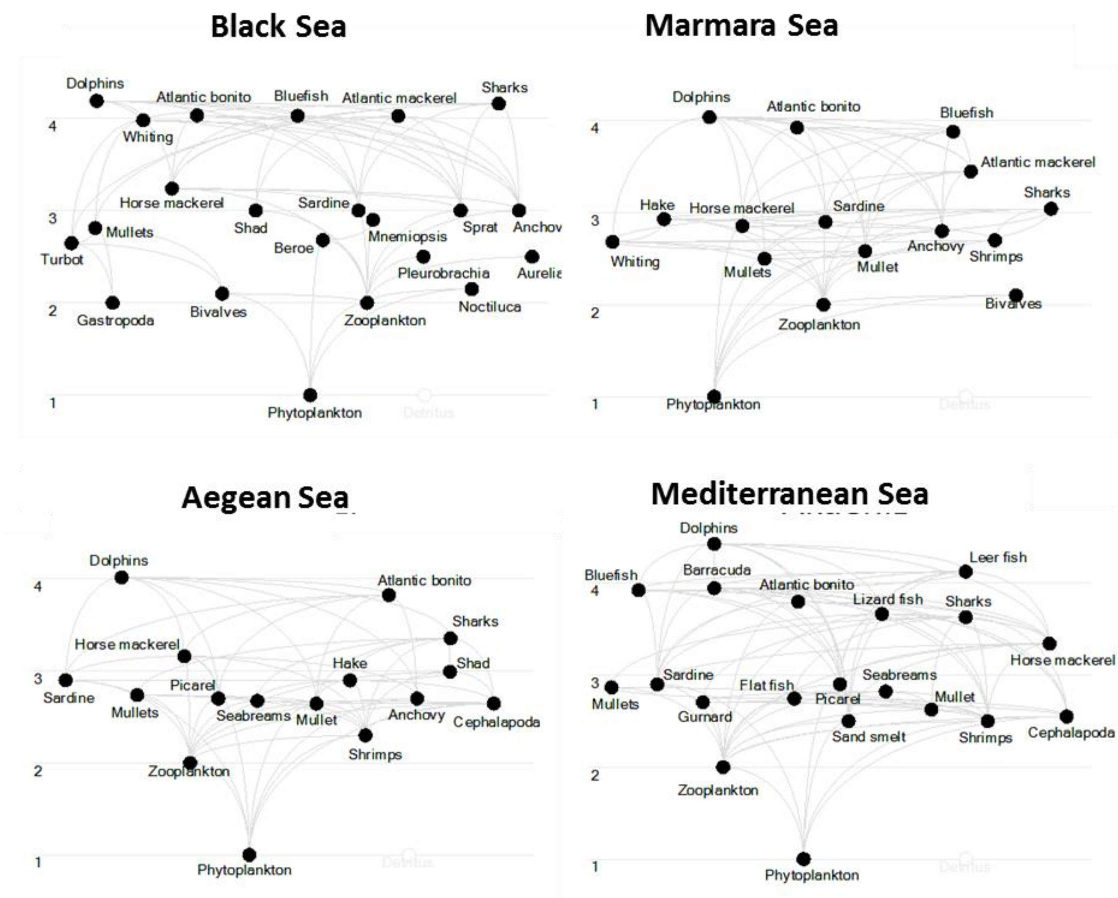

Figure 17. Schematic illustrations of the regional ecosystem networks produced by Ecopath.

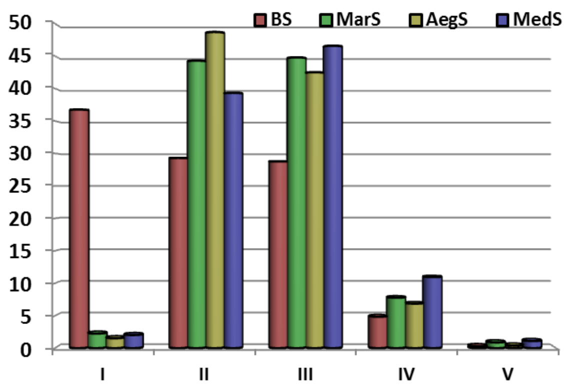

Figure 18. Distribution of the percentage biomass proportions within the first five trophic levels based on the average values in the 1995-2014 period in the regional seas.

Table 16. General ecosystem statistics of the regional ecosystems

Parameter	Black Sea	Marmara Sea	Aegean Sea	Medit. Sea	Units
Sum of all consumption	159.38	146.48	232.31	73.42	g/m^2/year
Sum of all exports	188.00	26.80	6.63	0.80	g/m^2/year
Sum of all respiratory flows	99.14	74.39	113.52	34.12	g/m^2/year
Sum of all flows into detritus	206.39	44.38	43.97	13.92	g/m^2/year
Total system throughput	652.91	292.05	396.43	122.27	g/m^2/year
Sum of all production	315.47	140.27	169.80	66.61	g/m^2/year
Mean trophic level of the catch	3.03	2.63	2.82	2.95	
Gross efficiency (catch/net p.p.)	0.00	0.01	0.01	0.01	
Calculated total net primary production	287.11	97.48	97.48	41.99	g/m^2/year
Total primary production/total respiration	2.90	1.31	0.86	1.23	
Net system production	187.97	23.09	-16.04	7.87	g/m^2/year
Total primary production/total biomass	106.91	6.54	4.46	5.90	
Total biomass/total throughput	0.00	0.05	0.06	0.06	/year
Total biomass (excluding detritus)	2.69	14.91	21.87	7.12	g/m^2
Total catch	0.22	0.49	1.46	0.40	g/m^2/year
Connectance Index	0.14	0.28	0.27	0.25	
System Omnivory Index	0.15	0.30	0.29	0.24	

The Keystonness index (KS) results for the functional groups in the regional ecosystems were given in Table 18. The average of the KS values for the functional groups were higher in the Mediterranean Sea (-0.57) and the Marmara Sea (-0.55) whereas the values were comparatively lower in the Aegean Sea (-0.47) and in the Black Sea (-0.43). KS values of the functional groups displayed differences in the four regional ecosystems. The groups that have highest keystonness value were flat fish, Atlantic mackerel and shad in the Black Sea, bivalves, shrimps and anchovy in the Marmara Sea, mullets, shad and shrimps in the Aegean Sea and sharks, mullets and gurnards in the Mediterranean Sea. KS values for the selected common functional groups, Atlantic bonito, mullets and sharks in the regional seas were shown in Figure 19. A gradual decrease in the KS value of Atlantic bonito (from -0.78 to -0.21) and a gradual increase in the KS values of mullets (from -0.14 to -

1.31) and sharks (from -0.06 to -1.53) were observed from the Black Sea towards the Mediterranean Sea.

Mixed trophic impact analyses were carried out for each regional ecosystem (Figure 20). According to the results, fisheries had higher negative impact on Atlantic bonito, bluefish and sharks in the Black Sea, on Atlantic bonito and bivalves in the Marmara Sea, on Atlantic bonito, hake, sharks and mullets in the Aegean Sea and on dolphins and sharks in the Mediterranean Sea. All the observed fisheries impacts on the functional groups were negative except from shad in the Black Sea and Aegean Sea and Atlantic mackerel in the Marmara Sea. Higher negative impacts were also observed between the functional groups such as bluefish-shad, Beroe-Mnemiopsis, zooplankton-zooplankton in the Black Sea, bluefish-Atlantic mackerel, horsemackarel-sardine-anchovy in the Marmara Sea, horse mackerel-picarel and hake-shad in the Aegean Sea and leerfish-bluefish and Atlantic bonito in the Mediterranean Sea.

Lindeman spine analysis of flows and biomasses, aggregated by discrete trophic levels for the four regional ecosystems were shown in Figure 21. Trophic efficiency from TL II to TL III and from TL III to TL IV were found to be higher in the Mediterranean Sea (0.384 and 0.211) and followed by the Aegean Sea (0.351 and 0.149), the Marmara Sea (0.306 and 0.104) and the Black Sea (0.112 and 0.039). Trophic efficiency from TL IV and V in the Black Sea was lower compared to the other seas.

Table 17. Keystoneness indexes for each functional group for the four regional ecosystems

Functional Groups	Black Sea	Marmara Sea	Aegean Sea	Mediterranean Sea
Dolphins	-0.09	-0.46	-0.07	-0.40
Atlantic bonito	**-0.78**	-0.40	-0.23	-0.21
Hake		-0.44	-0.19	
Mullets	-0.14	**-0.55**	**-0.97**	**-1.31**
Horse mackerel	-0.08	-0.17	-0.31	-0.25
Atlantic mackerel	**-1.09**	**-0.54**		
Seabreams			-0.43	-0.16
Flat fish	**-1.33**			-0.53
Sharks	-0.06	-0.42	-0.43	**-1.53**

Gurnards				**-0.98**
Anchovy	-0.32	**-0.64**	**-0.74**	
Sprat	-0.36			
Leer Fish				0.04
SandSmelt				-0.70
Barracuda				-0.34
Picarel			-0.69	-0.57
Mullet		-0.35	**-0.73**	**-0.89**
Blue Fish	-0.19	-0.32		-0.33
Whiting	-0.23	-0.20		
Sardine		-0.49	-0.42	-0.49
Shad	**-0.89**		**-0.94**	
Lizard Fish				-0.66
Shrimps		**-1.05**	**-0.80**	-0.69
Bivalves	**-0.56**	**-1.65**		
Cephalapods			-0.32	**-0.81**
Gastropods	-0.47			
Zooplankton	-0.16		-0.19	-0.25
Phytoplankton	-0.17		-0.08	-0.24

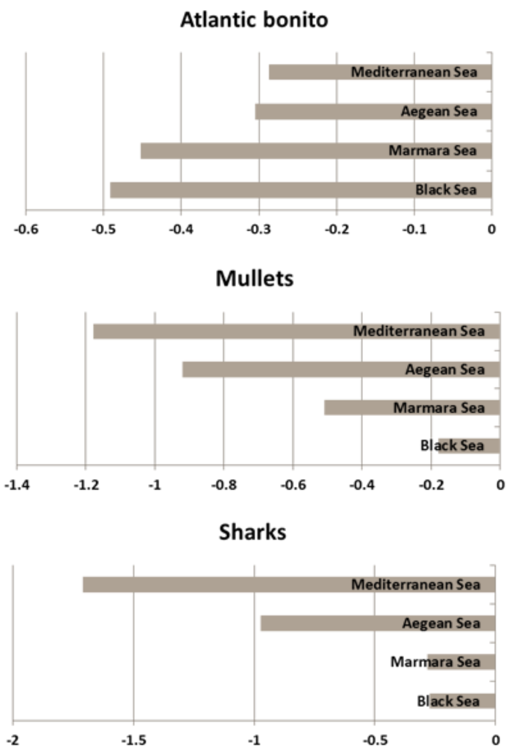

Figure 19. Keystoneness index value of Atlantic bonito, mullets and sharks in the regional ecosystems.

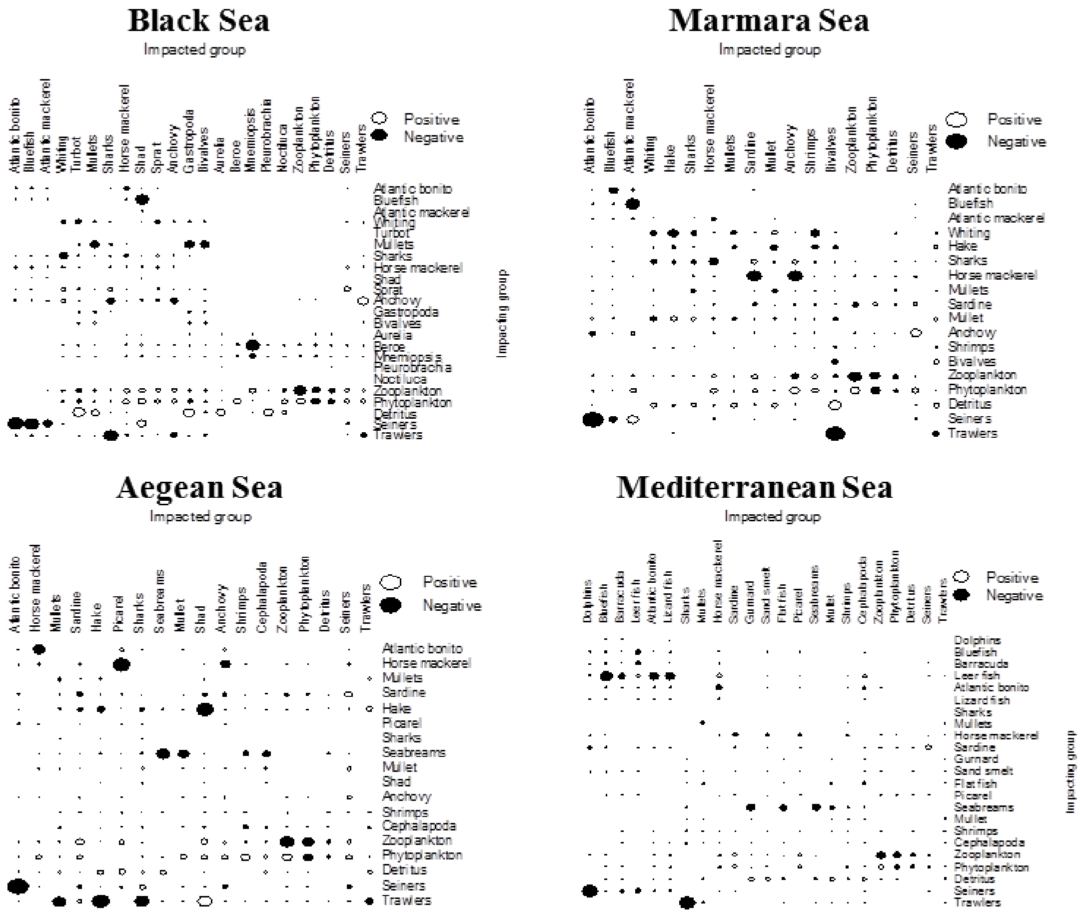

Figure 20. Mixed trophic impact of each functional group on the other groups in the regional ecosystems.

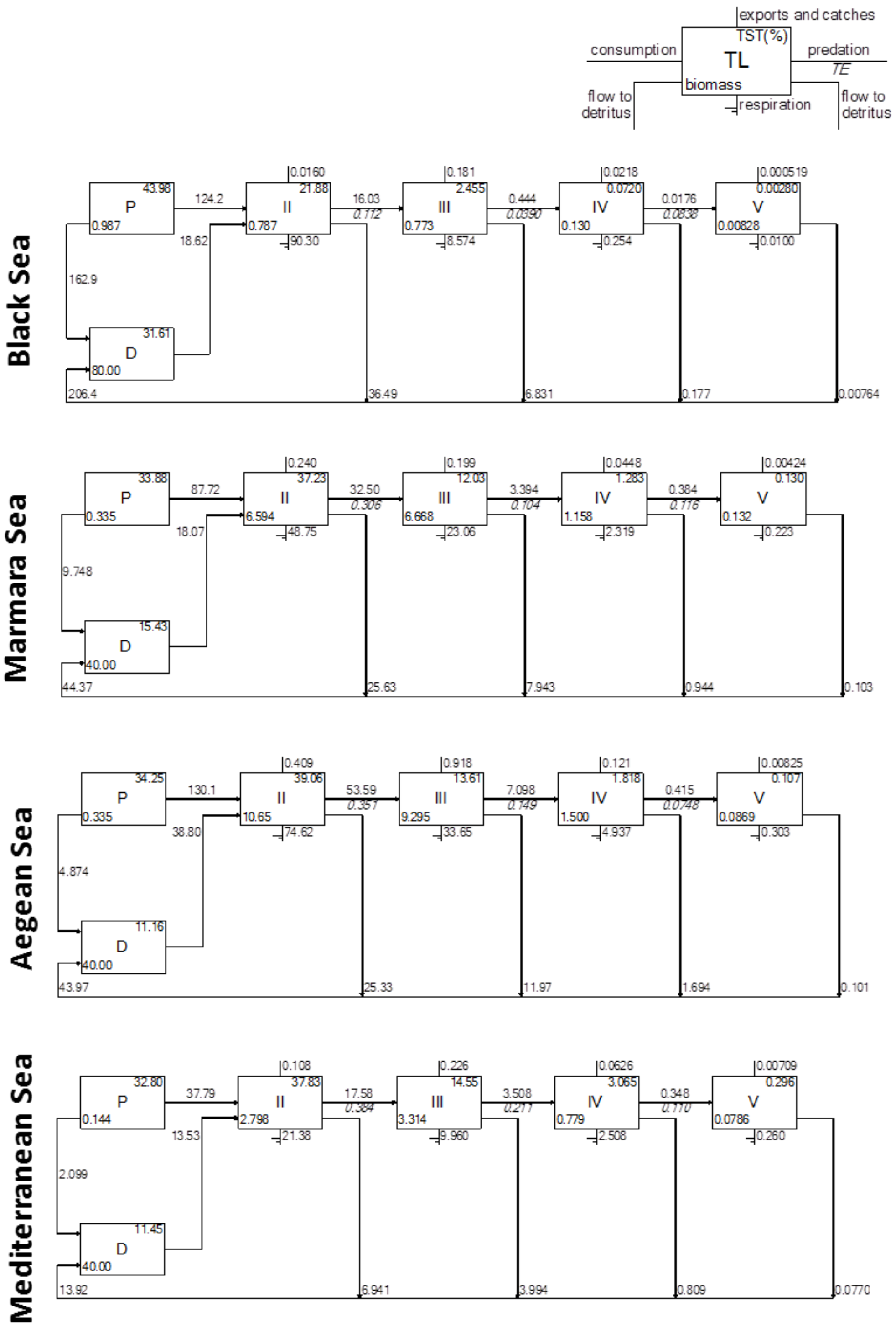

Figure 21. Lindeman spine plot of flows and biomasses, aggregated by discrete trophic levels for the four regional ecosystems.

4.3.2 Temporal dynamic modelling and scenario testing with Ecosim

Regional Ecopath models were fitted to available fish and biomass data in 1995 and Ecosim vulnerability parameters were adopted to optimize the fit of estimated and observed landings in 1995-2033 period. Reference scenario simulations were carried out for the 1995-2033 period. The comparisons of the observed and estimated landing and biomass values in the Black Sea, Marmara Sea, Aegean Sea and Mediterranean Sea EwE reference models were shown in Figure 22. The continuous lines in the figures represented the model results whereas dots were for the real data points. The regional EwE models were capable of reproducing historical trends in abundance and the catch for the period of 1995-2014 with a total Sum of Squares (SS) value of 178.9 in the Black Sea, 165.2 in the Marmara Sea, 77.2 in the Aegean Sea and 74.1 in the Mediterranean Sea.

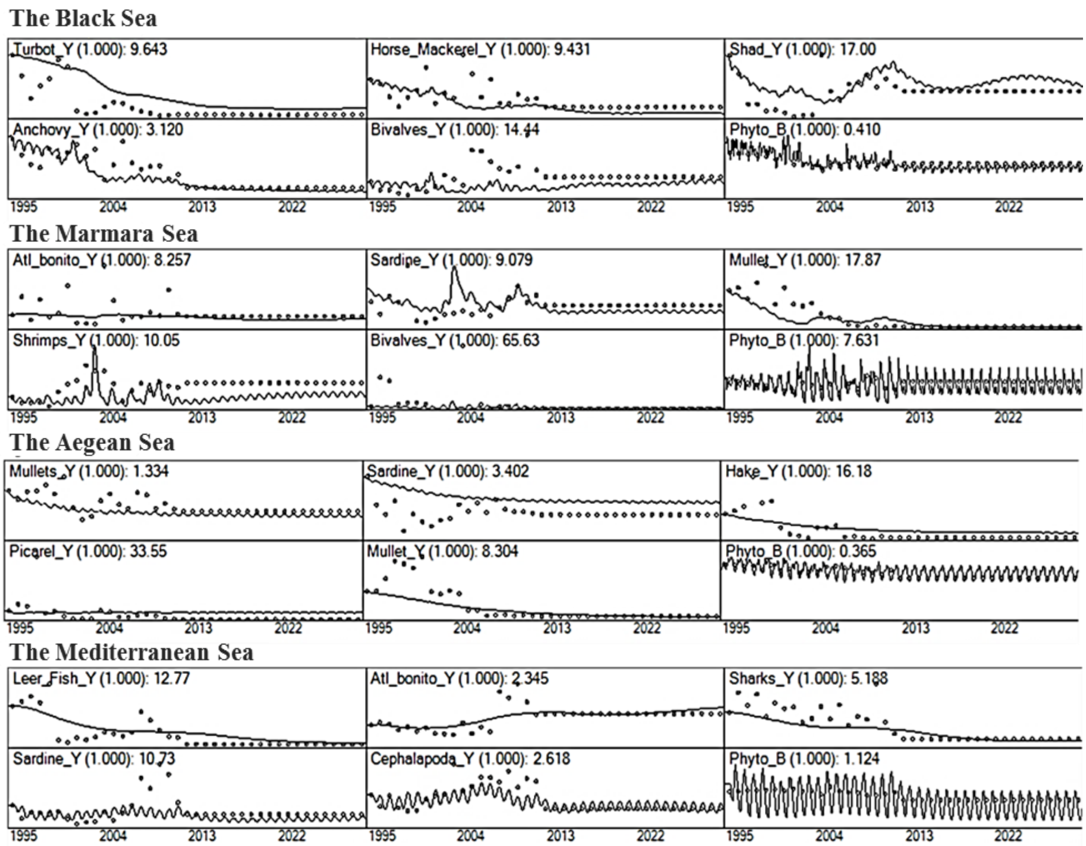

Figure 22. The comparisons of the Black Sea, Marmara Sea, Aegean Sea and Mediterranean Sea EwE reference model simulations with real data in 1995-2033 period.

The regional models then were used to predict the potential impacts of the selected fisheries management scenarios as previously defined as reference, economy weighted, ecology weighted and ecology and economy equally weighted. The impact of selected management scenarios on the percentage biomass, landing weight and value changes of the target species in the regional ecosystems were shown in Figure 23 for the periods of 1995-2014 and 2014-2020. The percentage changes in the targeted functional group biomass, landing weight and value for reference, economy, ecology and economy and ecology weighted scenarios in the 1995-2014 and 2014-2020 periods were given in Figures 24-27.

In the Black Sea, no significant change in the biomass, more than 50% change in landing weight and less than 50% change in the landing value were observed for the reference past scenario. Economy weigthed past scenario resulted with declined biomass and increased landing weigth and value. Ecology weigthed past scenario was lower decrease in the biomass but highest decreases in the landing weight and value. Only equal weigthed past scenario resulted with an increase in the biomass and decreases in the landing weigth and biomass compared to the reference and ecology weigthed scenarios. Future projections in the Black Sea resulted in similar censequences except from ecology weighted scenario.

In the Marmara Sea, all the past scenarios resulted with a similar decline in the total biomass whereas ecology weigthed scenario caused lower decreases in the landing weight and value. Future scenarios also resulted in similar biomass decreases however lower decrease was observed in the landing wiegt and value for the reference scenario.

In the Aegean Sea, all the scenarios except from the reference scenario increased the biomass, landing weight and value more than 100%. A similar increase in biomass was also recorded for the future scenarios. Future economy weigthed scenario did not change the landing weigth and even inceased the the landing value. The other future scenarios resulted with decreases in the landing weigth and value.

In the Mediterranean Sea, all the past scenarios resulted in around 20% decreases in the biomass. Reference scenario caused the highest decrease in the landing weight and value. Only ecology weigthed scenario gave a positive impact on landing weigth. Future scenarios resulted with 50% changes in the biomass. Reference scenario resulted with lowest decrease in the landing weight and even a small increase in the landing value.

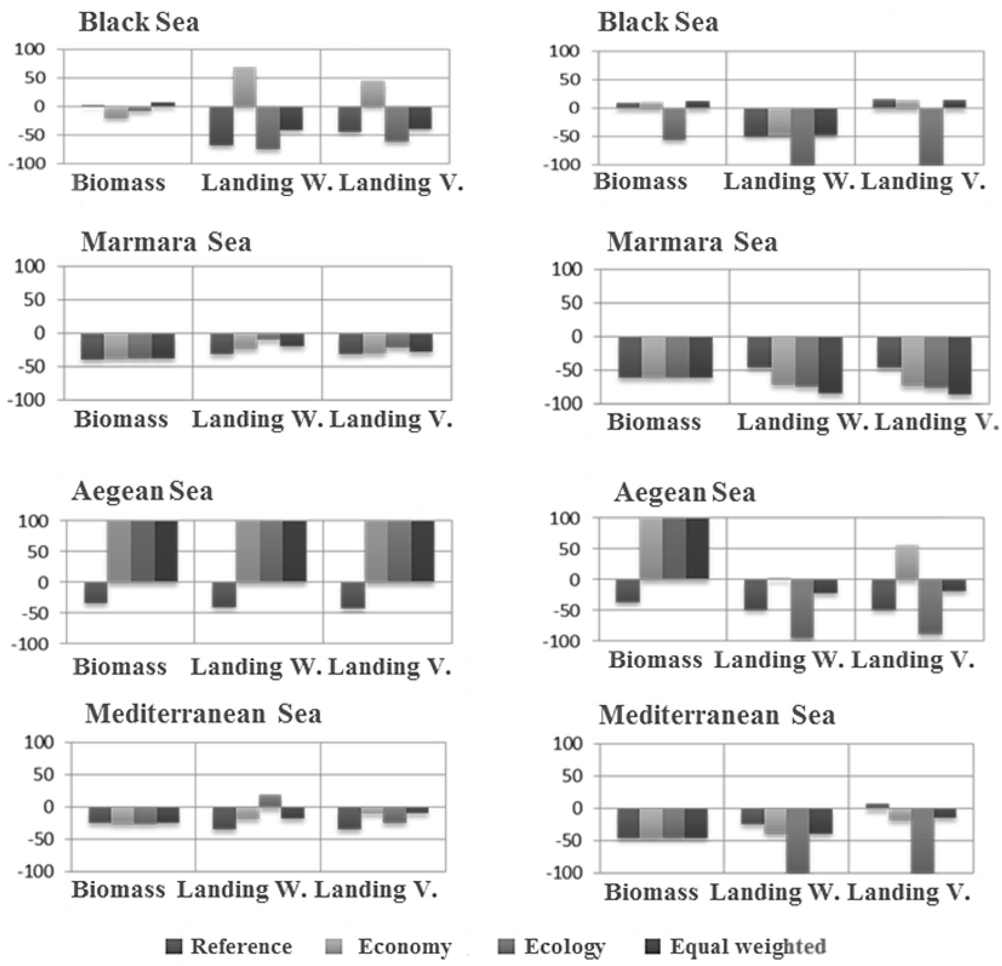

Figure 23. The percentage changes in the biomass, landing weight and value of the target species' under the reference, economy, ecology and equal weighted management scenario simulations in the periods of 1995-2014 (left column) and 2014-2020 (right column).

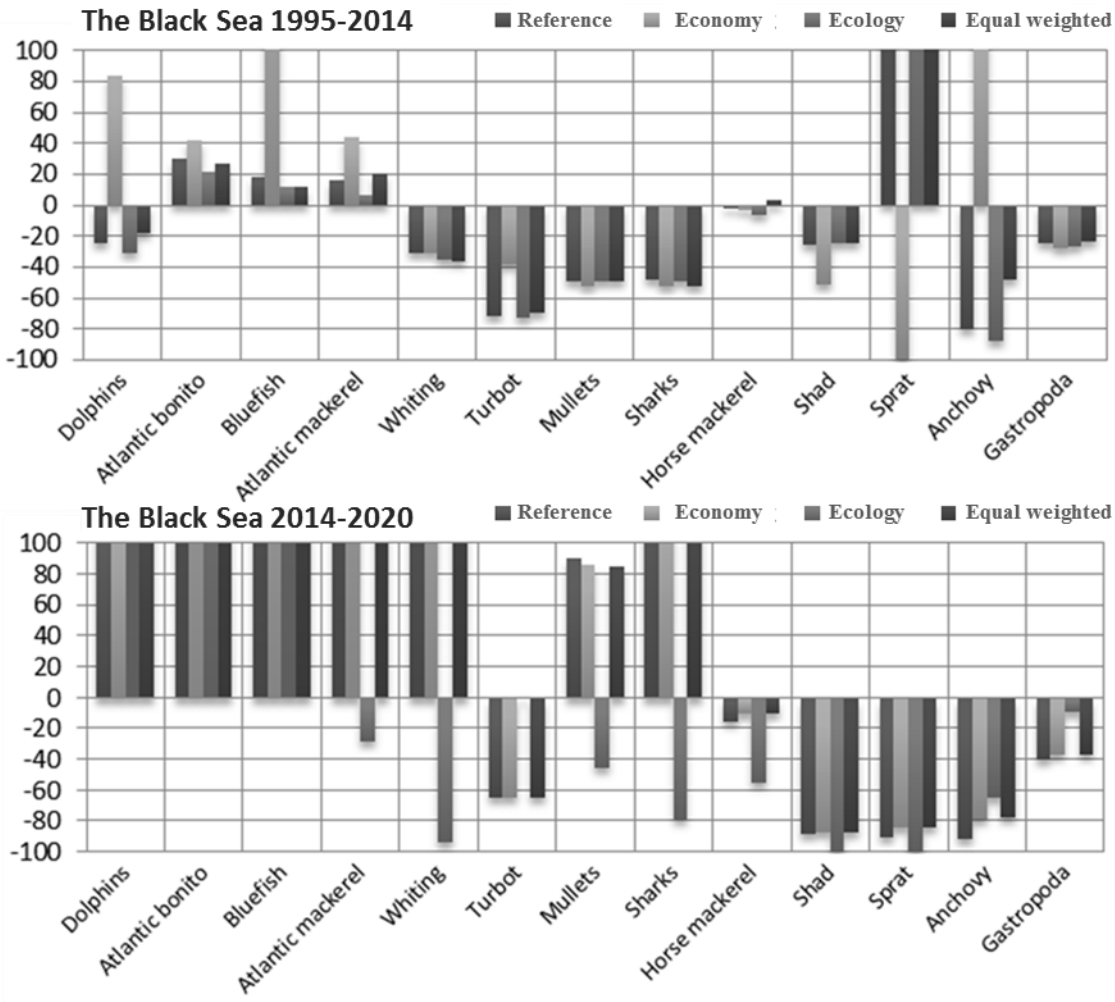

Figure 24. The percentage changes of the functional groups' biomasses according to the reference, economy, ecology and economy and ecology weighted scenario simulations in the periods of 1995-2014 and 2014-2020 in the Black Sea.

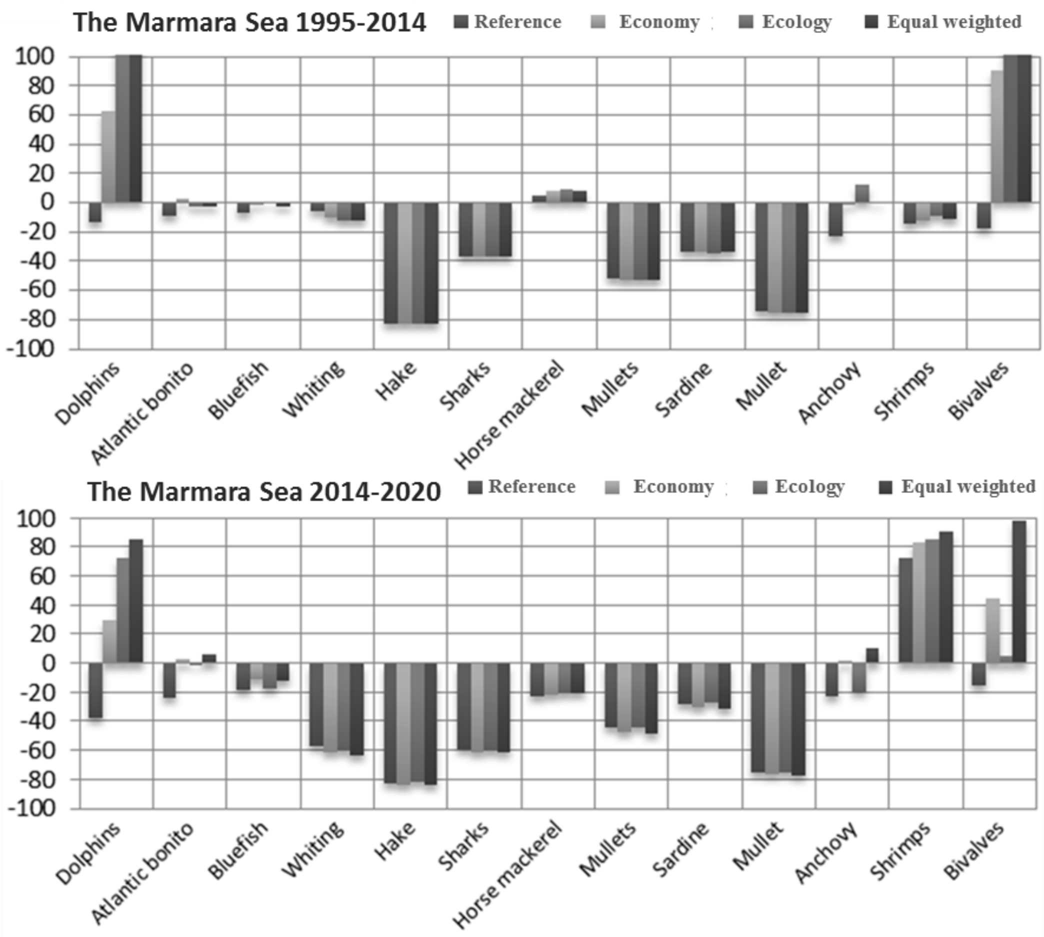

Figure 25. The percentage changes of the functional groups' biomasses according to the reference, economy, ecology and economy and ecology weighted scenario simulations in the periods of 1995-2014 and 2014-2020 in the Marmara Sea.

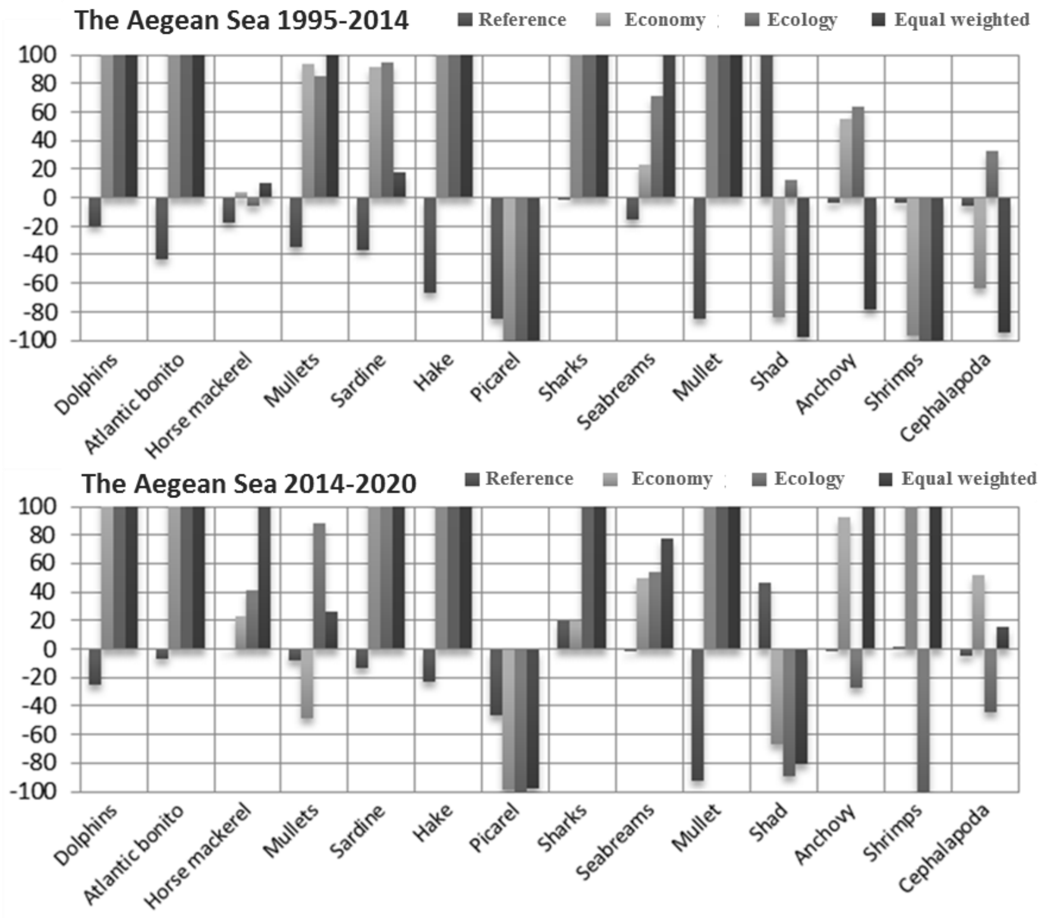

Figure 26. The percentage changes of the functional groups' biomasses according to the reference, economy, ecology and economy and ecology weighted scenario simulations in the periods of 1995-2014 and 2014-2020 in the Aegean Sea.

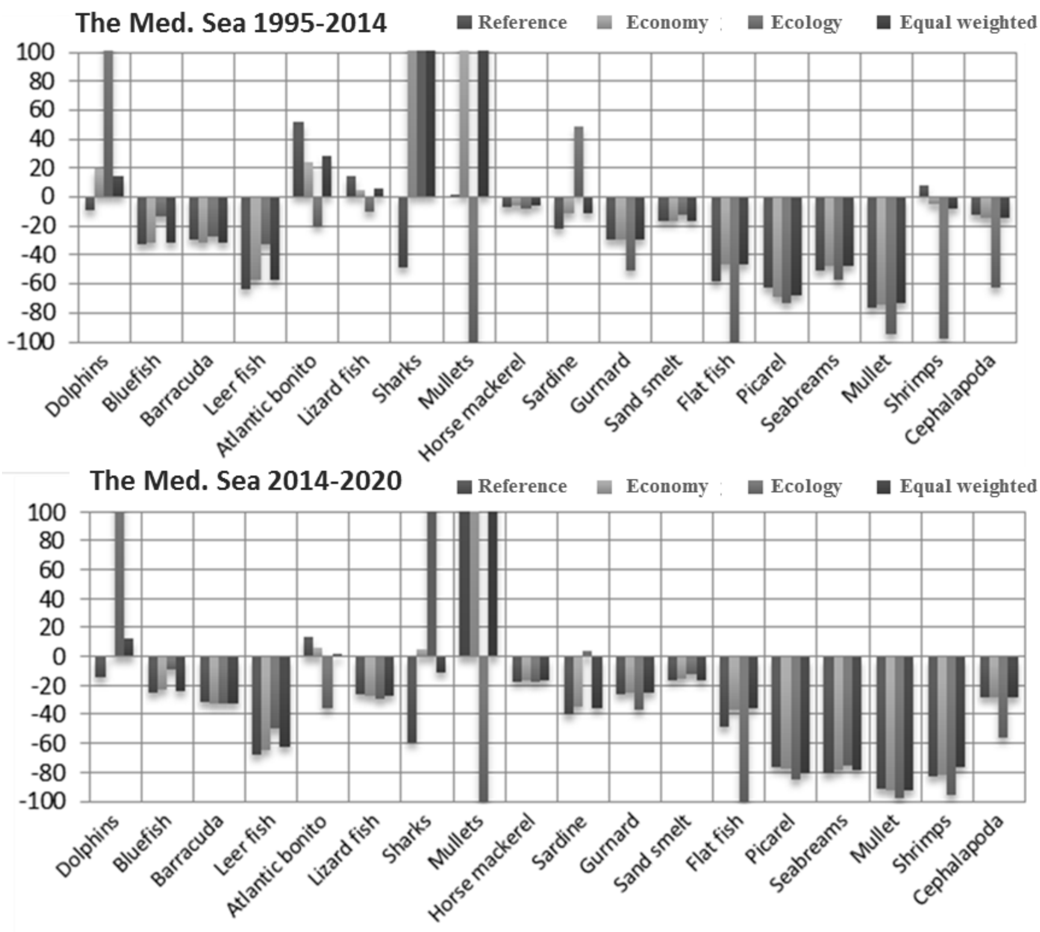

Figure 27. The percentage changes of the functional groups' biomasses according to the reference, economy, ecology and economy and ecology weighted scenario simulations in the periods of 1995-2014 and 2014-2020 in the Mediterranean Sea.

4.4. Discussions and Conclusions

This chapter provided new information on the comparative knowledge of structure, function and fisheries influence in the Turkey's regional marine ecosystems by mass balance ecosystem modelling with Ecopath. Regional models then used to explore the possible impact of various past and future fishing management options on the regional ecosystems by time dynamic scenario simulations.

Mass balance ecosystem modelling with Ecopath is a useful tool to make regional comparisons and applied to several marine ecosystems (Corrales et al., 2015; Tecchio et al., 2015; Hattab et al., 2013; Pranovi and Link, 2009; Tomczak et al., 2009; Coll et al., 2006). In this chapter, regional Ecopath models for the 1995-2014 period allowed the characterization and comparison of the structure and function of regional marine ecosystems and estimation of fisheries impacts upon them. Regional seas differed in their total biomass distributions along the trophic levels. The contribution of higher trophic levels to the total system biomass was higher towards the Mediterranean Sea. Based on the general ecosystem statistics, sum of all exports, flows into detritus and calculated net primary production values were decresed from the Black Sea towards to the Mediterranean Sea whereas sum of all consumption, all respiratory flows and total biomass (excluding detritus) and total catch were higher in the Aegean Sea. Net system production was very high in the Black Sea and lower in the Aegean Sea and Mediterranean Sea parallel to decreasing eutrophication towards the Mediterranean Sea. Higher trophic efficiency between TL II-III and III-IV observed towards the Mediterranean Sea indicated a significant difference in the efficiency between the ecosystems. PPR:R values indicating the maturity of an ecosystem were 2.90 in the Black Sea, 1.31 in the Marmara Sea, 0.86 in the Aegean Sea and 1.23 in the Mediterranean Sea and within the commonly observed range (0.8-3.2) described by Christensen and Pauly (1993). Lowest SOI (variance of trophic levels in the diet) and CI (the ratio of the number of actual links to the number of possible links) values were in the Black Sea (0.15 and 0.14, respectively) displaying that consumers are specialized and feed on single trophic levels. SOI and CI were at their maximum values in the Marmara Sea and gradually decreased towards the Mediterranean Sea. SOI values in the regional seas were in the range of the published literature for the Mediterranean Sea (0.19-0.36 (Libralato, 2008)) except from the Black Sea. The trophic interactions between different functional groups are quantified by the keystonnes and MTI index analysing the ecosystem function. These indices define the relative importance of the ecological role played by each group. Keystonness index values displayed that different fish species played different structuring roles in each of the four regional ecosystems. Heterogenous distribution observed in the keystonnes values along the tropic levels demonstrated that none of the ecosystems were top-down or bottom-up controlled. When the keystonnes values of the common functional groups within the four ecosystems were compared, the impact of a possible change in the biomass of Atlantic bonito biomass on the other functional groups was higher in the Black Sea and decreased towards the Mediterranean Sea contrary to sharks and mullets highlighting the necessity of region specific fisheries regulations. MTI analyses, indicating direct and indirect impact of any group (including fishing fleets) on all other groups trophically, demonstrated the unique interactions between the functional groups as well as the impacts of fisheries on contrasting functional groups in each ecosystem. The importance of ecological role of exploitation was shown with the highest negative ranks which possible possess important consequences in ecosystem function.

Time dynamic scenario simulations predicted the potential impacts of current, economy weigthed, ecology weigthed and economy and ecology equally weighted fisheries management scenarios on the biomass, landing weight and value of the target species in the periods of 1995-2014 and 2014-2020. In 1995-2014 period, compared to the reference scenario, higher biomass, landing weight and value were obtained under the economy, ecology and equal weighted scenarios in the Marmara Sea and Aegean Sea. Similarly, higher landing weight and value were observed under the test scenarios in the Mediterranean Sea though the biomass stayed at the same level with the reference scenario. In the Black Sea, only economy and ecology weighted scenarios generated higher biomass, landing weight and value of the target species. In 2014-2020 period, all the scenarios except from the ecology weighted generated similar biomass, landing weight and value in the Black Sea. This situation may indicate that the concurrent fisheries management in the Black Sea is economy oriented. Ecology oriented scenario was resulted in 50% decrease in the biomass and almost 100% decreases in the landing weight and value. In Marmara Sea, all the scenario simulations resulted with the similar biomass levels but there was a gradual decrease in their landing weights and values. In the Aegean Sea, 40% decrease was predicted in the target species' biomass values in the next 6 years under the current fishing regime. However, more than a 100% increase was foreseen under the other scenario simulations. The landing weight and values in the Aegean Sea were found to be diminished under the ecology oriented scenario and increased under the economy and equal weighted scenarios. In the Mediterranean Sea, the biomass of target species was found to be similar under the all scenarios, however, comparatively lower landing weight and values were predicted under the other test scenarios especially for the economy oriented. The final species composition of the retained biomass were differed for different scenarios as EwE considers the economic value of the species, their importance in the ecosystem and their interactions between the other ecosystem components.

Scenario simulations (except from the ecology weighted scenario in the Black Sea) indicated that if the histrorical management policies were based on the ecology weighted, the current targeted fish species biomass, landing weight and value would be in a better condition. Similar to the past scenario simulations, future predictions showed that ecosystem based fisheries management can contribute to the ecological health of the ecosystems as well as to their economic efficiency. Even though ecology weighted EBFM policies resulted in long term profitability, in the short term they may decrease the socio-economic benefits. The impact of the economy weighted policy can be realized in an adverse way. Different fisheries management scenarios were also tested in the northern Benguela ecosystem (Heymans et al., 2009), southern California (Cisneros-Montemayor et al., 2012), western Mediterranean Sea (Coll et al., 2013), Beibu Gulf (Chen et al., 2009), western English Channel (Araujo et al., 2008), South China Sea (Cheung and Sumaila, 2008), noertheastern Brazil (Freire et al., 2007), Baja California Sur (Arreguin-Sanchez et al., 2004), Prince William Sound (Okey and Wright, 2004), Gulf of Thailand (Christensen and Walters, 2004) and Raja Ampat (Ainsworth et al., 2008). Further from the single species assessments, this approach provided and insight to the general state of the ecosystem structure and function, economic and social profitability of the ecosystems with respect to different policy priorities as required by EBFM.

In this study, we tested different management scenarios by using a modelling approach that has an excellent ability to conduct assessment and policy exploration (Plagányi, 2007). Developed models for Turkey's EEZs in its surrounding seas provided an insight in the progressions occured in the Turkey's regional sea ecosystems in relation to fisheries. The implementation of an EBFM approach can benefit from the devoloped knowledge on ecosystem structure and functioning and ecosystem impact of fishing. Although the modelling studies in this chapter are the first attempts for the management of the regional seas there is a need to move towards. Shortcomings of the approach and future research needs were summarized below.

There were limitated data and knowledge on the biological proporties of the species such as biomass, growth rate, natural and fishing mortality rates and diet compositions for each regional sea. To achieve a better modelling capacity, these parameters should be investigated for each regional sea and form the base for future modelling studies.

An integrated data base in the regional seas does not exist. A data base construction program should be implemented to collect the raw data from past research allowing further calibration of the regional models.

There was lack of continuous ecological and socio-economical regional observation programs to develop operational models that provide up-to-date trustable, applicable managerial policy provision. Continuous ecological and socio-economical regional observation programs should be implemented at subregional scales comprehensively representing regional seas and feeding up-to-date operational models.

Obtaining realistic catch data was a difficult challenge. The reconstruction of the Turkish landings by Ullman (2014) represents a limitation of this study. Uncertainities in the fisheries statistical data should be decreased by developing a suitable methodology considering illegal and unreported part of the fisheries to better guide the ecosystem models.

There was limited information on the socio-economic structures of the regional fisheries. More detailed socio-economic data such as fisher/vessel based economic and social statistics should be collected for each region so as to make more comphrehensive analyses and produce more detailed management policy provision.

Regional EwE models were not coupled with low-trophic models and physicochemical dynamics. The two-way interactions between lower and higher trophic levels and interactions with atmosphere, sediment and land-based sources under changing physical, biogeochemical and climatic conditions should be combined in a single modelling framework (Rose et al., 2010).

The use of only one model may include uncertainities due to the inner dynamics of the model. By applying a multi-model ensemble approach, other relevant ecosystem models should be used together in the regional seas by using the same data sets so as to decrease the uncertainities and provide more robust basis for decision-making as it was applied to the Baltic Sea (Meier et al., 2014) and southern Benguela (Smith et al., 2015).

Regional models were set to each regional sea EEZs. All the regional seas bear very different sub-regions that have different ecosystem and socio-economic dynamics. The regional models can be adapted to sub-regions to provide management support to the local managements.

Current fisheries management scheme of Turkey is not ready to use operational ecosystem models. Fisheries management units in Turkey should be adapted to use the outputs from further developed operational models.

The currently developed modelling capacity, knowledge and expertise were not transferrable and usable for further research. The knowledge and expertise obtained from further developed regional and sub-regional models should be transferrable and usable by the other researchers via educational workshops and clearly explained manuals to accelerate the use and development of ecosystem based research in Turkey.

5. CHAPTER: Synthesis of the thesis

The thesis provides an extensive ecological and socio-economical analyses on the state of the ecosystem and fisheries in the national seas of Turkey with important implications on the development of EBFM policies by implementing a holistic approach as previously addressed in Chapter 1.

One of the important aspects of the EBFM requires a general understanding of the societal importance of the fisheries sector in a general sense. The analyses in Chapter 2 indicated significant changes in the captured/cultured sub-sectoral constitutents of the total fisheries, with no significant changes in the sub-regional contributions. Total fisheries production displayed only 14% growth from 1980s to the 2010-2015 period which was far below the 52% growth of the human population. The role of marine capture fisheries as providing healthy and cheap food to the society became limited within the last decades, meanwhile, its contribution to total fisheries production also decreased in weight and especially in value. The analyses showed that Turkey's per capita fish consumption extracted from Turkey's fish food balance was below the EU and the world as well as the low income food deficit countries' levels. The contribution of fisheries sector to GNP of Turkey was also found to be limited based on the officially reported economic revenue from the primary fisheries sectors. However, the role of fish food international trade in filling Turkey's international foreign trade deficit was important. The available data for assessing the real societal importance of the fisheries sector was limited especially for assessing the total social value and cumulative value of the sector together with associated secondary, tertiary and quaternary sectors. This lack of information also restricts the more advanced fisheries sector analyses especially for implementing the state-of-the art models so as to provide future forecasts to provide more comprehensive management advice for adaptation and mitigation to the foreseen future conditions.

The answers to the question: 'what were the mechanisms driving the limitation of marine capture fisheries landings' were provided in Chapter 3 to criticise the past management applications for better guidance of future EBFM policies. The third chapter, by applying an indicator based approach to easily achievable offical statistics, quantified the growth of the vessel number, engine power and employment of the Turkey's marine capture fishing fleet showing that it did not lead a similar increase in the marine landings within the last decades. Estimated socio-economic indicators of the Turkey's marine capture fisheries also showed a drastic decline. Despite the inefficiency of the fishing, the growth of the fleet's fishing power was sustained by i) the supportive management applications that were resulted in the increase of the total vessel number and engine power of the fleet in the year and/or in the succeeding year of their implementation and ii) economic crises that increased the unemployment in the country and resulted in positive growth in the employment of marine capture fisheries during the years of economic crises (except for the 1973-74 crisis) and negative in the subsequent years of the crises (except the 1998 crisis). Relatively lower CPUE and CPF values and profitability rates recorded at the national scale in the recent years had already given the potential signals of possible negative ecological changes in the regional ecosystems together with the existence of excessive fishing capacity and effort on both economic and ecological grounds. The regional application of the indicators demonstrated that i) The regional sea fisheries was achieved by too many fishers (which might be a strategy to create employment) on the board of too many vessels with too much engine power which resulted in a low fishing efficiency, ii) Exerted over-fishing capacity caused the dissappearance of long lengthed, long lived and lately matured species in the regional ecosystems and dominancy of low regeneration rated small pelagic fish in systems, iii) Even though the number of fishers, vessels and fishing power of the fleet were decreasing within the last decade, continous negative trends in the ecological indicators indicated that ecological demage of the fisheries still continued. Regional fishing capacities showed similar increases under the aforementioned national dynamics whereas the response of the regional ecosystems realized differently. The fourth chapter provides complementary information on the structure and function of regional marine ecosystems in relation to fisheries pressure. This indicated the necessity of region specific 'Ecosystem Based Fisheries Management' implementations. This chapter showed that indicator use on the official statistical data can be useful to understand and communicate long term progressions occurred in the marine ecosystems and fisheries therein the absence of reliable, continuous time series of data. This indicator based approach was based on the official statistics can be complemented by the observational data which needs the collection, calibration and mining of past raw research data.

Based on the knowledge from the previous chapters and also complementary to them, the fourth chapter provided an overall understanding on the structural and functional differences in the regional ecosystems in relation to fisheries and answered the questions of ‘what we could do for a better regulation of marine capture fisheries in the past and what we can expect from the future to fullfill the rising demand of the society’. The model simulations (except the ecology weighted scenario in the Black Sea) showed that if the historical fisheries management practices were implemented based on the ecosystem structure, the recent targeted species biomass, landing weight and value would be higher than the current levels. Similar to this, future ecosystem based fisheries management applications can contribute to the ecological health of the regional ecosystems as well as to fisheries landings weight and economical value. Fisheries management policies that consider the ecological health may decrease the short-term socio-economical benefits of the fisheries but will be resulted in long-term fisheries efficiency. However, the impact of the economy weighted fisheries management can be in contrary. For this reason, the achievement and sustainability of ecological and socio-economic targets are only possible with a successful implementation of ‘Ecosystem Based Fisheries Management’ to the regional seas.

5.1. Contribution of the thesis to the Turkish fisheries management

The difficulty of comprehensive management of marine ecosystem use is based on the restrictions in fully understanding and assessing the relative importance of processes which influence the dynamics of marine ecosystems and tracking their associated dynamics over time and space. There is a wide range of patterns, processes, and principles whose general directionality and outcomes we can use to inform and guide our management (Patrick and Link, 2015). The thesis contribution to the Turkish fisheries management can be summarized as below;

i) There is a growing need to provide fish food to society. The future fisheries management policies should focus on increasing the amount of total national domestic fish consumption which is possible with sustainable capture fisheries, further developed aquaculture fisheries, decreasing non-food use of fish products and increasing imports and decreasing exports in an optimum balance.

ii) Ecology and socio-economic performance of the regional fisheries are not sustainable. Indicator based assessments showed that over-fishing that occurred at the same time period which resulted in ecological degradation and socio-economic losses in the regional fisheries and ecosystems. The proposed indicators in the thesis can be used to asssess the effectiveness of the future management policies.

iii) Turkey's regional marine ecosystems and fisheries have different ecological and socio-economic characteristics and are needed to be managed under region-specific object-oriented management policies. The modelling studies indicated the differences between the structure and function of Turkey's marine ecosystems. Applied scenario simulations showed that better ecological and socio-economical performance could be obtained if the historical management was based on EBFM and more efficient fisheries management policies can be produced by using regionalised modelling tools.

5.2. Contribution of the thesis to the EU Fisheries Standards harmonization proccess

Fisheries, 13th section in the EU hormonization process, necessitates the adaptation and implementation of EU Common Fisheries Policy. EU Common Fisheries Policy includes the protection of the marine living resources and decreasing the environmental impact of the fisheries as well as setting the fishing quatas, management of fleet capacity, aquaculture regulations and supporting fisheries and coastal communities. In the "2015 progress report of Turkey", preparations on this area were in the preparation stage in our country. The nation and region wide research in this thesis can contribute to the acceleration of these preparations allowing the multi-sided socio-economical and ecological evaluations of the fisheries.

5.3. Contribution of the thesis to EU Marine Strategy Framework Directives

The official document of EU for the protection of European Seas aims achieve 'Good Environmental Status' in the European seas which is determined by 11 descriptors after an ecological and socio-economical pre-evaluation. This thesis contributes to the ecological and socio-economical pre-evaluation processes as well as to the first (D1, sustainability of biodiversity), third (D3, health of economically important fish and shellfish population) and the fourth (D4, abundance and reproduction capacities of the food web components are retained) descriptors.

5.4. Future research suggestions

The future research should focus on a better understanding and prediction capacity on todays' and future societal value of the fisheries sector by monitoring socio-economic and fisheries production data and application of state-of-the art models. The use of indicators should be combined with observational data and model outputs to effectively detect ecological changes, especially human induced degradation occurred in the fishing grounds of Turkey in the Black Sea, the Marmara Sea, the Aegean Sea and the Mediterranean Sea. Development of predictive modelling capacity deploying continuous ecological and socio-economical regional observation programs, coupling the fisheries model with lower trophic models, ensemble modelling and application of sub-regional models were needed to produce more comprehensive management advices.

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APPENDIX I. Summary of the general characteristics of the important species.

Species	Main prey	Habitat	Diversity	Trophic level	SE TL	Lmax	Mean length	Resillience	Vulnerability	Price category
Alosa fallax	feeds on small fishes and crustaceans, the young taking the fry of herrings, sprats and gobies	Demersal	0.5	3.6	0.6	60	40	medium	50	low
Atherina boyeri	Copepods, ostracods, polychaetes, amphipods, other	Demersal	0.5312	2.3	0.3	20	11	medium	43	high
Dentex dentex	Fish, cephalopods	Benthopelagic	0.5005	4.5	0.7	100	50	low	67	very high
Dentex macrophthalmus	Fish, cephalopods	Benthopelagic	0.5005	3.4	0.5		30	medium	51	very high
Diplodus annularis	Decapods, polychaetes, molluscs, other	Benthopelagic	0.5001	3.4	0.4	24	13	medium	42	low
Diplodus puntazzo	Decapods, polychaetes, molluscs, other	Benthopelagic	0.5001	2.9	0.4	60	30	medium	34	low
Diplodus vulgaris	Fish, echinoderms, annelids, molluscs, other	Benthopelagic	0.5001	3.2	0.4	45	22	medium	33	low
Engraulis encrasicolus	Copepods, cladocerans, crustaceans, appendicularians, molluscs, other	Pelagic	0.502	3.1	0.45	20	13.5	medium	14	medium
Lichia amia	on fish; juveniles prefer crustaceans		1	4.5	0.8	200	100	medium	75	medium
Merlangius merlangus	shrimps, crabs, mollusks, small fish, polychaetes and cephalopods	Demersal	1	4.4	0.8	70	23.5	medium	37	medium
Merluccius merluccius	fish (Sardina pilchardus, Cepola rubescens), decapods, euphausids, mysids	Demersal	0.5	4.4	0.8	140	45	low	65	high
Mugil cephalus	feed on zooplankton as larvae, detritus, micro-algae and benthic organisms as juvenile and adult fish	Demersal	0.5	2.1	0.2	100	50	medium	42	very high
Mullus barbatus	Decapods (Processa sp.), bivalves, amphipods, polychaetes, other	Demersal	0.5625	3.2	0.4	30	20	medium	36	medium
Mullus surmuletus	Polychaetes, amphipods, decapods, echinoderms, molluscs, isopods, other	Demersal	0.5625	3.4	0.5	40	25	medium	37	very high
Mustelus mustelus	crustaceans, but also cephalopods and bony fishes	Demersal	0.5	3.8	0.5	200	100	very low	74	medium
Oblada melanura	Copepods, amphipods, ostracods, other	Benthopelagic	1	3	0.1	34	20	medium	34	very high
Pagellus erythrinus	Decapods, fish, gastropods, polychaetes, bivalves, cephalopods, other	Benthopelagic	0.5156	3.4	0.5	60	25	medium	54	medium
Pagrus caeruleostictus	Molluscs, fish, crustaceans, polychaetes, other	Benthopelagic	0.5625	3.8	0.6	90	50	medium	46	high
Pagrus pagrus	Fish, molluscs, crustaceans, polychaetes, other		0.5625	3.7	0.6	91	35	medium	66	very high

APPENDIX I. Continued.

Species	Main prey	Habitat	Diversity	Trophic level	SE TL	Lmax	Mean length	Resillience	Vulnerability	Price category
Platichthys flesus	small fishes and invertebrates	Demersal	0.75	3.2	0.4	60	50	medium	45	very high
Pomatomus saltator	other fish, crustaceans and cephalopods	Pelagic	1.5	4.5	0.6	130	60	medium	58	very high
Sarda sarda	Fish (Sardina pilchardus, Trachurus spp.)	Pelagic	0.5625	4.5	0.7	91	50	medium	33	high
Sardina pilchardus	Diatoms, copepods, euphausids, eggs, larvae, algae	Pelagic	1	3.1	0.2	25	20	medium	36	low
Scomber japonicus	Copepods and other crustaceans, fishes and squids	Pelagic	0.5625	3.1	0.4	64	30	medium	46	high
Scomber scombrus	Fish (Sardina pilchardus), crustaceans, gastropods	Pelagic	0.5625	3.7	0.6	50	30	medium	44	medium
Scomberesox saurus	zooplankton and fish larvae; food also includes fish eggs and small fishes	Pelagic	0.8125	3.6	0.3	50	32	medium	25	low
Scophthalmus maximus	sand-eels, gobies, etc.), and also, to a lesser extent, on larger crustaceans and bivalves	Demersal	0.5645	4	0.63	100	50	medium	51	very high
Solea solea	Polychaetes, amphipods, tanaidaceans, decapods, bivalves, gastropods	Demersal	0.502	3.1	0.3	70	35	medium	35	very high
Sparus aurata	Molluscs (Ensis sp.), decapods, annelids, other	Demersal	1	3.3	0.5	70	35	medium	35	very high
Sphyraena sphyraena	fish, less often on cephalopods and crustaceans		0.5	4	0.51	165	60	medium	49	medium
Spicara smaris	Copepods, mysids	Demersal	0.5059	3	0	20	14	medium	39	medium
Spondyliosoma cantharus	Mysids, crustaceans	Benthopelagic	0.75	3.3	0.4	60	30	medium	52	very high
Sprattus sprattus	planktonic crustaceans	Pelagic	0.5312	3	0	16	12	medium	25	low
Squatina squatina	flatfishes and other benthic fishes, but also on skates, crustaceans and molluscs	Demersal	0.5	4.1	0.6	183	150	very low	85	medium
Trachurus mediterraneus	Fish, crustaceans, molluscs, algae	Pelagic	0.5	3.6	0.4	60	30	medium	46	low
Trachurus trachurus	Crustaceans, fish, molluscs, algae, polychaetes	Pelagic	0.5	3.6	0.6	70	22	medium	56	medium
Trigla lyra	decapods (Goneplax rhomboides, Pontocaris lacazei), ophiurids	Demersal	1	3.5	0.5	60	30	medium	63	low
Trigloporus lastoviza	crustaceans	Demersal	1	3.4	0.5	40	15	medium	32	medium
Upeneus molluccensis	Decapods (Leptochela pugnax, Parapenaeus longirostris), fish, polychaetes, molluscs, other	Demersal	0.5	3.6	0.6	20	18	high	22	high

APPENDIX II. Mann Kendall trend analyses results.

Parameters	Time series	Black Sea		Marmara sea		Aegean Sea		Medit. Sea	
		Test Z	Signific.	Test Z	Signific.	Test Z	Signific.	Test Z	Signific.
Landing weight	*46*	1.84	+	3.18	**	4.47	***	4.17	***
Landing value (nom TRY)	*22*	4.40	***	3.21	**	4.46	***	5.13	***
Landing value (real TRY)	*22*	-5.08	***	-3.89	***	-5.02	***	-2.99	**
Landing value (USD)	*22*	-2.37	*	-2.43	*	-2.14	*	0.28	
Landing price (nom TRY)	*22*	4.62	***	4.85	***	5.19	***	5.87	***
Landing price (real TRY)	*22*	-4.29	***	-4.34	***	-4.96	***	-4.23	***
Landing price (USD)	*22*	-1.18		-0.73		-0.68		1.69	+
Fishers	*46*	2.69	**	0.36		4.43	***	6.67	***
Vessels	*46*	6.49	***	2.76	**	7.09	***	7.61	***
HP power	*46*	7.48	***	6.61	***	8.16	***	8.77	***
CPUE	*46*	-5.45	***	-2.99	**	-3.33	***	-3.81	***
CPUE (nom TRY)	*22*	4.23	***	3.05	**	3.72	***	4.96	***
CPUE (real TRY)	*22*	-5.36	***	-4.17	***	-5.81	***	-4.57	***
CPUE (USD)	*22*	-3.10	**	-3.21	**	-3.61	***	-1.52	
CPF	*46*	-0.78		2.90	**	1.02		1.63	
CPF (nom TRY)	*22*	4.51	***	3.72	***	4.79	***	5.47	***
CPF (real TRY)	*22*	-4.79	***	-4.74	***	-4.74	***	-4.00	***
CPF (USD)	*22*	-2.65	**	-2.93	**	-2.76	**	-0.56	
mTL	*46*	-4.24	***	-2.99	**	0.62		-1.06	
mLength	*46*	-4.62	***	-3.69	***	-2.82	**	0.19	
IVI	*46*	-5.21	***	-2.22	*	-3.20	**	-3.14	**
SmallP	*46*	3.22	**	3.29	***	4.11	***	7.16	***

APPENDIX III. Spearman Rank Correlation analyses results between the regions (Values in bold are different from 0 with a significance level alpha=0.05).

	Regions	Black Sea	Mar. Sea	Aeg. Sea	Med. Sea
Landing weight	Black Sea	**1**	**0.497**	**0.334**	**0.360**
	Mar. Sea		**1**	**0.691**	**0.557**
	Aeg. Sea			**1**	**0.834**
	Med. Sea				**1**
Landing value	Black Sea	**1**	**0.657**	**0.770**	**0.537**
	Mar. Sea		**1**	**0.653**	0.055
	Aeg. Sea			**1**	**0.518**
	Med. Sea				**1**
Landing price	Black Sea	**1**	**0.808**	**0.671**	**0.512**
	Mar. Sea		**1**	**0.720**	**0.661**
	Aeg. Sea			**1**	**0.700**
	Med. Sea				**1**
Fishers	Black Sea	**1**	0.286	**0.816**	**0.596**
	Mar. Sea		**1**	0.086	0.257
	Aeg. Sea			**1**	**0.815**
	Med. Sea				**1**
Vessels	Black Sea	**1**	**0.619**	**0.902**	**0.910**
	Mar. Sea		**1**	**0.438**	**0.591**
	Aeg. Sea			**1**	**0.936**
	Med. Sea				**1**
HP Power	Black Sea	**1**	**0.829**	**0.947**	**0.948**
	Mar. Sea		**1**	**0.905**	**0.884**
	Aeg. Sea			**1**	**0.963**
	Med. Sea				**1**
CPUE (wei	Black Sea	**1**	**0.371**	**0.691**	**0.788**
	Mar. Sea		**1**	**0.494**	**0.354**
	Aeg. Sea			**1**	**0.803**
	Med. Sea				**1**
CPUE (valu	Black Sea	**1**	**0.721**	**0.863**	**0.692**
	Mar. Sea		**1**	**0.702**	0.345
	Aeg. Sea			**1**	**0.723**
	Med. Sea				**1**
CPF (weigh	Black Sea	**1**	**0.550**	**0.801**	**0.744**
	Mar. Sea		**1**	**0.666**	**0.572**
	Aeg. Sea			**1**	**0.813**
	Med. Sea				**1**
CPF (value)	Black Sea	**1**	**0.852**	**0.919**	**0.622**
	Mar. Sea		**1**	**0.771**	0.364
	Aeg. Sea			**1**	**0.592**
	Med. Sea				**1**

	Regions	Black Sea	Mar. Sea	Aeg. Sea	Med. Sea
mTL	Black Sea	**1**	**0.324**	-0.171	-0.139
	Mar. Sea		**1**	-0.159	0.058
	Aeg. Sea			**1**	0.223
	Med. Sea				**1**
mLength	Black Sea	**1**	**0.465**	0.113	-0.149
	Mar. Sea		**1**	**0.387**	0.271
	Aeg. Sea			**1**	0.172
	Med. Sea				**1**
IVI	Black Sea	**1**	0.277	0.134	0.156
	Mar. Sea		**1**	**0.312**	**0.421**
	Aeg. Sea			**1**	**0.399**
	Med. Sea				**1**
SmallP	Black Sea	**1**	**0.389**	**0.358**	**0.399**
	Mar. Sea		**1**	**0.521**	**0.405**
	Aeg. Sea			**1**	**0.592**
	Med. Sea				**1**

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Advanced English

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