ÇUKUROVA UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES

PhD THESIS

İsmet SAYGU

ECOSYSTEM BASED ASSESSMENT OF THE EFFECTS OF SHIFTING TRAWL CODENDS IN GULF OF MERSIN, EASTERN MEDITERRANEAN

FISH CAPTURE AND PROCESSING DEPARTMENT

ADANA, 2018

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We certify that this thesis satisfies all requirements as a thesis for the degree of Doctor of Philosophy.

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ABSTRACT

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The poor selectivity and high discard ratios of demersal trawls are of significant concern in the Mediterranean. A large number of studies exist on codend selectivity, most of which intensify on mesh size and shape. In consideration of these studies, the General Fisheries Commission for the Mediterranean recommends the use of 40 mm square-mesh (S40) or 50 mm diamond-mesh (D50) codends. However, the effects of improving codend selectivity on the ecology of the ecosystem are not well known. The goal of this study is to evaluate the potential effects of improved codend selectivity on the ecosystem and main target species. This study is based on well-described species-specific catch and selectivity data for commercial codend (44 mm diamond mesh hand-woven slack knotted, CD44), 44 mm diamond mesh codend (D44) and alternative codends (D50 and S40) fisheries from the Gulf of Mersin in the northeastern Mediterranean. Four Ecopath models, with 48 functional groups and similar topologies were developed to represent the effect of different codends on the ecosystem. The consequences of improved trawl selectivity were assessed in the context of ecological framework approved that selective fisheries would benefit for various commercial species and ecosystem. S40 was defined as the best alternative for the impacts of trawl fisheries on the ecosystem and various commercial species, particularly red mullet (*Mullus barbatus*) which is the most important commercial fish species in the region.

Keywords: Ecopath, food web model, trawl, codend selectivity, square mesh

ÖZ

DOKTORA TEZİ

MERSİN KÖRFEZİ'NDE TROL TORBA DEĞİŞİMLERİNİN EKOSİSTEM TEMELLİ DEĞERLENDİRİLMESİ

İsmet SAYGU

ÇUKUROVA ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ
SU ÜRÜNLERİ AVLAMA TEKNOLOJİSİ ANABİLİM DALI

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Akdeniz ekosistemi için önemli sorunlardan bir tanesi düşük torba seçiciliği ve yüksek ıskarta oranları ile karakterize olan dip trol balıkçılığıdır. Birçoğu trol torbasının göz açıklığı ve şekli ile ilgili olmak üzere, dip trol balıkçılığında torba seçiciliği üzerine çok sayıda araştırma mevcuttur. Bu çalışmalar çerçevesinde, Akdeniz Genel Balıkçılık Komisyonu (GFCM), Akdeniz'de 40 mm kare (S40) ya da 50 mm baklava (D50) şeklinde daha seçici trol torbalarının kullanımını tavsiye etmektedir. Ancak, artan seçiciliğin ekosistemin ekolojisi üzerine etkileri tam olarak bilinmemektedir. Bu çalışmanın amacı, artan trol torba seçiciliğinin ekosistem ve ana hedef türler üzerine potansiyel etkilerinin araştırılmasıdır. Bu çalışma, ticari trol torbası (44 mm baklava şeklinde el yapımı ve gevşek düğümlü trol torbası, CD44), 44 mm baklava şeklinde trol torbası ve alternatif torbalar (D50 ve S40) için türe özgü av ve seçicilik verisi temel alınarak kurgulanmıştır. Farklı trol torbalarının ekosistem üzerine etkilerini temsil eden 4 adet Ecopath modeli geliştirilmiştir. Bu modeller 48 adet fonksiyonel gruptan oluşmaktadır ve benzer topolojilere sahiptirler. Ekosistem temelli değerlendirmenin sonucunda, dip trol balıkçılığında daha seçici torbaların kullanımının ekosistemin ve çeşitli ana hedef türlerin yararına olduğu belirlenmiştir. Başta bölgenin hedef balık türü olan barbun (*Mullus barbatus*) olmak üzere çeşitli ekonomik türler ve ekosistem açısından en iyi alternatif trol torbası olarak S40 tanımlanmıştır.

Anahtar Kelimeler: Ecopath, besin zinciri modeli, trol, torba seçiciliği, kare gözlü ağ.

EXTENDED ABSTRACT

The Poor selectivity and high discard ratios of demersal trawls are of significant concern in the Mediterranean. A large number of studies exist on codend selectivity, most of which focus on mesh size and shape. In consideration of these studies, the General Fisheries Commission for the Mediterranean recommends the use of 40 mm square-mesh (S40) or 50 mm diamond-mesh (D50) codends.

However, the effects of improving codend selectivity on the ecology of the ecosystem are not well known. The goal of this study is to evaluate the potential effects of improved codend selectivity on the ecosystem and main target species, *Mullus barbatus, Saurida undosquamis*, *Pagellus erythrinus* as case species.

This study is based on well-described species-specific catch and selectivity data for commercial codend (44 mm diamond mesh handmade slack knotted net, CD44), 44 mm diamond mesh codend (D44) and alternative codends (D50 and S40) in demersal trawl fisheries from Gulf of Mersin in the eastern Mediterranean. Four Ecopath models, with 48 functional groups and similar topologies were developed to represent the effect of different codends on the ecosystem. Specifically, the impact on *M. barbatus S. undosquamis*, *P. erythrinus* were described by splitting the functional group into two components according to minimum landing size (MLS).

The consequences of improved trawl selectivity were assessed in the context of ecological framework approved that selective fisheries would benefit for various commercial species and ecosystem. S40 was found as the best alternative for the impacts of trawl fisheries on the ecosystem and various commercial species, particularly red mullet which is the most important commercial species in the region.

M. barbatus (<MLS, juvenile and >MLS, adult) showed the lowest trophic levels among demersal fish groups. For CD44, D44, D50 and S40 codends, the

catches were calculated as 0.013 $t.km^{-2}.y^{-1}$, 0.011 $t.km^{-2}.y^{-1}$, 0.006 $t.km^{-2}.y^{-1}$ and 0.003 $t.km^{-2}.y^{-1}$ for *M. barbatus* (<MLS), and 0.050 $t.km^{-2}.y^{-1}$, 0.049 $t.km^{-2}.y^{-1}$, 0.042 $t.km^{-2}.y^{-1}$ and 0.041 $t.km^{-2}.y^{-1}$ for *M. barbatus* (>MLS) respectively.

Ecological network analysis highlighted that if trawlers switched from CD44 to D50 or S40 codends, metabolic activity of *M. barbatus* (<MLS) would increase. Reasons for this are that exports due to the fishing removals would decrease from ~11% to 7% or 3% respectively and respiration would increase from ~57% to 60% or 62% respectively. In addition, the mixed trophic impact of demersal trawl fisheries on juvenile *M. barbatus* was less negative (decreased from -0.30 to -0.16) in the use of S40 codend. Thus, S40 is the best alternative for red mullet. There is no improvement in the use of other alternative codends with diamond meshes (D44 and D50).

Annem ve Babam, Hayriye ve Oktay SAYGU' ya İthaf Ediyorum…

To my mother and father, Hayriye and Oktay SAYGU…

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ABBREVIATIONS

B	: Biomass
BGC	: Biogeochemical
CD44	: 44 mm diamond mesh hand-woven slack knotted
CFP	: Common Fisheries Policy
D40	: 40 mm diamond mesh codend
D44	: 44 mm diamond mesh codend
D50	: 50 mm diamond-mesh codend
EAF	: Ecosystem Approach to Fisheries
EBFM	: Ecosystem Based Fisheries Management
EE	: Ecotrophic Efficiency
EU	: European Union
EwE	: Ecopath with Ecosim
FAO	: Food and Agriculture Organization
GES	: Good Environmental Status
GFCM	: General Fisheries Commission for the Mediterranean
GoM	: Gulf of Mersin
L	: Lessepsian
MLS	: Minimum Landing Size
MSFD	: Marine Strategy Framework Directive
MTI	: Mixed Trophic Impact
P	: Production
Q	: Consumption
S40	: 40 mm square-mesh codend
Sc.	: Scenario

TFR	: Turkish Fisheries Regulations
TL	: Trophic Level
TST	: Total System Throughput

1. CHAPTER: THESIS INTRODUCTION

The ecosystem approach to fisheries (EAF) has evolved during the last two decades in response to increasing pressures on marine ecosystems. EAF basically aims to achieve sustainable development in marine resources by taking into account ecological well-being, human well-being and governance (Staples and Funge-Smith, 2009). United Nations Food and Agriculture Organization (FAO) declared the importance of EAF (FAO, 2003). The frameworks of EAF have been implemented by the European Commission through the "Common Fisheries Policy" (CFP) and the "Marine Strategy Framework Directive" (MSFD) (Marshall et al., 2017). Such agreements (CFP and MSFD) call for the application of EAF. EAF has also been identified as the main instrument to structure the components of Ecosystem Based Fisheries Management (EBFM) (Staples and Funge-Smith, 2009).

The CFP aims to take actions for sustainable stocks such as landing obligation and minimum conservation reference sizes, to protect the juveniles of marine organism (Lutchman et al., 2009). The CFP, which includes the key components of the EBFM (Marshall et al., 2017; Trenkel et al., 2015), is considered the primary instrument to reach fisheries related "Good Environmental Status" (GES) in the context of the MSFD (Jennings et al., 2012; Lassen et al., 2013). Also, the MSFD gives support to the CFP as an environmental pillow (Lutchman et al., 2009).

The GES is a list of qualitative descriptors defined under the MSFD. The GES list includes the following 11 descriptors (Cardoso et al., 2010):

1. Biological diversity
2. Non-indigenous species
3. Commercially exploited fish and shellfish populations
4. Food webs

5. Eutrophication
6. Sea floor integrity
7. Hydrographical conditions
8. Contaminants
9. Food safety
10. Litter
11. Energy and noise

Four of these indicators are affected by fisheries: including 1. biological diversity, 3. commercially exploited fish and shellfish populations, 4. food webs, and 6. sea floor integrity (Lassen et al., 2013). In addition to these four, 2. non-indigenous species can also be considered as related to fisheries. The MSFD's GES have to be achieved in all European Regional Seas by the year 2020 by applying necessary research and management tools (Cardoso et al., 2010). Turkey is a candidate to become a full member of European Union (EU). So, the implementation of GES in Turkish Seas is for the benefit of Turkey as well as other European countries, due to the broader marine ecosystem.

Ecosystem models, particularly food-web models such as Ecopath with Ecosim (EwE), provide useful indicators described under the attributes of the fisheries related descriptors of MSFD's GES (Coll et al., 2015; Lassen et al., 2013; Piroddi et al., 2015a, 2015b; Rombouts et al., 2013). EwE is a useful tool to describe the five GES descriptors (1, 2, 3, 4 and 6) and particularly for the descriptor 4 which focuses on food-wed indicators (Rombouts et al., 2013). Ecological Network Analysis indices obtained from EwE are important to reach the descriptor 4 in GES (Guesnet et al., 2015).

The second chapter of this thesis was dedicated to understanding the ecosystem characteristics of the Gulf of Mersin (northeastern Mediterranean Sea) and to evaluate the interactions with large-scale fisheries, particularly demersal trawl fisheries. A mass balance food-web model Ecopath, which applied for these

purposes, was also used to describe fisheries related MSFD GES descriptors by providing a group of indicators.

Another international authority gives binding recommendations for fisheries management in the Mediterranean Sea is the General Fisheries Commission for the Mediterranean (GFCM) under the provisions of the FAO. The reduction of discards and the application of minimum legal landing sizes to protect juvenile marine organisms have been simultaneously recommended by FAO and GFCM. This is in line with the approach of CFP and EU. Within this scope, GFCM and EU recommended the use of 40 mm square mesh or at least 50 mm diamond mesh codends instead of the trawl codend which currently used by fishermen to improve selectivity and decrease discard in demersal trawl fisheries in the Mediterranean (E.C., 2006; GFCM, 2007).

The third chapter investigates the impacts of improved trawl selectivity on the main target species in the context of EBFM and the ecology of the ecosystem. This evaluation can be also considered as intersection sets of management advice both traditional single species and ecosystem based assessments. Finally, the fourth chapter includes a brief assessment of the thesis and recommendations for forthcoming work by considering the perspective of EBFM.

2. CHAPTER: A TROPHIC MASS-BALANCE MODEL AND FISHING IMPACTS IN GULF OF MERSIN, NORTHEASTERN MEDITERRANEAN

2.1. Introduction

Anthropogenic impacts such as fishing, pollution, eutrophication, habitat loss, introduction of non-indigenous species and climate change, and their natural consequences have been identified as the most pressing problems for the Mediterranean Sea ecosystem (Coll et al. 2010). Tsikliras et al. (2013) stated that fishing pressure is a significant problem and the main anthropogenic factor leading to degradation of the coastal areas in the Mediterranean Sea. Moreover, the ever-increasing introduction of Lessepsian (L) species, which migrate from the Red Sea to the Mediterranean Sea via the Suez Canal, is an important threat, especially in the eastern Mediterranean Sea. According to Golani (1998), the construction of the Suez Canal in the eastern Mediterranean and the Aswan High Dam on the Nile have been the man-made constructions with the greatest impacts on marine ecosystems.

Even though the continental shelf is narrow in most areas of the northeastern Mediterranean, Gulfs of Mersin and Iskenderun are relatively wide. Because of the large continental shelf, bottom type and riverine inputs, the latter two Gulfs are very productive for demersal fish and crustacean species (Gücü and Bingel, 1995). Thus, 30% of the Turkish demersal trawl fleet, operates in the area (Gökçe, 2012). A considerable amount of small-scale fisheries also occur here using static-gear including trammel nets, gillnets, and demersal longlines (Özbilgin et al., 2013; 2010). There are thus three main fleets in the region: bottom trawlers, purse seiners and small scale fishing boats. TUIK (2014) reported that officially there are 205 trawlers, 57 purse seiners, 12 trawlers – purse seiners (both trawl and purse seine), and 1677 small scale fishing boats registered in 20 fishing ports located around the region.

As in other parts of the Mediterranean Sea fisheries management is considerably complicated by the multi-species nature of the fishery (Gücü, 2012). The major management problems in the northeastern Mediterranean are overfishing and bycatch and/or discards (Gökçe, 2012). Özbilgin et al. (2013) reported that in terms of weight 47.6% is discarded (i.e. only 52.4% landed) in demersal trawl fisheries of Gulf of Mersin. Global experience suggests that discarding can lead to a number of negative impacts such as threatening endangered species, wasting resources, damaging habitat, impacting the food web and ecosystem pathways (Hall et al., 2000). However, the impacts of discarding have not been studied in the area. Moreover, Gulfs of Mersin and İskenderun are important habitats for invasive Lessepsian species to the extent that some have been commercially exploited (Gücü et al., 2010).

Fisheries in the region are regulated with area restrictions, seasonal closures, minimum distance off the coast, and the shape and size of the nets by Turkish Fisheries Regulations (TFR) (Official Gazette, 2016). These regulations are designed for the main targeted species and consider only their respective population characteristics. This approach runs counter to the Ecosystem Based Fisheries Management (EBFM). EBFM requires more consideration of the impacts of fishing on the ecosystem in terms of both target and non-target species plus the trophic interactions within the whole food web and environmental drivers and impacts (Botsford et al., 1997; Coll et al., 2008a; Coll and Libralato, 2012; Duda and Sherman, 2002). The EBFM approach has evolved over the last decades in response to increasing pressures on marine environment. In 2008, the EU established a framework for community action in marine environmental policy (Marine Strategy Framework Directive, MSFD) which explicitly cites environment-based management.

While hydrodynamic and biogeochemical (BGC) models have been used together to assess the interactions between the biological and physical processes in the marine environment on lower trophic level processes, models focusing on

higher trophic level processes have also been developed such as Ecopath (Polovina 1984a, Christensen and Pauly 1992), Ecosim (Walters et al., 2000, 1997), Ecospace (Walters et al., 1999) OSMOSE (Shin et al., 2004) and ATLANTIS (Fulton et al., 2011) to understand marine ecosystem structure and functioning, and assess the effect of anthropogenic factors on the ecosystems, particularly fisheries. It is difficult to link the BGC models with higher trophic level food web models due mostly to the time steps used by these models. The BGC model time steps are usually in minute/hour/days, while the higher trophic level food web model time steps are in months/years. So, one way coupling is possible and have been done often, but two way coupling is more difficult because the feedback to the BGS models cannot be done easily.

To date Ecopath with Ecosim (EwE) is the most widely used tool for modelling higher trophic level food webs in the world (Christensen, 2009; Heymans et al., 2014). EwE is a suite of algorithms that includes trophic levels from primary producers to top predators but generally with simplification of the lower trophic levels. Anthropogenic and environmental factors such as temperature, salinity, etc. can also be included (Bentley et al., 2017; Heymans et al., 2011; Plaganyi, 2007; Serpetti et al., 2017). The National Oceanographic and Atmospheric Administration declared that EwE was one of the 10 major scientific breakthroughs in the last 200 years in its own history (Christensen, 2013). The institute for European Environmental Policy also concluded that EwE is the most appropriate approach among the ecosystem models to describe ecosystem structure and provide future predictions (Coll and Libralato, 2012; Sukhdev, 2008). This is because the EwE approach is able to address a wide variety of policy and research questions, in addition to the virtue of data requirement and other logical constraints such as EwE's friendly interface, easily parameterized framework, and researchers working on this modelling approach (Heymans et al., 2016). Over 400 publications have been published utilising EwE and there are an estimated 7000 users of the software in the world (Colléter et al., 2015).

The main applications of EwE in the Mediterranean have been to describe and explore ecosystem structure and dynamics in the Southern Catalan Sea (Coll et al., 2006), North Central Adriatic Sea (Coll et al., 2007), North Adriatic Sea (Barausse et al., 2009), North Aegean Sea (Piroddi 2008, Piroddi et al. 2010), North Ionian Sea (Tsagarakis et al., 2010), North Central Adriatic Sea (Fouzai et al., 2012), South Western Spain (Torres et al., 2013), Ionian Sea (Moutopoulos et al., 2013), Gulf of Lions and Balearic Sea (Bănaru et al., 2013; Coll et al., 2013; Corrales et al., 2015), and Israeli Exclusive Economic Zone (Corrales et al., 2017a, 2017b).

Bottom trawl fisheries were determined to have the most notable impact on the trophic flows and commercially targeted demersal species among fisheries including purse seine (operating during the day), lamparo (purse-seine fishing using lights), sponge fishing, tuna fisheries, and coastal motorized fishing in the Gulf of Gabes ecosystem (Hattab et al., 2013). A mass balance food web model was developed in the Greek part of the Ionian Sea and the results highlighted that discards had greater impacts than landings on the food web energy flows and fisheries (Moutopoulos et al., 2013). Moreover, discards may be an important diet contribution for some species such as seabirds, crabs, and gadoids (Bosch et al., 1994; Hall, 1999) and this may cause indirect effects in the energy flow (Hall, 1999).

Comparative results of Ecopath applications in the Mediterranean Sea highlighted similar ecological structures across different regions, i.e. bentho – pelagic coupling, and indicated that groups such as small pelagic fishes, sharks, and detritus emerged to have key roles in their ecosystems (Coll and Libralato, 2012; Hattab et al., 2013; Torres et al., 2013; Tsagarakis et al., 2010).

A number of invasive species have had impacts on marine food webs in the Mediterranean. The effects of Manila clams, which was introduced into the Venice Lagoon, were identified by Pranovi et al. (2003), the ecological role of invasive comb jellyfish *Mnemiopsis leidyi*, its predation on anchovy eggs and larvae have

been described many times (Akoglu et al., 2014; Kideys, 2002; Lebedeva and Shushkina, 1994; Shiganova and Bulgakova, 2000) and the Black Sea trophic cascade caused by overfishing (Daskalov, 2002; Gücü, 2002) was depicted by Akoğlu et al. (2014). The synergy between the impacts of invasive species and over-fishing were explored by Akoglu et al. (2014); Bilio and Niermann (2004); Oguz (2007); Oguz et al. (2008a, 2008b). They concluded that the collapse in the Black Sea was related to more than one reason: Interspecies competition and overfishing were found to be the main drivers of the changes, and it was particularly enhanced by the introduction of alien organisms such as *Noctulica* and jellyfish species. Pauly et al. (2009) carried out a meta-analysis of Ecosim simulations to identify the trophic role of jellyfish blooms in the Mediterranean Sea. This showed that potential increase in jelly-fish biomass over time is likely to impact ecosystem structure and functioning, especially for smaller ecosystems. The effects of the invasive species, *M. leidyi,* on trophic flows in the eastern Mediterranean Sea have also been described by Tsagarakis et al. (2010). Ecopath models representing two time periods (1990-1994 and 2008-2012) in the Israeli Mediterranean EEZ revealed that there was an increasing impact of alien species on native species, and fishing had negative impacts on the ecosystem in both time periods according to mixed trophic impact results (Corrales et al., 2017b).

EwE has also been used to explore the consequences of some fisheries management actions in the Mediterranean. For example, Coll et al. (2008a, 2008b) evaluated the potential results of improved trawl selectivity within an ecosystem context by modifying the EwE model described for the same area (Coll et al., 2006). Moreover, EwE can shed light on individual species. For instance, Coll et al. (2013) investigated the ecological role and impact of fishing on Mediterranean endemic skate, *Raja asterias*.

Coll and Libralato (2012) compared the 40 published EwE models for the Mediterranean Sea with pair-wise tests. Results show that while there are different features of the ecosystems in terms of ecosystem types, the importance of benthos,

plankton organisms, small pelagic fishes, and top predators is common features, in addition to the high impact of the fishing on the ecosystem. Recently Piroddi et al. (2017) modelled the whole Mediterranean Sea using the Ecopath approach, and highlighted the importance of the changes in primary production and fishing pressure on the Mediterranean Sea ecosystem.

All these studies prove that the Mediterranean Sea is a hotspot for carrying out marine ecosystem research. Despite the large amount of published food-web research and modelling of the Mediterranean, the food-web and fisheries impacts within north eastern Mediterranean have never been explicitly modelled. The purpose of this chapter is thus to: *i*) characterise the structure of the mass balance food – web model, *ii*) understand trophic interactions among the functional groups, *iii*) identify direct and indirect impacts of fishing on the trophic energy flows.

2.2. Materials and Methods

2.2.1. Modelling Area

The modelled area covers 4352 km^2 of Gulf of Mersin on the northeastern Levantine Basin (northeastern Mediterranean) from the area where demersal trawling activity is banned within 2 nm and 3 nm to 200 m isobaths (Figure 2.1). The area is located between 36.230667° N - 33.946550° E and 36.589500° N - 35.419200° E. All maps were created with the Matlab R2014b. Modelled area was calculated by using the tool for Google Earth (http://earthpoint.us/Shapes.aspx). The mean annual bottom and water column (3 and 200 m) temperatures were estimated as 19.15°C (Ergev, 2002; Mutlu and Ergev, 2008), and 22.56°C (Gücü et al., 2011; Sakınan, 2014) respectively. The mean depth of the modelled area was calculated as 64.28 m (± 52.19 m) using the average of 1077 depth points extracted from the software Magellan MapSend BlueNav (version 1.01g).

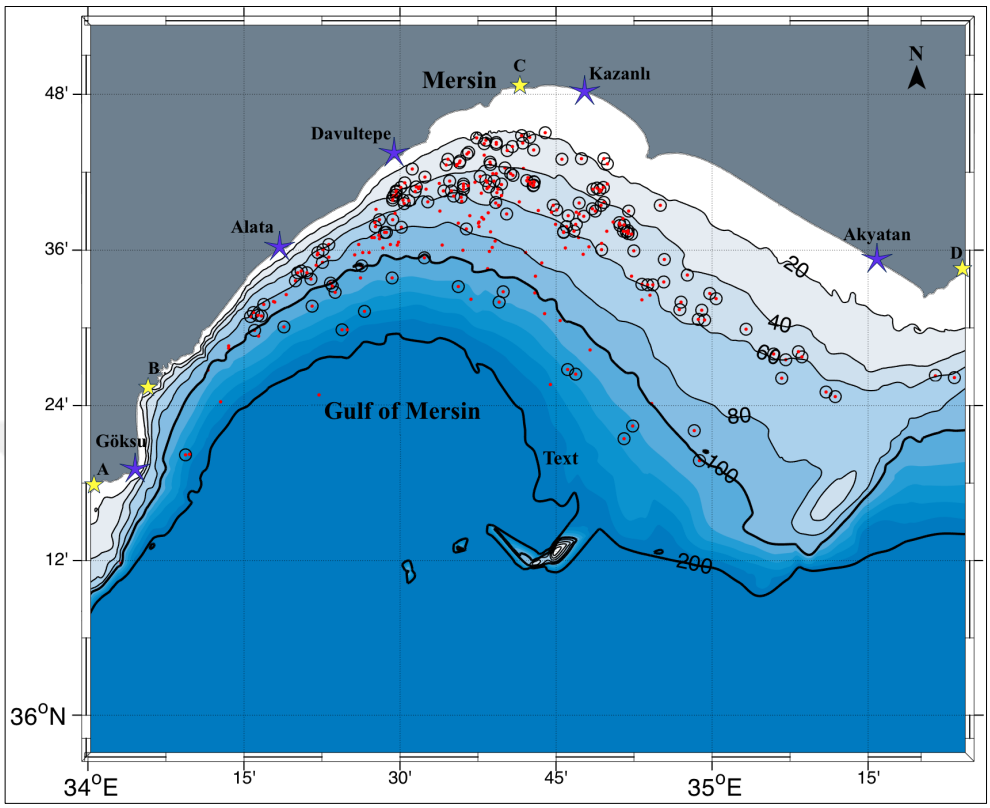

Figure 2.1. Modelled area, Gulf of Mersin in the northeastern Mediterranean. Trawl hauls for biomass estimation (black, circle) and demersal trawl catch estimation (red, dot). The area is located between "A" and "D". The area where demersal trawling activity is banned within 2 nm from "B" to "C" and 3 nm from "A" to "B" and "C" to "D": A (36.234518° - 33.965170°); B (36.416183° - 34.090967°); C (36.809100° - 34.697883°); D (36.589500° - 35.419200°)

2.2.2. Modelling Approach

A trophic mass-balance model representing the average state of Gulf of Mersin ecosystem for the period September 2009 to September 2013 was set up using Ecopath with Ecosim (EwE) version 6.5. Trophic mass-balance model (Ecopath) uses a set of linear equations to describe trophic interactions among functional groups, and provides a static snapshot of the ecosystem's food web. The topology of these networks or interactions are regulated by the energy balance in

the trophic energy flow constituted by feeding relationships of the functional groups, and Ecopath works with two master equations to ensure the masses are balanced in the final model (Christensen et al., 2008; Christensen and Walters, 2004).

Consumption (Q)=Production (P)+Respration (R)+Unassimilated food (E)

Production (P)=Catch (Y)+Predation mortality (M2)
+Biomass accumulation (BA)+Net migration (E)+Other mortality (1-EE)

$$\boldsymbol{P_i = \sum_j B_j \cdot M2_{ij} + Y_i + E_i + BA_i + P_i \cdot (1 - EE_i)} \quad (1)$$

where Pi is the total production of functional group i; Bj is the biomass of group j; $M2ij$ is the predation mortality caused by group j on group i; Yi is the total fishery catch rate of i; Ei is the net migration rate of i; BAi is the biomass accumulation rate for i; $1 - EEi$ is the other mortality rate that is not attributed to predation or catches for i; EEi is the ecotrophic efficiency for i. This equation can be re-expressed as:

$$\boldsymbol{B_i \cdot (\frac{P}{B})_i = \sum_j B_j \cdot (\frac{Q}{B})_j \cdot DC_{ij} + Y_i + E_i + BA_i + B_i \cdot (\frac{P}{B})_i \cdot (1 - EE_i)} \quad (2)$$

where where Bi is the biomass of group i; $(P/B)i$ is the production/biomass ratio for i; $(Q/B)i$ is the consumption/biomass ratio of predator j; $DCij$ is the fraction of prey i in the average diet of predator j.

Among the four basic parameters; namely Biomass (B), Production/Biomass (P/B), Consumption/Biomass (Q/B), and Ecotrophic Efficiency (EE), at least three have to be known or assumed. In addition, diets and catches are needed as inputs for each functional group. Normally Ecopath is allowed to estimate EE because of the difficulties in obtaining estimates of this parameter empirically. In the model, biomass was expressed in units of tonnes wet weight per square kilometre ($t.km^{-2}$), and flows were expressed as $t.km^{-2}y^{-1}$ of wet weight.

Default procedures based on ecological and thermodynamic rules were used to ensure mass-balance. The rules are EE (<1), Gross Efficiency (GE, 0.1<GE<0.3), Respiration/Assimilation (R/A, <1.0), Production/Respiration (P/R, <1.0), and Respiration/Biomass (R/B, 1–10 $year^{-1}$ for fish and may be as high as 50–100 $year^{-1}$ for groups with higher turnover) and P/Q < Net Efficiency (NE, production/assimilated food) (Christensen and Walters, 2004; Darwall et al., 2010; Heymans et al., 2016).

2.2.3. Network Analysis and Ecological Indicators

Trophic flow descriptions, and network analysis based on thermodynamic and ecosystem principals and information theory (Christensen and Walters, 2004; Müller, 1997) lead to a suite of ecological indicators which can describe the ecosystem (Finn, 1976; Heymans et al., 2014; Lindeman, 1942; Odum, 1969; Odum and Barrett, 1971; Ulanowicz, 1986). The following ecological and fisheries related indicators were calculated using EwE, and demonstrated in Table 2.1.

Table 2.1. Ecological and fisheries related indicators

Acronym	Indicators	Units	Eq.	Ref.
Ecosystem Theory Indices				
TL	Trophic Level		(3)	(Christensen et al., 2008)
TST	Total System Throughput	$t.km^{-2}.y^{-1}$	(4)	(Ulanowicz, 1986)
TPp/TR	Total Primary Production /Total Respiration			(Christensen et al., 2008)
NSP	Net System Production	$t.km^{-2}.y^{-1}$		Christensen et al., 2008)
TPp/TB	Total Primary Production /Total Biomass			Christensen et al., 2008)
TB/TST	Total Biomass/TST			Christensen et al., 2008)
R/B	Schrödinger ratio (Respiration/Biomass)	y^{-1}		Christensen et al., 2008)
TEm	Mean Transfer Efficiency	%		(Lindeman, 1942)
SOI	System Omnivory Index		(6)	(Christensen and Walters, 2004)
mTLco	Mean Trophic Level of the Community		(7)	(Christensen et al., 2008)
Cycling Indices				
FCI	The Finn Cycling Index	%	(8)	(Finn, 1976)
	Finn's mean path length		(9)	(Finn, 1976)
Information Indices				
A	Ascendency	Flowbits	(10)	(Ulanowicz, 1986)
C	Capacity	Flowbits	(11)	Ulanowicz, 1986)
O	Overhead	Flowbits	(12)	Ulanowicz, 1986)
Mixed Trophic Impact and Keystoneness				
MTI	Mixed Trophic Impact		(13)	(Ulanowicz and Puccia, 1990)
KS	Keystoneness		(16)	(Libralato et al., 2006)
Fishery Indices				
TC	Total Catches	$t.km^{-2}.y^{-1}$		Christensen et al., 2008)
mTLc	Mean Trophic Level of the Catch		(17)	(Pauly D. et al., 1998)
PPRc	Primary Pro. Required to Sustain the Catch		(18)	(Pauly and Christensen, 1995)
GE	Gross Efficiency			Christensen et al., 2008)
E	Exploration rate			Christensen et al., 2008)

2.2.3.1. Ecosystem Theory Indices

Based on the diet preference matrix, Ecopath calculates trophic level (TL) of each functional group by assuming that the TL of primary producers and detritus are 1 and calculating the trophic level as (Christensen et al., 2008):

$$\boldsymbol{TL_j = 1 + \sum_i DC_{ij} \cdot TL_i} \quad (3)$$

where TL_i is the trophic level of prey i and DC_{ij} is the proportion of prey i in the diet of predator j.

Total system throughput (TST) is an indicator of the size of the entire system. It is calculated as the sum of flows including total consumption, total export, total respiration and total flows into detritus, where the flow between any two of these parameters is called T_{ij} (Finn, 1976):

$$\boldsymbol{TST = \sum_{i=1,j=1}^{n} T_{ij}} \quad (4)$$

where i is prey and j is predator.

Christensen (1995) defined various functions and attributes. Total net primary production/total respiration (TPp/TR) is a ratio related to the maturity of the ecosystem. It is expected to be close to 1 in mature ecosystems, greater than 1 in the early developmental stage of ecosystems, and less than 1 in the ecosystems suffering organic pollution. Net system production (NSP) is the difference between TPp and TR, and it approaches zero in mature ecosystems. Also, mature ecosystems tend to have a low total primary production/total biomass (TPp/TB) ratio. However, immature ecosystems accumulate biomass over time due to the high TPp/TR ratio and large NSP, and this can lead to a decline in (TPp/TB) ratio as system matures because mature ecosystems tend to maximize total system biomass, and therefore the total biomass/total system throughput (TB/TST) ratio

will increase. The ratio respiration to biomass (R/B), also known as the Schrödinger ratio, is an indicator of the development status and maturity of the ecosystem. The ratio has been regarded a thermodynamic order function of the ecosystem and a measure of metabolic activity of related species or group (Odum and Barrett, 1971).

The ratio of the productions between adjacent trophic levels is the measure of the inefficiencies of the food web, and called transfer efficiency (TE) (Lindeman, 1942). The mean transfer efficiency (TEm) was calculated as the geometric mean for TL II to IV (Christensen et al., 2005). The ratio can be expected to increase as fishing impact increases (Libralato et al., 2005). The flows between the integer trophic levels were described using a Lindeman spine (Lindeman, 1942; Ulanowicz, 1986).

The system omnivory index (SOI) stated for the food web, is based on omnivory index (OI), defined each functional group. It is calculated as the variance of trophic levels in the diet (Christensen et al., 2005). That is:

$$\boldsymbol{OI_i = \sum_{j=1}^{n}(TL_j - (TL_i - 1))^2 \cdot (DC_{ij})} \quad (5)$$

$$\boldsymbol{SOI = \frac{\sum_{i=1}^{n}[OI_i \cdot \log(Q_i)]}{\sum_{i=1}^{n}\log(Q_i)}} \quad (6)$$

where Q_i is consumption of each predator (Christensen and Walters, 2004). Low OI infers that the diet preference of the relevant predator is more specialist whilst a complex diet preference results in a high OI.

Mean trophic level of the community (mTLco) represents ecosystem structure, and is calculated for functional groups with TL>2. B_i is the biomass of functional group i and weighting factor in the equation (Christensen et al., 2005):

$$\boldsymbol{mTL_{co}} = \frac{\sum_i \boldsymbol{TL_i \cdot B_i}}{\sum_i \boldsymbol{B_i}} \quad (7)$$

2.2.3.2. Cycling Indices

The Finn Cycling Index (FCI) is the quantification of cycling relative to total system throughput (TST) in the ecosystem (Finn, 1976), and calculated as:

$$\boldsymbol{FCI} = \frac{\boldsymbol{TST_c}}{\boldsymbol{TST}} \quad (8)$$

where FCI_c is the total flow that is recycled and *TSTc* is the total flow that is recycled. This indicator is strongly related to system maturity, resilience and stability. That is, a greater proportion of the energy entering the system travels further up the food web (Christensen et al., 2005). Also, the following related indices were calculated: Throughput cycled (excluding detritus), predatory cycling index, throughput cycled (including detritus), Finn's mean path length. The latter index shows the diversity of flows and cycling, and has positive correlation with ecosystem maturity. It is calculated as:

$$\boldsymbol{Finn's\ Mean\ Path\ Length} = \boldsymbol{TST / \sum Export + \sum Respiration} \quad (9)$$

2.2.3.3. Information Indices

Ascendency is linked average mutual information (AMI) indicating the distribution of links in the ecosystem and is related to the resilience of the ecosystem (Heymans and Tomczak, 2016; Ulanowicz, 2004). Ascendency is calculated (Ulanowicz, 1986):

$$\boldsymbol{A = \sum_{ij}(T_{ij}) \cdot \log \frac{T_{ij} \cdot TST}{T_j \cdot T_i}} \quad (10)$$

where *Tij* is the flow between any two compartments and includes respiration and export flows, TST is total system throughput.

Ecosystems tend to optimize ascendency. High ascendency represents low redundancy. This indicator is also related to ecosystem maturity and Odum's (1969) 24 attributes of ecosystem maturity (Christensen, 1995; Ulanowicz, 1986). The upper limit of ascendency is development capacity (C), and the differences between the capacity and the ascendency is the system overhead (O) giving the ascendency elbow room, and reflecting the ecosystem's strength in reserve (resilience) (Ulanowicz, 1986). The formulas are given below as:

$$\boldsymbol{C = -TST \cdot \sum_{ij} \frac{T_{ij}}{TST} \cdot \log\left(\frac{T_{ij}}{TST}\right)} \quad (11)$$

$$\boldsymbol{O = C - A} \quad (12)$$

2.2.3.4. Mixed Trophic Impact and Keystoneness

Mixed trophic impact (MTI) is derived from economic input-output theory. The application of MTI applied in Ecopath approach is adapted by Ulanowicz and Puccia (1990). MTI was calculated to analyse the relative direct and indirect effects of any one group, including fisheries, on another group by applying hypothetical biomass change. MTI values range from -1 to +1, and values close to these limits indicate strong effects. It is calculated as (Ulanowicz and Puccia, 1990):

$$\boldsymbol{[M] = \{[I] - [Q]\}^{-1} - [I]} \quad (13)$$

where M (MTI) is all the mixed trophic impacts that occur in the food web, Q is the net impact matrix involving all impacts, and I is the identity matrix. Q matrix has elements q_i which is the differences between the positive effects d_{ji}, the fraction of the prey i in the diet of the predator j and negative effects f_{ij}, the fraction of total consumption of i used by predator j (Libralato et al., 2006; Ulanowicz and Puccia, 1990).

$$\boldsymbol{q_{ij} = d_{ji} - f_{ij}} \quad (14)$$

The overall impact derived from the MTI (m_{ij}) and the keystoneness KS_i was used to estimate keystone groups affecting the other groups in the food web where keystone groups are defined as particularly important groups for maintaining the ecosystem dynamics although their biomass may not be especially high (Libralato et al., 2006). Finally, overall impact (ε_i) and keystoneness (KS_i) were plotted against each other. In other words:

$$\boldsymbol{\varepsilon_i = \sqrt{\sum_{j \neq i}^{n} m_{ij}^2}} \quad (15)$$

where ε_i is the overall impact on group j, and m_{ij} is the net MTI but the effect on the group itself is not included (Libralato et al., 2006).

$$\boldsymbol{KS_i = \log[\varepsilon_i(1 - p_i)]} \quad (16)$$

where p_i is the contribution of the group to the total biomass of the system (Power et al., 1996).

2.2.3.5. Fishery Indices

Mean trophic level of the catch (mTLc) is an indicator calculated as the average trophic level of all catch, and shows a decrease in response to fishing. It is calculated as (catch Y_i is the weighting factor) (Pauly et al., 1998):

$$\boldsymbol{mTL_c = \frac{\sum_i TL_i \cdot Y_i}{\sum_i Y_i}} \quad (17)$$

Primary production required to sustain the catch (PPRc) indicates primary production requirement to sustain the catches, and is calculated as (Christensen et al., 2005; Pauly and Christensen, 1995):

$$\boldsymbol{PPRc = \sum_{Paths}\left[Y \cdot \prod \frac{Q_{pred}}{P_{pred}} \cdot DC'_{Pred,prey}\right]} \quad (18)$$

where Y is catch of given group, P is production, Q is consumption, and DC' is the diet composition for each predator-prey interaction in each path (with cycles removed from the diet compositions). PP was used to standardise (PPRc/PP).

Total catch (TC), gross efficiency (GE, total catch/total primary production) and the exploitation rate (F/Z) were also estimated to evaluate the exploitation status of the ecosystem.

2.2.4. Model Parameters

Input data by functional groups are shown in Table 2.2. Input data were taken from published and unpublished literature including publications, theses, and project reports (Table 2.2 - 2.5). The model parameters were based on the data collected from local studies where possible and adjacent areas where local data were not available. The main data source for demersal groups was the project "Investigations to Improve Species and Size Selectivity in Mersin Bay Trawl Fisheries" (TUBITAK 1090684). The results from this project (called trawl surveys here) were described in Özbilgin et al. (2013) under the section "fisheries based demersal trawl survey" during the fishing months between 2009 and 2013. This study was also based on well-described species-specific retained and discarded catch data for demersal trawl fisheries in Gulf of Mersin in the eastern Mediterranean. Moreover, selectivity data were available for the commercial species.

2.2.5. Functional Groups

The definition of the functional groups was first based on the importance of commercial species in terms of research questions described in next chapter in this thesis, and then by taking into account commercial and Lessepsian (L) species, and similarities in ecological and biological characteristics. Each species important for the research questions is represented by a functional group.

Forty-eight functional groups were defined from primary producer to top predators including fisheries (Tables 2.2 and 2.3). Moreover, *M. barbatus, S. undosquamis*, and *P. erythrinus* were split into two age classes (juveniles and adults), to ensure that the model better represent these commercially important species. The components were defined according to minimum landing size (MLS) (Official Gazette, 2016), but we used length at first maturity for *S. undosquamis* (İşmen, 2003) because there is no regulation on this species in terms of MLS in Turkey. The information on the split points are given in Table 2.4. Leading stanza

groups were chosen to be the upper MLS or adult. In addition, cluster analysis was performed to split the 44 demersal and benthopelagic fish species into functional groups based on their similarities. Euclidean ecological distance and Ward's method (Kindt, 2005; Tsagarakis et al., 2010) were used, and applied to maximum total length, and percentage of discards (as weight) transformed using Log10(X+1) (Mutlu and Ergev, 2008) by using the fathom toolbox in MATLAB (Jones, 2014).

Three discrete groups were described from the 44 demersal and benthopelagic fish species, as illustrated in Figure 2.2. The groups are "small discarded demersal fishes", "large discarded demersal fishes", and "retained demersal fishes". For the groups, the mean maximum total length was 18.75±7.62 cm, 86.42±51.38 cm and 67.16±49.96 cm; and mean percentage of discards were 90.92±17.42%, 82.33±26.44%, 0.09±0.33% respectively (Table 2.3). All species composing functional groups, input data, data sources, estimation methods, the information of area & time, and references by functional group are compiled in detail in Tables 2.2 and 2.5.

The P/B, Q/B and diet of the combined functional groups were estimated as the average ratio on the basis of the biomass-weighted of each species where possible, and catch-weighted estimate if not (medium pelagic fishes, demersal sharks, and demersal rays and skates).

Table 2.2. Input parameters of Gulf of Mersin model by functional group: biomass (B, $t.km^{-2}$); production/biomass ratio (P/B, y^{-1}); consumption/biomass ratio (Q/B, y^{-1}); ecotrophic efficiency (EE); landing, discard and catch are expressed in $t.km^{-2}.y^{-1}$; lessepsian (L)

#	Functional Groups	B	P/B	Q/B	EE	P/Q	Total Catch	Pelagic Landing	Trawl Landing	Trawl Discard
1	Phytoplankton	4.7969	76.8525							
2	Micro and mesozooplankton	3.3381	30.4182			0.33				
3	Macrozooplankton		20.3329		0.95	0.33				
4	Benthic small crustaceans	1.1616	6.3153	39.5931						
5	Polychaetes	1.6200	3.6085	24.0627						
6	Shrimps (L)	0.0878	3.2039			0.25	0.0275		0.0251	0.0024
7	Shrimps	0.0335	3.1554			0.25	0.0150		0.0101	0.0050
8	*Charybdis longicollis* (L)	0.0841	2.4000	8.6763			0.0326			0.0326
9	Crab	0.0298	2.4000	8.1089			0.0142		0.0003	0.0139
10	Benthic invertebrates	7.3400	0.9425	3.9269			0.0000			
11	Octopuses and cuttlefish	0.0471	1.6100	6.3749			0.0237		0.0169	0.0068
12	Squids	0.0092	2.5966	27.4927			0.0031		0.0024	0.0007
13	*Mullus barbatus* (<MLS)	0.0128	2.1900	9.5630			0.0131		0.0104	0.0028
14	*Mullus barbatus* (>MLS)	0.1100	0.7860	4.1146			0.0502		0.0502	
15	*Mullus surmuletus*	0.0018	1.1520	7.2754			0.0004		0.0004	
16	*Upeneus molucensis & pori* (L)	0.0121	1.5372	11.0367			0.0034		0.0020	0.0014
17	Anglerfish		0.8468	3.9368	0.7		0.0004		0.0004	
18	*Solea solea*	0.0059	0.9210	6.9283			0.0025		0.0023	0.0002
19	Flatfishes	0.0140	1.1189	8.4916			0.0068		0.0000	0.0068
20	*Merluccius merluccius*	0.0096	1.0544	4.5606			0.0057		0.0055	0.0002
21	*Saurida undosquamis* (L) (<MLS)	0.0050	2.2692	9.5835			0.0030		0.0017	0.0013
22	*Saurida undosquamis* (L) (>MLS)	0.0392	0.7243	3.5627			0.0096		0.0096	

Table 2.2. (continued)

23	Puffer fish (L)	0.0091	1.2549	5.5250			0.0048			0.0048
24	Small discarded demersal fishes	0.0352	1.3516	9.0725			0.0174		0.0037	0.0137
25	Large discarded demersal fishes	0.0152	0.7599	4.2921			0.0060		0.0008	0.0052
26	Retained demersal fishes	0.0050	1.0478	4.6347			0.0023		0.0022	0.0001
27	Demersal Fish Species (L)	0.0480	1.5328	9.7938			0.0126		0.0000	0.0126
28	*Pagellus erythrinus* (<MLS)	0.0036	2.1990	9.7255			0.0042		0.0011	0.0030
29	*Pagellus erythrinus* (>MLS)	0.0301	0.7700	4.0000			0.0065		0.0065	
30	*Nemipterus randalli* (L)	0.0153	1.7344	8.8625			0.0044		0.0026	0.0017
31	*Pagellus acarne*	0.0220	1.2151	8.8903			0.0100		0.0079	0.0021
32	Benthopelagic fishes	0.0056	1.7408	10.1912			0.0036		0.0000	0.0036
33	Picarels and bogue	0.0237	1.2739	8.3835			0.0147		0.0134	0.0013
34	Demersal sharks		0.7000	4.0965	0.7		0.0008			0.0008
35	Demarsal rays and skates		0.5605	3.5161	0.7		0.0170		0.0002	0.0168
36	*Engraulis encrasicolus*	0.2038	2.7275	14.6207			0.0013	0.0013		
37	*Sardinella aurita*	2.0967	2.1500	10.8923			0.0461	0.0461		
38	Horse mackerel	0.9377	1.7538	10.3544			0.0078	0.0078		
39	*Scomber japonicus*	0.1456	1.1874	7.3199			0.0075	0.0075		
40	Other small pelagic fishes	0.4776	2.5614	12.7657			0.0096	0.0096		
41	Small pelagic fishes (L)	0.2679	2.0700	13.1561			0.0052	0.0052		
42	Medium pelagic fishes		0.9030	4.6308	0.9		0.0240	0.0240		
43	Large pelagic fishes	0.0255	0.3858	2.7134			0.0047	0.0047		
44	*Caretta caretta*	0.0170	0.1926	3.1494						
45	Seabirds	0.0010		71.8476		0.05				
46	*Tursiops truncatus*	0.0440		12.3397		0.05				
47	Discard	0.1397								
48	Detritus	67.4787								

Table 2.3. 44 demersal and benthopelagic fish species, and their maximum total length, and percentage of discards (as weight) applied for Cluster analysis

Species / Functional Groups	Max L.(cm)	Reference for Max. L.	Discard % (Weight)
Small discarded Demersal fishes	**18.75±7.62**		**90.92±17.42**
Anthias anthias	9.6	(Ilkyaz et al., 2008)	100.00
Blennius ocellaris	9.6	(Cicek et al., 2006)	100.00
Deltentosteus quadrimaculatus	9.2	(Metin et al., 2011)	100.00
Apogon nigripinnis	7.1	(Erguden et al., 2009)	100.00
Aphanius fasciatus	7.4	(Tsikliras and Stergiou, 2014)	100.0
Gobius geniporus	16.5	(Altin et al., 2015)	100.00
Scorpaena notata	17	(Ordines et al., 2009)	100.00
Trigloporus lastoviza	19	(Boudaya et al., 2010)	98.66
Atherina hepsetus	14.5	(Pallaoro et al., 2007)	100.00
Scorpaena maderensis	13.1	(La Mesa et al., 2005)	100.00
Chelidonichthys lucerna	30.3	(Cicek et al., 2008)	61.50
Balistes capriscus	25.5	(İşmen et al., 2004)	58.80
Dentex macrophthalmus	21.3	(Soykan et al., 2015)	44.95
Serranus cabrilla	22.5	(Ilhan et al., 2010)	76.26
Diplodus annularis	20	(Gordoa and Molí, 1997)	62.55
Oxyurichthys papuensis	22	(Edelist, 2012)	100.00
Atherinomorus lacunosus	25	Fishbase	100.00
Trachinus draco	25.8	(Ak and Genç, 2013)	100.00
Uranoscopus scaber	30	(Rizkalla and Bakhoum, 2009)	100.00
Callionymus lyra	27.7	(Bilge et al., 2014)	100.00
Lithognathus mormyrus	27.7	(Türkmen and Akyurt, 2003)	97.48
Serranus hepatus	11.7	(Bilecenoglu, 2009)	100.00
Large discarded demersal fishes	**86.42±51.38**		**82.33±26.44**
Pagellus bogaraveo	40.2	(Chilari et al., 2006)	42.20
Echelus myrus	49.5	(Cicek et al., 2006)	28.57
Zeus faber	50	(Akyol, 2001)	72.16
Dactylopterus volitans	48.6	(Morey et al., 2003)	100.00
Trichiurus lepturus	65	(Edelist, 2012)	93.70
Echeneis naucrates	63.5	(Edelist, 2012)	100.0
Remora remora	86.4	Fishbase	100.0
Conger conger	144	(Matić-Skoko et al., 2012)	87.50
Muraena helena	121	(Matić-Skoko et al., 2011)	100.00
Lepidopus caudatus	196	(Demestre et al., 1993)	99.21
Retained demersal fishes	**67.16±49.96**		**0.09±0.33**
Dentex gibbosus	90.1	(Alves and Vasconcelos, 2012)	0.00
Epinephelus marginatus	105.6	(Reñones et al., 2007)	0.00
Pseudocaranx dentex	122	Fishbase	0.00
Argyrosomus regius	189	(González-Quirós et al., 2011)	0.00
Epinephelus costae	55.4	(Can et al., 2002)	0.00
Phycis blennoides	60	(Tsikliras and Stergiou, 2014)	0.00
Epinephelus aeneus	85	(Edelist, 2012)	1.19
Synodus saurus	31	(Manaşırlı et al., 2008)	0.00
Sparus aurata	27.9	(Cicek et al., 2006)	0.00
Diplodus sargus sargus	39	(Gordoa and Molí, 1997)	0.00
Umbrina cirrosa	24.7	(Koutrakis and Tsikliras, 2003)	0.00
Pomadasys incisus	23.2	(Chater et al., 2015)	0.00
Diplodus vulgaris	20.2	(Soykan et al., 2015)	0.00

Table 2.4. The information on multi-stanza groups. Minimum landing size (MLS); curvature parameter (k, annual); weight (W)

Information/Species	*M. barbatus*	*S. undosquamis*	*P. erythrinus*
Population parameters			
k	0.716	0.420	0.597
Wmat. / Winf.	0.099	0.081	0.111
Split points			
MLS	13	16.5	15
Transition age (month)	12	15	13

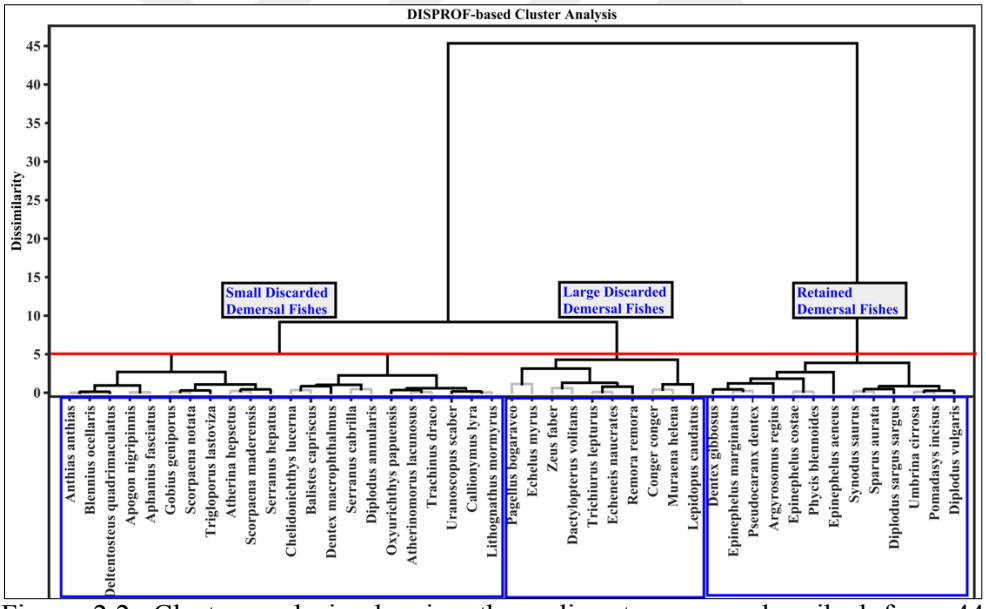

Figure 2.2. Cluster analysis showing three discrete groups described from 44 demersal and benthopelagic fish species

2.2.6. Biomass

Monthly averaged subsurface chlorophyll-a concentrations (Chl-a, $mg.m^{-3}$) of the study area were obtained from Aqua MODIS (Moderate Resolution Imaging Spectroradiometer) products with 4x4 km spatial resolution from September 2009 to 2013. The data were extracted by using NASA's Giovanni System (see Acker and Leptoukh (2007) for detailed information). The data were used to estimate overall parameter of Chl-a throughout the time period. In order to convert Chl-a from volume to area, euphotic depth was calculated by using reduction of light in water column. The attenuation coefficient was estimated from empirical conversion (1.7 over Secchi depth, Sayin et al., 2007 and references therein). Secchi depth was taken from Yücel (2013). Conversion factors of 1:40 Chl-a to carbon (Jones, 1979), and 1:9 carbon to wet weight (Pauly and Christensen, 1995) were then used to convert Chl-a ($mg.m^{-2}$) to carbon ($g.m^{-2}$), and wet weight ($g.m^{-2}$).

Monthly micro- and mesozooplankton biomass ($mgDW.m^{-3}$) at coastal (20-25 m) and offshore (187-216 m) stations were obtained from Yilmaz and Besiktepe (2010) (the authors sent the raw data). The biomass ($mgDW.m^{-2}$) was calculated by multiplying the volumetric biomass by the sample depth for each month and station. A conversion factor of 0.1348 was used to transform dry weight to wet weight (Jorgensen et al., 1991). The average annual micro and mesozooplankton biomass ($gWW.m^{-2} = tWW.km^{-2}$) was then calculated.

Demersal group biomass data were obtained from trawl surveys (Özbilgin et al., 2013) as catch per unit area (CPUA) as $t.km^{-2}$ (Sparre and Venema, 1992) for each haul and each species. The sum of all the biomass ($t.km^{-2}$) estimates was obtained for each of the functional groups.

Distance covered during each trawl tow was estimated by using the great-circle distance in km between two coordinate points based on following Haversine formula via the function of 'lldistkm.m' in MATLAB.

$$\mathbf{a = \sin^2(\Delta\varphi/2) + \cos\varphi 1 \cdot \cos\varphi 2 \cdot \sin^2(\Delta\lambda/2)} \quad (19)$$

$$\mathbf{c = 2 \cdot atan2(\sqrt{a}, \sqrt{(1-a)})} \quad (20)$$

$$\mathbf{D = R \cdot c} \quad (21)$$

where φ is latitude; λ is longitude; R is earth's radius (mean radius = 6,371 km).

Distance covered was also estimated as the product of the mean speed of the trawler over ground when trawling and haul duration to compare the result of the biomass calculations, however the Haversine formula was used in all future work. Because, trawl tow speed and time could be less reliable, despite similar results of both methods.

Finally, swept area was calculated by Sparre and Venema (1992),

$$\mathbf{a = D \cdot ws} \quad (22)$$

where a is swept area for haul i; D is distance covered for haul i; and ws is the wing spread of the trawl net. A horizontal wing spread of 610 cm for the full-scale conventional trawl net (Tosunoğlu et al., 2002) was used to avoid assumptions about the length of the head-rope of the trawl net as this is unknown for this survey.

A total of 80 valid hauls (Figure 2.1), carried out with a commercial codend (CD44) and 600 meshes around the mouth, were used to calculate biomass.

Estimates of biomass were not available for macrozooplankton and medium pelagic fishes and therefore values of 0.95 (Christensen and Pauly, 1992) and 0.90 (Hattab et al., 2013; Tsagarakis et al., 2010) were set for the Ecotrophic Efficiency (EE) respectively – assuming that we can explain the mortality of 90% and 95% of these species by the dynamics in the model. For demersal sharks, "demersal rays and skates" and anglerfish the estimates of biomass from the

surveys were considered to be unreliable due to the migration patterns of these species being larger than presented modelled area, and therefore an EE was used to estimate the biomass of these species. EE values for these functional groups were assumed to be 0.7. Thus, we assume that this model explains 70% of the mortality of these species, similar to what was found by Tsagarakis et al. (2010) in the eastern Mediterranean system.

Biomass of infaunal groups (benthic small crustaceans, polychaetes, benthic invertebrates) was estimated from standard Van Veen Grab hauls reported by Ergev (2002).

For small pelagic fish species, biomass estimates was obtained from acoustic surveys conducted by METU-IMS (Middle East Technical University, Marine Science Institute) as tonnes nautical mile^2 (Gücü et al., 2011), and converted into t.km^{-2}.

Atlantic bluefin tuna (*Thunnus thynnus*) is managed as eastern and western stocks (Block et al., 2001; Fromentin and Lopuszanski, 2013). The eastern stock resides throughout the Mediterranean (2,969,000 km^2) and eastern Atlantic (6,703,707 km^2). Biomass (tonnes) for the total stock was taken from the stock assessment report (ICCAT, 2007), and converted to t.km^{-2} by dividing by the total area (9,672,707 km^2) assuming that the stock is evenly spread throughout the range. A further correction was then made to take account of seasonal movements in Gulf of Mersin. Bluefin tuna breed in the Gulf of Mexico and the Mediterranean (Block et al., 2005). However, larval surveys and studies on gonadal development (Heinisch et al., 2008; S Karakulak et al., 2004; S. Karakulak et al., 2004; Oray et al., 2005; Oray and Karakulak, 2005) indicate an additional spawning area in the northern Levantine Basin (northeastern Mediterranean) (Corriero et al., 2003; Heinisch et al., 2008; Medina et al., 2002) and the highest tuna larvae abundance has been observed in Gulf of Mersin (Oray and Karakulak, 2005). Bluefin tuna fisheries in the region operate from 25 May to 25 June (1 month) according to ICCAT rules (Official Gazette, 2016) during their spawning period. However, an

electronic tagging programme carried out in the breeding ground of eastern Mediterranean showed that the stock resides in the Levantine Basin (De Metrio et al., 2004; Rooker et al., 2014) for a longer period each year. Therefore, local fishermen's knowledge has been employed, which indicates that tuna are targeted by the fishery, or caught as bycatch, for 9 months of the year in Gulf of Mersin (fishermen from the region, pers. comm.). Thus, the biomass ($t.km^{-2}$) of Atlantic bluefin tuna for Gulf of Mersin was estimated as 9/12 th of the total biomass.

Swordfish (*Xiphias gladius*) populations in the Mediterranean are represented by a unique stock (Tserpes et al., 2008). Biomass estimates for Gulf of Mersin were made in a similar manner to Bluefin tuna. Biomass (t) for the total stock was taken from the stock assessment report (ICCAT, 2010). Also, according to local and traditional fishermen's knowledge, swordfish can be caught for about 2 months in Gulf of Mersin (fishermen from the region, pers. comm.), so the final local biomass in $t.km^{-2}$ was estimated as 1/6th of the biomass across the Mediterranean.

Gulf of Mersin is one of the most important nesting grounds in the Mediterranean for loggerhead (*Caretta caretta*) and green turtles (*Chelonia mydas*) (Canbolat, 2004; Casale and Margaritoulis, 2010). For loggerhead turtle, it was assumed that the nesting beaches are in the Göksu with 120 nests (Durmuş et al., 2011), Alata with 32 nests (Casale and Margaritoulis, 2010), Kazanlı with 18 nests (Şengezer, 2012), Akyatan with 353 nests (Canbolat, 2004), and Davultepe with 4 nests (Ergene et al., 2010) (Figure 2.1). The total number of nests was divided by the average number of nests produced per individual turtle (3.5) (Margaritoulis et al., 2003) to produce an estimate of adult female abundance. The male abundance was estimated using a 1:1 sex ratio (Piroddi et al., 2010). Mean straight carapax length (SCL, cm) was obtained from Şengezer (2012), and mean body mass (BM, kg) for both species was calculated according to the length-weight relationship given in Catherine and Wabnitz (2010):

$$\mathbf{BM = 0.00053 \cdot SCL^{2.678}} \quad (23)$$

Total biomass ($t.km^{-2}$) was then calculated by dividing the product of the estimated total abundance and mean individual body mass by the modelled spatial area.

Little is known of the migration patterns of the sea turtles (loggerhead and green turtles). They are thought to move to the North African coasts of the Mediterranean to forage (Broderick et al., 2007; Godley et al., 2003; Türkecan and Yerli, 2011) after nesting between June and the end of September, possibly including May (Casale and Margaritoulis, 2010; Durmuş et al., 2011; Elmaz and Dalı, 2005; Şengezer, 2012). However, the Turkish coast of the Mediterranean may also be an important foraging ground (Broderick et al., 2007; Türkecan and Yerli, 2011). Some studies have shown that demersal trawl fisheries can capture turtles by accident during the fishing season (15 September to 15 April) in the eastern Mediterranean (Oruç, 2001). According to small-scale fishermen's knowledge, sea turtles are caught as by-catch throughout the year (fishermen from the region, pers. comm.). Moreover, dead sea-turtles can be washed up on the shore at any time of the year (http://kaplumbaga.ims.metu.edu.tr/). Thus, it was assumed that turtles would be present in the modelled area for either a minimum (breeding season, 5 months) or maximum (all year) time and the biomass scaled accordingly.

However, green turtle feeds mainly on seagrasses like *Posidonia oceanica* and *Zostera spp.*, and their post nesting migration depend on their diet (Short et al., 2007). Foraging and wintering areas are similar to that of loggerhead turtles (Türkecan and Yerli, 2011). The approach for calculating the migration patterns was the same as for loggerhead turtles. Although green turtles breed and forage on the eastern Mediterranean coast of Turkey, green turtle was not included in the model because their diets are not included in the model area. Furthermore, there is no record on green turtle captured by fisherman in legal trawling grounds of Gulf of Mersin (Özbilgin et al., 2013).

Seabird biomass is not well known for the research area. Audouin's Gull (*Larus audouinii*) is the main species in the region (Coll et al., 2010), but there is little information about the number of breeding pairs. Thus the mean body weights and the number of the seabirds (Audouin's Gull) were obtained from Zotier et al. (1999) and Coll et al. (2010). The modelled area was used to calculate biomass as $t.km^{-2}$.

Common bottlenose dolphin (*Tursiops truncatus*) abundance was obtained from visual surveys around the southern Mediterranean (Naceur et al., 2004) as individuals km^{-2}. The average distribution of common bottlenose dolphin was assumed for Gulf of Mersin, because there is no information on their spatial distribution in the area. Mean total length of an individual was obtained from the study describing the phenomenon of Levantine nanism (having smaller body size, dwarfism) for common bottlenose dolphin (Sharir et al., 2011). The weight of an average individual was calculated by using the empirical length – weight relationship (Kastelein et al., 2002):

$$\mathbf{W = 17.261 \cdot e^{0.0156(L-100)}} \quad (24)$$

where *W* is mean body weight (kg); *L* is mean total length (cm). The biomass per unit area was estimated as the product of the mean number. km-2 and the biomass of an average individual.

Detritus biomass was estimated from the empirical equation by Pauly et al. (1993):

$$\mathbf{Log(D) = -2.41 + 0.954 \cdot Log(PP) + 0.863 \cdot Log(E)} \quad (25)$$

where D is detritus (gC.m^{-2}); PP is primary production (gC.m^{-2}.y^{-1}); E is the average euphotic depth (m). In order to convert the biomass from carbon to wet weight it was assumed that the C/WW ratio was 0.10 (Opitz, 1996).

For the multi-stanza groups, length frequency distributions of fish (FL) that entered the gear (codend + cover) were re-expressed as the distribution of weight at length (S) using length-weight relationship:

$$\boldsymbol{W_{(i)} = a \cdot L_{(i)}^{b}} \quad (26)$$

$$\boldsymbol{S_{(i)} = F_{L(i)} \cdot W_{(i)}} \quad (27)$$

where i is the index of length classes.

$$\boldsymbol{B_{(i)} = B \cdot S_{(i)} / \sum_{i=1}^{N} S_{(i)}} \quad (28)$$

where B is biomass (t.km^{-2}) obtained from swept area method and described above in detailed. N is the number of size classes.

Finally, biomass values for the adult split groups (Ba: >MLS) were re-expressed as t.km^{-2}.y^{-1}:

$$\boldsymbol{B_a = \sum_{i=M}^{N} B_{(i)}} \quad (29)$$

where M is the size class of MLS. Leading stanza groups were used to let Ecopath estimate the biomass of juvenile split groups (<MLS).

2.2.7. Catch

This model included demersal trawling, and pelagic fisheries (purse seine, tuna and swordfish fisheries) that occur in the modelled area. Small scale fishing

gears including trammel nets, gillnets, and demersal loglines (Özbilgin et al., 2010) were not included as they generally operate within the 2 and/or 3 nm from the coast and this zone was excluded from the model.

The catch data for demersal groups were estimated from CPUE with 182 valid hauls (Figure 2.1) in the trawl surveys, describing species-specific landings and discards.

The mean catch per unit effort (CPUE) (Sparre and Venema, 1992) for species i was calculated and standardized in kg per hour for haul k:

$$\boldsymbol{CPUE_i} = \frac{\sum_{k=1}^{Nk}[C_{ik}/t_k]}{N_k} \tag{30}$$

where C_{ik} is the catch amount in W (kg) for species i in the haul k, N_k is the total number of valid hauls (182), and t_k is duration of haul k in hours.

The mean CPUE of species i was split into discard CPUE (CPUE_D) and landing CPUE (CPUE_L) by multiplying their discard ratio d_i, as following:

$$\boldsymbol{CPUE\_D_i} = \boldsymbol{CPUE_i \cdot d_i} \tag{31}$$

$$\boldsymbol{CPUE\_L_i} = \boldsymbol{CPUE_i - CPUE\_D_i} \tag{32}$$

There are about 40 active demersal trawlers operating in the area (Özbilgin et al., 2010), and it was assumed that they use the same conventional gear for 4 hauls a day, 150 days per fishing season (Eryaşar et al., 2014b) with a mean calculated mean tow duration of 2.75 hours. It means operation time in a day for a trawler is 11 hours. In the context of these assumptions, the coefficient of the proportion of time spent fishing in the modelled area assuming fishing activity is evenly distributed across the area, F_c was calculated for Gulf of Mersin to estimate catch information of demersal trawl fisheries:

$$\boldsymbol{F_c = \frac{Fd \cdot Ft \cdot Fn}{A}} \quad (33)$$

$$\boldsymbol{F_c} = 15.1445 \quad (34)$$

where F_d is fishing days per fishing season; F_t is mean tow duration (h); F_n is the number of active trawler; and A is modelled area (4352 km^2).

The mean CPUE, CPUE_D and CPUE_L of the species i composing related functional group j were summed to get functional group-specific CPUE information, and multiplied by the F_c. Finally, catch (C), discard (D) and landing (L) were estimated for functional group j as t.km^{-2} by using following equations:

$$\boldsymbol{C_j = \sum_{i=1}^{Sj} CPUE_i \cdot F_c} \quad (35)$$

$$\boldsymbol{D_j = \sum_{i=1}^{Sj} CPUE\_D_i \cdot F_c} \quad (36)$$

$$\boldsymbol{L_j = \sum_{i=1}^{Sj} CPUE\_L_i \cdot F_c} \quad (37)$$

where S_j is the number of species in functional group j.

For pelagic groups, catch data were taken from the official landing statistics (TUIK, 2014). The mean total landings were for the period of 2009 – 2013 are shown in Table 2.2. The statistics cover the entire Mediterranean coast of Turkey, and there is no information about the locations of contributing hauls. It was therefore assumed that the pelagic landings can come from anywhere within Turkey's Exclusive Economic Zone (EEZ) in the Mediterranean Sea. Unfortunately there is a conflict over EEZ delimitation in the Levant Basin and the two different approaches give total areas of either 145,000 km^2 or 41,000 km^2

(Çubukçuoğlu, 2014; Yaycı, 2013). This difference is due to political issues. Catch data for the model was estimated as $t.km^{-2}$ by dividing the area of the EEZ of Turkey. The area of 145,000 km^2 was chosen for the model of the estimated pelagic fish distribution and behaviour of purse seine fleets in the Levant Basin (Figure 2.3).

For the multi-stanza groups, length frequency distributions of fish (FL) that entered the gear (codend + cover) were re-expressed as the distribution of weight at length (S) using length-weight relationship as explained equation (26) and (27).

The distribution was multiplied by the estimation of the size selection in the codend (length-dependent retention probability) (r(Li)):

$$\boldsymbol{r(L_i) = exp(v_1 + v_2 \cdot L_{(i)}/[1 + exp(v_1 + v_2)]} \quad (38)$$

where v_1 and v_2 are regression parameters to be estimated. The information providing the consequences for the size selection process of applying the CD44 codend was obtained from Eryaşar (2014) and Özbilgin et al. (2013).

$$\boldsymbol{D_{(i)} = S_{(i)} \cdot r(L_i)} \quad (39)$$

where D_i is the retention probability in the codend as weight for each size class i. The aim of this process was to estimate the values of this function for all relevant size classes. Then, D_i' was expressed as:

$$\boldsymbol{D'_{(i)} = D_{(i)}/\sum_{i=1}^{N} S_{(i)}} \quad (40)$$

where N is the number of size classes. D_i' is percentage of fish in each size class i as weight. Retained weight in the codend (Rcod) ($t.km^{-2}.y^{-1}$) was estimated from commercial codend (CD44) experiments by using CPUE data as explained above.

Total retained catch which is the sum of retained weight in the codend (Rcod) and cover was calculated with a correction:

$$\boldsymbol{R_T = R_{cod} \cdot (\sum_{i=1}^{N} S_{(i)} / \sum_{i=1}^{N} D_{(i)})} \quad (41)$$

The aim of this correction was to recalculate retained codend catch in each size class i as weight by taking account of the estimation of the size selection in the codend. Thus, retained weight for each size class i in the codend ($C_{L(i)}$) was calculated as t.km^{-2}.y^{-1}:

$$\boldsymbol{C_{L(i)} = R_T \cdot D'_{(i)}} \quad (42)$$

Catch values for the species (CT) and split groups (CT1: <MLS, CT2: >MLS) were re-expressed as t.km^{-2}.y^{-1}:

$$\boldsymbol{C_T = \sum_{i=1}^{N} C_{L(i)}} \quad (43)$$

$$\boldsymbol{C_{T1} = \sum_{i=1}^{M} C_{L(i)}} \quad (44)$$

$$\boldsymbol{C_{T2} = \sum_{i=M}^{N} C_{L(i)}} \quad (45)$$

where M is the size class of Minimum Landing Size (MLS).

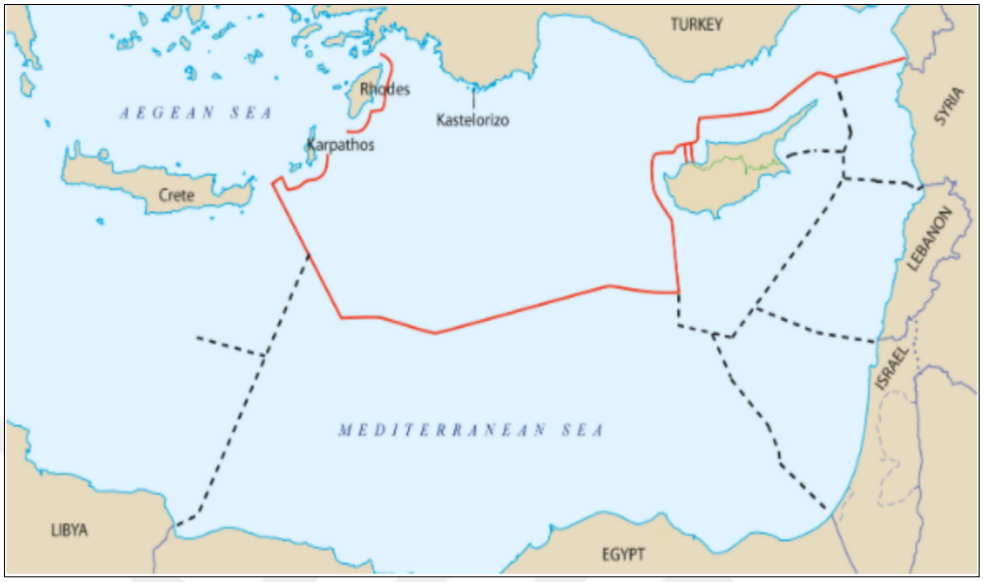

Figure 2.3. Turkey's Exclusive Economic Zone (EEZ) in the Mediterranean Sea delimiting pelagic landings. From (Çubukçuoğlu, 2014)

2.2.8. Production

Primary Production (PP) ($gC.m^{-2}.d^{-1}$) in Gulf of Mersin was obtained from satellite images (MODIS), and converted to annual production. A conversion factor of C/WW = 0.6 was used to estimate organic matter (Pauly and Christensen, 1995). The annual P/B ratio was calculated just as production divided by estimated biomass value as calculated in section 2.2.6 above.

Copepods are dominant zooplankton group in terms of depth and size fractions (112-200 µm, 200-500 µm, 500-1000 µm, and >1000 µm) in Gulf of Mersin (Yılmaz and Besiktepe, 2010). Copepod production (mgC.m-2.d-1) representing micro and mesozooplankton production was taken from Siokou-Frangou et al. (2002). Daily production was converted to annual production by multiplying the number of days in a year. Finally, the production ($gC.m^{-2}y^{-1}$) was divided by the estimated biomass value as calculated in section 2.2.6 above (g $C.m^{-2}$) to get P/B ratio (y^{-1}). A ratio of 0.40 was used to convert biomass from dry weight value to carbon unit (Gorsky et al., 1988).

For fished species, the P/B ratio was assumed to be equivalent to the total mortality (Z, y^{-1}) (Table 2.5), where is equal to the sum of fishing mortality (F, y^{-1}) and natural mortality (M, y^{-1}) under steady-state conditions (Allen, 1971). F is defined as the ratio of catch (C) and biomass (B) (F=C/B) for most species (Heymans et al., 2016), while F for medium pelagic fishes, demersal sharks, and "demersal rays and skates" was obtained from stock assessments because of the lack of the biomass estimation in the region. Natural mortality (M) was estimated from empirical equations for fish given by Pauly (1980) and for shrimps given by (Arce, 2006):

$$\mathbf{Log(M) = -0.0066 - 0.279 \cdot Log(L_\infty) + 0.6543 \cdot Log(K) + 0.4634 \cdot Log(T)} \quad (46)$$

where L_∞ (total length in cm) and K (y^{-1}) are the von Bertalanfy growth (VBGF) parameters; T (°C) is the mean habitat temperature, which is bottom temperature for demersal fishes, and water column (3-200 m) temperature for pelagic fishes (see section 2.2.1).

$$\mathbf{M = 1.325 \cdot K^{0.758}} \quad (47)$$

where K (y^{-1}) is the VBGF parameter.

For invertebrate species, we applied the model of Brey (2012) to estimate mean P/B ratios with 95% confidence limits. Mean body mass (mg) was estimated or obtained from Ergev 2002; Sangun et al. (2009) and trawl survey. The wet mass (mg) to energy (joule) conversion factors were taken from Brey (2001). The mean habitat temperature was the mean bottom temperature, and depth was the mean habitat depth in the model. For squid, the P/B ratio was derived from Corrales et al. (2017b) by applying Opitz's correction factor (V) (Opitz, 1996):

$$\mathbf{V = (T/T')^{0.6121}} \quad (48)$$

where *T* (°C) is the temperature at modelled area (water column temperature, 3-200 m); and *T'* (°C) is the original habitat temperature.

The P/B ratio for loggerhead turtles was obtained from Tsagarakis et al. (2010) using the Opitz correction (equation 48) (Opitz, 1996). The P/Q ratio of 0.05 was used to let Ecopath estimate the P/B ratio for seabirds and dolphins (Christensen et al., 2008; Torres et al., 2013).

The P/B ratios for multi-stanza groups were assumed as equivalent to the total mortality (Z, y^{-1}) (Allen, 1971). F was the ratio of C (section 2.2.7) and B (section 2.2.6) (Heymans et al., 2016) (Table 2.2), and M was estimated from the empirical equation (Pauly, 1980), and M at age was adjusted in the Ecopath model. The information on multi-stanza groups are given in Table 2.4.

2.2.9. Consumption

The P/Q ratio of 0.33 (y^{-1}) was assumed to allow the model to estimate Q/B from P/B due to poor data availability for consumption of zooplankton groups (Hansen et al., 1997; Tsagarakis et al., 2010).

For finfish, the Q/B ratio was estimated from the empirical ratio of Palomares and Pauly (1998):

$$\mathbf{\log\frac{Q}{B} = 7.964 - 0.204 \cdot \log W_{\infty} - 1.965 \cdot T' + 0.083 \cdot A + 0.532 \cdot h + 0.398 \cdot d} \quad (49)$$

where *T* is the mean habitat temperature of 1000/Kelvin (Kelvin = °C + 273.15), which is bottom temperature for demersal fishes, and water column (3-200 m) temperature for pelagic fishes; W_{∞} (wet weight in g) is asymptotic weight obtained from the literature or estimated using the empirical equation of $W_{\infty} = a \cdot L_{\infty}^{b}$ and

A is the aspect ratio of the tail, h=1 when the fish is a herbivore and 0 when not, and d=1 when the fish is a detritivore and 0 when not.

Estimates of daily feeding rates for "octopus and cuttlefish" were obtained from the literature (Iglesias et al., 1996; Quintela and Andrade, 2002).

Consumption rates for deposit feeders and detritivore feeders were calculated from daily ration as a function of body size using the following empirical equations (Cammen, 1980):

$$\mathbf{Log(Q) = -0.420 + 0.742 \cdot Log(B)} \quad (50)$$

where Q is mg.day^{-1}; and B is mg dry weight. Average wet weight (mg) was estimated or obtained from Ergev, (2002), Sangun et al. (2009) and trawl surveys. Weight (mg) to energy (joule) conversion factors were taken from Brey (2001). The Q/B ratio for polychaetes, benthic invertebrates and squids were obtained from other models (Corrales et al., 2017b; Tsagarakis et al., 2010) using the Opitz correction (equation 48) (Opitz, 1996). For seabirds the daily rate was calculated from Nilsson and Nilsson (1976):

$$\mathbf{Log(DR) = -0.293 + 0.85 \cdot Log(W)} \quad (51)$$

where DR (g.day^{-1}) is daily ration; and W (g) is body weight, and for dolphins from Innes et al. (1987):

$$\mathbf{R = 0.1 \cdot W^{0.8}} \quad (52)$$

where R (kg.day^{-1}) is daily ration; and W (kg) is body weight. Finally, consumption over biomass ratios (Q/B y^{-1}) was then calculated as the ratio of consumption and body weight, and converted to annual production by multiplying the number of

days in a year. The Q/B ratios of loggerhead turtle was obtained from Polovina, 1984b using the Opitz correction (equation 48) (Opitz, 1996). The P/Q ratio of 0.25 (y^{-1}) (Christian and Luczkovich, 1999) was used to let the model estimate Q/B for shrimps.

2.2.10. Diet Composition

The diet composition information was firstly obtained from local studies and adjacent ecosystems or modified from other Mediterranean models considering the structure of their functional groups and species composition in a functional group. The descriptions of diet information and compiled diet matrix are given in Table 2.5 and Table 2.6 respectively.

Table 2.5. The description of the input data: The species composing functional groups, data sources, estimation methods, the information of area & time, and references by functional group (B: Biomass, P/B: production/biomass ratio, Q/B: consumption/biomass ratio, EE: ecotrophic efficiency, P/Q: gross food conversion efficiency, Z: total mortality rate, F: fishing mortality rate, M: non-predation natural mortality rate, C: catch)

Description	B	P/B	Q/B	EE	P/Q	Diet
1. Pyhtoplankton						
Taxonomic Group						
Method	Satellite images	Satellite images		Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean	Gulf of Mersin, northeastern Mediterranean				
Year	2008-2011	2008-2011				
Reference	(Acker and Leptoukh, 2007)	(Acker and Leptoukh, 2007)				
2. Micro and mesozooplankton						
Taxonomic Group	Holoplankton; Meroplankton *(sum of the size fraction of 112-200, 200-500, 500-1000, 1000<)*					
Method	In situ sampling	In situ sampling	Estimated by EwE	Estimated by EwE	Assumption	
Area	Gulf of Mersin, northeastern Mediterranean	Aegean Sea, eastern Mediterranean				
Year	2004-2006	1997				
Reference	(Yılmaz and Besiktepe, 2010)	(Siokou-Frangou et al., 2002)			(Hansen et al., 1997)	(Zervoudaki et al., 2007)

Table 2.5. (continued)

3. Macrozooplankton						
Taxonomic Group						
Method	Estimated by EwE	Assumption from the other model with opitz correction	Estimated by EwE	Assumption	Assumption	
Area		Israel EEZ, northeastern Mediterranean				
Year		2008-2010				
Reference		(Corrales et al., 2017b)		(Christensen and Pauly, 1992)	(Hansen et al., 1997)	(Båmstedt and Karlson, 1998; Pauly et al., 2009)
4. Benthic small crustaceans						
Taxonomic Group	Decapoda; Amphipoda; Tanaidacea; Cumacea; Isopoda; Mysidacea; Leptostraca; Stomatopoda					
Method	Van Veen Grab Sampling	Multi-Parameter P/B-Model	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2000					
Reference	(Ergev, 2002)	(Brey, 2012)	(Cammen, 1980)			(Cartes et al., 2001)

Table 2.5. (continued)

5. Polychaetes						
Taxonomic Group	*Annelida*					
Method	Van Veen Grab Sampling	Multi-Parameter P/B-Model	Assumption from the other model with opitz correction	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean		Israel EEZ, northeastern Mediterranean			
Year	2000		1990-1994; 2008-2010			
Reference	(Ergev, 2002)	(Brey, 2012)	(Corrales et al., 2017b)			(Fauchald and Jumars, 1979)
6. Shrimps (L)						
Taxonomic Group	*Metapenaeus monoceros; Penaeus Japonicus; Penaeus semisulcatus*					
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Estimated by EwE	Estimated by EwE	Assumption	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey	Arce, 2006 for M			(Christian and Luczkovich, 1999)	(Corrales et al., 2017b; Tsagarakis et al., 2010)

Table 2.5. (continued)

7. Shrimps						
Taxonomic Group	*Parapenaeus longirostris; Penaeus kerathurus*					
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Estimated by EwE	Estimated by EwE	Assumption	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey	Arce, 2006 for M			(Christian and Luczkovich, 1999)	(Corrales et al., 2017b; Tsagarakis et al., 2010)
8. *Charybdis longicollis* (L)						
Taxonomic Group						
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from Multi-Parameter P/B-Model)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					-
Reference	Trawl survey	(Brey, 2012) for M	(Cammen, 1980)			(Corrales et al., 2017b, 2015; Tsagarakis et al., 2010)

Table 2.5. (continued)

9. Crab						
Taxonomic Group	*Callinectes sapidu; Goneplax rhomboides; Ixa monodi; Maja goltziana; Portunus pelagicus*					
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from Multi-Parameter P/B-Model)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Med.					
Year	2009-2013					
Reference	Trawl survey	(Brey, 2012) for M	(Cammen, 1980)			(Corrales et al., 2017b, 2015; Tsagarakis et al., 2010)
10. Benthic invertebrates						
Taxonomic Group	Ophiuroidea; Crinoidea; Asteroidea; Echinoidea; Holothuroidea; Aplacophora; Polyplacophora; Gastropoda; Bivalvia; Caudofoveata; Scaphopoda; Phascolosomida; Spinculida; Cnidaria; Hemichordata					
Method	Van Veen Grab Sampling	Multi-Parameter P/B-Model	Assumption from the other model with opitz correction	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean		Aegean Sea, eastern Mediterranean			
Year	2000		2003-2006			
Reference	(Ergev, 2002)	(Brey, 2012)	(Tsagarakis et al., 2010)			(Corrales et al., 2017b; Tsagarakis et al., 2010)

Table 2.5. (continued)

11. Octopuses and cuttlefish						
Taxonomic Group	*Eledone moschata; Octopus vulgaris; Sepia officinalis*					
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from Multi-Parameter P/B-Model)	Daily Feeding Rate	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey	(Brey, 2012) for M	Iglesias et al., 1996 (*O. vulgaris*); Quintela and Andrade, 2002 (*E. monschata* and *S. officinalis*)			(Tsagarakis et al., 2010)
12. Squids						
Taxonomic Group	*Illex coindetii; Loligo vulgaris*					
Method	Swept area	Assumption from the other model with opitz correction	Assumption from the other model with opitz correction	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean	Israel EEZ, northeastern Mediterranean	Israel EEZ, northeastern Mediterranean			
Year	2009-2013	1990-1994; 2008-2010	1990-1994; 2008-2010			
Reference	Trawl survey	(Corrales et al., 2017b)	(Corrales et al., 2017b)			(Tsagarakis et al., 2010)

Table 2.5. (continued)

13 and 14. *Mullus barbatus*						
Taxonomic Group						
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey	(Pauly, 1980) for M	(Palomares and Pauly, 1998)			(Bautista-Vega et al., 2008; Chérif et al., 2011; Esposito et al., 2014)
15. *Mullus surmuletus*						
Taxonomic Group						
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey	(Pauly, 1980) for M	(Palomares and Pauly, 1998)			(Bautista-Vega et al., 2008; Labropoulou et al., 1997)

Table 2.5. (continued)

***16. Upeneus molucensis* & *pori* (L)**						
Taxonomic Group						
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey	(Pauly, 1980) for M	(Palomares and Pauly, 1998)			(Kaya et al., 1999)
17. Anglerfish						
Taxonomic Group	*Lophius budegassa*					
Method	Estimated by EwE	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Empirical equation	Assumption	Estimated by EwE	
Area						
Year						
Reference		(Pauly, 1980) for M	(Palomares and Pauly, 1998)	(Hattab et al., 2013)		(Tsagarakis et al., 2010)

Table 2.5. (continued)

18.*Solea solea*						
Taxonomic Group						
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey	(Pauly, 1980) for M	(Palomares and Pauly, 1998)			(El-mor and Ahamed, 2008)
19. Flatfishes						
Taxonomic Group	*Arnoglossus kessleri; Bothus podas; Citharus linguatula; Microchirus ocellatus; Symphurus nigrescens*					
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey	(Pauly, 1980) for M	(Palomares and Pauly, 1998)			(El-mor and Ahamed, 2008)

Table 2.5. (continued)

20.*Merluccius merluccius*						
Taxonomic Group						
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey	(Pauly, 1980) for M	(Palomares and Pauly, 1998)			(Philips, 2012)
21 and 22. *Saurida undosquamis* (L)						
Taxonomic Group						
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey	(Pauly, 1980) for M	(Palomares and Pauly, 1998)			(Özyurt et al. , 2017)

Table 2.5. (continued)

23.Puffer fish (L)						
Taxonomic Group	*Lagocephalus sceleratus; Lagocephalus spadiceus; Lagocephalus suezensis; Torquigener flavimaculosus*					
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey	(Pauly, 1980) for M	(Palomares and Pauly, 1998)			(Aydın, 2011; Irmak, 2012)
24.Small discarded demersal fishes						
Taxonomic Group	*Aphanius fasciatus; Apogon nigripinnis; Atherina hepsetus; Atherinomorus lacunosus; Balistes capriscus; Blennius ocellaris; Callionymus lyra; Chelidonichthys lucerna; Deltentosteus quadrimaculatus; Dentex macrophthalmus; Diplodus annularis; Gobius geniporus; Lithognathus mormyrus; Oxyurichthys papuensis; Scorpaena maderensis; Scorpaena notata; Serranus cabrilla; Serranus hepatus; Trachinus draco; Trigloporus lastoviza; Uranoscopus scaber*					
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey	(Pauly, 1980) for M	(Palomares and Pauly, 1998)			(Stergiou and Karpouzi, 2002)

Table 2.5. (continued)

25.Large discarded demersal fishes						
Taxonomic Group	*Conger conger; Dactylopterus volitans; Echelus myrus; Echeneis naucrates; Lepidopus caudatus; Pagellus bogaraveo; Remora remora; Trichiurus lepturus; Zeus faber*					
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey	(Pauly, 1980) for M	(Palomares and Pauly, 1998)			(Stergiou and Karpouzi, 2002)
26. Retained demersal fishes						
Taxonomic Group	*Argyrosomus regius; Dentex gibbosus; Diplodus sargus sargus; Diplodus vulgaris; Epinephelus aeneus; Epinephelus costae; Epinephelus marginatus; Phycis blennoides; Pomadasys incisus; Pseudocaranx dentex; Sparus aurata; Synodus saurus; Umbrina cirrosa*					
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey	(Pauly, 1980) for M	(Palomares and Pauly, 1998)			(Stergiou and Karpouzi, 2002)

Table 2.5. (continued)

27. Demersal Fish Species (L)						
Taxonomic Group	*Champsodon nudivittis; Equulites klunzingeri; Pelates quadrilineatus; Sillago sihama; Stephanolepis diaspros*					
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey	(Pauly, 1980) for M	(Palomares and Pauly, 1998)			(Stergiou and Karpouzi, 2002)
28 and 29. *Pagellus erythrinus*						
Taxonomic Group						
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey	(Pauly, 1980) for M	(Palomares and Pauly, 1998)			(Šantić et al., 2011)

Table 2.5. (continued)

30. *Nemipterus randalli* (L)						
Taxonomic Group						
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey	(Pauly, 1980) for M	(Palomares and Pauly, 1998)			(Gurlek et al., 2010)
31. *Pagellus acarne*						
Taxonomic Group						
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey	(Pauly, 1980) for M	(Palomares and Pauly, 1998)			(Fehri-Bedoui et al., 2009)

Table 2.5. (continued)

32. Benthopelagic fishes						
Taxonomic Group	*Cepola macrophthalma; Lepidotrigla dieuzeidei; Macroramphosus scolopax; Trigla lyra*					
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey	(Pauly, 1980) for M	(Palomares and Pauly, 1998)			(Stergiou and Karpouzi, 2002)
33. Picarels and bogue						
Taxonomic Group	*Boops boops; Spicara maena; Spicara smaris*					
Method	Swept area	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey	(Pauly, 1980) for M	(Palomares and Pauly, 1998)			(Stergiou and Karpouzi, 2002)

Table 2.5. (continued)

34.Demersal sharks						
Taxonomic Group	*Mustelus mustelus; Oxynotus centrina; Scyliorhinus stellaris*					
Method	Estimated by EwE	Assumption from the other model with opitz correction	Empirical equation	Assumption	Estimated by EwE	
Area		Israel EEZ, northeastern Mediterranean		Gulf of Gabes, central Mediterranean		
Year		1990-1994; 2008-2010		2000-2005		
Reference		(Corrales et al., 2017b)	(Palomares and Pauly, 1998)	(Hattab et al., 2013)		(Saïdi et al. , 2009)
35.Demarsal rays and skates						
Taxonomic Group	*Dasyatis pastinaca; Dasyatis tortonesei; Gymnura altavela; Raja clavata; Raja miraletus; Rhinobatos rhinobatos; Torpedo marmorata; Torpedo nobiliana*					
Method	Estimated by EwE	P/B = Z = F +M (M calculated from empirical equation)	Empirical equation	Assumption	Estimated by EwE	
Area						
Year						
Reference		(Pauly, 1980) for M	(Palomares and Pauly, 1998)	(Hattab et al., 2013)		(Enajjar et al., 2007; Ismen, 2003; Romanelli et al., 2006; Valls et al., 2011)

Table 2.5. (continued)

36.*Engraulis encrasicolus*						
Taxonomic Group						
Method	Acoustic survey	P/B = Z = F +M (F= C/B and M obtained from stock assessment)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulfs of Mersin and Iskenderun, northeastern Mediterranean	Gulfs of Mersin and Iskenderun, northeastern Mediterranean (for M)				
Year	2009-2011	2009-2011 (for M)				
Reference	(Gücü et al., 2011)	(Gücü et al., 2011) for M	(Palomares and Pauly, 1998)			(Karachle and Stergiou, 2014)
37.*Sardinella aurita*						
Taxonomic Group	-					
Method	Acoustic survey	P/B = Z = F +M (F= C/B and M obtained from stock assessment)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulfs of Mersin and Iskenderun, northeastern Mediterranean	Gulfs of Mersin and Iskenderun, northeastern Mediterranean (for M)				
Year	2009-2011	2009-2011 (for M)				
Reference	(Gücü et al., 2011)	(Gücü et al., 2011) for M	(Palomares and Pauly, 1998)			(Karachle and Stergiou, 2014; Madkour, 2012; Tsikliras et al., 2005)

Table 2.5. (continued)

38.Horse mackerel						
Taxonomic Group	*Trachurus trachurus; Trachurus mediterraneus; Trachurus picturatus*					
Method	Acoustic survey	P/B = Z = F +M (F= C/B and M obtained from stock assessment)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulfs of Mersin and Iskenderun, northeastern Mediterranean	Gulfs of Mersin and Iskenderun, northeastern Mediterranean (for M)				
Year	2009-2011	2009-2011 (for M)				
Reference	(Gücü et al., 2011)	(Gücü et al., 2011) for M	(Palomares and Pauly, 1998)			(Bayhan et al., 2013; Bayhan and Sever, 2009)
39.*Scomber japonicus*						
Taxonomic Group						
Method	Acoustic survey	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulfs of Mersin and Iskenderun, northeastern Mediterranean					
Year	2009-2011					
Reference	(Gücü et al., 2011)	(Pauly, 1980) for M	(Palomares and Pauly, 1998)			(Sever et al., 2006)

Table 2.5. (continued)

40.Other small pelagic fishes						
Taxonomic Group	*Sardina pilchardus; Sardinella madarensis; Caranx rhonchus; Caranx crysos*					
Method	Acoustic survey	P/B = Z = F +M (F= C/B and M obtained from stock assessment)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulfs of Mersin and Iskenderun, northeastern Mediterranean	Gulfs of Mersin and Iskenderun, northeastern Mediterranean (for M)				
Year	2009-2011	2009-2011 (for M)				
Reference	(Gücü et al., 2011)	(Gücü et al., 2011) for M	(Palomares and Pauly, 1998)			(Karachle and Stergiou, 2014; Sley et al., 2009)
41.Small pelagic fishes (L)						
Taxonomic Group	*Etrumeus teres; Dussumieria elopsoides, Herklotsichthys punctatus, Alepes djedaba*					
Method	Acoustic survey	P/B = Z = F +M (F= C/B and M obtained from stock assessment)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Gulfs of Mersin and Iskenderun, northeastern Mediterranean	Gulfs of Mersin and Iskenderun, northeastern Mediterranean (for M)				
Year	2009-2011	2009-2011 (for M)				
Reference	(Gücü et al., 2011)	(Gücü et al., 2011) for M	(Palomares and Pauly, 1998)			(Karachle and Stergiou, 2014; Osman et al., 2013)

Table 2.5. (continued)

42.Medium pelagic fishes						
Taxonomic Group	*Euthynnus alletteratus; Thunnus alalunga; Sarda sarda; Auxis rochei; Seriola dumerili; Lichia amia*					
Method	Estimated by EwE	P/B = Z = F +M (F obtained from literature and M calculated from empirical equation)	Empirical equation	Assumption	Estimated by EwE	
Area						
Year						
Reference		(Pauly, 1980) for M	(Palomares and Pauly, 1998)	(Christensen and Pauly, 1992)		(Campo et al., 2006; Falautano et al., 2007; Matallanas et al., 1995; Salman and Karakulak, 2009)
43.Large pelagic fishes						
Taxonomic Group	*Thunnus thynnus; Xiphias gladius*					
Method	Estimated from stock assessment	P/B = Z = F +M (F= C/B and M calculated from empirical equation)	Empirical equation	Estimated by EwE	Estimated by EwE	
Area	Mediterranean Sea					
Year						
Reference	(ICCAT, 2010, 2007)	(Pauly, 1980) for M	(Palomares and Pauly, 1998)			(Karakulak et al., 2009; Romeo et al., 2009)

Table 2.5. (continued)

44. *Caretta caretta*						
Taxonomic Group						
Method		P/B = Z = survival rate (Z obtained from other model with opitz correction)	Assumption from other model with opitz correction	Estimated by EwE	Estimated by EwE	
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2008-2010					
Reference		(Piroddi et al., 2010; Tsagarakis et al., 2010)	(Corrales et al., 2017b; J.J. Polovina, 1984a)			(Tomas et al., 2001)
45. Seabirds						
Taxonomic Group	*Calonectris diomedea; Puffinus yelkouan; Hydrobates pelagicus; Phalacrocorax aristotelis; Larus audouinii; Larus cachinnans; Sterna sandvicensis; Sterna bengalensis*					
Method		Estimated by EwE	Empirical equation	Estimated by EwE	Assumption	
Area	Gulf of Mersin, northeastern Mediterranean					
Year						
Reference	(Coll et al., 2010)		(Nilsson and Nilsson, 1976)		(Christensen et al., 2008)	(Arcos and Oro, 2002; Bourgeois et al., 2011; Gremillet et al., 1995)

Table 2.5. (continued)

46. *Tursiops truncatus*						
Taxonomic Group						
Method	Visual surveys	Estimated by EwE	Empirical equation	Estimated by EwE	Assumption	
Area	Tunisian coasts					
Year	2001-2003					
Reference	(Naceur et al., 2004)		(Innes et al., 1987)		(Christensen et al., 2008; Piroddi et al., 2010)	(Blanco et al. , 2001)
47. Discard						
Taxonomic Group						
Method	Trawl survey			Estimated by EwE		
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2009-2013					
Reference	Trawl survey					
48. Detritus						
Taxonomic Group						
Method	Empirical equation			Estimated by EwE		
Area	Gulf of Mersin, northeastern Mediterranean					
Year	2008-2011					
Reference	(Christensen and Pauly, 1993)					

Table 2.6. Diet matrix adjusted for Ecopath model of Gulf of Mersin

No	Prey/Predator	2	3	4	5	6
1	Pyhtoplankton	0.700	0.150	0.020	0.000	0.000
2	Micro and mesozooplankton	0.050	0.650	0.100	0.000	0.043
3	Macrozooplankton	0.000	0.050	0.000	0.000	0.065
4	Benthic small crustaceans	0.000	0.000	0.030	0.000	0.249
5	Polychaetes	0.000	0.000	0.020	0.056	0.216
6	Shrimps (L)	0.000	0.000	0.000	0.000	0.024
7	Shrimps	0.000	0.000	0.000	0.000	0.008
8	*Charybdis longicollis (L)*	0.000	0.000	0.000	0.000	0.000
9	Crab	0.000	0.000	0.000	0.000	0.000
10	Benthic invertebrates	0.000	0.000	0.030	0.056	0.303
11	Octopuses and cuttlefish	0.000	0.000	0.000	0.000	0.000
12	Squids	0.000	0.000	0.000	0.000	0.000
13	*Mullus barbatus (<MLS)*	0.000	0.000	0.000	0.000	0.000
14	*Mullus barbatus (>MLS)*	0.000	0.000	0.000	0.000	0.000
15	*Mullus surmuletus*	0.000	0.000	0.000	0.000	0.000
16	*Upeneus molucensis & pori*	0.000	0.000	0.000	0.000	0.000
17	Anglerfish	0.000	0.000	0.000	0.000	0.000
18	*Solea solea*	0.000	0.000	0.000	0.000	0.000
19	Flatfishes	0.000	0.000	0.000	0.000	0.000
20	*Merluccius merluccius*	0.000	0.000	0.000	0.000	0.000
21	*Saurida undosquamis (L)*	0.000	0.000	0.000	0.000	0.000
22	*Saurida undosquamis (L)*	0.000	0.000	0.000	0.000	0.000
23	Puffer fish (L)	0.000	0.000	0.000	0.000	0.000
24	Small discarded demersal	0.000	0.000	0.000	0.000	0.000
25	Large discarded demersal	0.000	0.000	0.000	0.000	0.000
26	Retained demersal fishes	0.000	0.000	0.000	0.000	0.000
27	Demersal Fish Species (L)	0.000	0.000	0.000	0.000	0.000
28	*Pagellus erythrinus (<MLS)*	0.000	0.000	0.000	0.000	0.000
29	*Pagellus erythrinus (>MLS)*	0.000	0.000	0.000	0.000	0.000
30	*Nemipterus randalli (L)*	0.000	0.000	0.000	0.000	0.000
31	*Pagellus acarne*	0.000	0.000	0.000	0.000	0.000
32	Benthopelagic fishes	0.000	0.000	0.000	0.000	0.000
33	Picarels and bogue	0.000	0.000	0.000	0.000	0.000
34	Demersal sharks	0.000	0.000	0.000	0.000	0.000
35	Demarsal rays and skates	0.000	0.000	0.000	0.000	0.000
36	*Engraulis encrasicolus*	0.000	0.000	0.000	0.000	0.000
37	*Sardinella aurita*	0.000	0.000	0.000	0.000	0.000
38	Horse mackerel	0.000	0.000	0.000	0.000	0.000
39	*Scomber japonicus*	0.000	0.000	0.000	0.000	0.000
40	Other Small pelagic fishes	0.000	0.000	0.000	0.000	0.000
41	Small Pelagic fishes (L)	0.000	0.000	0.000	0.000	0.000
42	Medium pelagic fishes	0.000	0.000	0.000	0.000	0.000
43	Large pelagic fishes	0.000	0.000	0.000	0.000	0.000
44	*Caretta caretta*	0.000	0.000	0.000	0.000	0.000
45	Seabirds	0.000	0.000	0.000	0.000	0.000
46	*Tursiops truncatus*	0.000	0.000	0.000	0.000	0.000
47	Discard	0.000	0.000	0.000	0.000	0.000
48	Detritus	0.250	0.150	0.800	0.889	0.092
	Import	0.000	0.000	0.000	0.000	0.00
	SUM	1	1	1	1	1

Table 2.6. (continued)

No	Prey/Predator	7	8	9	10	11
1	Pyhtoplankton	0.000	0.000	0.000	0.000	0.000
2	Micro and mesozooplankton	0.043	0.000	0.000	0.000	0.000
3	Macrozooplankton	0.065	0.000	0.000	0.000	0.041
4	Benthic small crustaceans	0.249	0.062	0.062	0.000	0.031
5	Polychaetes	0.216	0.423	0.423	0.021	0.092
6	Shrimps (L)	0.024	0.015	0.015	0.000	0.041
7	Shrimps	0.008	0.005	0.005	0.000	0.016
8	*Charybdis longicollis (L)*	0.000	0.016	0.016	0.000	0.124
9	Crab	0.000	0.005	0.005	0.000	0.040
10	Benthic invertebrates	0.303	0.320	0.320	0.032	0.544
11	Octopuses and cuttlefish	0.000	0.000	0.000	0.000	0.021
12	Squids	0.000	0.000	0.000	0.000	0.000
13	*Mullus barbatus (<MLS)*	0.000	0.000	0.000	0.000	0.001
14	*Mullus barbatus (>MLS)*	0.000	0.000	0.000	0.000	0.004
15	*Mullus surmuletus*	0.000	0.000	0.000	0.000	0.000
16	*Upeneus molucensis & pori*	0.000	0.000	0.000	0.000	0.001
17	Anglerfish	0.000	0.000	0.000	0.000	0.000
18	*Solea solea*	0.000	0.000	0.000	0.000	0.000
19	Flatfishes	0.000	0.000	0.000	0.000	0.000
20	*Merluccius merluccius*	0.000	0.000	0.000	0.000	0.000
21	*Saurida undosquamis (L)*	0.000	0.000	0.000	0.000	0.000
22	*Saurida undosquamis (L)*	0.000	0.000	0.000	0.000	0.000
23	Puffer fish (L)	0.000	0.000	0.000	0.000	0.000
24	Small discarded demersal	0.000	0.000	0.000	0.000	0.000
25	Large discarded demersal	0.000	0.000	0.000	0.000	0.000
26	Retained demersal fishes	0.000	0.000	0.000	0.000	0.002
27	Demersal Fish Species (L)	0.000	0.000	0.000	0.000	0.002
28	*Pagellus erythrinus (<MLS)*	0.000	0.000	0.000	0.000	0.000
29	*Pagellus erythrinus (>MLS)*	0.000	0.000	0.000	0.000	0.007
30	*Nemipterus randalli (L)*	0.000	0.000	0.000	0.000	0.010
31	*Pagellus acarne*	0.000	0.000	0.000	0.000	0.009
32	Benthopelagic fishes	0.000	0.000	0.000	0.000	0.000
33	Picarels and bogue	0.000	0.000	0.000	0.000	0.010
34	Demersal sharks	0.000	0.000	0.000	0.000	0.000
35	Demarsal rays and skates	0.000	0.000	0.000	0.000	0.000
36	*Engraulis encrasicolus*	0.000	0.000	0.000	0.000	0.000
37	*Sardinella aurita*	0.000	0.000	0.000	0.000	0.000
38	Horse mackerel	0.000	0.000	0.000	0.000	0.000
39	*Scomber japonicus*	0.000	0.000	0.000	0.000	0.000
40	Other Small pelagic fishes	0.000	0.000	0.000	0.000	0.000
41	Small Pelagic fishes (L)	0.000	0.000	0.000	0.000	0.000
42	Medium pelagic fishes	0.000	0.000	0.000	0.000	0.000
43	Large pelagic fishes	0.000	0.000	0.000	0.000	0.000
44	*Caretta caretta*	0.000	0.000	0.000	0.000	0.000
45	Seabirds	0.000	0.000	0.000	0.000	0.000
46	*Tursiops truncatus*	0.000	0.000	0.000	0.000	0.000
47	Discard	0.000	0.000	0.000	0.000	0.000
48	Detritus	0.092	0.155	0.155	0.947	0.005
	Import	0.000	0.000	0.000	0.000	0.00
	SUM	1	1	1	1	1

Table 2.6. (continued)

No	Prey/Predator	12	13	14	15	16
1	Pyhtoplankton	0.000	0.000	0.000	0.000	0.000
2	Micro and mesozooplankton	0.062	0.023	0.017	0.020	0.020
3	Macrozooplankton	0.092	0.110	0.110	0.110	0.110
4	Benthic small crustaceans	0.020	0.115	0.145	0.130	0.130
5	Polychaetes	0.060	0.190	0.190	0.190	0.190
6	Shrimps (L)	0.008	0.052	0.052	0.052	0.052
7	Shrimps	0.003	0.018	0.018	0.018	0.018
8	*Charybdis longicollis (L)*	0.008	0.023	0.023	0.023	0.023
9	Crab	0.002	0.007	0.007	0.007	0.007
10	Benthic invertebrates	0.020	0.072	0.048	0.060	0.060
11	Octopuses and cuttlefish	0.050	0.000	0.000	0.000	0.000
12	Squids	0.023	0.000	0.000	0.000	0.000
13	*Mullus barbatus (<MLS)*	0.000	0.000	0.000	0.000	0.000
14	*Mullus barbatus (>MLS)*	0.000	0.000	0.000	0.000	0.000
15	*Mullus surmuletus*	0.000	0.000	0.000	0.000	0.000
16	*Upeneus molucensis & pori*	0.000	0.000	0.000	0.000	0.000
17	Anglerfish	0.000	0.000	0.000	0.000	0.000
18	*Solea solea*	0.000	0.000	0.000	0.000	0.000
19	Flatfishes	0.000	0.000	0.000	0.000	0.000
20	*Merluccius merluccius*	0.000	0.000	0.000	0.000	0.000
21	*Saurida undosquamis (L)*	0.000	0.000	0.000	0.000	0.000
22	*Saurida undosquamis (L)*	0.000	0.000	0.000	0.000	0.000
23	Puffer fish (L)	0.000	0.000	0.000	0.000	0.000
24	Small discarded demersal	0.000	0.000	0.000	0.000	0.000
25	Large discarded demersal	0.000	0.000	0.000	0.000	0.000
26	Retained demersal fishes	0.000	0.000	0.000	0.000	0.000
27	Demersal Fish Species (L)	0.000	0.000	0.000	0.000	0.000
28	*Pagellus erythrinus (<MLS)*	0.000	0.000	0.000	0.000	0.000
29	*Pagellus erythrinus (>MLS)*	0.000	0.000	0.000	0.000	0.000
30	*Nemipterus randalli (L)*	0.000	0.000	0.000	0.000	0.000
31	*Pagellus acarne*	0.001	0.000	0.000	0.000	0.000
32	Benthopelagic fishes	0.002	0.000	0.000	0.000	0.000
33	Picarels and bogue	0.000	0.000	0.000	0.000	0.000
34	Demersal sharks	0.000	0.000	0.000	0.000	0.000
35	Demarsal rays and skates	0.000	0.000	0.000	0.000	0.000
36	*Engraulis encrasicolus*	0.032	0.000	0.000	0.000	0.000
37	*Sardinella aurita*	0.329	0.000	0.000	0.000	0.000
38	Horse mackerel	0.147	0.000	0.000	0.000	0.000
39	*Scomber japonicus*	0.023	0.000	0.000	0.000	0.000
40	Other Small pelagic fishes	0.075	0.000	0.000	0.000	0.000
41	Small Pelagic fishes (L)	0.042	0.000	0.000	0.000	0.000
42	Medium pelagic fishes	0.000	0.000	0.000	0.000	0.000
43	Large pelagic fishes	0.000	0.000	0.000	0.000	0.000
44	*Caretta caretta*	0.000	0.000	0.000	0.000	0.000
45	Seabirds	0.000	0.000	0.000	0.000	0.000
46	*Tursiops truncatus*	0.000	0.000	0.000	0.000	0.000
47	Discard	0.000	0.000	0.000	0.000	0.000
48	Detritus	0.000	0.390	0.390	0.390	0.390
	Import	0.000	0.000	0.000	0.000	0.00
	SUM	1	1	1	1	1

Table 2.6. (continued)

No	Prey/Predator	17	18	19	20	21
1	Pyhtoplankton	0.000	0.000	0.000	0.000	0.000
2	Micro and mesozooplankton	0.013	0.012	0.012	0.000	0.000
3	Macrozooplankton	0.000	0.129	0.130	0.093	0.000
4	Benthic small crustaceans	0.047	0.257	0.260	0.062	0.002
5	Polychaetes	0.047	0.175	0.177	0.021	0.003
6	Shrimps (L)	0.011	0.076	0.067	0.053	0.004
7	Shrimps	0.006	0.020	0.020	0.019	0.001
8	*Charybdis longicollis (L)*	0.000	0.053	0.054	0.000	0.000
9	Crab	0.000	0.017	0.017	0.000	0.000
10	Benthic invertebrates	0.127	0.187	0.189	0.042	0.015
11	Octopuses and cuttlefish	0.129	0.000	0.000	0.082	0.001
12	Squids	0.000	0.000	0.000	0.005	0.000
13	*Mullus barbatus (<MLS)*	0.000	0.000	0.000	0.001	0.008
14	*Mullus barbatus (>MLS)*	0.025	0.000	0.000	0.013	0.001
15	*Mullus surmuletus*	0.000	0.000	0.000	0.000	0.001
16	*Upeneus molucensis & pori*	0.002	0.000	0.000	0.002	0.028
17	Anglerfish	0.012	0.000	0.000	0.000	0.000
18	*Solea solea*	0.010	0.003	0.003	0.003	0.000
19	Flatfishes	0.025	0.008	0.008	0.007	0.000
20	*Merluccius merluccius*	0.110	0.000	0.000	0.041	0.000
21	*Saurida undosquamis (L)*	0.000	0.000	0.000	0.000	0.000
22	*Saurida undosquamis (L)*	0.000	0.000	0.000	0.000	0.000
23	Puffer fish (L)	0.000	0.000	0.000	0.000	0.000
24	Small discarded demersal	0.000	0.023	0.024	0.000	0.034
25	Large discarded demersal	0.070	0.000	0.000	0.010	0.000
26	Retained demersal fishes	0.001	0.000	0.000	0.000	0.000
27	Demersal Fish Species (L)	0.055	0.022	0.022	0.010	0.042
28	*Pagellus erythrinus (<MLS)*	0.000	0.000	0.000	0.003	0.020
29	*Pagellus erythrinus (>MLS)*	0.008	0.000	0.000	0.000	0.000
30	*Nemipterus randalli (L)*	0.017	0.007	0.007	0.003	0.014
31	*Pagellus acarne*	0.025	0.010	0.010	0.004	0.014
32	Benthopelagic fishes	0.117	0.000	0.000	0.021	0.000
33	Picarels and bogue	0.013	0.000	0.000	0.009	0.000
34	Demersal sharks	0.000	0.000	0.000	0.000	0.000
35	Demarsal rays and skates	0.000	0.000	0.000	0.000	0.000
36	*Engraulis encrasicolus*	0.047	0.000	0.000	0.034	0.135
37	*Sardinella aurita*	0.000	0.000	0.000	0.246	0.521
38	Horse mackerel	0.058	0.000	0.000	0.110	0.068
39	*Scomber japonicus*	0.023	0.000	0.000	0.017	0.017
40	Other Small pelagic fishes	0.000	0.000	0.000	0.056	0.059
41	Small Pelagic fishes (L)	0.000	0.000	0.000	0.031	0.011
42	Medium pelagic fishes	0.000	0.000	0.000	0.000	0.000
43	Large pelagic fishes	0.000	0.000	0.000	0.000	0.000
44	*Caretta caretta*	0.000	0.000	0.000	0.000	0.000
45	Seabirds	0.000	0.000	0.000	0.000	0.000
46	*Tursiops truncatus*	0.000	0.000	0.000	0.000	0.000
47	Discard	0.000	0.000	0.000	0.000	0.000
48	Detritus	0.000	0.000	0.000	0.000	0.000
	Import	0.000	0.000	0.000	0.000	0.000
	SUM	1	1	1	1	1

Table 2.6. (continued)

No	Prey/Predator	22	23	24	25	26
1	Pyhtoplankton	0.000	0.000	0.000	0.000	0.000
2	Micro and mesozooplankton	0.000	0.000	0.094	0.002	0.020
3	Macrozooplankton	0.000	0.000	0.056	0.021	0.000
4	Benthic small crustaceans	0.002	0.000	0.507	0.011	0.049
5	Polychaetes	0.003	0.000	0.075	0.011	0.388
6	Shrimps (L)	0.004	0.033	0.063	0.039	0.015
7	Shrimps	0.001	0.012	0.022	0.014	0.005
8	*Charybdis longicollis (L)*	0.000	0.263	0.036	0.048	0.030
9	Crab	0.000	0.197	0.011	0.015	0.010
10	Benthic invertebrates	0.015	0.092	0.019	0.098	0.466
11	Octopuses and cuttlefish	0.001	0.127	0.000	0.126	0.000
12	Squids	0.000	0.003	0.000	0.011	0.000
13	*Mullus barbatus (<MLS)*	0.001	0.008	0.028	0.002	0.003
14	*Mullus barbatus (>MLS)*	0.010	0.029	0.033	0.007	0.011
15	*Mullus surmuletus*	0.001	0.001	0.001	0.000	0.000
16	*Upeneus molucensis & pori*	0.028	0.004	0.007	0.001	0.002
17	Anglerfish	0.000	0.000	0.000	0.000	0.000
18	*Solea solea*	0.000	0.004	0.000	0.006	0.000
19	Flatfishes	0.000	0.004	0.000	0.015	0.000
20	*Merluccius merluccius*	0.000	0.000	0.000	0.000	0.000
21	*Saurida undosquamis (L)*	0.010	0.016	0.000	0.009	0.000
22	*Saurida undosquamis (L)*	0.001	0.013	0.000	0.007	0.000
23	Puffer fish (L)	0.000	0.013	0.000	0.000	0.000
24	Small discarded demersal	0.034	0.071	0.009	0.000	0.000
25	Large discarded demersal	0.000	0.010	0.000	0.021	0.000
26	Retained demersal fishes	0.000	0.021	0.000	0.000	0.000
27	Demersal Fish Species (L)	0.042	0.000	0.009	0.035	0.000
28	*Pagellus erythrinus (<MLS)*	0.002	0.000	0.001	0.002	0.001
29	*Pagellus erythrinus (>MLS)*	0.047	0.000	0.002	0.003	0.002
30	*Nemipterus randalli (L)*	0.014	0.000	0.003	0.060	0.000
31	*Pagellus acarne*	0.014	0.000	0.004	0.016	0.000
32	Benthopelagic fishes	0.000	0.002	0.000	0.060	0.000
33	Picarels and bogue	0.000	0.002	0.000	0.010	0.000
34	Demersal sharks	0.000	0.001	0.000	0.000	0.000
35	Demarsal rays and skates	0.000	0.022	0.000	0.000	0.000
36	*Engraulis encrasicolus*	0.133	0.000	0.000	0.022	0.000
37	*Sardinella aurita*	0.499	0.016	0.000	0.171	0.000
38	Horse mackerel	0.059	0.011	0.000	0.101	0.000
39	*Scomber japonicus*	0.015	0.000	0.000	0.000	0.000
40	Other Small pelagic fishes	0.055	0.016	0.000	0.034	0.000
41	Small Pelagic fishes (L)	0.008	0.009	0.000	0.019	0.000
42	Medium pelagic fishes	0.000	0.000	0.000	0.000	0.000
43	Large pelagic fishes	0.000	0.000	0.000	0.000	0.000
44	*Caretta caretta*	0.000	0.000	0.000	0.000	0.000
45	Seabirds	0.000	0.000	0.000	0.000	0.000
46	*Tursiops truncatus*	0.000	0.000	0.000	0.000	0.000
47	Discard	0.000	0.000	0.000	0.000	0.000
48	Detritus	0.000	0.000	0.019	0.005	0.000
	Import	0.000	0.000	0.000	0.000	0.000
	SUM	1	1	1	1	1

Table 2.6. (continued)

No	Prey/Predator	27	28	29	30	31
1	Pyhtoplankton	0.000	0.000	0.000	0.000	0.000
2	Micro and mesozooplankton	0.000	0.000	0.000	0.000	0.000
3	Macrozooplankton	0.000	0.000	0.000	0.000	0.000
4	Benthic small crustaceans	0.188	0.174	0.016	0.188	0.188
5	Polychaetes	0.418	0.219	0.165	0.418	0.418
6	Shrimps (L)	0.085	0.162	0.191	0.085	0.085
7	Shrimps	0.030	0.057	0.067	0.030	0.030
8	*Charybdis longicollis (L)*	0.016	0.163	0.191	0.016	0.016
9	Crab	0.005	0.052	0.061	0.005	0.005
10	Benthic invertebrates	0.219	0.171	0.256	0.219	0.219
11	Octopuses and cuttlefish	0.010	0.000	0.003	0.010	0.010
12	Squids	0.000	0.000	0.000	0.000	0.000
13	*Mullus barbatus (<MLS)*	0.000	0.000	0.000	0.000	0.000
14	*Mullus barbatus (>MLS)*	0.000	0.000	0.000	0.000	0.000
15	*Mullus surmuletus*	0.000	0.000	0.000	0.000	0.000
16	*Upeneus molucensis & pori*	0.000	0.000	0.000	0.000	0.000
17	Anglerfish	0.000	0.000	0.000	0.000	0.000
18	*Solea solea*	0.000	0.000	0.000	0.000	0.000
19	Flatfishes	0.000	0.000	0.000	0.000	0.000
20	*Merluccius merluccius*	0.000	0.000	0.000	0.000	0.000
21	*Saurida undosquamis (L)*	0.000	0.000	0.000	0.000	0.000
22	*Saurida undosquamis (L)*	0.000	0.000	0.000	0.000	0.000
23	Puffer fish (L)	0.000	0.000	0.000	0.000	0.000
24	Small discarded demersal	0.000	0.000	0.016	0.000	0.000
25	Large discarded demersal	0.000	0.000	0.000	0.000	0.000
26	Retained demersal fishes	0.000	0.000	0.000	0.000	0.000
27	Demersal Fish Species (L)	0.010	0.000	0.026	0.010	0.010
28	*Pagellus erythrinus (<MLS)*	0.001	0.000	0.000	0.001	0.001
29	*Pagellus erythrinus (>MLS)*	0.001	0.000	0.000	0.001	0.001
30	*Nemipterus randalli (L)*	0.003	0.000	0.000	0.003	0.003
31	*Pagellus acarne*	0.004	0.000	0.000	0.004	0.004
32	Benthopelagic fishes	0.000	0.000	0.000	0.000	0.000
33	Picarels and bogue	0.010	0.000	0.005	0.010	0.010
34	Demersal sharks	0.000	0.000	0.000	0.000	0.000
35	Demarsal rays and skates	0.000	0.000	0.000	0.000	0.000
36	*Engraulis encrasicolus*	0.000	0.000	0.000	0.000	0.000
37	*Sardinella aurita*	0.000	0.000	0.000	0.000	0.000
38	Horse mackerel	0.000	0.000	0.000	0.000	0.000
39	*Scomber japonicus*	0.000	0.000	0.000	0.000	0.000
40	Other Small pelagic fishes	0.000	0.000	0.000	0.000	0.000
41	Small Pelagic fishes (L)	0.000	0.000	0.000	0.000	0.000
42	Medium pelagic fishes	0.000	0.000	0.000	0.000	0.000
43	Large pelagic fishes	0.000	0.000	0.000	0.000	0.000
44	*Caretta caretta*	0.000	0.000	0.000	0.000	0.000
45	Seabirds	0.000	0.000	0.000	0.000	0.000
46	*Tursiops truncatus*	0.000	0.000	0.000	0.000	0.000
47	Discard	0.000	0.000	0.000	0.000	0.000
48	Detritus	0.000	0.003	0.003	0.000	0.000
	Import	0.000	0.000	0.000	0.000	0.000
	SUM	1	1	1	1	1

Table 2.6. (continued)

No	Prey/Predator	32	33	34	35	36
1	Pyhtoplankton	0.000	0.000	0.000	0.000	0.000
2	Micro and mesozooplankton	0.460	0.870	0.000	0.005	1.000
3	Macrozooplankton	0.460	0.100	0.060	0.054	0.000
4	Benthic small crustaceans	0.040	0.020	0.000	0.000	0.000
5	Polychaetes	0.000	0.010	0.160	0.087	0.000
6	Shrimps (L)	0.015	0.000	0.093	0.064	0.000
7	Shrimps	0.005	0.000	0.044	0.023	0.000
8	*Charybdis longicollis (L)*	0.008	0.000	0.000	0.066	0.000
9	Crab	0.002	0.000	0.000	0.007	0.000
10	Benthic invertebrates	0.010	0.000	0.279	0.091	0.000
11	Octopuses and cuttlefish	0.000	0.000	0.053	0.000	0.000
12	Squids	0.000	0.000	0.011	0.000	0.000
13	*Mullus barbatus (<MLS)*	0.000	0.000	0.006	0.006	0.000
14	*Mullus barbatus (>MLS)*	0.000	0.000	0.029	0.029	0.000
15	*Mullus surmuletus*	0.000	0.000	0.001	0.001	0.000
16	*Upeneus molucensis & pori*	0.000	0.000	0.003	0.003	0.000
17	Anglerfish	0.000	0.000	0.000	0.000	0.000
18	*Solea solea*	0.000	0.000	0.003	0.000	0.000
19	Flatfishes	0.000	0.000	0.007	0.000	0.000
20	*Merluccius merluccius*	0.000	0.000	0.000	0.000	0.000
21	*Saurida undosquamis (L)*	0.000	0.000	0.011	0.000	0.000
22	*Saurida undosquamis (L)*	0.000	0.000	0.009	0.000	0.000
23	Puffer fish (L)	0.000	0.000	0.000	0.000	0.000
24	Small discarded demersal	0.000	0.000	0.022	0.022	0.000
25	Large discarded demersal	0.000	0.000	0.000	0.000	0.000
26	Retained demersal fishes	0.000	0.000	0.000	0.000	0.000
27	Demersal Fish Species (L)	0.000	0.000	0.048	0.048	0.000
28	*Pagellus erythrinus (<MLS)*	0.000	0.000	0.001	0.001	0.000
29	*Pagellus erythrinus (>MLS)*	0.000	0.000	0.001	0.001	0.000
30	*Nemipterus randalli (L)*	0.000	0.000	0.019	0.019	0.000
31	*Pagellus acarne*	0.000	0.000	0.007	0.007	0.000
32	Benthopelagic fishes	0.000	0.000	0.000	0.000	0.000
33	Picarels and bogue	0.000	0.000	0.001	0.010	0.000
34	Demersal sharks	0.000	0.000	0.000	0.000	0.000
35	Demarsal rays and skates	0.000	0.000	0.000	0.000	0.000
36	*Engraulis encrasicolus*	0.000	0.000	0.006	0.022	0.000
37	*Sardinella aurita*	0.000	0.000	0.066	0.231	0.000
38	Horse mackerel	0.000	0.000	0.030	0.103	0.000
39	*Scomber japonicus*	0.000	0.000	0.005	0.016	0.000
40	Other Small pelagic fishes	0.000	0.000	0.015	0.053	0.000
41	Small Pelagic fishes (L)	0.000	0.000	0.008	0.030	0.000
42	Medium pelagic fishes	0.000	0.000	0.000	0.000	0.000
43	Large pelagic fishes	0.000	0.000	0.000	0.000	0.000
44	*Caretta caretta*	0.000	0.000	0.000	0.000	0.000
45	Seabirds	0.000	0.000	0.000	0.000	0.000
46	*Tursiops truncatus*	0.000	0.000	0.000	0.000	0.000
47	Discard	0.000	0.000	0.000	0.000	0.000
48	Detritus	0.000	0.000	0.000	0.000	0.000
	Import	0.000	0.000	0.000	0.000	0.000
	SUM	1	1	1	1	1

Table 2.6. (continued)

No	Prey/Predator	37	38	39	40	41
1	Pyhtoplankton	0.000	0.000	0.000	0.010	0.010
2	Micro and mesozooplankton	0.985	0.691	0.533	0.697	0.697
3	Macrozooplankton	0.000	0.226	0.278	0.091	0.091
4	Benthic small crustaceans	0.015	0.082	0.044	0.202	0.202
5	Polychaetes	0.000	0.000	0.000	0.000	0.000
6	Shrimps (L)	0.000	0.000	0.000	0.000	0.000
7	Shrimps	0.000	0.000	0.000	0.000	0.000
8	*Charybdis longicollis (L)*	0.000	0.000	0.000	0.000	0.000
9	Crab	0.000	0.000	0.000	0.000	0.000
10	Benthic invertebrates	0.000	0.000	0.000	0.000	0.000
11	Octopuses and cuttlefish	0.000	0.000	0.000	0.000	0.000
12	Squids	0.000	0.000	0.000	0.000	0.000
13	*Mullus barbatus (<MLS)*	0.000	0.000	0.000	0.000	0.000
14	*Mullus barbatus (>MLS)*	0.000	0.000	0.000	0.000	0.000
15	*Mullus surmuletus*	0.000	0.000	0.000	0.000	0.000
16	*Upeneus molucensis & pori*	0.000	0.000	0.000	0.000	0.000
17	Anglerfish	0.000	0.000	0.000	0.000	0.000
18	*Solea solea*	0.000	0.000	0.000	0.000	0.000
19	Flatfishes	0.000	0.000	0.000	0.000	0.000
20	*Merluccius merluccius*	0.000	0.000	0.000	0.000	0.000
21	*Saurida undosquamis (L)*	0.000	0.000	0.000	0.000	0.000
22	*Saurida undosquamis (L)*	0.000	0.000	0.000	0.000	0.000
23	Puffer fish (L)	0.000	0.000	0.000	0.000	0.000
24	Small discarded demersal	0.000	0.000	0.000	0.000	0.000
25	Large discarded demersal	0.000	0.000	0.000	0.000	0.000
26	Retained demersal fishes	0.000	0.000	0.000	0.000	0.000
27	Demersal Fish Species (L)	0.000	0.000	0.000	0.000	0.000
28	*Pagellus erythrinus (<MLS)*	0.000	0.000	0.000	0.000	0.000
29	*Pagellus erythrinus (>MLS)*	0.000	0.000	0.000	0.000	0.000
30	*Nemipterus randalli (L)*	0.000	0.000	0.000	0.000	0.000
31	*Pagellus acarne*	0.000	0.000	0.000	0.000	0.000
32	Benthopelagic fishes	0.000	0.000	0.000	0.000	0.000
33	Picarels and bogue	0.000	0.000	0.000	0.000	0.000
34	Demersal sharks	0.000	0.000	0.000	0.000	0.000
35	Demarsal rays and skates	0.000	0.000	0.000	0.000	0.000
36	*Engraulis encrasicolus*	0.000	0.000	0.020	0.000	0.000
37	*Sardinella aurita*	0.000	0.000	0.092	0.000	0.000
38	Horse mackerel	0.000	0.000	0.000	0.000	0.000
39	*Scomber japonicus*	0.000	0.000	0.000	0.000	0.000
40	Other Small pelagic fishes	0.000	0.000	0.021	0.000	0.000
41	Small Pelagic fishes (L)	0.000	0.000	0.012	0.000	0.000
42	Medium pelagic fishes	0.000	0.000	0.000	0.000	0.000
43	Large pelagic fishes	0.000	0.000	0.000	0.000	0.000
44	*Caretta caretta*	0.000	0.000	0.000	0.000	0.000
45	Seabirds	0.000	0.000	0.000	0.000	0.000
46	*Tursiops truncatus*	0.000	0.000	0.000	0.000	0.000
47	Discard	0.000	0.000	0.000	0.000	0.000
48	Detritus	0.000	0.000	0.000	0.000	0.000
	Import	0.000	0.000	0.000	0.000	0.000
	SUM	1	1	1	1	1

Table 2.6. (continued)

No	Prey/Predator	42	43	44	45	46
1	Pyhtoplankton	0.000	0.000	0.000	0.000	0.000
2	Micro and mesozooplankton	0.000	0.000	0.000	0.000	0.000
3	Macrozooplankton	0.000	0.000	0.114	0.000	0.000
4	Benthic small crustaceans	0.021	0.000	0.000	0.000	0.000
5	Polychaetes	0.000	0.000	0.000	0.000	0.000
6	Shrimps (L)	0.000	0.000	0.000	0.000	0.000
7	Shrimps	0.000	0.000	0.000	0.000	0.000
8	*Charybdis longicollis (L)*	0.000	0.000	0.135	0.000	0.000
9	Crab	0.000	0.000	0.043	0.000	0.000
10	Benthic invertebrates	0.000	0.000	0.528	0.000	0.000
11	Octopuses and cuttlefish	0.000	0.000	0.000	0.000	0.006
12	Squids	0.005	0.074	0.000	0.000	0.013
13	*Mullus barbatus (<MLS)*	0.000	0.000	0.000	0.000	0.000
14	*Mullus barbatus (>MLS)*	0.000	0.000	0.000	0.000	0.000
15	*Mullus surmuletus*	0.000	0.000	0.000	0.000	0.000
16	*Upeneus molucensis & pori*	0.000	0.000	0.000	0.000	0.000
17	Anglerfish	0.000	0.000	0.000	0.000	0.000
18	*Solea solea*	0.000	0.000	0.000	0.000	0.000
19	Flatfishes	0.000	0.000	0.000	0.000	0.000
20	*Merluccius merluccius*	0.000	0.000	0.000	0.000	0.003
21	*Saurida undosquamis (L)*	0.006	0.006	0.000	0.000	0.000
22	*Saurida undosquamis (L)*	0.005	0.005	0.000	0.000	0.023
23	Puffer fish (L)	0.016	0.000	0.000	0.000	0.000
24	Small discarded demersal	0.000	0.000	0.000	0.000	0.000
25	Large discarded demersal	0.000	0.023	0.000	0.000	0.002
26	Retained demersal fishes	0.000	0.000	0.000	0.000	0.002
27	Demersal Fish Species (L)	0.000	0.000	0.000	0.000	0.001
28	*Pagellus erythrinus (<MLS)*	0.000	0.000	0.000	0.000	0.000
29	*Pagellus erythrinus (>MLS)*	0.000	0.000	0.000	0.000	0.004
30	*Nemipterus randalli (L)*	0.000	0.000	0.000	0.000	0.006
31	*Pagellus acarne*	0.000	0.000	0.000	0.000	0.001
32	Benthopelagic fishes	0.000	0.000	0.000	0.000	0.000
33	Picarels and bogue	0.000	0.000	0.000	0.000	0.000
34	Demersal sharks	0.000	0.000	0.000	0.000	0.000
35	Demarsal rays and skates	0.000	0.000	0.000	0.000	0.000
36	*Engraulis encrasicolus*	0.047	0.044	0.000	0.037	0.048
37	*Sardinella aurita*	0.481	0.453	0.000	0.376	0.475
38	Horse mackerel	0.215	0.203	0.000	0.168	0.212
39	*Scomber japonicus*	0.033	0.031	0.000	0.026	0.033
40	Other Small pelagic fishes	0.110	0.103	0.000	0.086	0.108
41	Small Pelagic fishes (L)	0.061	0.058	0.000	0.048	0.061
42	Medium pelagic fishes	0.000	0.000	0.000	0.000	0.000
43	Large pelagic fishes	0.000	0.000	0.000	0.000	0.000
44	*Caretta caretta*	0.000	0.000	0.000	0.000	0.000
45	Seabirds	0.000	0.000	0.000	0.000	0.000
46	*Tursiops truncatus*	0.000	0.000	0.000	0.000	0.000
47	Discard	0.000	0.000	0.180	0.100	0.000
48	Detritus	0.000	0.000	0.000	0.000	0.000
	Import	0.000	0.000	0.000	0.000	0.160
	SUM	1	1	1	1	1

2.3. Results

2.3.1. Balanced Food Web and Ecosystem Description

Gulf of Mersin food web model was represented by 48 functional groups integrating four trophic levels (TLs). EE (<1), GE (0.1<GE<0.3), Respiration/Assimilation (R/A, <1.0), Production/Respiration (P/R, <1.0), and Respiration/Biomass (R/B, 1–10 $year^{-1}$ for fish and may be as high as 50–100 $year^{-1}$ for groups with higher turnover) were in expected limits. P/Q ratio was also smaller than net efficiency (NE, production/assimilated food) (Christensen and Walters, 2004; Darwall et al., 2010; Heymans et al., 2016) (Table 2.7). Pre-balance (PREBAL) diagnostics, based on general ecological and fisheries principals, have been applied to check the slopes of B, P/B, Q/B and P/Q based on TL in the model before the model was balanced (Heymans et al., 2016; Link, 2010). The PREBAL diagnostics of this model are given in Figure 2.4. Results show that biomass estimates of horse mackerel, *Sardinella aurita*, benthic invertebrate and "micro and mesozooplankton" may be underestimated, while majority of demersal fished groups may be overestimated. As with biomass, P/B ratios more or less between TL 2 and 3 seem very low. Q/B ratios of lower trophic level demersal and pelagic groups such as crabs, shrimps, mullets and small pelagic fishes might be underestimated. Although some estimations seem very low, the basic input parameters of B, P/B and Q/B has not been modified because the input data was obtained from survey based studies and there is no data to enhance the estimations of these input parameters. The Ecopath pedigree index was estimated at 0.63 (Table 2.8). The value indicated that the input parameters used in this model was between acceptable range when compared other Ecopath models in the Mediterranean (Corrales et al., 2015) and world (Morissette, 2007).

Figure 2.4. PREBAL of the Gulf of Mersin model plotting (A) biomass estimates (t.km-2), (B) production/biomass ratio (per year), and (C) consumption/biomass ratio (per year) on a log scale vs functional group ranked by trophic level, from lowest to highest trophic level (TL). Solid bars represent input to the model and transparent bars represent model estimated parameters

At the functional group level, the top predators in Gulf of Mersin were calculated as: large pelagic fishes (TL=4.22), while "micro and mesozooplankton" (TL=2.05) fed at the lowest TLs. The demersal groups with the lowest TLs were red mullets (between 2.85 and 2.86), and the lowest pelagic groups were *Sardinella aurita* (TL=3.05) and *Engraulis encrasicolus* (TL=3.05). A flow diagram illustrating trophic positions of biomass pools and their links is presented in Figure 2.5.

Ecotrophic Efficiency (EE) that shows how relevant groups are used within the system as prey or catch, was approximately as expected (Table 2.7), except for small pelagic fish groups showing quite low EE, contrary to expectations. This may be explained by taking account of the fact that high biomass of small pelagic fish groups and their low production/biomass ratio, according to the PREBAL analysis (Figure 2.4).

Most of the total system biomass (excluding detritus groups) was comprised of functional groups at the lowest TLs; these include benthic invertebrates (31.2%), phytoplankton (20.4%), "micro and mesozooplankton" (14.2%), *Sardinella aurita* (8.9%), polychaetes (6.9%), and small benthic crustaceans (4.9%). "micro and mesozooplankton" accounted for 62.9% (307.7 $t.km^{-2}.y^{-1}$, Table 2.7) of the total consumption of the system (488.6 t.km-2.y-1, Table 2.8) excluding detritus and discards. The sum of flow to detritus in the system, was 291.9 $t.km^{-2}.y^{-1}$, flowing mainly from phytoplankton (51.4%) and "micro and mesozooplankton" (32.2%). Moreover, small pelagic fish species, and benthic non-fish groups both had high flow to detritus values.

Table 2.7. Outputs of the Gulf of Mersin model by functional group: Trophic level (TL); final biomass (Bf, $t.km^{-2}$); production/biomass ratio (P/B, y^{-1}); consumption/biomass ratio (Q/B, y^{-1}); ecotrophic efficiency (EE); gross food conversion efficiency (P/Q); consumption (Q, $t.km^{-2}\ y^{-1}$); flow to detritus (FD, $t.km^{-2}\ y^{-1}$); net efficiency (NE); omnivory index (OI); fishing mortality (F, y^{-1}); predation mortality (M2, y^{-1}); other natural mortality (M0, y^{-1}); exploitation rate (F/Z); respiration/assimilation ratio (R/A); production/respiration ratio (P/R); respiration/biomass ratio (R/B)

#	Functional Groups	Basic Estimates					
		TL	Bf	P/B	Q/B	EE	P/Q
1	Phytoplankton	1.00	4.80	76.85	0.00	0.59	
2	Micro and mesozooplankton	2.05	3.34	30.42	92.18	0.68	0.33
3	Macrozooplankton	2.77	0.23	20.33	61.61	0.95	0.33
4	Benthic small crustaceans	2.20	1.16	6.32	39.59	0.74	0.16
5	Polychaetes	2.12	1.62	3.61	24.06	0.87	0.15
6	Shrimps (L)	3.09	0.09	3.20	12.82	0.99	0.25
7	Shrimps	3.09	0.03	3.16	12.62	0.98	0.25
8	*Charybdis longicollis* (L)	2.97	0.08	2.40	8.68	0.99	0.28
9	Crab	2.97	0.03	2.40	8.11	0.99	0.30
10	Benthic invertebrates	2.06	7.34	0.94	3.93	0.83	0.24
11	Octopuses and cuttlefish	3.38	0.05	1.61	6.37	0.98	0.25
12	Squids	3.95	0.01	2.60	27.49	0.97	0.09
13	*Mullus barbatus* (<MLS)	2.85	0.01	2.19	9.56	0.88	0.23
14	*Mullus barbatus* (>MLS)	2.86	0.11	0.79	4.11	0.82	0.19
15	*Mullus surmuletus*	2.85	0.00	1.15	7.28	0.55	0.16
16	*Upeneus molucensis & pori* (L)	2.85	0.01	1.54	11.04	0.66	0.14
17	Anglerfish	4.17	0.00	0.85	3.94	0.70	0.22
18	*Solea solea*	3.45	0.01	0.92	6.93	0.72	0.13
19	Flatfishes	3.45	0.01	1.12	8.49	0.62	0.13
20	*Merluccius merluccius*	4.05	0.01	1.05	4.56	0.91	0.23
21	*Saurida undosquamis* (L) (<MLS)	4.09	0.00	2.27	9.58	0.63	0.24

Table 2.7. (continued)

22	*Saurida undosquamis* (L) (>MLS)	4.11	0.04	0.72	3.56	0.86	0. 20
23	Puffer fish (L)	4.07	0.01	1.25	5.52	0.66	0.23
24	Small discarded demersal fishes	3.37	0.04	1.35	9.07	0.83	0.15
25	Large discarded demersal fishes	4.08	0.02	0.76	4.29	0.97	0.18
26	Retained demersal fishes	3.16	0.00	1.05	4.63	0.99	0.23
27	Demersal Fish Species (L)	3.30	0.05	1.53	9.79	0.68	0.16
28	*Pagellus erythrinus* (<MLS)	3.51	0.00	2.20	9.73	0.85	0.23
29	*Pagellus erythrinus* (>MLS)	3.63	0.03	0.77	4.00	0.83	0.19
30	*Nemipterus randalli* (L)	3.30	0.02	1.73	8.86	0.95	0.20
31	*Pagellus acarne*	3.30	0.02	1.22	8.89	0.95	0.14
32	Benthopelagic fishes	3.42	0.01	1.74	10.19	0.97	0.17
33	Picarels and bogue	3.13	0.02	1.27	8.38	0.98	0.15
34	Demersal sharks	3.69	0.00	0.70	4.10	0.70	0.17
35	Demarsal rays and skates	3.91	0.05	0.56	3.52	0.70	0.16
36	*Engraulis encrasicolus*	3.05	0.20	2.73	14.62	0.18	0.19
37	*Sardinella aurita*	3.05	2.10	2.15	10.89	0.17	0.20
38	Horse mackerel	3.23	0.94	1.75	10.35	0.16	0.17
39	*Scomber japonicus*	3.41	0.15	1.19	7.32	0.27	0.16
40	Other small pelagic fishes	3.14	0.48	2.56	12.77	0.13	0.20
41	Small pelagic fishes (L)	3.14	0.27	2.07	13.16	0.16	0.16
42	Medium pelagic fishes	4.13	0.03	0.90	4.63	0.90	0.20
43	Large pelagic fishes	4.22	0.03	0.39	2.71	0.48	0.14
44	*Caretta caretta*	3.11	0.02	0.19	3.15	0.00	0.06
45	Seabirds	3.87	0.00	3.59	71.85	0.00	0.05
46	*Tursiops truncatus*	4.16	0.04	0.62	12.34	0.00	0.05
47	Discard	1.00	0.14			0.32	
48	Detritus	1.00	67.48			0.61	

Table 2.7. (continued)

#	Functional Groups	Key Indices			Mortalities				Respiration		
		FD	NE	OI	F	M2	M0	F/Z	R/A	P/R	R/B
1	Phytoplankton	150.15		0.00	0.00	45.55	31.30	0.00			
2	Micro and mesozooplankton	94.20	0.41	0.05	0.00	20.63	9.79	0.00	0.59	0.70	43.32
3	Macrozooplankton	3.03	0.41	0.28	0.00	19.32	1.02	0.00	0.59	0.70	28.96
4	Benthic small crustaceans	11.09	0.20	0.17	0.00	4.69	1.63	0.00	0.80	0.25	25.36
5	Polychaetes	8.58	0.19	0.12	0.00	3.12	0.49	0.00	0.81	0.23	15.64
6	Shrimps (L)	0.23	0.31	0.18	0.31	2.86	0.03	0.10	0.69	0.45	7.05
7	Shrimps	0.09	0.31	0.18	0.45	2.64	0.07	0.14	0.69	0.45	6.94
8	*Charybdis longicollis* (L)	0.15	0.35	0.21	0.39	1.99	0.02	0.16	0.65	0.53	4.54
9	Crab	0.05	0.37	0.21	0.48	1.91	0.01	0.20	0.63	0.59	4.09
10	Benthic invertebrates	6.92	0.30	0.06	0.00	0.79	0.16	0.00	0.70	0.43	2.20
11	Octopuses and cuttlefish	0.06	0.32	0.22	0.50	1.07	0.04	0.31	0.68	0.46	3.49
12	Squids	0.05	0.12	0.18	0.34	2.17	0.09	0.13	0.88	0.13	19.40
13	*Mullus barbatus* (<MLS)	0.03	0.29	0.55	1.02	0.89	0.27	0.47	0.71	0.40	5.46
14	*Mullus barbatus* (>MLS)	0.11	0.24	0.55	0.46	0.19	0.14	0.58	0.76	0.31	2.51
15	*Mullus surmuletus*	0.00	0.20	0.55	0.25	0.38	0.52	0.22	0.80	0.25	4.67
16	*Upeneus molucensis & pori* (L)	0.03	0.17	0.55	0.28	0.73	0.52	0.18	0.83	0.21	7.29
17	Anglerfish	0.00	0.27	0.45	0.55	0.05	0.25	0.65	0.73	0.37	2.30
18	*Solea solea*	0.01	0.17	0.20	0.43	0.23	0.26	0.47	0.83	0.20	4.62
19	Flatfishes	0.03	0.16	0.20	0.48	0.21	0.42	0.43	0.84	0.20	5.67
20	*Merluccius merluccius*	0.01	0.29	0.19	0.59	0.37	0.09	0.56	0.71	0.41	2.59
21	*Saurida undosquamis* (L) (<MLS)	0.01	0.30	0.04	0.60	0.82	0.85	0.27	0.70	0.42	5.40
22	*Saurida undosquamis* (L) (>MLS)	0.03	0.25	0.06	0.24	0.38	0.10	0.34	0.75	0.34	2.13
23	Puffer fish (L)	0.01	0.28	0.19	0.53	0.31	0.42	0.42	0.72	0.40	3.17
24	Small discarded demersal fishes	0.07	0.19	0.18	0.50	0.63	0.22	0.37	0.81	0.23	5.91
25	Large discarded demersal fishes	0.01	0.22	0.22	0.39	0.34	0.03	0.52	0.78	0.28	2.67
26	Retained demersal fishes	0.00	0.28	0.06	0.46	0.57	0.02	0.44	0.72	0.39	2.66

Table 2.7. (continued)

27	Demersal Fish Species (L)	0.12	0.20	0.15	0.26	0.77	0.50	0.17	0.80	0.24	6.30		
28	*Pagellus erythrinus* (<MLS)	0.01	0.28	0.21	1.16	0.71	0.33	0.53	0.72	0.39	5.58		
29	*Pagellus erythrinus* (>MLS)	0.03	0.24	0.24	0.22	0.42	0.13	0.28	0.76	0.32	2.43		
30	*Nemipterus randalli* (L)	0.03	0.24	0.15	0.29	1.36	0.09	0.16	0.76	0.32	5.36		
31	*Pagellus acarne*	0.04	0.17	0.15	0.45	0.70	0.06	0.37	0.83	0.21	5.90		
32	Benthopelagic fishes	0.01	0.21	0.13	0.64	1.05	0.05	0.37	0.79	0.27	6.41		
33	Picarels and bogue	0.04	0.19	0.05	0.62	0.63	0.02	0.49	0.81	0.23	5.43		
34	Demersal sharks	0.00	0.21	0.34	0.46	0.03	0.21	0.66	0.79	0.27	2.58		
35	Demarsal rays and skates	0.04	0.20	0.17	0.37	0.02	0.17	0.66	0.80	0.25	2.25		
36	*Engraulis encrasicolus*	1.05	0.23	0.00	0.01	0.49	2.23	0.00	0.77	0.30	8.97		
37	*Sardinella aurita*	8.31	0.25	0.00	0.02	0.34	1.79	0.01	0.75	0.33	6.56		
38	Horse mackerel	3.33	0.21	0.09	0.01	0.27	1.48	0.00	0.79	0.27	6.53		
39	*Scomber japonicus*	0.34	0.20	0.17	0.05	0.27	0.87	0.04	0.80	0.25	4.67		
40	Other small pelagic fishes	2.28	0.25	0.06	0.02	0.32	2.22	0.01	0.75	0.33	7.65		
41	Small pelagic fishes (L)	1.17	0.20	0.06	0.02	0.30	1.75	0.01	0.80	0.24	8.45		
42	Medium pelagic fishes	0.03	0.24	0.05	0.81	0.00	0.09	0.90	0.76	0.32	2.80		
43	Large pelagic fishes	0.02	0.18	0.08	0.18	0.00	0.20	0.48	0.82	0.22	1.78		
44	*Caretta caretta*	0.01	0.08	0.41	0.00	0.00	0.19	0.00	0.92	0.08	2.33		
45	Seabirds	0.02	0.06	0.58	0.00	0.00	3.59	0.00	0.94	0.07	53.89		
46	*Tursiops truncatus*	0.14	0.06	0.04	0.00	0.00	0.62	0.00	0.94	0.07	9.25		
47	Discard	0.00	0.00	0.00									
48	Detritus	0.00	0.00	0.44									

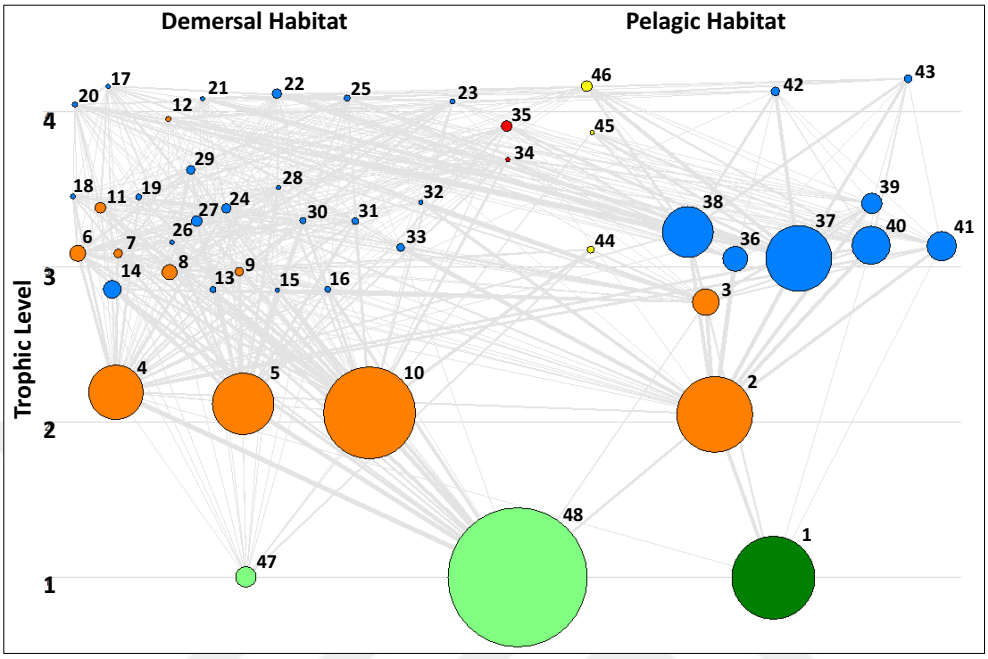

Figure 2.5. Flow diagram of Gulf of Mersin ecosystem among functional groups organised by their trophic levels. The numbers and the size of circles indicate functional group name and their biomass respectively (just look at Table 2.7 above). Dark green (primary producer); green (detritus); orange (invertebrates); blue (fishes); red (elasmobranchs); yellow (others)

According to the omnivory index (OI, Table 2.7), whilst food spectra of *Engraulis encrasicolus* and *Sardinella aurita* (planktivore fishes), *Saurida undosquamis* (<MLS) and *Tursiops truncatus* (predator) were narrow, red mullets, seabirds, anglerfish, *Caretta caretta* and demersal sharks had much more complex food preference. Moreover, predators such as large pelagic fishes, *T. truncatus*, medium pelagic fishes, *S. undosquamis,* etc., which prefer to feed on small pelagic fishes, had low OI. This may be because the biomass of small pelagic fish is relatively quite high in the region, and one of them, *Sardinella aurita*, is a dominant group. These predator groups can be expected to find plenty of small pelagic fishes as prey. Thus, the low OI for these predator groups (Table 2.7) can be considered as an indication of plenty of food (prey).

Mortality rates associated with natural causes (M) were split into predation mortality (M2) and other mortality (M0) by the model. Phytoplankton and "micro and mesozooplankton" showed the highest value of both M2 and M0. Macrozooplankton, benthic small crustaceans, polychaetes, squids, and shrimp-crab groups also presented high M2, and seabirds and small pelagic fish groups had high M0 rates. The groups with high M2, such as squids and shrimp-crab groups and some demersal fish groups, presented low M0 values. Naturally, predatory groups such as dolphin, seabirds, sea turtle, medium and large pelagic fishes and elasmobranchs had the lowest M2 rates. Fishing was responsible for the main mortality of some commercial demersal fish resources, as well as medium pelagic fishes. However, small pelagic fishes showed the lowest fishing mortality after unfished groups (*Tursiops truncatus*, seabirds and sea turtle, benthic invertebrates, polychaetes and benthic small crustaceans).

2.3.2. Network Analysis and Ecological Indicators

Indices describing ecosystems in terms of community energetics, cycling and information, are summarized in Table 2.8. The total system throughput (TST) and total biomass (excluding detritus) of the system were calculated as 1149.5 $t.km^{-2}.y^{-1}$ and 23.5 $t.km^{-2}$ respectively. TST comprised 43% total consumption, 25% total flows into detritus, 22% total respiration, and 10% total exports. The mean trophic level of the community (excluding TL1) was 2.38 (Table 2.8). A total of 75.4% of the consumption excluding primary producers, detritus and others was related to the pelagic compartment, and 24.6% to the demersal. However, 58.4% of the total biomass was in the demersal domain and 41.6% in the pelagic.

Table 2.8. Summary statistics and indicators for Gulf of Mersin model: Trophic level (TL)

Parameter	Values	Units
Ecosystem theory indices		
Sum of all consumption	488.61	$t.km^{-2}.y^{-1}$
Sum of all exports	114.17	$t.km^{-2}.y^{-1}$
Sum of all respiratory flows	254.63	$t.km^{-2}.y^{-1}$
Sum of all flows into detritus	292.12	$t.km^{-2}.y^{-1}$
Total system throughput	1149.53	$t.km^{-2}.y^{-1}$
Sum of all production	504.91	$t.km^{-2}.y^{-1}$
Calculated total net primary production (TPp)	368.65	$t.km^{-2}.y^{-1}$
Total primary production/total respiration	1.45	
Net system production	114.02	$t.km^{-2}.y^{-1}$
Total primary production/total biomass	15.69	
Total biomass/total throughput	0.02	
Total biomass (excluding detritus)	23.49	$t.km^{-2}.y^{-1}$
Mean transfer efficiency	9.37	%
Mean TL of the community	1.28	
Mean TL of the community (excluding TL1)	2.38	
Connectance index	0.27	
System omnivory index	0.16	
Shannon diversity index	2.13	
Ecopath pedigree index	0.63	
Parameter	**Values**	**Units**
Fishery indices		
Total catch	0.42	$t.km^{-2}.y^{-1}$
Mean TL of the catch	3.29	
Total demersal trawl catch	0.32	$t.km^{-2}.y^{-1}$
Mean TL of demersal trawl catch	3.26	
Landing/discard ratio of demersal trawl catch	1.26	
Total pelagic catch	0.11	$t.km^{-2}.y^{-1}$
Mean TL of pelagic catch	3.4	
Gross efficiency (catch/net p.p.)	0.001	
PPR to sustain the fishery/TPp	6.79	%
Cycling indices		
Finn's cycling index (of total throughput)	10.09	%
Throughput cycled (excluding detritus)	20.72	$t.km^{-2}.y^{-1}$
Throughput cycled (including detritus)	116.02	$t.km^{-2}.y^{-1}$
Predatory cycling index (of throughput without	3.67	%
Finn's mean path length	3.12	
Information indices		
Ascendency (A)	24.32	%
Overhead (O)	75.66	%
Capacity (C)	4773.98	Flowbits

At the ecosystem level, energy flow associated with the main trophic components in the food web are given in Figure 2.6. The Lindeman spine showed that, TL II and III had the highest % of TST and biomass (excluding TLI). Energy was transferred most efficiently between TL II and III. While the energy used for respiration (212.4 $t.km^{-2}.y^{-1}$), and flow to detritus (119.84 $t.km^{-2}.y^{-1}$) was the highest in TL II, the highest total export occurred in TL III with 0.26 $t.km^{-2}.y^{-1}$.

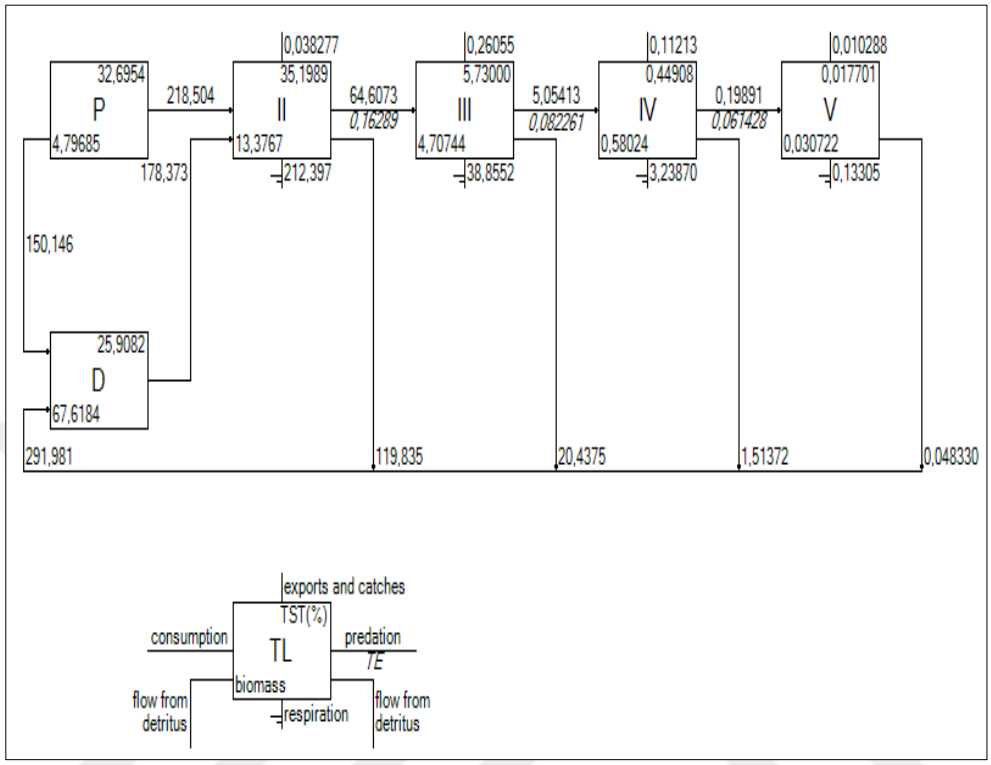

Figure 2.6. Lindeman spine demonstrating trophic flows between integer trophic levels (TL). Primary producer (P); detritus (D); Total system throughput (TST)

The mean transfer efficiency of the system was estimated as 9.37% (Table 2.8). The ratio of TPp to TR and the differences between them (NSP) were calculated as 1.44 and 114.02 $t.km^{-2}.y^{-1}$ respectively, while the ratios related to biomass were estimated at 15.69 for TPp/TB and 0.02 for TB/TST. The SOI was 0.16, Finn's mean path length 3.12 and the Ascendency was estimated at about 24% of system capacity (4773.98 t flowbits $.km^{-2}.y^{-1}$).

2.3.3. Mixed Trophic Impacts and Keystone Groups

Direct and indirect impacts have been detected using mixed trophic impact (MTI) (Figure 2.7). Generally, a functional group had negative impact on their prey and competitors, and a positive impact on their predators, although it is possible for a predator to have a positive impact on its prey if it also feeds one of the prey's other predators. Also, a group usually has a negative impact on itself as it competes for resource (F. 7). These results were re-presented by trophic level in Figure 2.8. The pattern in Figure 2.8 may prove the general cases described above in terms of relation type between impacting and impacted groups as prey, predator and competitor. Moreover, these results highlight the pattern that as the distance (in trophic level, TL) between impacting and impacted groups increases, the impact tends to approach zero (Figure 2.8).

Planktivore ("micro and mesozooplankton" and macrozooplankton) and benthivore (benthic small crustaceans, polychaetes and benthic invertebrates) groups representing the base of the food web had direct and indirect impacts throughout the food web. This might be a preview of possible bottom-up control in the system (Figure 2.7). Also, Figure 2.8 support this finding, because the effects of functional groups under TL-II (<TL-II) on the upper TLs were significant. In this figure, <TL-II was demonstrated in the second (upper) x-axis as impacting group, while upper TLs were demonstrated in the first (lower) x-axis as impacted group.

Tursiops truncatus had a direct negative effect on its prey groups such as small pelagic fish groups and squids and an indirect negative effect on the prey's predators such as *Saurida undosquamis* (L) (>MLS), seabirds and squids. An indirect positive effect on the prey's prey and on their predators, such as macrozooplankton and benthopelagic fishes, was also observed (Figure 2.7). Some functional groups had no noticeable impact on other groups such as demersal sharks, "demersal rays and skates", *Caretta caretta*, seabirds, retained demersal fishes, *Solea solea*, flatfishes, anglerfish and red mullets excluding *Mullus*

barbatus (>MLS) (Figure 2.7). This is probably related to their small biomass in the system.

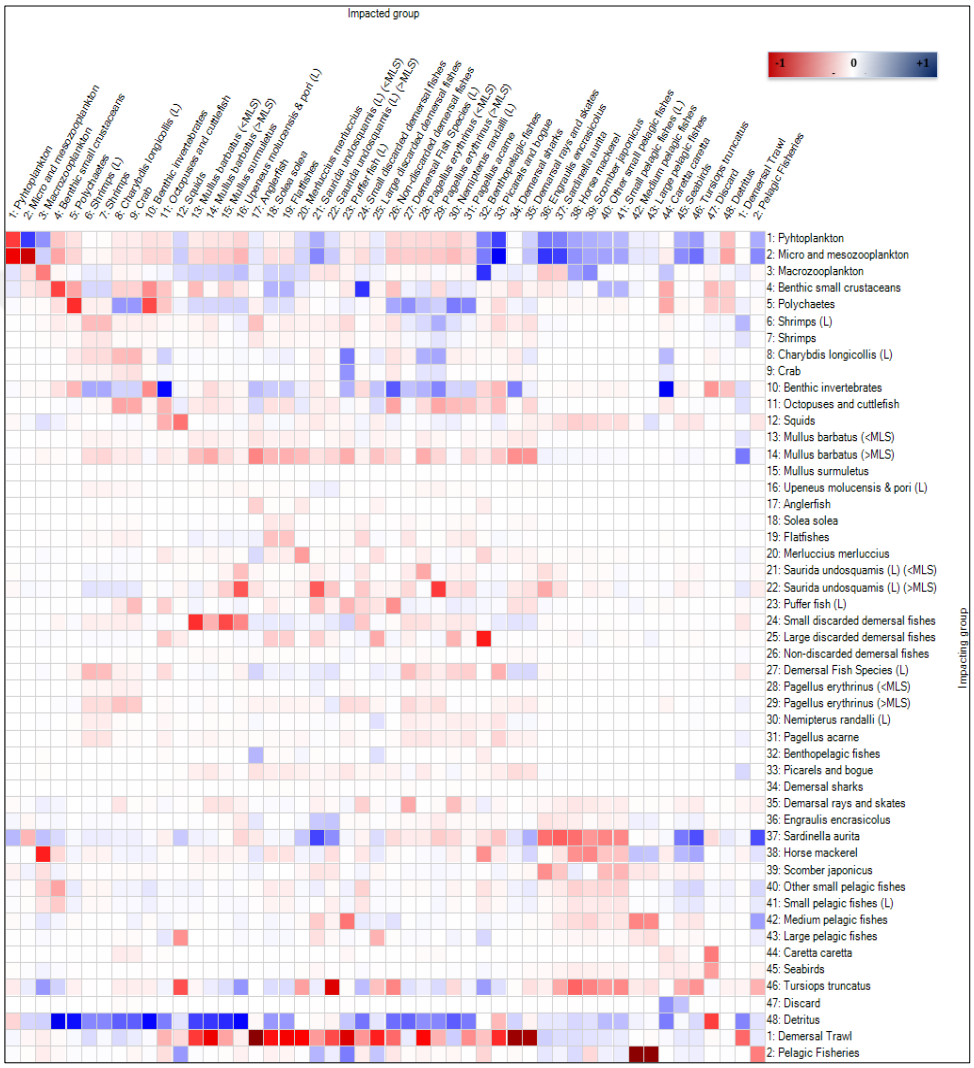

Figure 2.7. Mixed trophic impact analysis (MTI). MTI values range -1 (red) and +1 (blue) and limits indicate strong effect

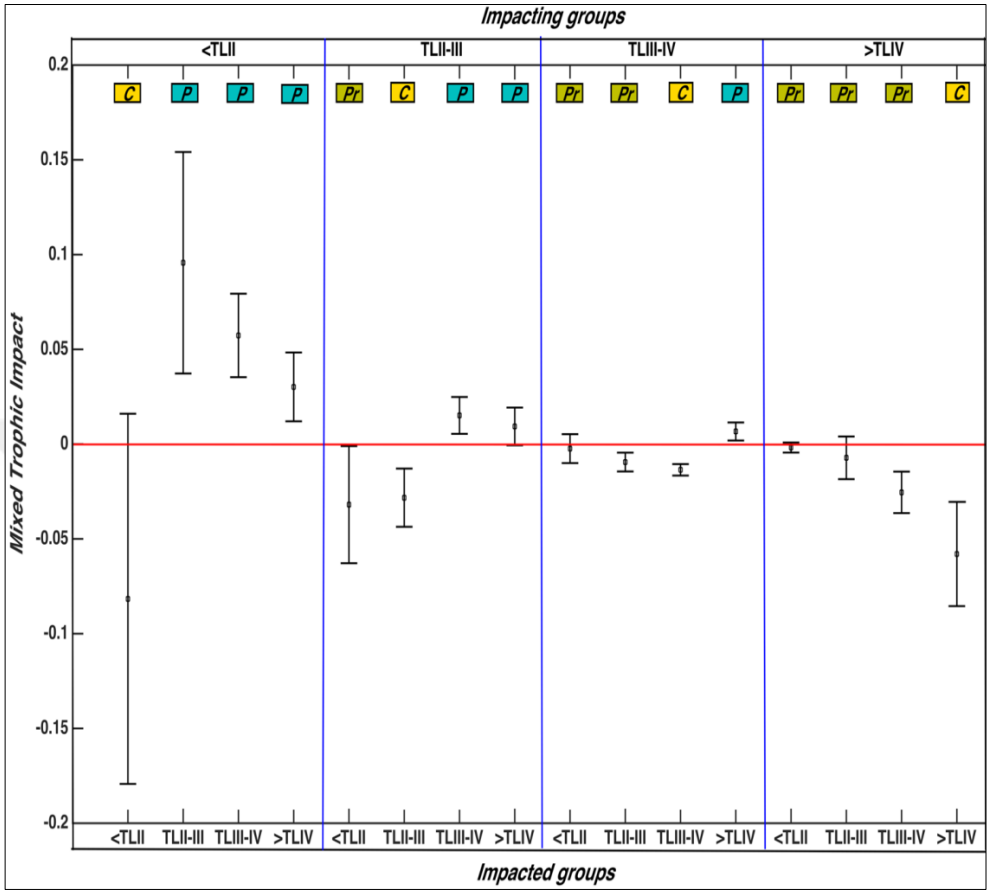

Figure 2.8. Direct and indirect relationships among TLs in terms of mixed trophic impact analysis. First (lower) x-axis shows impacted TLs and the second (upper) shows impacting TLs by main relation type between impacting and impacted TLs: Competition (C); Prey (P); Predator (Pr). Y-axis represents MTI value

The keystoneness analyses show that "micro- and mesozooplankton", benthic invertebrates and *Sardinella aurita* had high keystoneness and high biomass, while *Tursiops truncatus* had relatively low biomass but a high overall impact (Figure 2.9). Although no functional groups were identified as a real keystone species due to the fact that their keystoneness indexes are not greater than zero, "micro and mesozooplankton", benthic invertebrates, *Sardinella aurita* and *Tursiops truncatus* can be considered as a keystone species (Libralato et al., 2006).

Moreover, both MTI and keystone indexes indicated the importance of these functional groups as having a structuring role in the Gulf of Mersin ecosystem.

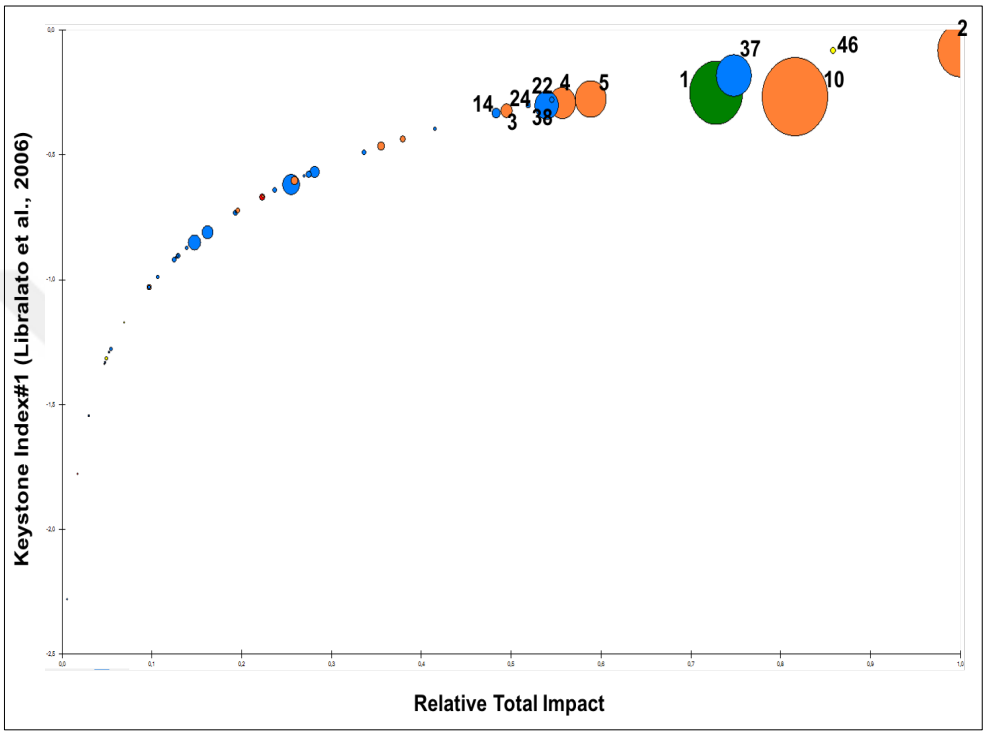

Figure 2.9. The keystone and the relative total impact of the functional groups in the model. The numbers and the size of circles indicate functional group name and their biomass respectively

2.3.4. Fisheries Impacts on the Ecosystem

Demersal trawling was responsible for approximately 76.2% of the total catch of 0.42 $t.km^{-2}.y^{-1}$ (Table 2.8). The ratio of landing/discard in the trawl fisheries was 1.26 (Table 2.8). Discards were an important component of the total fish removals. The highest landings and discards proportions were calculated for *Mullus barbatus* (>MLS) (29%) and *Charybdis longicollis* (L) (23%) respectively (Table 2.2). Mean TL of the catch (mTLc) was 3.26 for demersal trawl fisheries, 3.40 for pelagic fisheries, and 3.29 for both (Table 2.8).

Fishing mortality (F) was highest for *Pagellus erythrinus* (<MLS), *Mullus barbatus* (>MLS) and medium pelagic fishes (Table 2.7).

Fisheries had a wide impact on numerous functional groups in the food web. Demersal trawl fisheries showed high direct and indirect negative effects on demersal fish groups (Fig 7); moreover, the highest negative effects were on low biomass and high TL demersal groups such as anglerfish, demersal sharks and "demersal rays and skates". Shrimps (functional groups 6 and 7), crabs (functional groups 8 and 9) and small pelagic fishes were slightly positively affected by demersal trawl fisheries. Pelagic fisheries had strong direct and indirect negative effects on medium and large pelagic fishes, and a positive impact on squids, *Saurida undosquamis* (L) (<MLS), pufferfish and some small pelagic fishes (Figure 2.7).

Primary production required to sustain these catches (%PPRc) considering primary producers and detritus was 6.79%. The gross efficiency (GE, total catch/total primary production) was higher than its mean global value (0.0002) (Christensen et al., 2005) with 0.0011 (Table 2.8).

2.4. Discussion

This is the first Ecopath model that identifies the structure and impacts of fishing on the ecosystem in the Mediterranean coast of Turkey, and the second model for the Levant Sea after the Israeli marine continental shelf (Corrales et al., 2017a, 2017b). The topology of this model differ in several important aspects from other models for the Mediterranean. The major differences are: model structure; production; biodiversity; depth etc. Research questions and modeller's approach are responsible for the discrepancy in the number of functional groups. This is also because of differences in biodiversity in the Mediterranean from west to east (Coll et al., 2010; Tortonese, 1964) in addition to the discrepancy of primary production (Bosc et al., 2004; Lazzari et al., 2012) and secondary production (Mazzocchi et al., 2014). Thus, the closest structure can be observed in Tsagarakis et al. (2010),

and Corrales et al. (2017b). Moreover, the area modelled here is different in terms of geographic and physical characteristics. The depth range of other Ecopath models in the Mediterranean generally includes waters deeper than 200 m. This model and a few others (Corrales et al., 2017b; Hattab et al., 2013) do not cover the areas deeper than 200 m. Thus, the biomass of some functional groups, such as anglerfish, *Merluccius merluccius,* is low in comparison to other Mediterranean models. Another limitation in terms of species distribution related to habitat depth is that the modelling area does not include depths shallower than 20 m, which are important fishing grounds for some demersal species. This also results in low biomass for some groups including, but not limited to, *Upeneus molucensis* & *pori* (L) and "demersal rays and skates". The findings of Gücü (2012) support this consideration. Another difference is the timeframe: other Ecopath models are not for the same period. To conclude, ecosystem indices cannot be compared across systems as they are dependent on the topology of the ecosystem, and ecosystems do not have the same topology. Thus, comparisons among models are difficult. However, some indices may just provide an opportunity to understand fundamental differences among the models.

2.4.1. Network Analysis and Ecological Indicators

This model reflects the common properties of the Mediterranean models in terms of ecosystem characteristics. The size of the entire system (TST) and total biomass were lower than in the central and west basins of the Mediterranean, which is as expected because of the oligotrophic nature of the eastern Mediterranean (Siokou-Frangou et al., 2010; Yücel, 2013) (particularly the Levant Basin), excluding Moutopoulos et al. (2013) and Tecchio et al. (2013), but higher than Corrales et al. (2017) which is another model in the Levant Basin. However, the highest ratio for total respiration (22% of TST) and lowest ratio for total flow to detritus in the system (25% of TST) were observed in the Mediterranean. The dominance of pelagic compartments in terms of flow seen in the present model, is

well-known for the Mediterranean (Coll et al., 2007; 2006; Corrales et al., 2017b; 2015; Tsagarakis et al., 2010). Total biomass is generally dominated by pelagic compartments in the Mediterranean (Coll et al., 2007; Corrales et al., 2015). In the present model, the total biomass of pelagic groups was lower than that of demersals. This discrepancy is probably due to high biomass of benthic invertebrates, because benthic invertebrates were responsible for 31.2% of total biomass (excluding detritus and discard), and *Sardinella aurita* which is the dominant pelagic fish constituted only 8.9% of total biomass.

At the functional group level, TLs of functional groups were generally in concordance with those previously estimated by other Ecopath models for the Mediterranean. The TL of dolphin (*T. truncates*) (4.16) was lower than other estimates (between 4.30 – 4.58 for the Mediterranean: (Corrales et al., 2017b; Tsagarakis et al., 2010) but more similar to that of the Greek Ionian Sea model (TL=4.05 for common dolphin, TL=4.16 for bottlenose dolphin, *T. truncates* and TL=4.24 for other dolphins) (Moutopoulos et al., 2013). In this model, the diet preference of dolphin was dominantly (more than 90%) on small pelagic fishes which have low TL. Those relatively high biomasses in the region may be responsible for this preference. The TL of red mullets was similar to the finding by Tsagarakis et al. (2010) and lower than the other Mediterranean models. Also, the TL of *S. undosquamis* was high when compared with the estimate from the other Levant Sea model taking into account this Lessepsian species as a functional group (Corrales et al., 2017b). In this study, the findings show that discard is an important direct food resource for some groups such as seabirds and sea turtle *(C. caretta)* (Table 2.6), and effects their TLs as seen in other ecosystem models of the Mediterranean Sea (Coll et al., 2006; Corrales et al., 2017b; Tsagarakis et al., 2010).

S. aurita was the dominant small pelagic species in the region (Table 2.7 and Figure 2.5). However, in other areas the dominant species among small pelagics are *E. encrasicolus* in the north Aegean Sea (Tsagarakis et al., 2010) and

S. pilchardus in the central and west Mediterranean (Coll et al., 2007, 2006; Corrales et al., 2015; Hattab et al., 2013; Moutopoulos et al., 2013). Thus, the most important area for *S. aurita* is around the Levantine Sea (Sabates et al., 2006; Tsikliras, 2008), specifically the Gulfs of Mersin and Iskenderun and Nile delta region in terms of its habitat preference (Sakınan, 2014). The dominance of a small pelagic group is a characteristic of the Mediterranean food webs (Coll and Libralato, 2012) as well as upwelling ecosystems (Cury et al., 2000; Heymans et al., 2004).

Ecotrophic efficiency (EE), which shows how relevant groups are used within the system as prey or catch, was approximately compatible with the results of other Mediterranean models. Low EE of apex predators (*C. caretta*, seabirds, and *T. truncatus*) was also expected due to zero fishing and predation mortalities (Christensen et al., 2008). However, EEs of small pelagic fish groups were found quite low, contrary to expectations (Table 2.7). This low EE can imply unmodelled predation (Ainsworth and Walters, 2015), or bad parameterisation of the model: Overestimation of the biomass of small pelagic fish groups and/or underestimation of their predator's biomass may be responsible for this low result. It may be also associated with a wrong catch estimation of pelagic compartments in this model. The estimations used here were taken from government statistics which are well known to be unreliable, and the estimation of reconstructed catch is more than reported catch (Ulman, 2014; Ulman et al., 2013). Thus, in future work better catch estimates need to be derived to improve this model.

The Omnivory index (OI) depends entirely on the variety of prey's TL. Thus, OIs of small pelagic fishes, zooplankton groups and some benthic groups are generally close to zero. In this model, large pelagic fishes, medium pelagic fishes, and *T. truncatus* which prefer to feed on small pelagic fishes (Table 2.6) had a low OI (Table 2.7). This is because the biomass of small pelagic fish is relatively high in the region, and one, *S. aurita*, is a dominant group. Thus, there is easy and plentiful food for their predators. The importance of small pelagic fishes has been

described in many ecosystems (Libralato et al., 2006). OI of some predators such as large pelagic fishes (Corrales et al., 2015), medium pelagic fishes (Tsagarakis et al., 2010) and dolphins (Coll et al., 2007, 2006) are also low in some other Mediterranean models.

The northeastern Mediterranean is a hot spot for the introduction of Lessepsian species in the Mediterranean Sea (Katsanevakis et al., 2014; Mavruk et al., 2017). Some Lessepsian species have even been commercially exploited (Gücü et al., 2010), and are an important part of the ecosystem (Mavruk et al., 2017). One of the major concerns in this system should be *S. undosquamis* due to its feeding habits. Although it has a wide range of prey in its own diet, dominant small pelagic species are a major part of its diet (Özyurt et al., 2017). This behaviour was also reported in the Mediterranean coast of Israel (Golani, 1993). Conversely, another report from the same area reveals that this species feed on red mullet (Bingel and Avsar, 1988). Thus, although there are some controversy about the feeding ecology of this species, current reports show that it prefers to eat dominant pelagic fishes. According to this model results, the OI of *S. undosquamis* was low because of the dominance of small pelagic fishes. When considering the predation history of this species, this feeding behaviour can be considered an advantage for the Mediterranean ecology.

At the ecosystem level, total flows in the system were inversely correlated with TL as ecological theory dictates (Lalli and Parsons, 1997). Mean transfer efficiency (TE) was the lowest for the Mediterranean, and slightly lower than the values obtained for the north-central Adriatic Sea model (10%) (Coll et al., 2007), and the average reported worldwide (10%) (Pauly and Christensen, 1995). The calculated (possibly wrongly) low EE of small pelagic fishes, which are in the middle of the food web with their high biomass, decreases the mean TL of the system, because energy cannot go through the food web efficiently. While TE was about 16% between TL II and TL III (from zooplankton to small pelagic fishes), TE decreased to around 8% between TL III and TL IV (small pelagic fishes to

upper TLs) (Figure 2.6). Coll et al. (2007) also shows this decrease, but do not show the low EE of small pelagic fishes. The Lindeman spine showed a strong link between TLII and detritus, and this link highlighted one of the ways the benthic pelagic coupling occurs through planktonic groups and detritivores via detritus, and shows the indirect importance of the microbial food web. These attributes could be described as a key functioning for the Mediterranean (Coll et al., 2006; Corrales et al., 2017b, 2015; Tsagarakis et al., 2010).

The indices related to ecosystem energetics revealed that Gulf of Mersin ecosystem is at a low ecosystem development state (Christensen, 1995; Odum, 1969; Odum and Barrett, 1971), because there was more energy produced than respired within the system (TPp/TR and NSP) and a low level of biomass accumulation (TPp/TB), and the food web was more chain-like than web-like (FCI, SOI) (Table 2.8).

2.4.2. Mixed Trophic Impacts and Keystone Groups

According to various authors, low trophic level groups are critical components of the ecosystem in the Mediterranean Sea, particularly small pelagic fishes, and zooplankton is an important component of the coastal systems (Libralato et al 2016; Coll et al., 2007; Corrales et al., 2015; Hattab et al., 2013; Tsagarakis et al., 2010). This was also found in this model: “micro and mesozooplankton”, *S. aurita*, a dominant small pelagic fish, and low benthic trophic groups such as benthic invertebrates, polychaetes and benthic small crustaceans were identified as important groups in terms of overall effect (Figure 2.9).

The MTI results highlighted the structural role of “micro and mesozooplankton” because of its direct and indirect effect on the food web (Figure 2.7). This is indicative of a possible bottom-up mechanism, in line with the previous studies in the Mediterranean and Atlantic (Piroddi et al., 2017; Torres et al., 2013). The MTI also revealed that hypothetical changes in the biomass of small

pelagic fishes would affect both their prey and predators in Gulf of Mersin ecosystem (Figure 2.7), similar to other marine ecosystems (Bănaru et al., 2013; Coll et al., 2007, 2006; Corrales et al., 2015; Tsagarakis et al., 2010), highlighting the importance of these groups in terms of possible wasp-waist predator-prey interactions (Cury et al., 2000). These high biomass groups can be considered as structuring components due to their critical roles of energy transfer through the food chain (Coll et al., 2013; Heymans et al., 2011).

The relative total impact versus keystoneness showed that *T. truncatus* (dolphin) is a key species, having relatively low biomass but high overall impact in the region (Figure 2.9). Dolphins were also identified as keystone species by Coll et al. (2006); Piroddi et al. (2010); Torres et al. (2013). The MTI revealed how dolphins affect the food web. For example, *T. truncatus* had *i)* direct negative effect on its prey groups such as small pelagic fishes and squids, *ii)* indirect negative effect on the prey's predators such as *S. undosquamis* (>MLS), seabirds and squids, and *iii)* indirect positive effect on prey's prey and even their predators such as macrozooplankton (prey's prey) and benthopelagic fishes (predators of macrozooplankton). Dolphin populations have been declining in most ecosystems and it is suggested that they can be used as an indicator to follow fishing impact (Libralato et al., 2006).

2.4.3. Fisheries Impacts on the Ecosystem

Fishing, especially demersal trawl fisheries, was found as an important component of the food web model in Gulf of Mersin. This finding agrees with previous Ecopath models in the Mediterranean (Boudaya et al., 2010). Demersal trawl catch (0.32 $t.km^{-2}.y^{-1}$) made up the majority (76.2%) of the total catch (0.42 $t.km^{-2}.y^{-1}$). Discard estimation is important to calculate real fishing mortality which enhances the prediction of real fishing impact (Zeller and Pauly, 2007), and this model includes the discard estimation for each demersal species. However, the catch ($t.km^{-2}.y^{-1}$) was lower than the other Ecopath models in the Mediterranean,

except for the deep sea (1000-1400m) model of (Tecchio et al., 2013) (1000-1400 m). This may be because of an underestimation of catch in pelagic fisheries in the region (Pauly et al., 2014; Ulman, 2014; Ulman et al., 2013), and also this model did not cover small scale fisheries because of the model limitations. Small scale fisheries are responsible for significant fish removals in the Mediterranean (Papaconstantinou and Farrugio, 2016). Thus, the lack of small scale fishing in this model would need to be addressed in the future if we want a full picture of the ecosystem, and manage the fishery in an ecosystem based manner.

Mean TL of the catch is used to explore overfishing risk on the ecosystem (Libralato et al., 2008) and allow researchers to identify the known phenomenon "fishing down marine food webs" (Pauly and Palomares, 2005; Pauly D. et al., 1998). The mean TL of the catch in this model is lower than the models produced by Corrales et al. (2017); Hattab et al. (2013); Moutopoulos et al. (2013); Torres et al. (2013); Tsagarakis et al. (2010), but higher than others (Bănaru et al., 2013; Coll et al., 2007, 2006; Corrales et al., 2015; Piroddi et al., 2010), and also higher than the value (TL=3) calculated and reported for the entire Mediterranean in 1994 (Pauly D. et al., 1998). Moreover, the GE index (0.0011) was found to be high when comparing to the global value (GE=0.0002) (Christensen et al., 2008), but compatible with the other Mediterranean models (Corrales et al., 2015). The MTI results highlighted that fisheries had large-scale impacts on many medium and high TL groups. This was also compatible with other ecosystem models in the Mediterranean (Bănaru et al., 2013; Coll et al., 2007, 2006; Corrales et al., 2015; Tsagarakis et al., 2010). Exploitation rates of the functional groups seem to be low. This is because no demersal group exceeded the recommended exploitation rate (F/Z) of 0.8 for demersal stocks (Mertz and Myers, 1998), but several demersal groups and medium pelagic fishes had a higher than recommended F/Z of 0.5 by Rochet and Trenkel (2003) (Table 2.7). Medium and large pelagic fishes had a higher than recommended F/Z of 0.4 which is more conservative for pelagic stocks for sustainable fisheries management (Patterson, 1992).

3. CHAPTER: POTENTIAL IMPACT OF SHIFTING TRAWL CODENDS IN THE GULF OF MERSIN, NORTHEASTERN MEDITERRANEAN

3.1. Introduction

Fisheries management in the Mediterranean Sea appears to be considerably complicated due to the multi-species nature of demersal trawl fishery. Poor selectivity and high discard ratios of demersal trawls are of significant concern in the Mediterranean Sea (Tudela, 2000). The fisheries are regulated with area restrictions for demersal trawl fisheries, fishing effort control, the establishment of seasonal closures and minimum distance off the coast, codend selectivity, and minimum landing size defined by (Papaconstantinou and Farrugio, 2016).

A large number of studies exist on codend selectivity of demersal trawl fisheries, including in the Mediterranean Sea, most of which focus on mesh size, mesh geometry or panels (ICES, 2007; Stewart, 2002). The 40 mm (D40) and 44 mm (D44) diamond mesh codends used in the Mediterranean are characterized by poor selectivity for commercial species (Ateş et al., 2010; Bahamon et al., 2006; Eryaşar et al., 2014a; Guijarro and Massutí, 2006; Lucchetti, 2008; Ordines et al., 2006; Özbilgin et al., 2007, 2015, 2013, 2012; Özbilgin and Tosunoğlu, 2003; Sala et al., 2008; Sala and Lucchetti, 2010; Tokaç et al., 2010, 2004) and high discard ratios (Bahamon et al., 2006; Gökçe et al., 2016; Guijarro and Massutí, 2006; Lucchetti, 2008; Ordines et al., 2006; Özbilgin et al., 2015, 2013; Sanches et al., 2004; Tudela, 2000). Several studies have demonstrated that the implementation of 40 mm square mesh (S40) codend in the Mediterranean demersal trawl fisheries improve size selection of commercial species (Bahamon et al., 2006; Guijarro and Massutí, 2006; Lucchetti, 2008; Ordines et al., 2006; Özbilgin et al., 2015, 2013, 2012; Sala et al., 2008; Sala and Lucchetti, 2010) and reduce discards (Bahamon et al., 2006; Guijarro and Massutí, 2006; Lucchetti, 2008; Ordines et al., 2006; Özbilgin et al., 2015, 2013).

The General Fisheries Commission for the Mediterranean (GFCM) recommended the use of S40 or a diamond mesh size of at least 50 mm (D50) codends (GFCM, 2007). Currently, the Commission has the authority to make binding recommendations for fisheries management. In addition, the replacement of S40 codend by D40 codend has been amended by European Commission regulations (EC, 1967/2006), and D50 codend can be used, if fishermen makes a justified request (E.C., 2006). These regulations are designed for the targeted species, considering only their respective population characteristics, and ignoring species interactions. The effects of improving codend selectivity on the ecology of the ecosystem are not well known.

Due to its topographic characteristics the Gulf of Mersin is one of the important demersal trawl fishing grounds of the Turkish Mediterranean coast. It is one of the widest Gulfs in the eastern Mediterranean (Gökçe, 2012). Demersal trawling is regulated with restrictions such as closed zones, seasons, distance, and the shape and size of the codend by Turkish Fisheries Regulations (TFR). Demersal trawling is prohibited from 15 April to 15 September (Official Gazette, 2016), and banned within 2 - 3 nm from the coast during the whole year. Currently, TFR prescribe a minimum 44 mm diamond-mesh (D44) codend for the Mediterranean coast of Turkey (Official Gazette, 2016).The usage of S40 codend in demersal trawl fisheries is left to fishermen's choice. However, 44 mm diamond mesh handmade slack knotted nets (CD44) have been commercially used in the region (Eryaşar et al., 2014a; Özbilgin et al., 2015). CD44 has rather poor selectivity and a high discard rate (Eryaşar et al., 2014a; Özbilgin et al., 2015), with 50% of the catch by weight and 70% by numbers discarded in Gulf of Mersin (Özbilgin et al., 2015).

Ecosystem Based Fisheries Management (EBFM) is an important approach to management of complex ecosystems. It considers the impacts of fishing on the ecosystem in terms of target and non-target species, reflecting trophic interactions within the whole food web as well as environmental factors (Botsford et al., 1997;

Coll et al., 2008a; Coll and Libralato, 2012; Duda and Sherman, 2002). The EU established a framework for community action in marine environmental policy (Marine Strategy Framework Directive, MSFD) and many scientific studies have been carried out around this framework, including the ecosystem approach to fisheries (Staples and Funge-Smith, 2009) and how to achieve MSFD's good environmental status (Coll et al., 2015; Lassen et al., 2013; Piroddi et al., 2015a, 2015b; Rombouts et al., 2013).

The goals of this chapter are to evaluate the potential effects of improved codend selectivity on the ecosystem and the main target species in Gulf of Mersin and to supply a more tangible assessment to understand EBFM by using an Ecopath model.

The main research question of this chapter is: If we switched from CD44 codend, which traditionally fishermen use, to D44, D50 or S40 codends which are more selective, would the shift have a noticeable impact on the ecosystem and main target species? And the secondary question is: What are the outcomes from the ecosystem model?

3.2. Materials and Methods

3.2.1. Model Structure

This study was based on well-described species-specific catch and selectivity data for CD44 codend and alternative codends (D44, D50 and S40) fisheries from Gulf of Mersin in the eastern Mediterranean (Figure 3.1). The data was obtained from the "Investigations to Improve Species and Size Selectivity in Gulf of Mersin Trawl Fisheries" project (TUBITAK 1090684). The results from this project (called trawl surveys here) were described in Özbilgin et al. (2013) under the section "fisheries based demersal trawl survey" during the fishing months between 2009 and 2013.

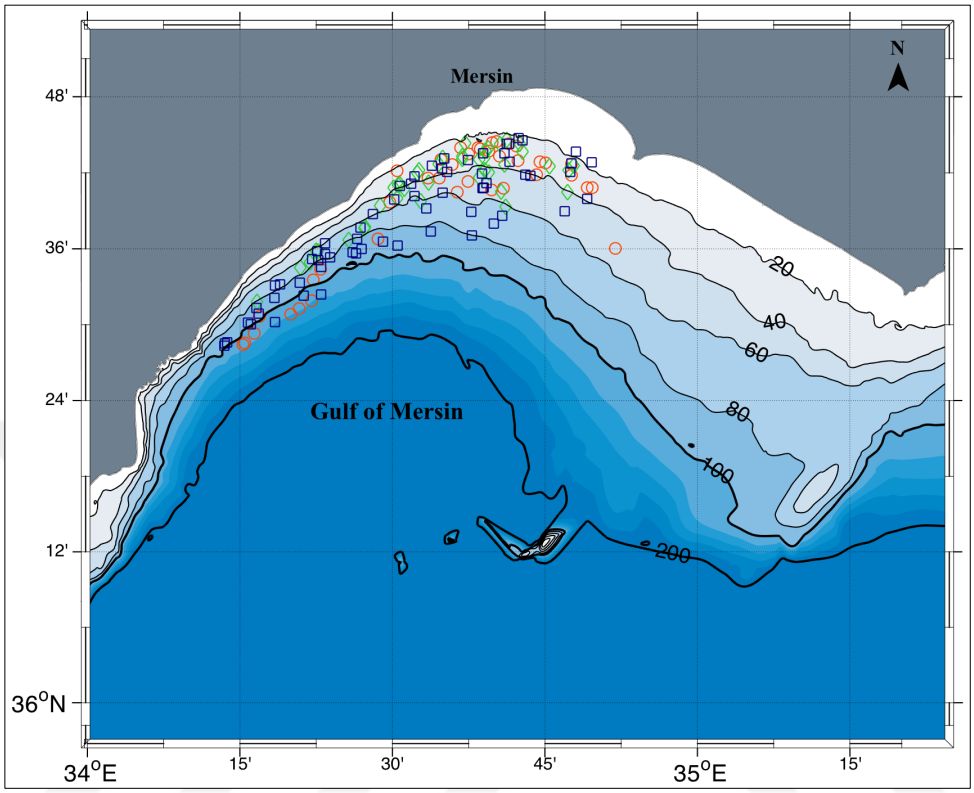

Figure 3.1. Trawl hauls for catch estimation of D44 Codend (orange, circle), D50 Codend (green, diamond), and S40 Codend (blue, square)

The baseline Ecopath model of the Gulf of Mersin (GoM), representing the structure of the ecosystem and identifying direct and indirect impacts of fishing on trophic energy flows in the Gulf of Mersin was set up using catch (C) (as landing + discard) data calculated for traditional gear with 44 mm mesh size hand-woven slack knotted codend (44 mm commercial diamond, CD44) currently used by trawl fishermen (as explained in chapter II).

In the context of the main research question, three additional mass-balance Ecopath models were developed to represent the effect of D44, D50 and S40 codends on the ecosystem, called GoM_D44, GoM_D50, and GoM_S40 respectively. The food web topology (number compartments, links among compartments, etc.) and methodology of construction for the three Ecopath models

(GoM_D44, GoM_D50 and GoM_S40) were the same. Moreover, all models were balanced using the same biomass and diet matrix to ensure similar topology, with the only differences being the catch.

Finally, three scenarios were defined to investigate the main question;

- **Scenario 1 (Sc. 1):** Switching from CD44 codend to D44 codend,
- **Scenario 2 (Sc. 2):** Switching from CD44 codend to D50 codend,
- **Scenario 3 (Sc. 3):** Switching from CD44 codend to S40 codend.

For fished species, the Production/Biomass (P/B) ratio were re-estimated for each model as the P/B ratio is equivalent to the total mortality (Z, y^{-1}) (Table 2.3 in chapter II). Z is equal to the sum of fishing mortality (F, y^{-1}) and natural mortality (M, y^{-1}) under steady-state conditions (Allen, 1971), and F is the ratio of catch (C) and biomass (B) (F=C/B) (Heymans et al., 2016). Catch per functional group for each model were calculated using species-specific catch. The Production/Consumption (P/Q) ratio produced by the baseline model (GoM model) was assumed to stay constant and these were therefore used estimate the Consumption/Biomass (Q/B) ratio for the other models. Input data are given in detail in Table 3.1.

3.2.2. Catch Estimates

All models included demersal and pelagic fisheries that occur in the modelled area. However, as the focus of this study was mainly demersal fisheries, the pelagic catches remained the same in all models. Demersal catches for each model have been estimated by using the trawl survey describing species-specific landing and discard data, and also selectivity data for main target species. The following assumptions were made;

For many demersal fished groups, the catch data for D44, D50 and S40 codends were estimated from CPUE values with 33, 21 and 33 valid hauls in the trawl surveys, respectively (Figure 3.1) as explained in Chapter II, section 2.2.7. Here, we assumed that there is negative correlation between CPUE and selectivity performance (Bahamon et al., 2007; Ordines et al., 2006). This assumption was only applied for the species on which there is no selectivity data.

Some groups such as anglerfish, puffer fish (L), demersal sharks, and "demersal rays and skates" were excluded because they were assumed to be non-selected groups due to their quite low abundance, body shape and size (Saygu and Deval, 2014). Thus, their catch data were assumed to the same in all models.

For some main commercial species (Table 3.2), the size selections by codend data were obtained from the trawl survey (Eryaşar, 2014; Eryaşar et al., 2014a; Özbilgin et al., 2015). The calculation processes applied for each codend separately was described as:

Length frequency distributions of fish (F_L) that entered the gear (codend + cover) were re-expressed as the distribution of weight at length (S) using length-weight relationship:

$$\boldsymbol{W_{(i)} = a * L_{(i)}^{b}}$$

$$\boldsymbol{S_{(i)} = F_{L(i)} * W_{(i)}}$$

where i is the index of length classes, $W(i)$ is the weight of the fish and $L(i)$ its length. The distribution was multiplied by the estimation of the size selection in the codend (length-dependent retention probability) ($r(L_i)$):

$$\boldsymbol{r(L_i) = exp(v_1 + v_2 * L_{(i)}/[1 + exp(v_1 + v_2)]}$$

where v_1 and v_2 are regression parameters to be estimated (Table 3.2).

$$\boldsymbol{D_{(i)} = S_{(i)} * r(L_i)}$$

where D_i is the retention probability in the codend as weight for each size class i.

The aim of this process was to estimate the values of this function for all relevant size classes. Then, $D'_{(i)}$ was expressed as:

$$\boldsymbol{D'_{(i)} = D_{(i)} \Big/ \sum_{i=1}^{N} S_{(i)}}$$

where N is the number of size classes. $D'_{(i)}$ is percentage of fish in each size class i as weight. Retained weight for each size class i in the codend ($C_{L(i)}$) was calculated as t.km^{-2}.y^{-1}:

$$\boldsymbol{C_{L(i)} = R_T * D'_{(i)}}$$

where R_T is total retained weight (t.km^{-2}.y^{-1}) which is the sum of retained weight in the codend (Rcod) and cover (Rcov), and estimated from commercial codend (CD44) experiments as explained in Chapter II, Section 2.2.7.

Finally, catch values for the species (C_T) and split groups (C_{T1}: <MLS, C_{T2}: >MLS) were re-expressed as t.km^{-2}.y^{-1}:

$$\boldsymbol{C_T = \sum_{i=1}^{N} C_{L(i)}}$$

$$C_{T1} = \sum_{i=1}^{M} C_{L(i)}$$

$$C_{T2} = \sum_{i=M}^{N} C_{L(i)}$$

where M is the size class of Minimum Landing Size (MLS). The parameters used to estimate in this process was demonstrated in Table 3.2.

Table 3.1. Input parameters of Gulf of Mersin models (GoM_D44, GoM_D50 and GoM_S40) by functional group: biomass (B, tonne.km^{-2}); production/biomass ratio (P/B, yr^{-1}); ecotrophic efficiency (EE); trawl landing and discard expressed in tonne.km^{-2}.y^{-1}; lessepsian (L)

#	Functional Groups	All models			
		B	EE	P/Q	Pelagic Landing
1	Phytoplankton	4.7969			
2	Micro and mesozooplankton	3.3381		0.3300	
3	Macrozooplankton		0.95	0.3300	
4	Benthic small crustaceans	1.1616		0.1595	
5	Polychaetes	1.6200		0.1500	
6	Shrimps (L)	0.0878		0.2500	
7	Shrimps	0.0335		0.2500	
8	*Charybdis longicollis* (L)	0.0841		0.2766	
9	Crab	0.0298		0.2960	
10	Benthic invertebrates	7.3400		0.2400	
11	Octopuses and cuttlefish	0.0471		0.2526	
12	Squids	0.0092		0.0944	
13	*Mullus barbatus* (<MLS)	-			
14	*Mullus barbatus* (>MLS)	0.1100			
15	*Mullus surmuletus*	0.0018		0.1583	
16	*Upeneus molucensis&pori*(L)	0.0121		0.1393	
17	Anglerfish		0.7	0.2151	
18	*Solea solea*	0.0059		0.1329	
19	Flatfishes	0.0140		0.1318	
20	*Merluccius merluccius*	0.0096		0.2312	
21	*Saurida undosquamis* (L) (<MLS)	-			
22	*Saurida undosquamis* (L) (>MLS)	0.0392			

Table 3.1. (continued)

23	Puffer fish (L)	0.0091		0.2271	
24	Small discarded demersal fishes	0.0352		0.1490	
25	Large discarded demersal fishes	0.0152		0.1770	
26	Retained demersal fishes	0.0050		0.2261	
27	Demersal Fish Species (L)	0.0480		0.1565	
28	*Pagellus erythrinus* (<MLS)	-			
29	*Pagellus erythrinus* (>MLS)	0.0301			
30	*Nemipterus randalli* (L)	0.0153		0.1957	
31	*Pagellus acarne*	0.0220		0.1367	
32	Benthopelagic fishes	0.0056		0.1708	
33	Picarels and bogue	0.0237		0.1520	
34	Demersal sharks		0.7	0.1709	
35	Demarsal rays and skates		0.7	0.1594	
36	*Engraulis encrasicolus*	0.2038		0.1865	0.0013
37	*Sardinella aurita*	2.0967		0.1974	0.0461
38	Horse mackerel	0.9377		0.1694	0.0078
39	*Scomber japonicus*	0.1456		0.1622	0.0075
40	Other small pelagic fishes	0.4776		0.2007	0.0096
41	Small pelagic fishes (L)	0.2679		0.1573	0.0052
42	Medium pelagic fishes		0.9	0.1950	0.0240
43	Large pelagic fishes	0.0255		0.1422	0.0047
44	*Caretta caretta*	0.0170		0.0612	
45	Seabirds	0.0010		0.0500	
46	*Tursiops truncatus*	0.0440		0.0500	
47	Discard	-			
48	Detritus	67.4787			

Table 3.1. (continued)

#	Functional Groups	GoM_D44 model			GoM_D50 model			GoM_S40 model		
		P/B	Trawl Landing	Trawl Discard	P/B	Trawl Landing	Trawl Discard	P/B	Trawl Landing	Trawl Discard
1	Phytoplankton	76.8525			76.8525			76.8525		
2	Micro and mesozooplankton	30.4182			30.4182			30.4182		
3	Macrozooplankton	20.3329			20.3329			20.3329		
4	Benthic small crustaceans	6.3153			6.3153			6.3153		
5	Polychaetes	3.6085			3.6085			3.6085		
6	Shrimps (L)	3.0115	0.0107	0.0008	3.0283	0.0123	0.0005	2.9989	0.0098	0.0005
7	Shrimps	2.7407	0.0004	0.0024	2.6893	0.0007	0.0006	2.6732	0.0006	0.0002
8	*Charybdis longicollis* (L)	2.1672	0.0000	0.0130	2.1758	0.0000	0.0137	2.1288	0.0000	0.0098
9	Crab	2.0652	0.0000	0.0052	1.9386	0.0000	0.0018	2.0602	0.0000	0.0051
10	Benthic invertebrates	0.9425			0.9425			0.9425		
11	Octopuses and cuttlefish	1.4984	0.0136	0.0048	1.5358	0.0185	0.0018	1.5927	0.0176	0.0053
12	Squids	3.0236	0.0057	0.0013	2.7037	0.0034	0.0006	2.6073	0.0027	0.0005
13	*Mullus barbatus* (<MLS)	2.1068	0.0113	0.0000	1.8878	0.0065	0.0000	1.7106	0.0026	0.0000
14	*Mullus barbatus* (>MLS)	0.7670	0.0487	0.0000	0.6807	0.0419	0.0000	0.6679	0.0408	0.0000
15	*Mullus surmuletus*	1.1520	0.0004	0.0000	1.1520	0.0004	0.0000	1.1520	0.0004	0.0000
16	*Upeneus molucensis&pori*(L)	1.3748	0.0014	0.0000	1.2990	0.0005	0.0000	1.2920	0.0004	0.0000
17	Anglerfish	0.8468	0.0004	0.0000	0.8468	0.0004	0.0000	0.8468	0.0004	0.0000
18	*Solea solea*	0.9114	0.0025	0.0000	0.8585	0.0022	0.0000	0.9210	0.0025	0.0000
19	Flatfishes	0.6979	0.0000	0.0009	0.6774	0.0000	0.0006	0.8001	0.0000	0.0023
20	*Merluccius merluccius*	1.0544	0.0057	0.0000	1.0544	0.0057	0.0000	1.0544	0.0057	0.0000
21	*Saurida undosquamis* (L) (<MLS)	2.0547	0.0007	0.0000	2.0118	0.0002	0.0000	2.0000	0.0001	0.0000
22	*Saurida undosquamis* (L) (>MLS)	0.5358	0.0041	0.0000	0.4640	0.0020	0.0000	0.4900	0.0027	0.0000
23	Puffer fish (L)	0.8221	0.0000	0.0048	1.2549	0.0000	0.0048	1.2549	0.0000	0.0048
24	Small discarded demersal fishes	0.9597	0.0010	0.0026	0.9277	0.0006	0.0019	0.9301	0.0012	0.0014

Table 3.1. (continued)

25	Large discarded demersal fishes	0.4986	0.0001	0.0020	0.3994	0.0000	0.0005	0.4154	0.0001	0.0007
26	Retained demersal fishes	1.0372	0.0022	0.0000	0.8491	0.0013	0.0000	1.0479	0.0023	0.0000
27	Demersal Fish Species (L)	1.3036	0.0000	0.0016	1.2886	0.0003	0.0005	1.2815	0.0000	0.0005
28	*Pagellus erythrinus* (<MLS)	2.0264	0.0030	0.0000	1.8083	0.0015	0.0000	1.8887	0.0020	0.0000
29	*Pagellus erythrinus* (>MLS)	0.7421	0.0062	0.0000	0.5952	0.0047	0.0000	0.7630	0.0064	0.0000
30	*Nemipterus randalli* (L)	1.6475	0.0030	0.0000	1.6496	0.0031	0.0000	1.5900	0.0022	0.0000
31	*Pagellus acarne*	1.1830	0.0093	0.0000	0.9272	0.0037	0.0000	0.9392	0.0039	0.0000
32	Benthopelagic fishes	1.1850	0.0000	0.0005	1.0997	0.0000	0.0000	1.2987	0.0000	0.0011
33	Picarels and bogue	1.1098	0.0107	0.0001	0.6992	0.0010	0.0001	0.7608	0.0024	0.0001
34	Demersal sharks	0.7000	0.0000	0.0008	0.7000	0.0000	0.0008	0.7000	0.0000	0.0008
35	Demarsal rays and skates	0.5605	0.0002	0.0168	0.5605	0.0002	0.0168	0.5605	0.0002	0.0168
36	*Engraulis encrasicolus*	2.7275			2.7275			2.7275		
37	*Sardinella aurita*	2.1500			2.1500			2.1500		
38	Horse mackerel	1.7538			1.7538			1.7538		
39	*Scomber japonicus*	1.1874			1.1874			1.1874		
40	Other small pelagic fishes	2.5614			2.5614			2.5614		
41	Small pelagic fishes (L)	2.0700			2.0700			2.0700		
42	Medium pelagic fishes	0.9030			0.9030			0.9030		
43	Large pelagic fishes	0.3858			0.3858			0.3858		
44	*Caretta caretta*	0.1926			0.1926			0.1926		
45	Seabirds									
46	*Tursiops truncatus*									
47	Discard									
48	Detritus									

Table 3.2. Parameters used in catch calculation process

Species		*M. barbatus*	*S. undosquamis*	*P. erythrinus*	*N. randalli*	*U. molucensis*	*P. acarne*
L-W relationship							
a		0.0067	0.0029	0.0109	0.0011	0.0050	0.0090
b		3.1789	3.2664	3.0536	3.0610	3.2890	3.1380
Ref.		(Ok, 2012)	(Ok, 2012)	(Ok, 2012)	(Erguden et al., 2010)	(Ok, 2012)	(Soykan et al., 2015)
Selectivity Regression Parameters							
D44	**V1**	-4.175	-4.075	-6.205	-5.457	-4.001	-5.784
	V2	0.482	0.169	0.549	0.453	0.330	0.623
D50	**V1**	-5.113	-5.528	-5.950	-2.323	-3.856	-2.172
	V2	0.418	0.186	0.408	0.200	0.181	0.113
S40	**V1**	-11.648	-9.154	-15.688	-8.323	-6.285	-11.075
	V2	0.836	0.374	1.207	0.574	0.385	0.799
Size classes							
Length interval		0.5	0.5	0.5	0.5	0.5	0.5
The number of size classes (N)		46	57	34	43	32	21
The size class of MLS (M)		13	22	17	-	-	-

3.3. Results

3.3.1. Balanced Models and Their Structures

The baseline Gulf of Mersin (GoM) food web model consisting of 48 functional groups was set up in Chapter II. Three additional mass-balance Ecopath models (GoM_D44, GoM_D50 and GoM_S40) were developed to represent the effect of different trawl codends on the ecosystem. Default procedures based on ecological and thermodynamic rules were used to ensure mass-balance for all models. That is, EE (<1), GE (0.1<GE<0.3), Respiration/Assimilation (R/A, <1.0), Production/Respiration (P/R, <1.0), and Respiration/Biomass (R/B, 1–10 $year^{-1}$ for fish and may be as high as 50–100 $year^{-1}$ for groups with higher turnover) were in expected limits. P/Q ratio was smaller than net efficiency (NE, production/assimilated food) (Christensen and Walters, 2004; Darwall et al., 2010; Heymans et al., 2016).

3.3.2. Impact of Improved Trawl Selectivity at the Functional Group Level

Detailed outputs obtained from the Ecopath models are given in Table 3.3-3.5. Output biomasses and net growth efficiency (production/consumption, P/Q) of the functional groups were the same in all models. Similarly, the diet matrixes were the same. Thus, the flow diagram illustrating the trophic positions of biomass pools and their links is the same as the baseline model described in chapter 2, section 2.3.1. However, energy flows among functional groups were naturally different for each model.

Impacts on basic estimates of functional groups were presented in Table 3.3. The greatest increase in P/B occurred squids 16.4% in the Sc. 1, while demersal fished groups showed a decrease (1% - 37.6%) under all scenarios. The increases in Q/B were observed for squids and juvenile *S. undosquamis* under all scenarios.

Under all scenarios, the ecotrophic efficiency (EE) of *S. undosquamis* increased 21.5%, 50.6% and 35.3 for juvenile and 2.5%, 6.1% and 5.1% for adult, respectively. EEs of demersal fished groups decreased in all scenarios.

Table 3.4 presents key indices for all models. A change (increase, 0% - 14.9% and decrease, 0% - 66.1%) in flow to detritus (FD) of some demersal groups was observed under all scenarios. A decrease in net efficiency of multi stanza groups was predicted. However, due to the constant topology of the models, there is no change in omnivory index (OI).

Table 3.5 gives the outputs of mortality indices for all models. All scenarios illustrated that an improvement in trawl selectivity would cause a decrease in fishing mortality (F) - exploitation rate (F/Z), natural mortality (M0) and an increase in predation mortality (M2) on demersal fished groups, particularly multi-stanza groups. Also, results show that Schrödinger's ratios of multi-stanza groups and squids would significantly increase as selectivity increases (Table 3.6).

Table 3.3. Outputs of the all models (GoM_CD44, GoM_D44, GoM_D50 and GoM_S40) by functional group (basic estimates): production/biomass ratio (P/B, yr^{-1}); consumption/biomass ratio (Q/B, yr^{-1}); ecotrophic efficiency (EE); lessepsian (L)

#	Functional Groups	Basic Estimates											
		GoM_CD44 model			GoM_D44 model			GoM_D50 model			GoM_S40 model		
		P/B	Q/B	EE	P/B	Q/B	EE	P/B	Q/B	EE	P/B	Q/B	EE
1	Phytoplankton	76.85	0.00	0.59	76.85	0.00	0.59	76.85	0.00	0.59	76.85	0.00	0.59
2	Micro and mesozooplankton	30.42	92.18	0.68	30.42	92.18	0.68	30.42	92.18	0.68	30.42	92.18	0.68
3	Macrozooplankton	20.33	61.61	0.95	20.33	61.61	0.95	20.33	61.61	0.95	20.33	61.61	0.95
4	Benthic small crustaceans	6.32	39.59	0.74	6.32	39.59	0.73	6.32	39.59	0.72	6.32	39.59	0.72
5	Polychaetes	3.61	24.06	0.87	3.61	24.06	0.84	3.61	24.06	0.84	3.61	24.06	0.84
6	Shrimps (L)	3.20	12.82	0.99	3.01	12.05	0.90	3.03	12.11	0.87	3.00	12.00	0.88
7	Shrimps	3.16	12.62	0.98	2.74	10.96	0.90	2.69	10.76	0.87	2.67	10.69	0.88
8	*Charybdis longicollis* (L)	2.40	8.68	0.99	2.17	7.83	0.89	2.18	7.87	0.90	2.13	7.70	0.92
9	Crab	2.40	8.11	0.99	2.07	6.98	0.88	1.94	6.55	0.92	2.06	6.96	0.94
10	Benthic invertebrates	0.94	3.93	0.83	0.94	3.93	0.82	0.94	3.93	0.81	0.94	3.93	0.81
11	Octopuses and cuttlefish	1.61	6.37	0.98	1.50	5.93	0.91	1.54	6.08	0.91	1.59	6.31	0.91
12	Squids	2.60	27.49	0.97	3.02	32.01	1.00	2.70	28.63	0.96	2.61	27.61	0.96
13	*Mullus barbatus* (<MLS)	2.19	9.56	0.88	2.11	9.55	0.78	1.89	9.61	0.84	1.71	9.53	0.74
14	*Mullus barbatus* (>MLS)	0.79	4.11	0.82	0.77	4.11	0.78	0.68	4.11	0.79	0.67	4.11	0.79
15	*Mullus surmuletus*	1.15	7.28	0.55	1.15	7.28	0.48	1.15	7.28	0.48	1.15	7.28	0.49
16	*Upeneus molucensis & pori* (L)	1.54	11.04	0.66	1.37	9.87	0.54	1.30	9.33	0.50	1.29	9.28	0.50
17	Anglerfish	0.85	3.94	0.70	0.85	3.94	0.70	0.85	3.94	0.70	0.85	3.94	0.70
18	*Solea solea*	0.92	6.93	0.72	0.91	6.86	0.64	0.86	6.46	0.62	0.92	6.93	0.66
19	Flatfishes	1.12	8.49	0.62	0.70	5.30	0.31	0.68	5.14	0.28	0.80	6.07	0.41
20	*Merluccius merluccius*	1.05	4.56	0.91	1.05	4.56	0.91	1.05	4.56	0.91	1.05	4.56	0.91
21	*Saurida undosquamis* (L) (<MLS)	2.27	9.58	0.63	2.05	10.08	0.76	2.01	10.36	0.94	2.00	10.23	0.85
22	*Saurida undosquamis* (L) (>MLS)	0.72	3.56	0.86	0.54	3.56	0.88	0.46	3.56	0.91	0.49	3.56	0.90
23	Puffer fish (L)	1.25	5.52	0.66	0.82	3.62	0.46	1.25	5.52	0.66	1.25	5.52	0.66

Table 3.3. (continued)

24	Small discarded demersal fishes	1.35	9.07	0.83	0.96	6.44	0.65	0.93	6.23	0.67	0.93	6.24	0.68
25	Large discarded demersal fishes	0.76	4.29	0.97	0.50	2.82	0.86	0.40	2.26	0.83	0.42	2.35	0.84
26	Retained demersal fishes	1.05	4.63	0.99	1.04	4.59	0.90	0.85	3.76	0.97	1.05	4.63	0.98
27	Demersal Fish Species (L)	1.53	9.79	0.68	1.30	8.33	0.55	1.29	8.23	0.53	1.28	8.19	0.53
28	*Pagellus erythrinus* (<MLS)	2.20	9.73	0.85	2.03	9.67	0.76	1.81	9.92	0.85	1.89	9.52	0.64
29	*Pagellus erythrinus* (>MLS)	0.77	4.00	0.83	0.74	4.00	0.83	0.60	4.00	0.94	0.76	4.00	0.81
30	*Nemipterus randalli* (L)	1.73	8.86	0.95	1.65	8.42	0.84	1.65	8.43	0.81	1.59	8.12	0.82
31	*Pagellus acarne*	1.22	8.89	0.95	1.18	8.66	0.87	0.93	6.78	0.81	0.94	6.87	0.83
32	Benthopelagic fishes	1.74	10.19	0.97	1.18	6.94	0.77	1.10	6.44	0.66	1.30	7.60	0.72
33	Picarels and bogue	1.27	8.38	0.98	1.11	7.30	0.93	0.70	4.60	0.86	0.76	5.01	0.87
34	Demersal sharks	0.70	4.10	0.70	0.70	4.10	0.70	0.70	4.10	0.70	0.70	4.10	0.70
35	Demarsal rays and skates	0.56	3.52	0.70	0.56	3.52	0.70	0.56	3.52	0.70	0.56	3.52	0.70
36	*Engraulis encrasicolus*	2.73	14.62	0.18	2.73	14.62	0.18	2.73	14.62	0.17	2.73	14.62	0.17
37	*Sardinella aurita*	2.15	10.89	0.17	2.15	10.89	0.17	2.15	10.89	0.17	2.15	10.89	0.17
38	Horse mackerel	1.75	10.35	0.16	1.75	10.35	0.16	1.75	10.35	0.15	1.75	10.35	0.15
39	*Scomber japonicus*	1.19	7.32	0.27	1.19	7.32	0.27	1.19	7.32	0.27	1.19	7.32	0.26
40	Other small pelagic fishes	2.56	12.77	0.13	2.56	12.77	0.13	2.56	12.77	0.13	2.56	12.77	0.13
41	Small pelagic fishes (L)	2.07	13.16	0.16	2.07	13.16	0.16	2.07	13.16	0.16	2.07	13.16	0.15
42	Medium pelagic fishes	0.90	4.63	0.90	0.90	4.63	0.90	0.90	4.63	0.90	0.90	4.63	0.90
43	Large pelagic fishes	0.39	2.71	0.48	0.39	2.71	0.48	0.39	2.71	0.48	0.39	2.71	0.48
44	*Caretta caretta*	0.19	3.15	0.00	0.19	3.15	0.00	0.19	3.15	0.00	0.19	3.15	0.00
45	Seabirds	3.59	71.85	0.00	3.59	71.85	0.00	3.59	71.85	0.00	3.59	71.85	0.00
46	*Tursiops truncatus*	0.62	12.34	0.00	0.62	12.34	0.00	0.62	12.34	0.00	0.62	12.34	0.00
47	Discard			0.32			0.83			0.99			0.89
48	Detritus			0.61			0.61			0.61			0.61

Table 3.4. Outputs of the all models (GoM_CD44, GoM_D44, GoM_D50 and GoM_S40) by functional group (key indices): flow to detritus (FD, $t.km^{-2} yr^{-1}$); net efficiency (NE); omnivory index (OI); lessepsian (L)

#	Functional Groups	Key Indices											
		GoM_CD44 model			GoM_D44 model			GoM_D50 model			GoM_S40 model		
		FD	NE	OI	FD	NE	OI	FD	NE	OI	FD	NE	OI
1	Phytoplankton	150.15		0.00	150.16		0.00	150.17		0.00	150.17		0.00
2	Micro and mesozooplankton	94.20	0.41	0.05	94.32	0.41	0.05	94.42	0.41	0.05	94.40	0.41	0.05
3	Macrozooplankton	3.03	0.41	0.28	3.01	0.41	0.28	2.99	0.41	0.28	3.00	0.41	0.28
4	Benthic small crustaceans	11.09	0.20	0.17	11.20	0.20	0.17	11.22	0.20	0.17	11.22	0.20	0.17
5	Polychaetes	8.58	0.19	0.12	8.71	0.19	0.12	8.74	0.19	0.12	8.74	0.19	0.12
6	Shrimps (L)	0.23	0.31	0.18	0.24	0.31	0.18	0.25	0.31	0.18	0.24	0.31	0.18
7	Shrimps	0.09	0.31	0.18	0.08	0.31	0.18	0.08	0.31	0.18	0.08	0.31	0.18
8	*Charybdis longicollis* (L)	0.15	0.35	0.21	0.15	0.35	0.21	0.15	0.35	0.21	0.14	0.35	0.21
9	Crab	0.05	0.37	0.21	0.05	0.37	0.21	0.04	0.37	0.21	0.05	0.37	0.21
10	Benthic invertebrates	6.92	0.30	0.06	7.04	0.30	0.06	7.05	0.30	0.06	7.05	0.30	0.06
11	Octopuses and cuttlefish	0.06	0.32	0.22	0.06	0.32	0.22	0.06	0.32	0.22	0.07	0.32	0.22
12	Squids	0.05	0.12	0.18	0.06	0.12	0.18	0.05	0.12	0.18	0.05	0.12	0.18
13	*Mullus barbatus* (<MLS)	0.03	0.29	0.55	0.03	0.28	0.55	0.02	0.25	0.55	0.02	0.22	0.55
14	*Mullus barbatus* (>MLS)	0.11	0.24	0.55	0.11	0.23	0.55	0.11	0.21	0.55	0.11	0.20	0.55
15	*Mullus surmuletus*	0.00	0.20	0.55	0.00	0.20	0.55	0.00	0.20	0.55	0.00	0.20	0.55
16	*Upeneus molucensis & pori* (L)	0.03	0.17	0.55	0.03	0.17	0.55	0.03	0.17	0.55	0.03	0.17	0.55
17	Anglerfish	0.00	0.27	0.45	0.00	0.27	0.45	0.00	0.27	0.45	0.00	0.27	0.45
18	*Solea solea*	0.01	0.17	0.20	0.01	0.17	0.20	0.01	0.17	0.20	0.01	0.17	0.20
19	Flatfishes	0.03	0.16	0.20	0.02	0.16	0.20	0.02	0.16	0.20	0.02	0.16	0.20
20	*Merluccius merluccius*	0.01	0.29	0.19	0.01	0.29	0.19	0.01	0.29	0.19	0.01	0.29	0.19
21	*Saurida undosquamis* (L) (<MLS)	0.01	0.30	0.04	0.01	0.25	0.04	0.00	0.24	0.04	0.01	0.24	0.04
22	*Saurida undosquamis* (L) (>MLS)	0.03	0.25	0.06	0.03	0.19	0.06	0.03	0.16	0.06	0.03	0.17	0.06
23	Puffer fish (L)	0.01	0.28	0.19	0.01	0.28	0.19	0.01	0.28	0.19	0.01	0.28	0.19
24	Small discarded demersal fishes	0.07	0.19	0.18	0.06	0.19	0.18	0.05	0.19	0.18	0.05	0.19	0.18

Table 3.4. (continued)

25	Large discarded demersal fishes	0.01	0.22	0.22	0.01	0.22	0.22	0.01	0.22	0.22	0.01	0.22	0.22
26	Retained demersal fishes	0.00	0.28	0.06	0.01	0.28	0.06	0.00	0.28	0.06	0.00	0.28	0.06
27	Demersal Fish Species (L)	0.12	0.20	0.15	0.11	0.20	0.15	0.11	0.20	0.15	0.11	0.20	0.15
28	*Pagellus erythrinus* (<MLS)	0.01	0.28	0.21	0.01	0.26	0.21	0.00	0.23	0.21	0.01	0.25	0.21
29	*Pagellus erythrinus* (>MLS)	0.03	0.24	0.24	0.03	0.23	0.24	0.03	0.19	0.24	0.03	0.24	0.24
30	*Nemipterus randalli* (L)	0.03	0.24	0.15	0.03	0.24	0.15	0.03	0.24	0.15	0.03	0.24	0.15
31	*Pagellus acarne*	0.04	0.17	0.15	0.04	0.17	0.15	0.03	0.17	0.15	0.03	0.17	0.15
32	Benthopelagic fishes	0.01	0.21	0.13	0.01	0.21	0.13	0.01	0.21	0.13	0.01	0.21	0.13
33	Picarels and bogue	0.04	0.19	0.05	0.04	0.19	0.05	0.02	0.19	0.05	0.03	0.19	0.05
34	Demersal sharks	0.00	0.21	0.34	0.00	0.21	0.34	0.00	0.21	0.34	0.00	0.21	0.34
35	Demarsal rays and skates	0.04	0.20	0.17	0.04	0.20	0.17	0.04	0.20	0.17	0.04	0.20	0.17
36	*Engraulis encrasicolus*	1.05	0.23	0.00	1.05	0.23	0.00	1.06	0.23	0.00	1.06	0.23	0.00
37	*Sardinella aurita*	8.31	0.25	0.00	8.31	0.25	0.00	8.33	0.25	0.00	8.33	0.25	0.00
38	Horse mackerel	3.33	0.21	0.09	3.33	0.21	0.09	3.33	0.21	0.09	3.33	0.21	0.09
39	*Scomber japonicus*	0.34	0.20	0.17	0.34	0.20	0.17	0.34	0.20	0.17	0.34	0.20	0.17
40	Other small pelagic fishes	2.28	0.25	0.06	2.28	0.25	0.06	2.28	0.25	0.06	2.28	0.25	0.06
41	Small pelagic fishes (L)	1.17	0.20	0.06	1.17	0.20	0.06	1.17	0.20	0.06	1.17	0.20	0.06
42	Medium pelagic fishes	0.03	0.24	0.05	0.03	0.24	0.05	0.03	0.24	0.05	0.03	0.24	0.05
43	Large pelagic fishes	0.02	0.18	0.08	0.02	0.18	0.08	0.02	0.18	0.08	0.02	0.18	0.08
44	*Caretta caretta*	0.01	0.08	0.41	0.01	0.08	0.41	0.01	0.08	0.41	0.01	0.08	0.41
45	Seabirds	0.02	0.06	0.58	0.02	0.06	0.58	0.02	0.06	0.58	0.02	0.06	0.58
46	*Tursiops truncatus*	0.14	0.06	0.04	0.14	0.06	0.04	0.14	0.06	0.04	0.14	0.06	0.04
47	Discard	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48	Detritus	0.00	0.00	0.44	0.00	0.00	0.44	0.00	0.00	0.44	0.00	0.00	0.44

Table 3.5. Outputs of the all models (GoM_CD44, GoM_D44, GoM_D50 and GoM_S40) by functional group (mortalities): fishing mortality (F, y^{-1}); predation mortality (M2, y^{-1}); other natural mortality (M0, y^{-1}); exploitation rate (F/Z); lessepsian (L); functional group no (#)

#	Mortalities															
	GoM_CD44 model				GoM_D44 model				GoM_D50 model				GoM_S40 model			
	F	M2	M0	F/Z	F	M2	M0	F/Z	F	M2	M0	F/Z	F	M2	M0	F/Z
1	0.00	45.55	31.30	0.00	0.00	45.55	31.30	0.00	0.00	45.55	31.31	0.00	0.00	45.55	31.31	0.00
2	0.00	20.63	9.79	0.00	0.00	20.60	9.82	0.00	0.00	20.57	9.85	0.00	0.00	20.57	9.84	0.00
3	0.00	19.32	1.02	0.00	0.00	19.32	1.02	0.00	0.00	19.32	1.02	0.00	0.00	19.32	1.02	0.00
4	0.00	4.69	1.63	0.00	0.00	4.59	1.73	0.00	0.00	4.57	1.74	0.00	0.00	4.57	1.74	0.00
5	0.00	3.12	0.49	0.00	0.00	3.05	0.56	0.00	0.00	3.02	0.58	0.00	0.00	3.02	0.58	0.00
6	0.31	2.86	0.03	0.10	0.13	2.58	0.31	0.04	0.15	2.49	0.39	0.05	0.12	2.51	0.37	0.04
7	0.45	2.64	0.07	0.14	0.08	2.38	0.28	0.03	0.04	2.30	0.35	0.01	0.02	2.32	0.33	0.01
8	0.39	1.99	0.02	0.16	0.15	1.78	0.23	0.07	0.16	1.79	0.22	0.07	0.12	1.83	0.18	0.05
9	0.48	1.91	0.01	0.20	0.18	1. 65	0.24	0.08	0.06	1.73	0.15	0.03	0.17	1.77	0.12	0.08
10	0.00	0.79	0.16	0.00	0.00	0.77	0.17	0.00	0.00	0.77	0.18	0.00	0.00	0.77	0.17	0. 00
11	0.50	1.07	0.04	0.31	0.39	0.98	0.13	0.26	0.43	0.96	0.14	0.28	0.49	0.96	0.15	0.31
12	0.34	2.17	0.09	0.13	0.76	2.25	0.01	0.25	0.44	2.16	0.10	0.16	0.35	2.14	0.12	0.13
13	1.02	0.89	0.27	0.47	0.94	0.70	0.46	0.45	0.69	0.89	0.31	0.37	0.30	0.97	0.44	0.18
14	0.46	0.19	0.14	0.58	0.44	0.15	0.17	0.58	0.38	0.16	0.14	0.56	0.37	0.16	0.14	0.56
15	0.25	0.38	0.52	0.22	0.25	0.31	0.59	0.22	0.25	0.30	0.59	0.22	0.25	0.31	0.59	0.22
16	0.28	0.73	0.52	0.18	0.12	0.62	0.64	0.09	0.04	0.61	0.65	0.03	0.04	0.61	0.64	0.03
17	0.55	0.05	0.25	0.65	0.55	0.05	0.25	0.65	0.55	0.05	0.25	0.65	0.55	0.05	0.25	0.65
18	0.43	0.23	0.26	0.47	0.42	0.17	0.32	0.46	0.37	0.17	0.32	0.43	0.43	0.18	0.31	0.47
19	0.48	0.21	0.42	0.43	0.06	0.15	0.48	0.09	0.04	0.15	0.49	0.06	0.17	0.16	0.48	0.21
20	0.59	0.37	0.09	0.56	0.59	0. 37	0.09	0.56	0.59	0.37	0.09	0.56	0.59	0.37	0.09	0.56
21	0.60	0.82	0.85	0.27	0.26	1.31	0.49	0.13	0.12	1.79	0.11	0.06	0.05	1.65	0.30	0. 03
22	0.24	0.38	0.10	0.34	0.10	0.37	0.06	0.19	0.05	0.37	0.04	0.11	0.07	0.37	0.05	0.14

Table 3.5. (continued)

23	0.53	0.31	0.42	0.42	0.09	0.28	0.45	0.11	0.53	0.31	0.42	0.42	0.53	0.31	0.42	0.42			
24	0.50	0.63	0.22	0.37	0.10	0.52	0.34	0.11	0.07	0.55	0.31	0.08	0.07	0.56	0.30	0.08			
25	0.39	0.34	0.03	0.52	0.13	0.30	0.07	0.27	0.03	0.30	0.07	0.09	0.05	0.30	0.07	0.12			
26	0.46	0.57	0.02	0.44	0.45	0.49	0.10	0.43	0.26	0.56	0.03	0.31	0.46	0.57	0.02	0.44			
27	0.26	0.77	0.50	0.17	0.03	0.68	0.59	0.03	0.02	0.66	0.61	0.01	0.01	0.67	0.60	0.01			
28	1.16	0.71	0.33	0.53	0.93	0.61	0.49	0.46	0.69	0.85	0.27	0.38	0.64	0.57	0.68	0.34			
29	0.22	0.42	0.13	0.28	0.21	0.41	0.13	0.28	0.16	0.41	0.03	0.26	0.21	0.41	0.14	0.28			
30	0.29	1.36	0.09	0.16	0.20	1.18	0.27	0.12	0.20	1.14	0.31	0.12	0.14	1.16	0.29	0. 09			
31	0.45	0.70	0.06	0.37	0.42	0.60	0.16	0.36	0.17	0.58	0.18	0.18	0.18	0.60	0.16	0.19			
32	0.64	1.05	0.05	0.37	0.09	0.82	0.27	0.07	0.00	0.73	0.37	0.00	0.20	0.74	0.36	0.15			
33	0.62	0.63	0.02	0.49	0.46	0.57	0.08	0.41	0.04	0.55	0.10	0.06	0.11	0.56	0.10	0.14			
34	0.46	0.03	0.21	0.66	0.47	0.02	0.21	0.67	0.46	0.03	0.21	0.66	0.46	0.03	0.21	0.66			
35	0.37	0.02	0.17	0.66	0.38	0.02	0.17	0.67	0.37	0.02	0.17	0.66	0.37	0.02	0.17	0.66			
36	0.01	0.49	2.23	0.00	0.01	0.48	2.24	0.00	0.01	0.47	2.25	0.00	0.01	0.47	2.25	0.00			
37	0.02	0.34	1.79	0.01	0.02	0.34	1.79	0.01	0.02	0.34	1.79	0.01	0.02	0.33	1.79	0.01			
38	0.01	0.27	1.48	0.00	0.01	0.27	1.48	0.00	0.01	0.26	1.48	0.00	0.01	0.26	1.49	0.00			
39	0.05	0.27	0.87	0.04	0.05	0.27	0.87	0.04	0.05	0.26	0.87	0.04	0.05	0.26	0.87	0.04			
40	0.02	0.32	2.22	0.01	0.02	0.32	2.22	0.01	0.02	0.32	2.23	0.01	0.02	0.32	2.23	0.01			
41	0.02	0.30	1.75	0.01	0.02	0.31	1.74	0.01	0.02	0.30	1.75	0.01	0.02	0.30	1.75	0.01			
42	0.81	0.00	0.09	0.90	0.81	0.00	0.09	0.90	0.81	0.00	0.09	0.90	0.81	0.00	0.09	0.90			
43	0.18	0.00	0.20	0.48	0.18	0.00	0.20	0.48	0.18	0.00	0.20	0.48	0.18	0.00	0.20	0.48			
44	0.00	0.00	0.19	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.19	0.00			
45	0.00	0.00	3.59	0.00	0.00	0.00	3.59	0.00	0.00	0.00	3.59	0.00	0.00	0.00	3.59	0.00			
46	0.00	0.00	0.62	0.00	0.00	0.00	0.62	0.00	0.00	0.00	0.62	0.00	0.00	0.00	0.62	0.00			
47																			
48																			

Table 3.6. Outputs of the all models (GoM_CD44, GoM_D44, GoM_D50 and GoM_S40) by functional group (respiration): respiration/assimilation ratio (R/A); production/respiration ratio (P/R); respiration/biomass ratio (R/B); lessepsian (L)

#	Functional Groups	Respiration											
		GoM_CD44 model			GoM_D44 model			GoM_D50 model			GoM_S40 model		
		R/A	P/R	R/B	R/A	P/R	R/B	R/A	P/R	R/B	R/A	P/R	R/B
1	Phytoplankton												
2	Micro and mesozooplankton	0.59	0.70	43.32	0.59	0.70	43.32	0.59	0.70	43.32	0.59	0.70	43.32
3	Macrozooplankton	0.59	0.70	28.96	0.59	0.70	28.96	0.59	0.70	28.96	0.59	0.70	28.96
4	Benthic small crustaceans	0.80	0.25	25.36	0.80	0.25	25.36	0.80	0.25	25.36	0.80	0.25	25.36
5	Polychaetes	0.81	0.23	15.64	0.81	0.23	15.64	0.81	0.23	15.64	0.81	0.23	15.64
6	Shrimps (L)	0.69	0.45	7.05	0.69	0.45	6.63	0.69	0.45	6.66	0.69	0.45	6.60
7	Shrimps	0.69	0.45	6.94	0.69	0.45	6.03	0.69	0.45	5.92	0.69	0.45	5.88
8	*Charybdis longicollis* (L)	0.65	0.53	4.54	0.65	0.53	4.10	0.65	0.53	4.12	0.65	0.53	4.03
9	Crab	0.63	0.59	4.09	0.63	0.59	3.52	0.63	0.59	3.30	0.63	0.59	3.51
10	Benthic invertebrates	0.70	0.43	2.20	0.70	0.43	2.20	0.70	0.43	2.20	0.70	0.43	2.20
11	Octopuses and cuttlefish	0.68	0.46	3.49	0.68	0.46	3.25	0.68	0.46	3.33	0.68	0.46	3.45
12	Squids	0.88	0.13	19.40	0.88	0.13	22.59	0.88	0.13	20.20	0.88	0.13	19.48
13	*Mullus barbatus* (<MLS)	0.71	0.40	5.46	0.72	0.38	5.53	0.75	0.33	5.80	0.78	0.29	5.91
14	*Mullus barbatus* (>MLS)	0.76	0.31	2.51	0.77	0.30	2.52	0.79	0.26	2.61	0.80	0.25	2.62
15	*Mullus surmuletus*	0.80	0.25	4.67	0.80	0.25	4.67	0.80	0.25	4.67	0.80	0.25	4.67
16	*Upeneus molucensis & pori* (L)	0.83	0.21	7.29	0.83	0.21	6.52	0.83	0.21	6.16	0.83	0.21	6.13
17	Anglerfish	0.73	0.37	2.30	0.73	0.37	2.30	0.73	0.37	2.30	0.73	0.37	2.30
18	*Solea solea*	0.83	0.20	4.62	0.83	0.20	4.57	0.83	0.20	4.31	0.83	0.20	4.62
19	Flatfishes	0.84	0.20	5.67	0.84	0.20	3.54	0.84	0.20	3.44	0.84	0.20	4.06
20	*Merluccius merluccius*	0.71	0.41	2.59	0.71	0.41	2.59	0.71	0.41	2.59	0.71	0.41	2.59
21	*Saurida undosquamis* (L) (<MLS)	0.70	0.42	5.40	0.75	0.34	6.01	0.76	0.32	6.28	0.76	0.32	6.18
22	*Saurida undosquamis* (L) (>MLS)	0.75	0.34	2. 13	0.81	0.23	2.31	0.84	0.19	2.39	0.83	0.21	2.36

Table 3.6. (continued)

23	Puffer fish (L)	0.72	0.40	3.17	0.72	0.40	2.07	0.72	0.40	3.17	0.72	0.40	3.17
24	Small discarded demersal fishes	0.81	0.23	5.91	0.81	0.23	4.19	0.81	0.23	4.05	0.81	0.23	4.06
25	Large discarded demersal fishes	0.78	0.28	2.67	0.78	0.28	1.75	0.78	0.28	1.41	0.78	0.28	1.46
26	Retained demersal fishes	0.72	0.39	2.66	0.72	0.39	2.63	0.72	0.39	2.16	0.72	0.39	2.66
27	Demersal Fish Species (L)	0.80	0.24	6.30	0.80	0.24	5.36	0.80	0.24	5.30	0.80	0.24	5.27
28	*Pagellus erythrinus* (<MLS)	0.72	0.39	5.58	0.74	0.35	5.71	0.77	0.30	6.13	0.75	0.33	5.73
29	*Pagellus erythrinus* (>MLS)	0.76	0.32	2.43	0.77	0.30	2.46	0.81	0.23	2.60	0.76	0.31	2.44
30	*Nemipterus randalli* (L)	0.76	0.32	5.36	0.76	0.32	5.09	0.76	0.32	5.09	0.76	0.32	4.91
31	*Pagellus acarne*	0.83	0.21	5.90	0.83	0.21	5.74	0.83	0.21	4.50	0.83	0.21	4.56
32	Benthopelagic fishes	0.79	0.27	6.41	0.79	0.27	4.36	0.79	0.27	4.05	0.79	0.27	4.78
33	Picarels and bogue	0.81	0.23	5.43	0.81	0.23	4.73	0.81	0.23	2.98	0.81	0.23	3.24
34	Demersal sharks	0.79	0.27	2.58	0.79	0.27	2.58	0.79	0.27	2.58	0.79	0.27	2.58
35	Demarsal rays and skates	0.80	0.25	2.25	0.80	0.25	2.25	0.80	0.25	2.25	0.80	0.25	2.25
36	*Engraulis encrasicolus*	0.77	0.30	8.97	0.77	0.30	8.97	0.77	0.30	8.97	0.77	0.30	8.97
37	*Sardinella aurita*	0.75	0.33	6.56	0.75	0.33	6.56	0.75	0.33	6.56	0.75	0.33	6.56
38	Horse mackerel	0.79	0.27	6.53	0.79	0.27	6.53	0.79	0.27	6.53	0.79	0.27	6.53
39	*Scomber japonicus*	0.80	0.25	4.67	0.80	0.25	4.67	0.80	0.25	4.67	0.80	0.25	4.67
40	Other small pelagic fishes	0.75	0.33	7.65	0.75	0.33	7.65	0.75	0.33	7.65	0.75	0.33	7.65
41	Small pelagic fishes (L)	0.80	0.24	8.45	0.80	0.24	8.45	0.80	0.24	8.45	0.80	0.24	8.45
42	Medium pelagic fishes	0.76	0.32	2.80	0.76	0.32	2.80	0.76	0.32	2.80	0.76	0.32	2.80
43	Large pelagic fishes	0.82	0.22	1.78	0.82	0.22	1.78	0.82	0.22	1.78	0.82	0.22	1.78
44	*Caretta caretta*	0.92	0.08	2.33	0.92	0.08	2.33	0.92	0.08	2.33	0.92	0.08	2.33
45	Seabirds	0.94	0.07	53.89	0.94	0.07	53.89	0.94	0.07	53.89	0.94	0.07	53.89
46	*Tursiops truncatus*	0.94	0.07	9.25	0.94	0.07	9.25	0.94	0.07	9.25	0.94	0.07	9.25
47	Discard												
48	Detritus												

3.3.3. Impact of Improved Trawl Selectivity at the Ecosystem Level

3.3.3.1. Ecosystem Indicators

Ecosystem indicators in terms of ecosystem theory, cycling and information show that the implementation of selectivity measurement could cause just a slight change (Table 3.7). The highest change among the ecosystem indices was mean transfer efficiency with a decrease of 4.5% in Sc. 1, 6% in Sc. 2, and 5.7% in Sc. 3 (Table 3.7). Moreover, transfer efficiency between main trophic components slightly decreased in the case of the implementation of more selective trawl codends (Table 3.7). Also, energy flow associated with the main trophic components in the food web was the most intense between TL II and TL III under all scenarios (Figure 3.2).

Table 3.7. Summary statistics and indicators for Gulf of Mersin model: Trophic level (TL).

Parameter	Values				Units
	GoM_CD44	GoM_D44	GoM_D50	GoM_S40	
Ecosystem theory indices					
Sum of all consumption	488.61	487.93	487.68	487.72	$t.km^{-2}.y^{-1}$
Sum of all exports	114.17	114.45	114.58	114.57	$t.km^{-2}.y^{-1}$
Sum of all respiratory flows	254.63	254.26	254.13	254.14	$t.km^{-2}.y^{-1}$
Sum of all flows into detritus	292.12	292.47	292.62	292.60	$t.km^{-2}.y^{-1}$
Total system throughput	1149.53	1149.12	1149.00	1149.03	$t.km^{-2}.y^{-1}$
Sum of all production	504.91	504.74	504.67	504.68	$t.km^{-2}.y^{-1}$
Calculated total net primary production (TPp)	368.65	368.65	368.65	368.65	$t.km^{-2}.y^{-1}$
Total primary production/total respiration	1.45	1.45	1.45	1.45	
Net system production	114.02	114.39	114.52	114.51	$t.km^{-2}.y^{-1}$
Total primary production/total biomass	15.69	15.70	15.70	15.70	
Total biomass/total throughput	0.02	0.02	0.02	0.02	
Total biomass (excluding detritus)	23.49	23.49	23.48	23.48	$t.km^{-2}.y^{-1}$
Mean transfer efficiency	9.37	8.95	8.81	8.84	%
Mean TL of the community	1.28	1.28	1.28	1.28	
Mean TL of the community (excluding TL1)	1.89	1.89	1.89	1.89	
Connectance index	0.27	0.27	0.27	0.27	
System omnivory index	0.16	0.16	0.16	0.16	
Shannon diversity index	2.13	2.13	2.13	2.13	
Ecopath pedigree index	0.63	0.63	0.63	0.63	

Table 3.7. (continued)

Cycling indices					
Finn's cycling index (of total throughput)	10.09	10.13	10.14	10.14	%
Throughput cycled (excluding detritus)	20.72	20.71	20.71	20.71	$t.km^{-2}.y^{-1}$
Throughput cycled (including detritus)	116.02	116.41	116.50	116.49	$t.km^{-2}.y^{-1}$
Predatory cycling index (of throughput without detritu	3.67	3.67	3.67	3.67	%
Finn's mean path length	3.12	3.12	3.12	3.12	
Information indices					
Ascendency (A)	24.32	24.36	24.38	24.38	%
Overhead (O)	75.66	75.64	75.62	75.62	%
Capacity (C)	4773.98	4761.09	4756.04	4756.94	Flowbits

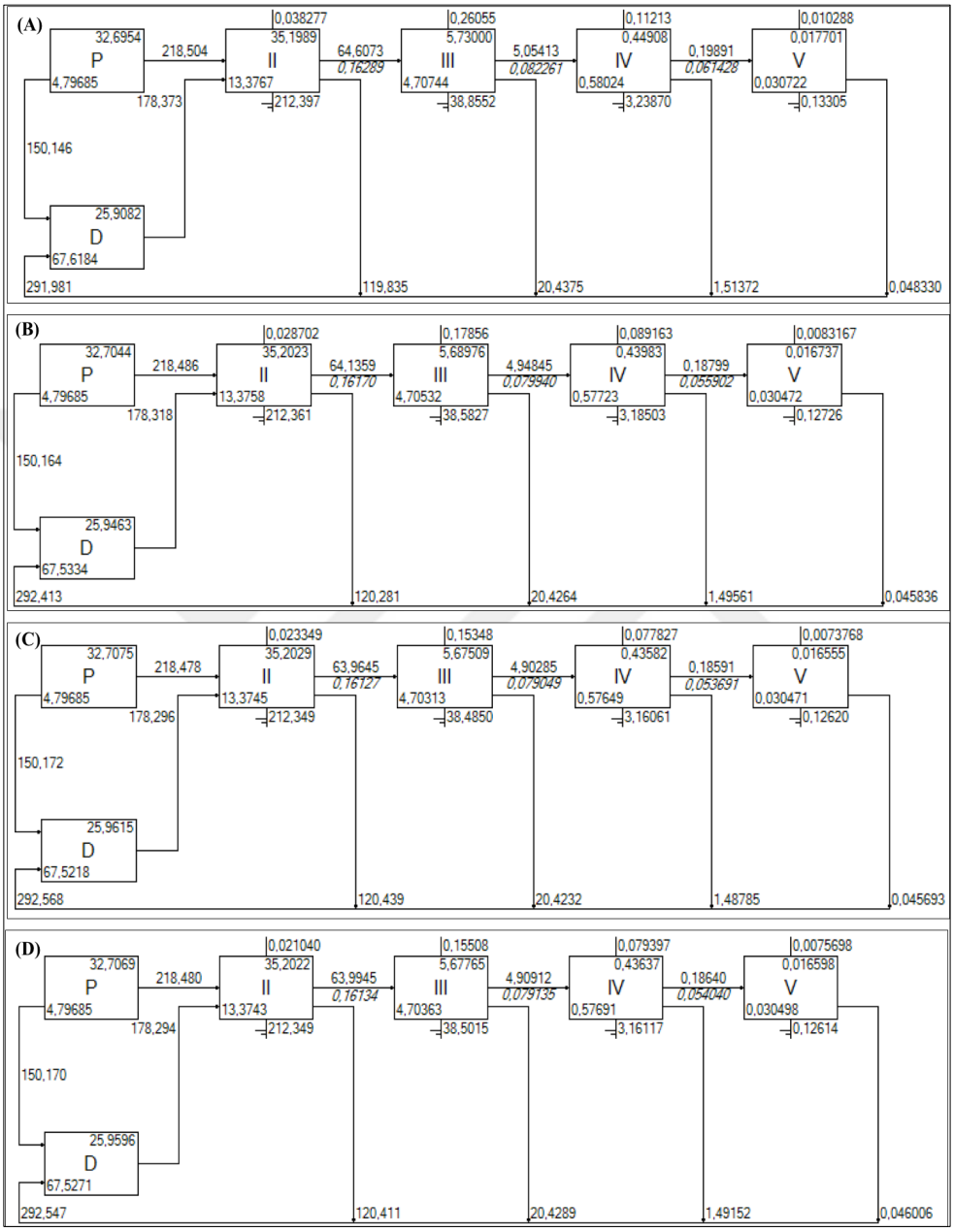

Figure 3.2. Lindeman spine demonstrating trophic flows between integer trophic levels (TL) for (A) GoM_CD44 model, (B) GoM_D44 model, (C) GoM_D50 model and (D) GoM_S40 model. Primary producer (P); detritus (D); Total system throughput (TST). See Figure 2.6 to read this figure

Although no functional group was described as a keystone species in the baseline model (GoM), *T. truncatus* (dolphin) could be considered a keystone species (Figure 3.3) due to the value close to zero (KS: -0.08; ε_i: 0.86) according to description by Libralato et al. (2006). However, *T. truncatus* was identified as a real keystone species in the GoM_D50 and GoM_S40 models (Figure 3.3). The Keystone index (KS) - relative overall effect (ε_i) of *T. truncatus* increased to 0.02 (123%) - 1.00 (16%) in GoM_D50 model (Sc. 2) and 0.004 (105%) – 1.00 (16%) in GoM_S40 model (Sc. 3). Moreover, there were some differences between models in terms of KS and ε_i, particularly in *S. undosquamis* (>MLS) (Figure 3.3) which represents an increase under all scenarios. In the baseline model, its KS was -0.28 and ε_i was 0.55. The increase was from -0.28 to -0.19 (33%), -0.15 (46%), and -0.15 (44%) in KS and from 0.55 to 0.68 (24%), 0.68 (24%), and 0.69 (26%) in ε_I for Sc. 1, Sc. 2 and Sc. 3, respectively. In addition, "micro and mesozooplankton", benthic invertebrates and *S. aurita* had high keystoneness following *T. truncatus* in all models (Figure 3.3).

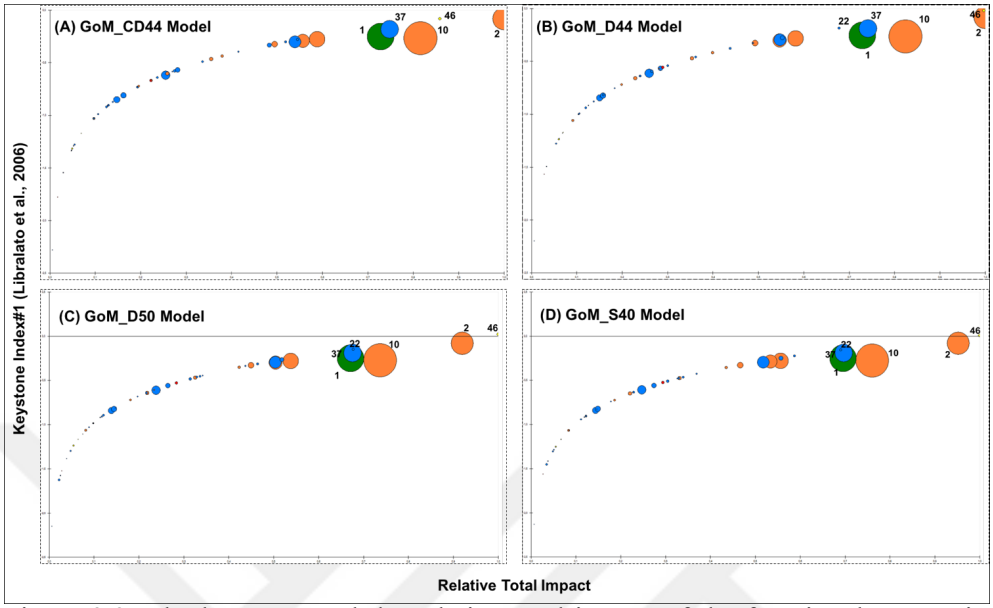

Figure 3.3. The keystone and the relative total impact of the functional groups in the models. The numbers and the size of circles indicate functional group name and their biomass respectively. The numbers represent functional groups of the models (1 Pyhtoplankton; 2 Micro and mesozooplankton; 10 Benthic invertebrates; 22 *Saurida undosquamis* (L) (>MLS); 37 *Sardinella aurita*; 46 *Tursiops truncatus*

3.3.3.2. Fishing Indicators

Results highlighted that the implementation of more selective trawl codend in demersal trawl fisheries in Gulf of Mersin would end up with an improvement in fishing indicators which evaluates the impact of fishing on the ecosystem (Table 3.8). Total catch ($t.km^{-2}.y^{-1}$) was predicted to decrease from 0.42 $t.km^{-2}.y^{-1}$ to 0.30 $t.km^{-2}.y^{-1}$, 0.26 $t.km^{-2}.y^{-1}$and 0.26 $t.km^{-2}.y^{-1}$ respectively and mean TL of the catch (mTLc) increased from 3.29 to 3.31, 3.33 and 3.35 under the Sc. 1, 2 and 3, respectively. Although the gross efficiency (GE, total catch/total primary production) was higher than its mean global value (0.0002) (Christensen et al., 2005) with 0.0008 for GoM_D44 model, 0.0007 for GoM_D50 model and 0.0007 for GoM_S40 model, a decrease was observed. Primary production required to sustain the catch (%PPRc) considering primary producers and detritus also decreased.

Table 3.8. Fishery indicators for the models: Trophic level (TL); primary production to sustain the catch (PPRc); Total primary production (TPp)

Parameter	Values				Units
	GoM_CD44	GoM_D44	GoM_D50	GoM_S40	
Fishery indices					
Total catch	0.42	0.30	0.26	0.26	$t.km^{-2}.y^{-1}$
Mean TL of the catch	3.29	3.31	3.33	3.35	
Total demersal trawl catch	0.32	0.20	0.16	0.16	$t.km^{-2}.y^{-1}$
Mean TL of demersal trawl catch	3.26	3.26	3.28	3.31	
Total pelagic catch	0.11	0.11	0.11	0.11	$t.km^{-2}.y^{-1}$
Mean TL of pelagic catch	3.40	3.40	3.40	3.40	
Gross efficiency (catch/ TPp.)	0.0011	0.0008	0.0007	0.0007	
PPRc/TPp.	6.79	6.47	5.64	5.54	%

3.3.4. Case study: Red Mullet, *Mullus barbatus*

In the context of the ecosystem approach to demersal trawl selectivity in the Gulf of Mersin, the outputs of the models related to *M. barbatus* are given in detail in Table 3.9. The energy balance which is similar for all compartments in the model is demonstrated in Figure 3.4 to describe the changes in energy flows of *M. barbatus*.

The following energy flow related demonstrations was based on the demonstration in Figure 3.4.

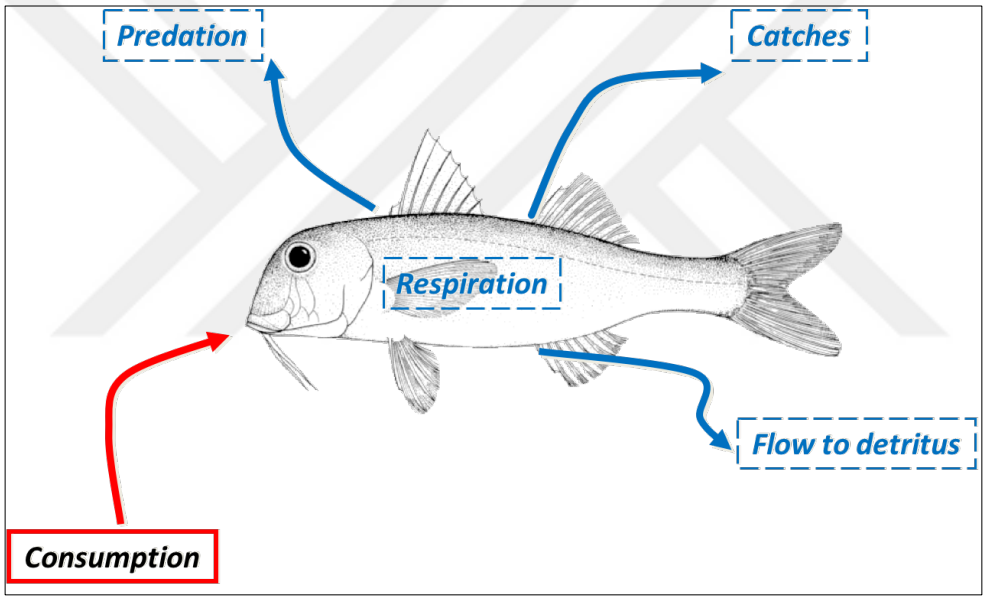

Figure 3.4. The demonstration of energy balance of each component in the food web

Switching from commercial to more selective codends result in less fishing mortality on both juvenile (<MLS) and adult (>MLS) red mullet, as well as less predation mortality on the adult group under all scenarios. However, there is an increase in predation mortality of the juvenile red mullet under Sc. 3 (Figure 3.5).

Table 3.9. Outputs of *Mullus barbatus*: fishing mortality (F, y^{-1}); predation mortality (M2, y^{-1}); other natural mortality (M0, y^{-1}); exploitation rate (F/Z) ; respiration/biomass ratio (The Schrödinger ratio, R/B); primary production to sustain the catch (PPRc); total primary production (TPp); mixed trophic impact (MTI)

Parameters	*Mullus barbatus* (<MLS)				*Mullus barbatus* (>MLS)			
	GoM_CD44	GoM_D44	GoM_D50	GoM_S40	GoM_CD44	GoM_D44	GoM_D50	GoM_S40
Mortalities								
F	1.0244	0.9397	0.6901	0.2995	0.4560	0.4424	0.3805	0.3713
M2	0.8947	0.7043	0.8888	0.9734	0.1909	0.1550	0.1574	0.1585
M0	0.2709	0.4628	0.3089	0.4377	0.1391	0.1697	0.1428	0.1381
F/Z	0.4677	0.4460	0.3656	0.1751	0.5802	0.5768	0.5590	0.5560
Flows								
Consumption=	0.1226	0.1149	0.0903	0.0823	0.4526	0.4526	0.4526	0.4526
+Predation	0.0115	0.0085	0.0084	0.0084	0.0210	0.0170	0.0173	0.0174
+Catch	0.0131	0.0113	0.0065	0.0026	0.0502	0.0487	0.0419	0.0408
+Respiration	0.0700	0.0666	0.0545	0.0511	0.2756	0.2777	0.2872	0.2886
+Flow to Detritus	0.0280	0.0285	0.0210	0.0202	0.1058	0.1092	0.1062	0.1057
Energetics								
R/B	5.4604	5.5334	5.7972	5.9123	2.5057	2.5247	2.6109	2.6237
Fishing Impact								
PPRc/TPp (%)	0.0720	0.0685	0.0447	0.0194	0.3397	0.3589	0.3528	0.3491
MTI of trawl fish. on	-0.3019	-0.3750	-0.3009	-0.1563	-0.4417	-0.4672	-0.4605	-0.4540

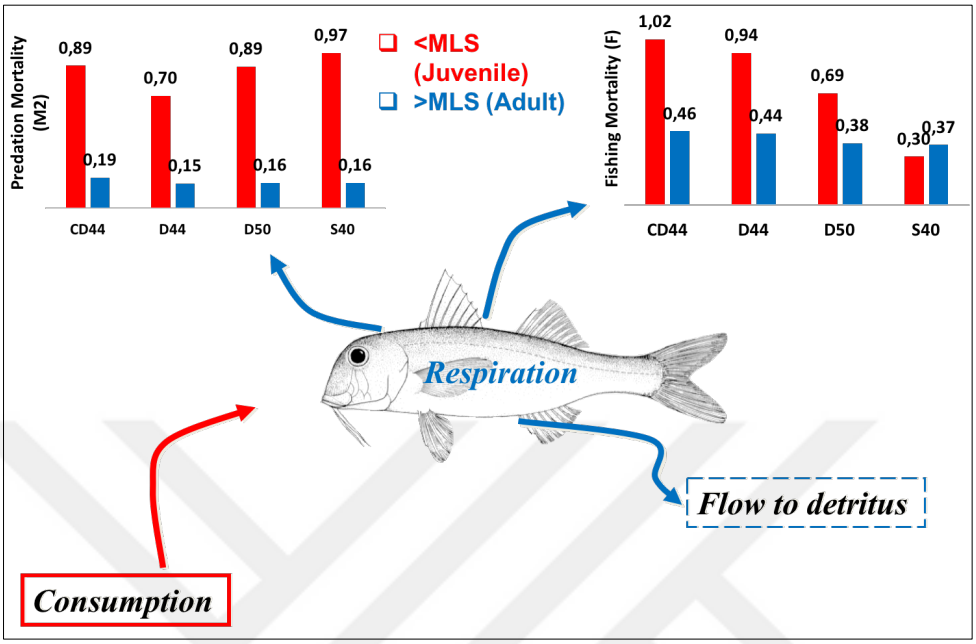

Figure 3.5. Fishing and predation mortality rates for juvenile red mullet. GoM_CD44 model (CD44); GoM_D44 model (D44); GoM_D50 model (D50); GoM_S40 model (S40)

Figure 3.6 shows that the percentage distribution of consumption (Q) for juvenile red mullet. Overall, the implementation of more selective trawl codend result in a decrease the energy exported by fisheries, and an increase of its respiration (or metabolism) and flow to detritus (death or faeces). The highest changes were observed in GoM_S40 model with a decrease of 7.57% in the export by fisheries, and with an increase of 0.86% in export by predation, 4.95% in respiration and 1.76% in flow to detritus.

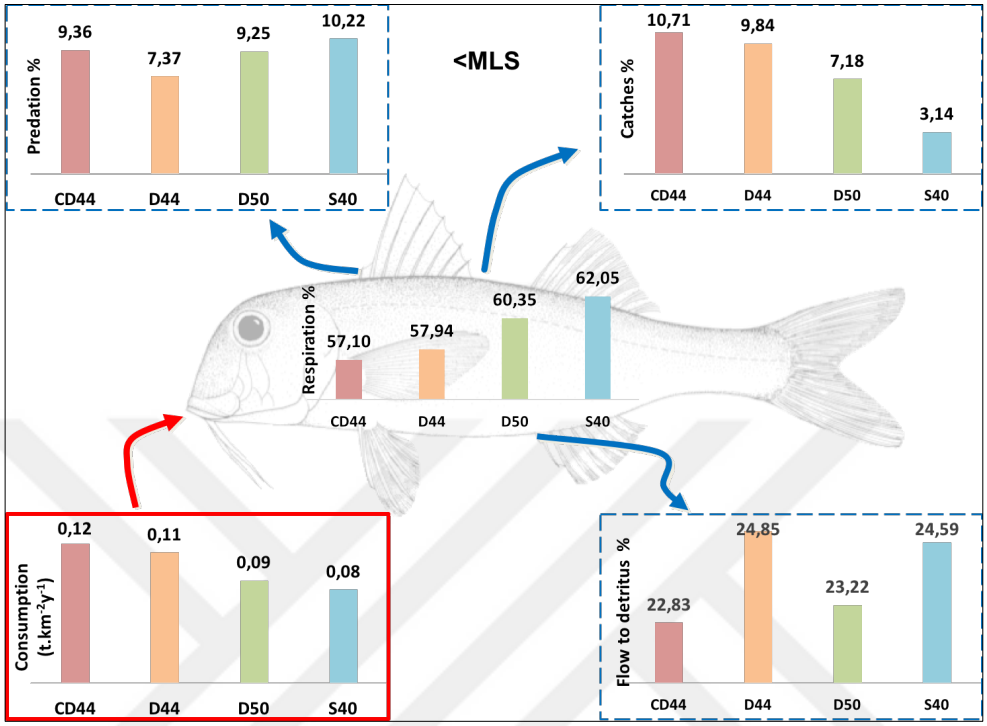

Figure 3.6. The percentage distribution of consumption (Q) for juvenile red mullet. GoM_CD44 model (CD44); GoM_D44 model (D44); GoM_D50 model (D50); GoM_S40 model (S40)

For adult red mullet, the shift would cause just a slight change in energy flow. While exports by fisheries and predation slightly decreased, respiration increased (Figure 3.7).

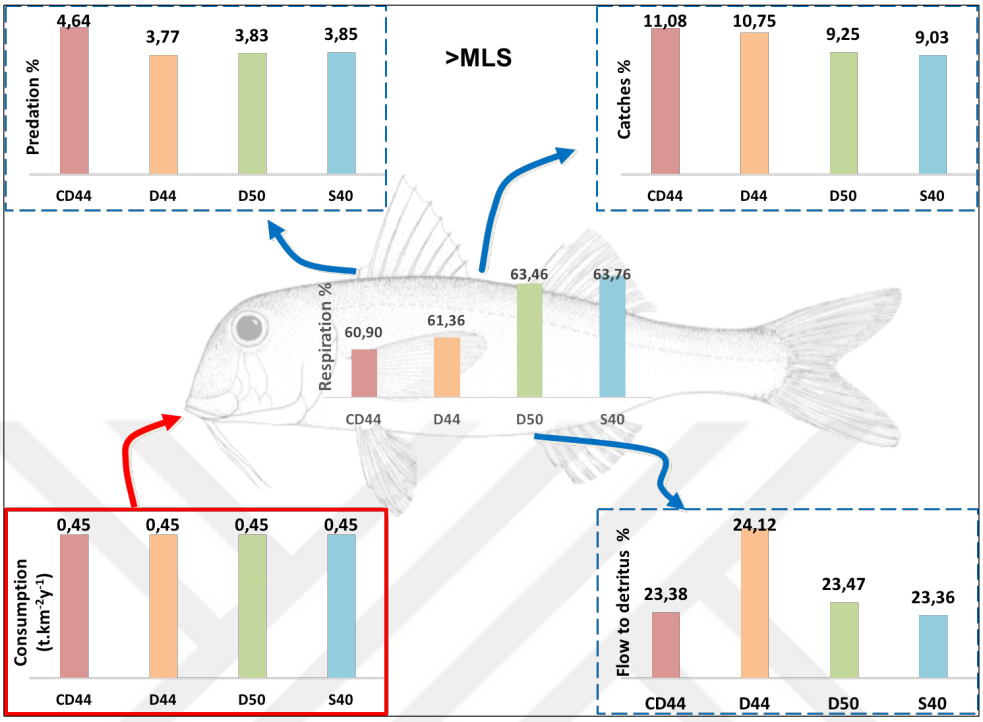

Figure 3.7.The percentage distribution of consumption (Q) for adult red mullet. GoM_CD44 model (CD44); GoM_D44 model (D44); GoM_D50 model (D50); GoM_S40 model (S40)

The ratio of respiration to biomass (R/B) named Schrödinger ratio may be considered a measure of metabolic activity of related species or group. The ratio slightly increased as selectivity increased (Table 3.9).

The mixed trophic impact (MTI) analysis, show that if fishermen were to change from commercial to relatively more selective codends, the 40 mm square mesh codend (S40) would be preferable, because the mixed trophic effect of demersal trawl fisheries on juvenile red mullet was less negative (decreased from -0.30 to -0.16) in the use of S40 codend (Sc. 3) (Figure 3.8). Thus, S40 is the best alternative for red mullet in terms of MTI (Figure 3.8). There is no improvement in the use of other alternative codends with diamond meshes (D44 and D50).

Moreover, there is no change in MTI of demersal trawl fisheries on adult red mullets (Figure 3.8).

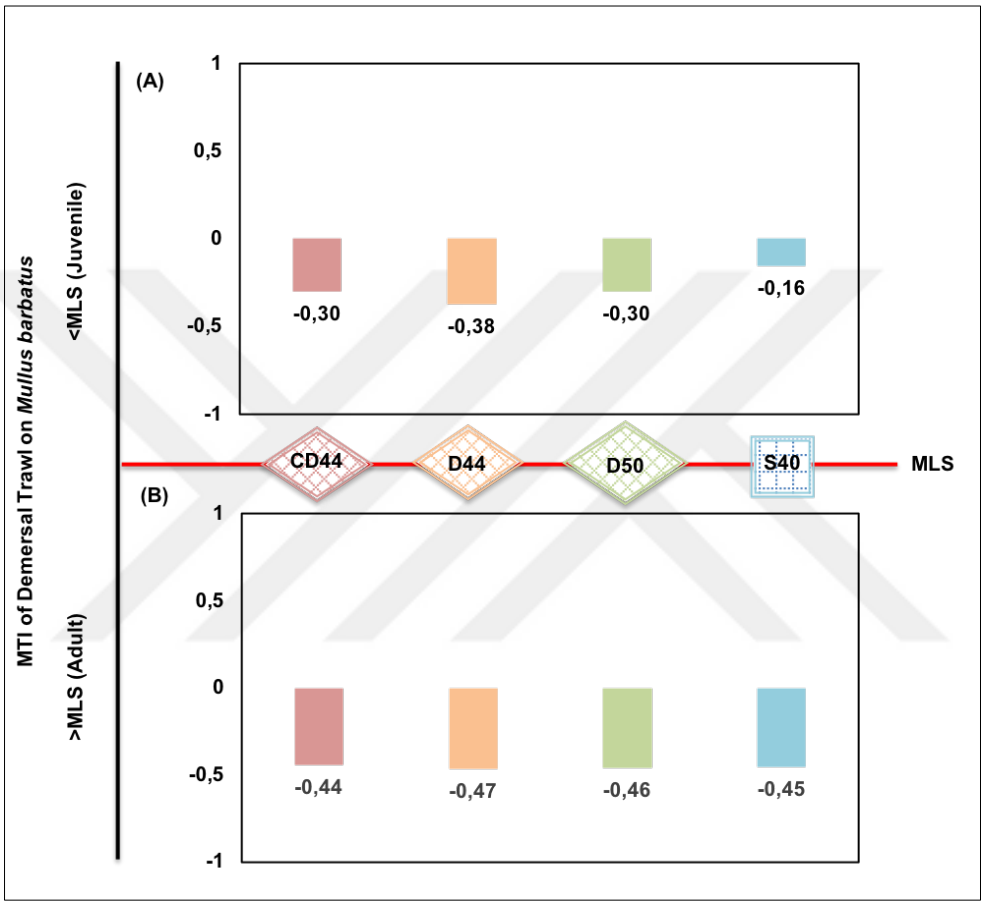

Figure 3.8. The Mixed Trophic Impact (MTI) of demersal trawl fisheries on juvenile (<MLS) (A) and adult (>MLS) (B) red mullet. GoM_CD44 model (CD44); GoM_D44 model (D44); GoM_D50 model (D50); GoM_S40 model (S40); minimum landing size (MLS)

3.3.5. Case study: Brushtooth Lizardfish, *Saurida undosquamis*

The outputs of the models related to *S. undosquamis* are given in detail in Table 3.10. The changes in energy flows of *S. undosquamis* were examined in the following figures by using the demonstration depicted in Figure 3.4.

Table 3.10. Outputs of *Saurida undosquamis*: fishing mortality (F, y^{-1}); predation mortality (M2, y^{-1}); other natural mortality (M0, y^{-1}); exploitation rate (F/Z); respiration/biomass ratio (The Schrödinger ratio, R/B); primary production to sustain the catch (PPRc); total primary production (TPp); mixed trophic impact (MTI)

Parameters	*Saurida undosquamis* (<MLS)				*Saurida undosquamis* (>MLS)			
	GoM_CD44	GoM_D44	GoM_D50	GoM_S40	GoM_CD44	GoM_D44	GoM_D50	GoM_S40
Mortalities								
F	0.6044	0.2574	0.1159	0.0520	0.2444	0.1040	0.0504	0.0698
M2	0.8195	1.3095	1.7850	1.6466	0.3786	0.3686	0.3730	0.3732
M0	0.8452	0.4878	0.1109	0.3014	0.1013	0.0632	0.0406	0.0470
F/Z	0.2664	0.1253	0.0576	0.0260	0.3374	0.1940	0.1087	0.1425
Flows								
Consumption=	0.0476	0.0277	0.0221	0.0237	0.1397	0.1397	0.1397	0.1397
+Predation	0.0041	0.0036	0.0038	0.0038	0.0148	0.0145	0.0146	0.0146
+Catch	0.0030	0.0007	0.0002	0.0001	0.0096	0.0041	0.0020	0.0027
+Respiration	0.0268	0.0165	0.0134	0.0143	0.0833	0.0907	0.0935	0.0925
+Flow to Detritus	0.0137	0.0069	0.0047	0.0054	0.0319	0.0304	0.0295	0.0298
Energetics								
R/B	5.3976	6.0110	6.2764	6.1840	2.1258	2.3143	2.3862	2.3602
Fishing Impact								
PPRc/TPp (%)	0.2838	0.0811	0.0305	0.0149	0.1696	0.1174	0.0649	0.0873
MTI of trawl fish. on	-0.1533	0.0050	0.1013	0.1421	-0.2749	-0.1423	-0.0648	-0.0897

If fishermen switched from the traditional CD44 codend to D44, D50 or S40 codends which are more selective, the shift would result in a decrease in fishing mortality of juvenile (<MLS) and adult (>MLS) lizardfish, and an increase in predation mortality of juvenile lizardfish (Figure 3.9).

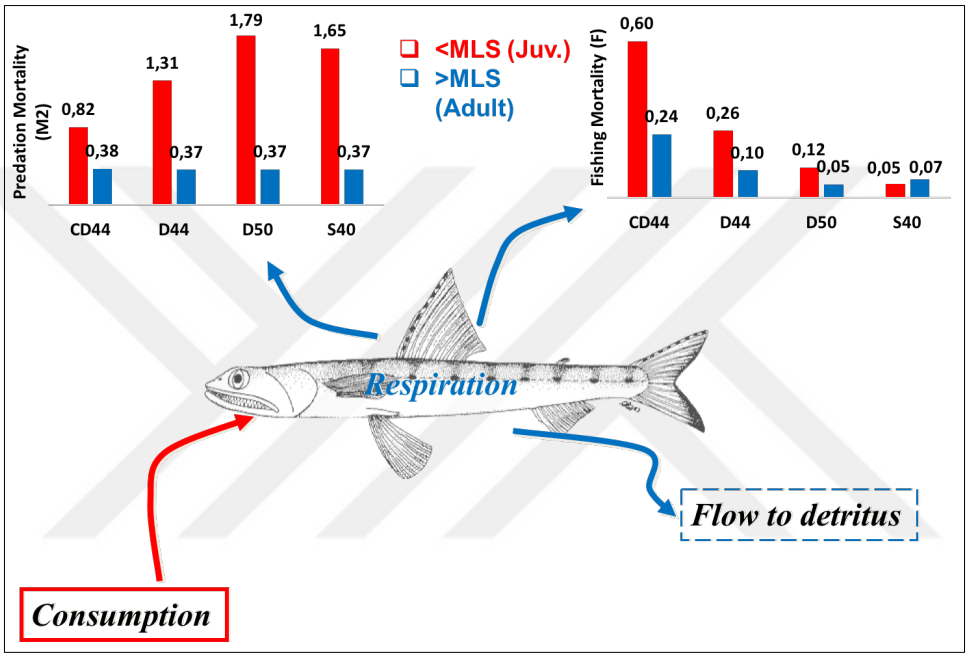

Figure 3.9. Fishing and predation mortality rates for juvenile lizardfish. GoM_CD44 model (CD44); GoM_D44 model (D44); GoM_D50 model (D50); GoM_S40 model (S40)

For juvenile lizardfish, the implementation of more selective trawl codend was predicted to result in a decrease in the energy exported by fisheries and predation, and an increase of its respiration and flow to detritus (unassimilated food and other natural mortality) (Figure 3.10). The highest change was predicted with a decrease from 6.31% in baseline model to 0.51% in GoM_S40 model (Figure 3.10).

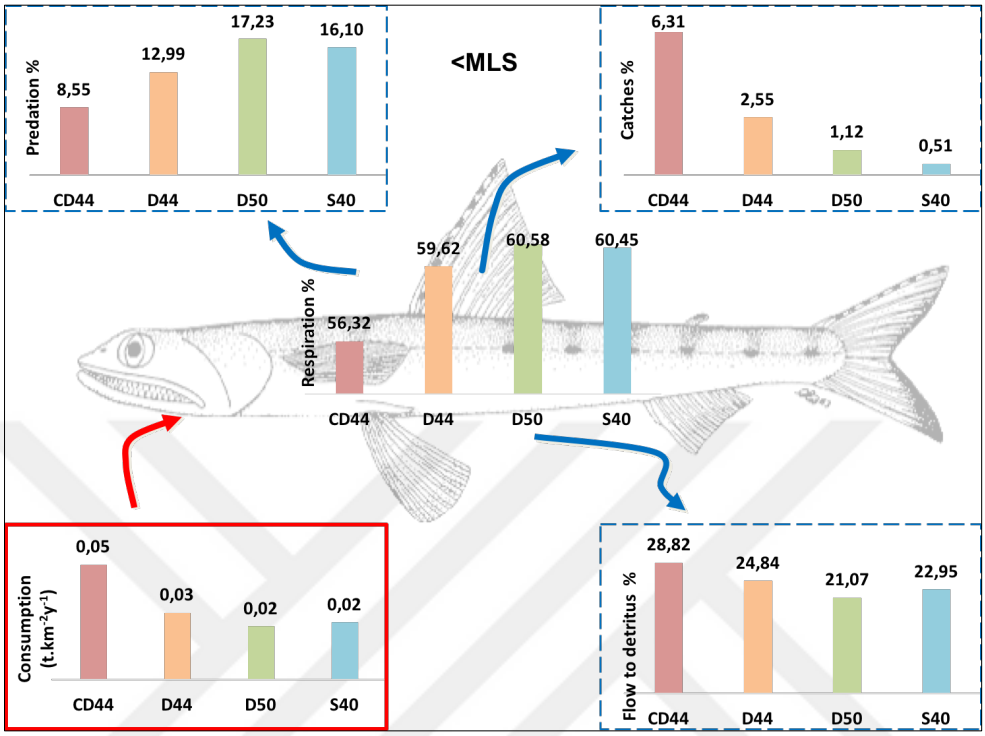

Figure 3.10. The percentage distribution of consumption (Q) for juvenile lizardfish. GoM_CD44 model (CD44); GoM_D44 model (D44); GoM_D50 model (D50); GoM_S40 model (S40)

For the adult group, the shift caused a decrease in exports (fisheries and predation) and flow to detritus, while respiration showed just an increase in respiration. The energy exported by fishing removal was decreased from 6.86% to 1.96%. Figure 3.11 shows that the percentage distribution of input energy in adult lizardfish group in the food web.

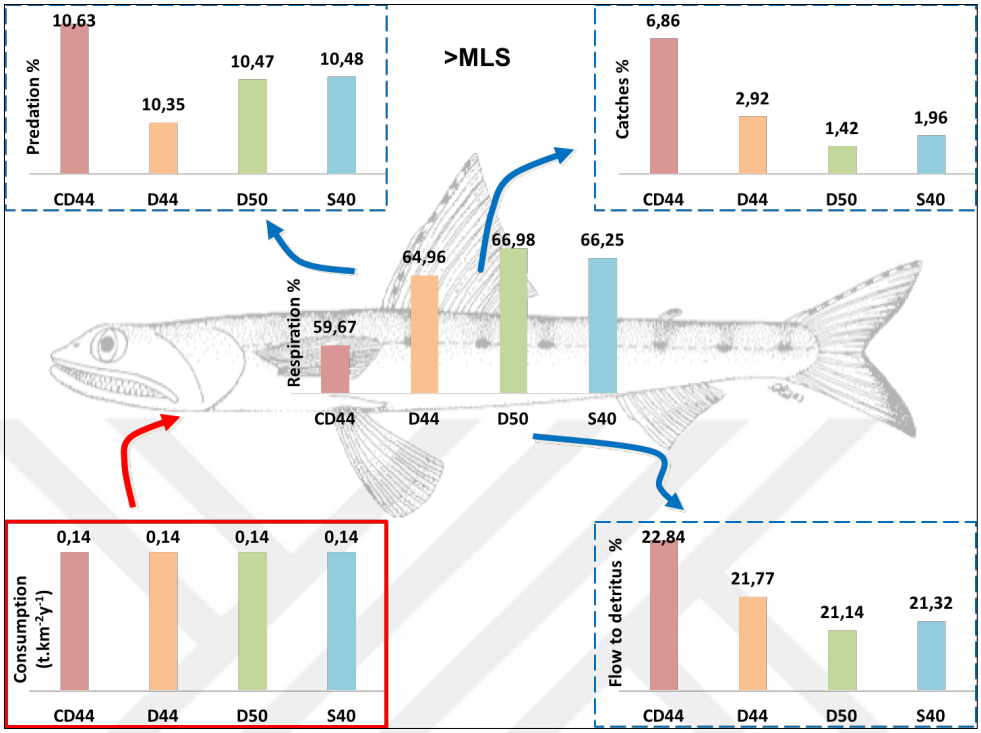

Figure 3.11. The percentage distribution of consumption (Q) for adult lizardfish. GoM_CD44 model (CD44); GoM_D44 model (D44); GoM_D50 model (D50); GoM_S40 model (S40)

Respiration over biomass (R/B) tended to slightly rise for adult and juvenile groups under the all scenarios. (Table 3.10).

Figure 3.12 shows that the potential benefit of improved trawl selectivity on the juvenile and adult lizardfish groups. The highest positive improvement in the impact of demersal trawl fisheries on juvenile lizardfish predicted in GoM_S40 model. When it is considered that MTI shows the effect on the biomass of each functional group against a hypothetical tiny increase in each functional group. The MTI shows that if fishermen used a more selective codend, the biomass of lizardfish would increase.

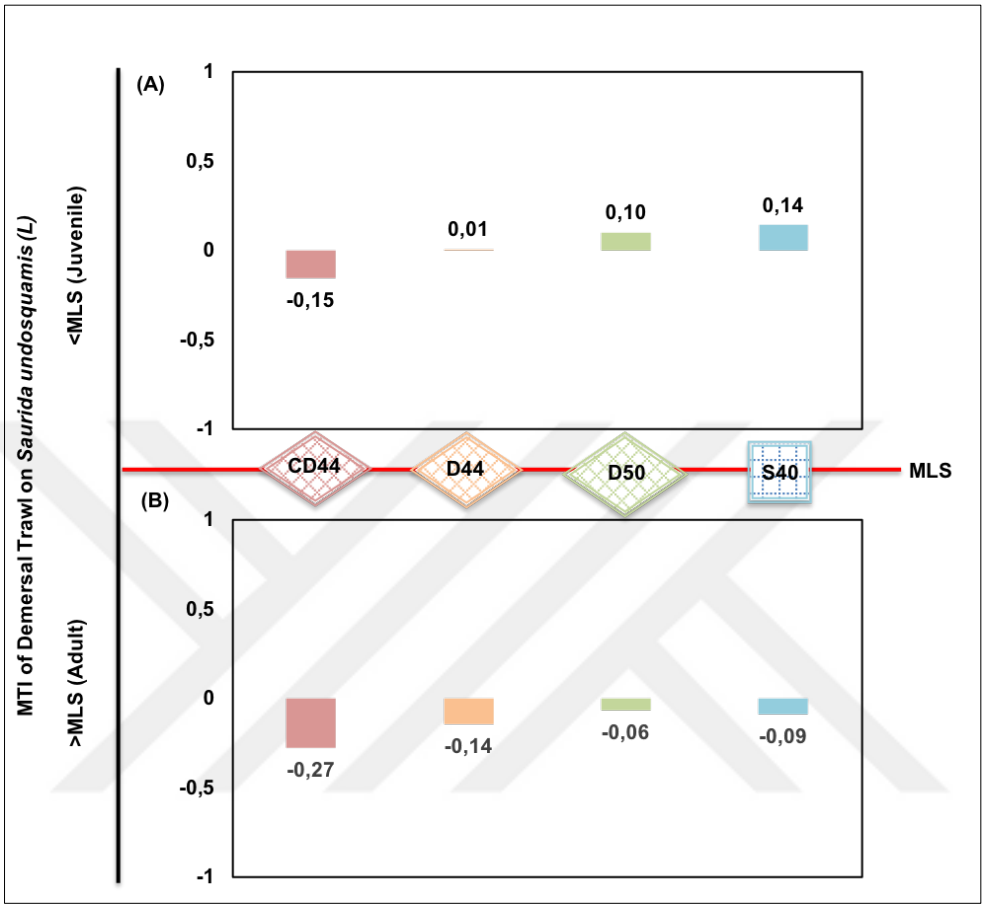

Figure 3.12. The Mixed Trophic Impact (MTI) of demersal trawl fisheries on juvenile (<MLS) (A) and adult (>MLS) (B) lizardfish. GoM_CD44 model (CD44); GoM_D44 model (D44); GoM_D50 model (D50); GoM_S40 model (S40); minimum landing size (MLS)

3.3.6. Case study: Common Pandora, *Pagellus erythrinus*

The output parameters of *P. erythrinus* for each model are presented in Table 3.11. In the following figures, the changes in energy flows of *P. erythrinus* were depicted via the demonstration in Figure 3.4.

Table 3.11. Outputs of *Pagellus erythrinus*.: fishing mortality (F, y^{-1}); predation mortality (M2, y^{-1}); other natural mortality (M0, y^{-1}); exploitation rate (F/Z); respiration/biomass ratio (The Schrödinger ratio, R/B); primary production to sustain the catch (PPRc); total primary production (TPp); mixed trophic impact (MTI)

Parameters	*Pagellus erythrinus* (<MLS)				*Pagellus erythrinus* (>MLS)			
	GoM_CD44	GoM_D44	GoM_D50	GoM_S40	GoM_CD44	GoM_D44	GoM_D50	GoM_S40
Mortalities								
F	1.1555	0.9292	0.6936	0.6358	0.2153	0.2059	0.1565	0.2130
M2	0.7102	0.6086	0.8453	0.5740	0.4221	0.4067	0.4059	0.4086
M0	0.3333	0.4886	0.2694	0.6789	0.1326	0.1294	0.0328	0.1414
F/Z	0.5255	0.4586	0.3836	0.3366	0.2796	0.2775	0.2630	0.2791
Flows								
Consumption=	0.0353	0.0311	0.0211	0.0305	0.1204	0.1204	0.1204	0.1204
+Predation	0.0026	0.0020	0.0018	0.0018	0.0127	0.0122	0.0122	0.0123
+Catch	0.0042	0.0030	0.0015	0.0020	0.0065	0.0062	0.0047	0.0064
+Respiration	0.0202	0.0184	0.0130	0.0183	0.0731	0.0740	0.0784	0.0734
+Flow to Detritus	0.0083	0.0078	0.0048	0.0083	0.0281	0.0280	0.0251	0.0283
Energetics								
R/B	5.5814	5.7094	6.1263	5.7282	2.4300	2.4579	2.6048	2.4370
Fishing Impact								
PPRc/TPp (%)	0.0509	0.0435	0.0251	0.0314	0.1235	0.1447	0.1404	0.1473
MTI of trawl fish. on	-0.3783	-0.3643	-0.2801	-0.3397	-0.1165	-0.1316	-0.1209	-0.1544

Switching from commercial to more selective codends result in less fishing mortality on juvenile (<MLS) group under all scenarios as well as less predation mortality on the juvenile group under Sc. 1 and 3. However, there is an increase in predation mortality of the juvenile group under Sc. 2 (Figure 3.13).

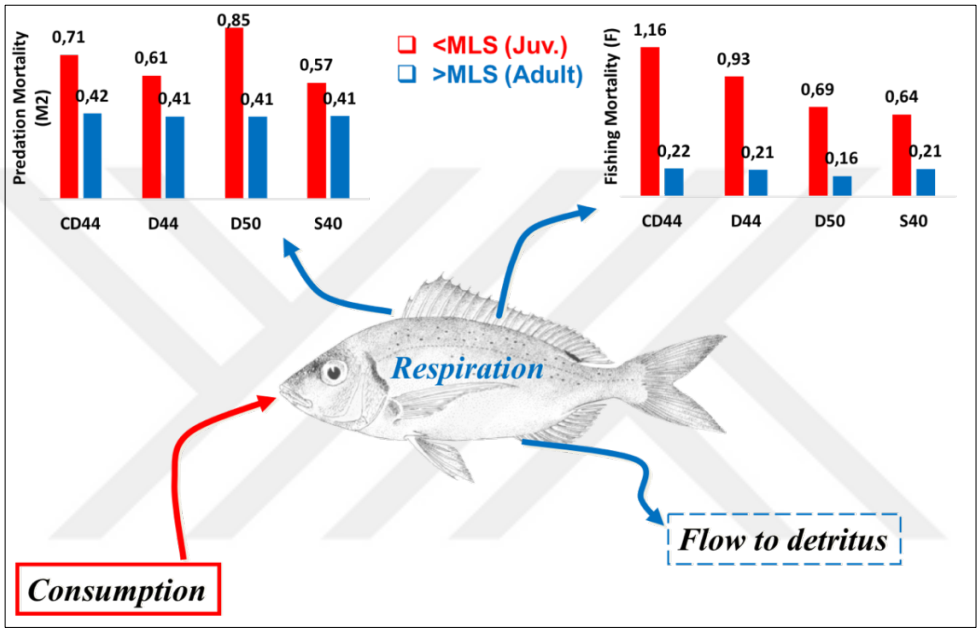

Figure 3.13. Fishing and predation mortality rates for juvenile common pandora. GoM_CD44 model (CD44); GoM_D44 model (D44); GoM_D50 model (D50); GoM_S40 model (S40)

Figure 3.14 and 3.15 demonstrate the percentage distribution of consumption (Q) for juvenile and adult groups, respectively. For juvenile group, the implementation of more selective trawl codend result in a decrease the energy exported by fisheries, and an increase of its respiration (or metabolism). Flow to detritus (death or faeces) increases under Sc. 1 and 3, while Sc. 2 causes a slight decrease. Moreover, Sc. 2 is responsible for more energy export by predation (Figure 3.14). For adult group, the shift would cause just a decrease in energy by fisheries, predation and flow to detritus under Sc. 2. This less exported energy

would cause an increase in the energy used for metabolic activity (respiration) (Figure 3.15).

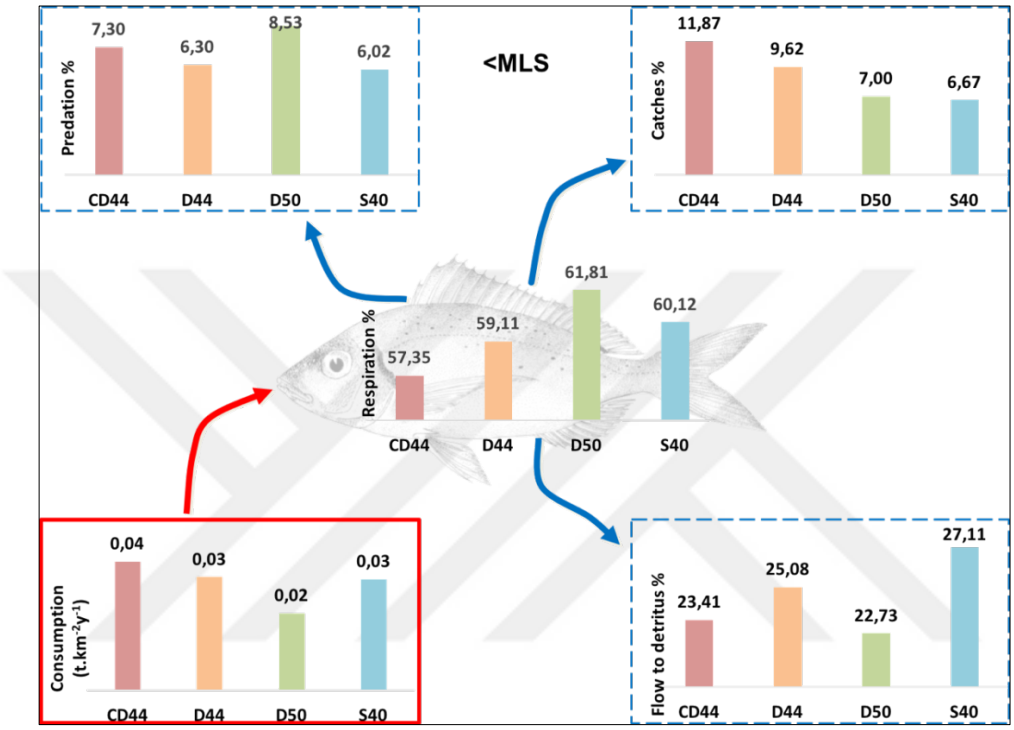

Figure 3.14. The percentage distribution of consumption (Q) for juvenile common pandora. GoM_CD44 model (CD44); GoM_D44 model (D44); GoM_D50 model (D50); GoM_S40 model (S40)

Moreover, Schrödinger ratio (R/B) of common pandora highlights that measure of metabolic activity changes in parallel with the energy used for its respiration (Table 3.11).

Figure 3.15. The percentage distribution of consumption (Q) for adult common pandora. GoM_CD44 model (CD44); GoM_D44 model (D44); GoM_D50 model (D50); GoM_S40 model (S40)

D50 codend could be considered the best alternative for common pandora. Because, Sc. 2 shows that the mixed trophic effect of demersal trawl fisheries on juvenile group of common pandora was less negative (decreased from -0.38 to -0.28). There is tiny improvement under the other scenarios. There is no improvement in the mixed trophic effect of demersal trawl fisheries on its adult group (Figure 3.16).

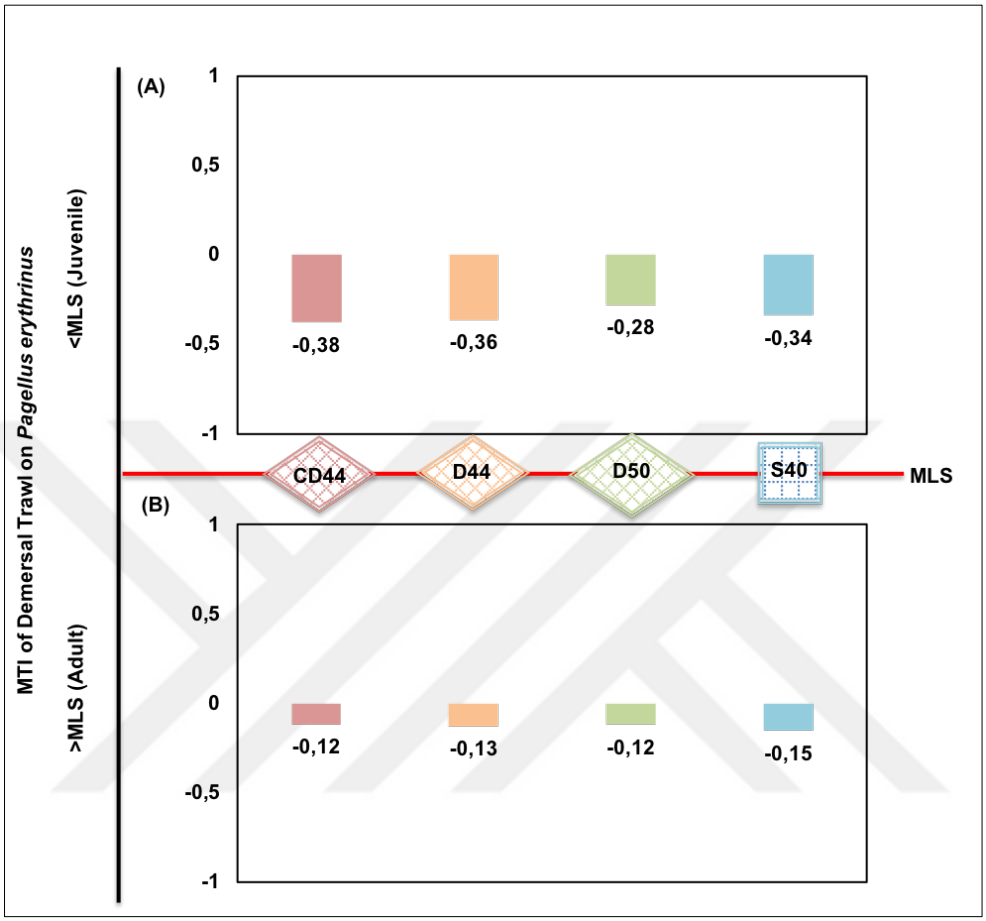

Figure 3.16. The Mixed Trophic Impact (MTI) of demersal trawl fisheries on juvenile (<MLS) (A) and adult (>MLS) (B) common pandora. GoM_CD44 model (CD44); GoM_D44 model (D44); GoM_D50 model (D50); GoM_S40 model (S40); minimum landing size (MLS)

3.4. Discussion

This study shows that improved trawl selectivity would result in a smaller effect of the demersal trawl fisheries on the Gulf of Mersin ecosystem. This is shown by the ecological indicators such as mean transfer efficiency (TEm) (Table 3.7), mean trophic level of the catch (mTLc), gross efficiency (GE) and primary production required to sustain the catch (PPRc) (Table 3.8). TEm, which is the measure of the inefficiencies of the food web, can be expected to increase as fishing impact increases (Libralato et al., 2005). mTLc shows a decrease in response to fishing (Pauly et al., 1998). GE and PPRc increase as fishing pressure increases. Thus, this overall finding can be considered that improved trawl selectivity would be for the benefit of ecosystem. In addition, the 40 mm square mesh (S40) trawl codend seem to be a better alternative than the diamond mesh codends with 44 mm and 50 mm mesh sizes.

Results at the ecosystem level also show that improved trawl selectivity would affect the compartments not directly impacted by the demersal trawl fisheries such as small pelagic fishes and *T. truncatus* because of indirect trophic interactions. Ecopath considers the impacts of fishing on the ecosystem in terms of both target and non-target species plus the trophic interactions within the whole food web (Botsford 1997; Duda and Sherman 2002, Coll *et al.* 2008a, Coll and Libralato 2012). Coll et al. (2008a) also stated that the importance of considering trophic interactions for the evaluation in the impact of selectivity measures. Thus, positive impacts of improved selectivity on the pelagic compartments of the food web can be suggested and confirmed by mixed trophic impact (MTI) analysis. These findings are supported the time simulation results by Coll et al. (2008a).

Keystone analysis demonstrates that improved trawl selectivity was responsible for the slight changes of keystoneness (KSi) of functional groups in the food web (Figure 3.3). *T. truncatus* was described as a keystone species under all scenarios, and adult *S. undosquamis* showed high increasing change in the KSi (Figure 3.3). Both are high trophic level (TL) species and feed predominantly on

small pelagic fishes which are positively affected by the trawl fisheries. No significant changes were seen in the KSi of low TL organisms. The differences of keystoneness under fishing and non-fishing scenarios described by Coll et al. (2009). Both higher and lower TL organisms show remarkable increasing changes under non-fishing scenario. Dolphin and adult hake are keystone species among high TL organisms (Coll et al., 2009).

Fisheries is responsible for the changes to ecosystem functioning and structure through species interactions in the food web (Hall, 1999). Fisheries alter predation mortality and competition (Cury et al., 2001). All scenarios in this study illustrated that an improvement in trawl selectivity would cause a change in ecosystem indicators at the functional group level in the ecosystem such as mortalities (F, M0, M2), flow related indicators (P/B, Q/B, EE, FD) and respiration related indicator (R/B) on demersal fished groups (Table 3.3-3.6). These changes in energy flows at the functional group level also demonstrated for red mullet and lizardfish which have been split into adult and juvenile stage (multi-stanza groups, Figure 3.5 – 3.7 for red mullet and Figure 3.9 – 3.11 for lizardfish).

No demersal group exceeded the recommended exploitation rate (F/Z) of 0.8 for demersal stocks (Mertz and Myers, 1998) in all models, but several demersal groups had a higher than recommended F/Z of 0.5 by Rochet and Trenkel (2003). Exploitation rate of adult *M. barbatus* was higher than 0.5 in all models. Improving in codend selectivity directly reduced the exploitation rate of juvenile *M. barbatus*, but the rate was lower than 0.5 in all models. Nevertheless, it is worthy to note that the rate decreased from 0.47 to 0.18 in GoM_S40 model. The rates of large discarded demersal fishes and juvenile *P. erythrinus* were higher than 0.5 in the baseline model, but the values were lower than this recommended value in other models representing more selective codends (Table 3.5).

The MTI analysis reveal that improved demersal trawl fisheries in Gulf of Mersin would have positive impacts on various functional groups in the food web. This is probably because of a decrease in F (Coll et al., 2008a).

According to selectivity studies, S40 codend in demersal trawl fisheries is the most selective codend and the best alternative in Gulf of Mersin (Özbilgin et al., 2015) and in other Mediterranean areas (Bahamon et al., 2006; Ordines et al., 2006). This confirms the results of single species studies which found that the use of S40 would benefit commercial demersal species (Bahamon et al., 2007). However, the proper assessment of improved trawl selectivity requires ecosystem based approaches (Bahamon et al., 2007; Coll et al., 2006). (Coll et al., 2008a) also found that improved trawl selectivity would impact on ecosystem positively, and also found benefits to various commercial groups (Coll et al., 2008a).

In parallel, the consequences of improved trawl selectivity were assessed in the context of ecological framework approved that selective fisheries would benefit for various commercial species and ecosystem. S40 was defined as the best alternative for various commercial species, particularly red mullet which is the most important commercial fish species in the region, and the impacts of trawl fisheries on the ecosystem (Figure 3.8). However, the switching from commercial codend (CD44) to D50 would not provide an advantage to red mullet populations because of the complex trophic cascade according to MTI analysis (Figure 3.8). It may be worthy note that although D50 codend is less selective than S40 codend (Özbilgin et al., 2015), it looks other selective codend according to selectivity studies in the region (Özbilgin et al., 2015). Moreover, GFCM recommended the use of S40 or a diamond mesh size of at least 50 mm (D50) codends (GFCM, 2007), if fishermen makes a justified request (E.C., 2006).

The MTI analyses may be used as a measure of biomass change to compare the models setup with differing catch profiles due to the constant topology adopted in this study. A change from CD44 to S40 codends altered the MTIs on juvenile red mullet from -0.3 to -0.16. The improvement in this MTI value was

related to a biomass increase of 14% when S40 codends were applied. However, even using S40, fishing still had a negative impact on juvenile red mullet. Applying D50 codends resulted in no change for juvenile red mullet. For the adult fish, there was also no improvement when making this codend change. However, the model predicted that there would be a biomass increase of 25% and 30% for juvenile lizardfish, 21% and 19% for adult lizardfish for D50 and S40 codends, respectively. While biomass of juvenile common pandora can be expected to increase 10% and 4% in the use of D50 and S40 codends, respectively, no improvement can be expected in its adult groups. In addition, discarded fish groups represented as small discarded (26% and 29%) and large discarded (37% and 33%) fish groups in this model and "picarels and bogue" (34% and 27%) would be positively affected by selective fisheries. Brackets show hypothetical biomass increase response to the use of D50 and S40 codends respectively.

According to MTI results, more selective fisheries would also affect Lessepsian species. The greatest impact would be on lizarfish as explained above. In addition, remarkable improvement on demersal fish species (L) (16%) can be expected. Moreover, small changes on other Lessepsian groups can be mentioned as positively for C. longicollis (7%) and U. molucensis & pori (6%) and negatively for shrimps (1%) and N. randalli (2%).

The introduction of more selective fisheries could affect predator-prey relationships and have unintended consequences for commercial species. e.g. *S. undosquamis* have been reported to feed predominantly on *M. barbatus* (Bingel and Avsar, 1988). However, a more recent study around the modelled area and a study from an adjacent ecosystem revealed that more than 90% of the diet of *S. undosquamis* is comprised of small pelagic fishes (Golani, 1993; Özyurt et al., 2017). The current diet information was confirmed by personal observations and used in this model. According to results, *S. undosquamis* do not have negative impact on *M. barbatus* when more selective codends were applied (also see in section 2.4.1).

Recent studies revealed that Ecopath with Ecosim (EwE) models provide some valuable indicators described under the descriptors of MSFD's GES (Coll et al., 2015; Lassen et al., 2013; Piroddi et al., 2015b; Rombouts et al., 2013). However, Heymans et al. (2014) highlighted the differences of the topology of EwE models, and advised to consider these differences for the application of the management advices. In this study, the constant topology of the models provides an advantage to avoid the warning problem above.

Coll et al. (2006) described the EwE model for the south Catalan Sea. Afterwards, an EwE model developed to evaluate the consequences of improved selectivity by Coll et al. (2008a). Former model had been used as baseline model for latter model. Virtual Population Analysis was applied to estimate fishing mortality rates of some commercial demersal species in latter model in an attempt to evaluate the impacts of selectivity measures. But, different methodology was performed for the implementation of selectivity in this study (Section 3.2.2). This different methodical aspect allows to estimate selectivity measures for various demersal species, not only commercial ones. However, the codend selectivity studies would include all by-catch and discard species, as well as commercial species, or the assumption on the correlation between biomass or abundance index and selectivity performance would be enhanced via experimental studies.

To enhance this study, the information on post-escape mortality rates of demersal species in demersal trawl fisheries is important (Coll et al., 2008a). Düzbastılar et al. (2010a) assessed the survival of *Mullus barbatus*, *Diplodus annularis*, *Spicara maena* and *Pagellus erythrinus* escaping from 40 mm square (S40) and diamond (D40) mesh codends in demersal trawl fisheries in the Aegean Sea. The findings highlighted that the low mortality of these species for S40 and D40 codends. Nevertheless, diamond mesh codends cause more mortality than square mesh codends for red mullet (Düzbastılar et al., 2010a). In addition, there have been some efforts to assess the post-escape mortality under different conditions (Düzbastilar et al., 2010; Düzbastılar et al., 2010b; Kaiser and Spencer,

1995; Metin et al., 2004). Post-escape mortality rates of all demersal species were assumed as zero in this model. In addition, discard survival would be important. A little is known on the discard survival for fished species in demersal trawl fisheries. So, the discard survival rates of the species being thrown back into the sea as discard were assumed 0% in this work.

The role of length frequency distributions of the fish was explained at the equation (27) under the section 2.2.6 of chapter II. The improvement of the length distribution would directly affect to the implementation of the selectivity. In addition, the number of split of multi-stanza groups were 2 as juvenile and adult in this model. However, the increase in the number of split would help to assess the effects of improved trawl selectivity on commercial species in the context of ecosystem based fisheries management.

Ecosim, which is the time series analysis of Ecopath, should be set up in order to enhance this model. In addition, Ecosim would provide dynamic predictions on the research questions tested in this thesis.

4. CHAPTER: THESIS CONCLUSION

This thesis presents an ecosystem based assessment on the potential consequences of improved trawl selectivity. Main research question is: If we switched from commercial trawl codend to more selective codends, would the shift have a noticeable impact on the ecosystem and main target species? For this purpose, two works were designed in this PhD thesis. The first is to describe ecosystem structure and functioning of Gulf of Mersin, and provide a baseline model to address main research question (Chapter 2). The second is to investigate potential consequences of improved trawl selectivity on ecosystem and main target species (Chapter 3).

In the second chapter, results highlight that the Ecopath model reflects the common properties of the Mediterranean ecosystem characteristics, low trophic level groups are critical components of the ecosystem, and dolphin is a key species. In addition, demersal trawl fisheries are found as an important component of the ecosystem. The Ecopath model is the first food-web model in the Mediterranean coast of Turkey. Ultimately it is hoped that this model can provide the necessary knowledge and baseline that will help develop an EBFM for Gulf of Mersin and will thus assist in developing sustainable fisheries in this area.

In the third chapter, results reveal that the implementation of more selective trawl codend in demersal trawl fisheries in Gulf of Mersin would end up with an improvement in fishing indicators which evaluates the impact of fishing on the ecosystem. Thus, it can be considered that improved trawl selectivity would be for the benefit of ecosystem. In addition, the 40 mm square mesh trawl codend seem to be a better alternative than the diamond mesh codends with 44 mm and 50 mm mesh sizes. This chapter may contribute to address selectivity options in the Mediterranean from an ecosystem point of view.

This study underlines the need to develop a better understanding of the thesis research questions. Major limitation in this thesis is the absence of a

time series data and future effort should be directed an Ecosim prediction. In addition, future work may also include alternative research questions such as "effort reduction or selective fisheries" in order to evaluate alternative management strategies. Moreover, Gulf of Mersin ecosystem could be also assessed under the no-fishing scenario.

Saygu and Akoğlu (2016) revealed that potentialities for EwE in the eastern Mediterranean coast of Turkey. The problem is that majority of the field data is unavailable. Therefore, a priori database construction is important in order to properly reveal the data that could be used in modelling approaches. Although the data on fisheries statistics and fishing effort are less reliable compared to the EU and Nordic countries, the data may be enough to set up models and investigate fisheries related research questions. However, standardized time series catch and biomass data are crucial. In addition to all these, the area is very dynamic and precious for evaluating ecosystem impact of Lessepsian migration. Therefore, providing updated information on input data such as diet, discards, catch, and biomass is important.

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