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**Contribution to a better knowledge of biology,
distribution and diversity of demersal species along the
Lebanese coast, eastern Mediterranean : a focus on
Lessepsian fish species**

Stefano Lelli

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THÈSE

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Docteur

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UNIVERSITE DE PERPIGNAN VIA DOMITIA

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Energie et Environnement

Et de l'unité de recherche
CEntre de Formation et de Recherche sur les
Environnements Méditerranéens (CEFREM)
UMR 5110 CNRS UPVD

Spécialité : Océanologie

Présentée par **Stefano LELLI**

**Contribution to a better knowledge of biology,
distribution and diversity of demersal species along
the Lebanese coast, eastern Mediterranean: a focus
on Lessepsian fish species.**

Soutenue le 22 Décembre 2017 devant le jury composé de

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Chapter 1

General Introduction

Chapter

1

General Introduction

Overview

The Mediterranean Sea is the crossroads of three continents, the waterway that enables an active exchange among different cultures and populations; and, not surprisingly, it is the area where philosophy, literature, and sciences have flourished for thousands of years. Today the Mediterranean is a sea under siege suffering on the one hand mismanagement and abuses putting coastal ecosystems at risk of ecological collapse and on the other social and political crises such as war, poverty, migration and political strife that are further negatively affecting the status of its natural resources.

The Mediterranean basin is the largest and deepest enclosed sea on Earth, surrounded by 22 countries and home to around 480 million people ([European Environment Agency, 2015](#)). Approximately one-third of the Mediterranean population is concentrated along its coastal stretch where also Countries' main economic and social activities are established. Environmental risks associated with such activities are having a negative impact on the marine ecosystem ([UNEP/MAP-Plan Bleu, 2009](#)), also affecting people's quality of life. In addition, the introduction of non-indigenous species (NIS) and different human practices leading to the rapid and uncontrolled modification of the Earth's climate as well as the unsustainable exploitation of natural resources (such as the overfishing) are deeply altering the Mediterranean marine biodiversity.

However, the Mediterranean Sea is one of the major reservoirs of marine biodiversity, which is estimated at 17,000 species ([Coll, et al., 2010](#)). Among these, some of the world's most endangered and "emblematic" species as well as sensitive habitats can be found ([Zenetos, et al., 2002](#)).

Bearing all this in mind, marine research is increasingly becoming key to strengthening the capabilities of countries for socio-economic progress while contributing to the wellbeing and sustainable development of human communities. The outstanding expansion of knowledge of the marine environment as a whole should not lead us to overlook the cost, scale, and complexity of marine studies. They demand clear goals, domestic support, international cooperation, and integrated plans. In this regard, the Mediterranean region has been a pioneer in the advancement of collaboration towards common management of fisheries resources ([GFCM & FAO, 2016](#)).

The present thesis originates from the activities implemented in the framework of two projects financed by the Italian Cooperation and steered by the CIHEAM-Bari and the Lebanese National Council for Scientific Research (CNRS-L). These projects foresaw the collaboration of Italian, Lebanese and international organizations and involved scientists and students from Italy, Lebanon and France. Aiming at establishing monitoring programmes while promoting sustainable development of the Lebanese coastal areas, aforementioned projects produced a relevant amount of raw data that needed to be elaborated for future effective marine spatial planning, identifying spawning grounds, establishing fishing restricted areas, discovering new fishing grounds, and identifying the feasibility of alternative fishing gears.

It is our hope that this work will elevate knowledge and understanding of Lebanese fisheries, contributing to ensure future sustainable exploitation of fisheries resources.

The Mediterranean Sea: Biodiversity, threats and fisheries

Geographical overview

The Mediterranean (from Latin, in the midst of lands, known in Modern Arabic as المتوسط الأبيض [al-Baḥr al-Abyaḍ al-Mutawassiṭ] "the White Middle Sea") is a semi-closed sea situated at the crossroads of Africa, Europe, and Asia. It occupies an area of approximately 2,510,000 km² and its greatest depth is about 4,400 m, off Cape Matapan, Greece. It connects with the Atlantic Ocean through the Strait of Gibraltar; with the Black Sea through the Dardanelles, the Sea of Marmara, and the Bosphorus; and with the Red Sea through the man-made Suez Canal. In the Strait of Sicily, a 400 meters depth ridge separates Sicily and Tunisia, dividing the Mediterranean Sea into the western and eastern sub-regions.

It is a concentration basin, with higher evaporation in its eastern half. Water loss through evaporation is greater than the inputs from rain and river runoff. Hence, a resulting gradient pushes about 1 700 km³ /year cooler and low-salinity Atlantic waters inside the Mediterranean basin (Bas Peired, 2005). Moving eastward, waters become warm and saltier since they sink down in the Levantine Sea. Heavy water masses run back westward exiting through the Strait of Gibraltar. The Mediterranean Sea water masses are stratified in summer, but the temperature of the water masses below 400 m is very stable at 13 ± 0.3 °C throughout the year. The Mediterranean is globally considered as an oligotrophic sea (Margalef, 1985), and the gradual decline in nutrient content as the water moves from west to east leads to an overall reduction in productivity.

Mediterranean climate is characterized by hot, dry summers and cool, humid winters. Sea surface water temperatures show high seasonality and significant gradients along the axes west-east and north-south (Hopkins, 1985). The continental shelves are generally narrow. The geological history, biogeography, ecology, and human history have contributed to the Mediterranean's high cultural and biological diversity (Danovaro & Pusceddu, 2007; Sundseth, 2009).

Biodiversity

The Mediterranean Sea is considered as a hot spot of biodiversity (Myers, et al., 2000). In 2000, Bianchi & Morri estimated 4 to 18 percent of world's marine species occurring in it (more than 8500 macroscopic marine species) whereas Coll et al. (2010) in 2010 listed approximately 17,000 living species. The recent Mediterranean marine biota is primarily of Atlantic origin but the wide range of historic climate and hydrology have contributed to the co-occurrence and survival of both temperate and subtropical organisms (Sarà, 1985). A relatively high number of endemism occur in the Mediterranean (Boudouresque, 2004; Cuttelod, et al., 2008); this is even more evident in islands where species have evolved to survive in very specific habitats (Blondel & Aronson, 1999). For the past two centuries, the biodiversity has been altering at an alarmingly high rate due to human-mediated arrival of new species, with an apparent acceleration in the rate of recorded invasions in the last decades (Rilov & Galil, 2009).

There are several unique and endangered habitats, including the seagrass meadows of the endemic *Posidonia oceanica*, vermetid reefs built by the endemic gastropod and deep-sea and pelagic habitats that support unique species and ecosystems. Only four elasmobranchs species (all batoids) are Mediterranean endemics and nine species of marine mammals are encountered regularly in the Mediterranean (Coll, et al., 2010). Three species of sea turtles dwell in the Mediterranean: the green turtle and the loggerhead turtle (*Chelonia mydas* and *Caretta caretta*) and the leatherback turtle *Dermochelys coriacea*. However, there is no evidence of nesting of the last one in the basin. Mediterranean is also home to the Mediterranean Monk

Seal *Monachus monachus*. The Mediterranean's importance is not limited to the sea: richness or uniqueness of its resident terrestrial fauna and flora goes hand in hand with millions of migratory birds using Mediterranean wetlands and other habitats as stopover or breeding sites (Cuttelod, et al., 2008). A total of 89 species of Chondrichthyes were recorded in the Mediterranean Sea (49 sharks, 38 rays and 2 Holocephali species) (Meléndez, et al., 2017), 57 of which were assessed in the IUCN Red List of Threatened Species (IUCN, 2017).

Threats

The Mediterranean region has been inhabited for millennia by humans that shaped – along with the effects of natural events – ecosystems and biodiversity (Bas, 2009; Hsü, et al., 1977). It is currently home to some 480 million human inhabitants from 22 countries and a wide variety of cultures. The Mediterranean region has been identified as one of the main climate change hotspots (Giorgi, 2006) due to water scarcity, concentration of economic activities in coastal areas, earthquakes and coastal erosion. As Mediterranean countries are already facing important issues of water stress and extreme climate events such as floods and droughts, climate change will most probably exacerbate these problems, resulting in significant human and economic losses (EEA - UNEP/MAP, 2104). In addition to that, the region is affected by relevant economic disparities, rapid demographic changes and associated urban sprawl resulting in an increased pressure on the environment and reduced security of populations (in terms of food, health, etc.). A global mean of sea-level rise of around 3 mm per year over the last two decades is also of concern especially in the Southern shores of the Mediterranean (IPCC, 2013).

The coast is under the influence of competing interests which have caused a marked deterioration in the coastal water quality, ecological sites and natural resources. Land-based activities are modifying natural habitats due to runoff of sediments, nutrients, toxins and pollutants, and sometime even altering the flow of currents and tides. Changes in offshore ecosystems include the extraction of mineral resources, pollution from vessel traffic, and the construction of infrastructure for oil development or offshore wind farms (Halpern, et al., 2008). Not differently from other human activities, aquaculture and capture fisheries have a relevant impact on coastal ecosystems. Intensive fish farms can release enormous quantities of organic waste and contaminated water into the natural environment and spread parasites and diseases.

In the Mediterranean, many commercially exploited stocks are still not properly assessed. Among those assessed, 91 percent of the stocks were being overfished in 2014 (European Commission, 2014). More in specific, the overexploitation of large predators, with change in biomass and composition, is possibly having a great impact on the stability of the marine ecosystem than removing species farther down the food chain (Larkin, 1979; Watson & Pauly, 2001). Bycatch along with the unreported discard of marine resources and incidental catch of vulnerable species can lead to the loss of biological resources along resulting in relevant biological and ecological impacts (Hall, et al., 2000; FAO, 2016).

Fisheries

Communities of fishers have existed throughout the Mediterranean basin since time immemorial. There is abundant mention of this phenomenon of civilization in historic, geographic and ethnographic literature (Féral, 2004; Voultsiadou & Vafidis, 2007). Nowadays, industrial, semi-industrial and small-scale fisheries coexist in the region, using a large variety of fishing gear. Mediterranean fisheries generally exploit a large array of benthic and pelagic stocks of fish, as well as molluscs and crustaceans. Due to the semi-enclosed configuration of the Mediterranean basin, many stocks are commonly shared among fleets from different countries (Figure 1).

According to the most recent data submitted to the GFCM, the fishing fleet in operation in the Mediterranean consists of about 81 600 vessels (GFCM & FAO, 2016). This number should be considered an underestimate of the real size of the fleet, given the lack of data on some parts of the fleet (especially small-scale fleets) from some Mediterranean and Black Sea riparian States or non-State actors (FAO, 2015). Mediterranean fish catches represent a small part of total catches worldwide (a bit more than 1 percent of total catches). Fishing in the Mediterranean tends to be concentrated in inshore areas, with some boats fishing on the continental slope for prized species such as the red shrimp, the deep-water rose shrimp, and hake (UNEP/MAP-Plan Bleu, 2009). Production currently ranges between 1,500,000 t to 1,700,000 t per year, more than 85 percent are attributable to six countries, i.e. Italy, Turkey, Greece, Spain, Tunisia and Algeria (GFCM & FAO, 2016).

The artisanal fishing sector provides direct employment to tens of millions of people, and indirect employment to tens of millions more (UNEP, 2005). Artisanal fishing comprises 90 percent of all fishing jobs worldwide, approximately 45 percent of the world’s fisheries, and nearly a quarter of the world catch (UNEP, 2004). They provide critical income and edible protein to hundreds of millions across the globe. In the Mediterranean Sea, artisanal fisheries represent roughly 86 percent of the approximately 42 000 fishing boats exploiting coastal and offshore stocks (Maynou, et al., 2013) and 60 percent of the 250 000 people employed in the fishing industry (GFCM & FAO, 2016). Foremost characteristics of the sector are the high diversification of gears and techniques, the multitude of species exploited, the changing patterns of gears use in time and space and the varying degree of fishermen’s dependence on fishing (Tzanatos, et al., 2006).

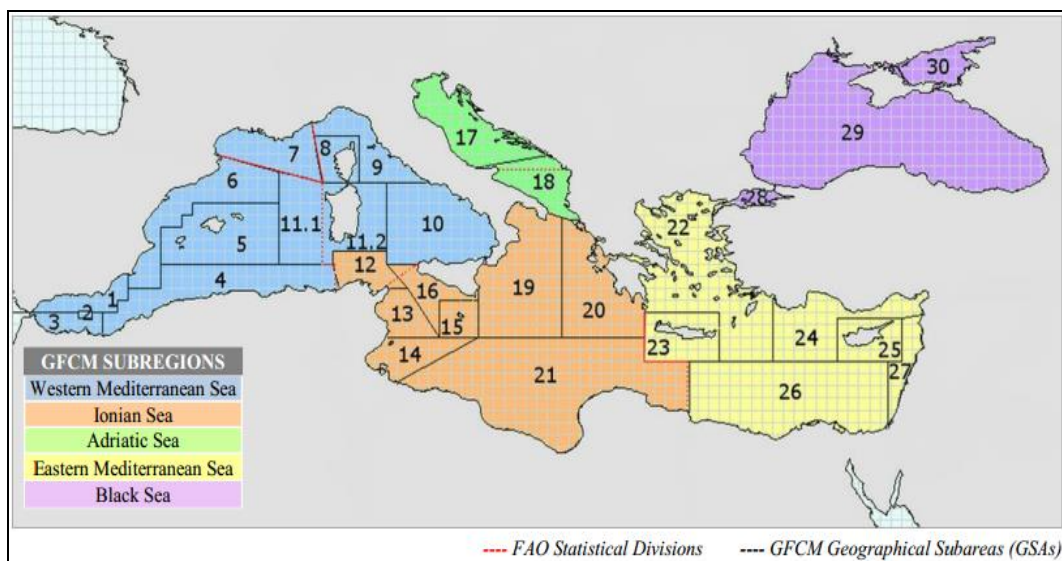


Figure 1. The Mediterranean Sea and Black Sea make up together FAO Fishing Area 37. The GFCM, that has the responsibility and authority to oversee the full process of fisheries management, undertake scientific evaluations and take decisions to ensure sustainability of fisheries resources in its area of application, identified five subregions (Western Mediterranean Sea, Ionian Sea, Adriatic Sea, Eastern Mediterranean Sea and Black Sea). On basis of the new GFCM agreement (www.fao.org/gfcm/background/legal-framework) that refers to the “subregional approach to fisheries management and aquaculture development in order to better address the specificities of the Mediterranean and the Black Sea”, the concept of subregions has been introduced during the revision process of the fishery data collection framework of GFCM and then reflected into the DCRF document. Subregions are furtherly divided in Geographical Subareas (GSAs) for a total of 30 GSAs in the Mediterranean and Black Sea region. Modified from (GFCM, 2016).

Demersal species: Status, fisheries and threats

Worldwide overview

Fisheries and aquaculture remain important sources of food, nutrition, income and livelihoods for hundreds of millions of people around the world. World per capita fish supply reached a new record high of 20 kg in 2014, thanks to vigorous growth in aquaculture, which now provides half of all fish for human consumption, and to a slight improvement in the state of certain fish stocks due to improved fisheries management (FAO, 2016). Moreover, fish continues to be one of the most-traded food commodities worldwide with more than half of fish exports by value originating in developing countries.

With capture fishery production relatively static since the late 1980s, aquaculture has been responsible for the impressive growth in the supply of fish for human consumption (Figure 2). Whereas aquaculture provided only 7 percent of fish for human consumption in 1974, this share had increased to 26 percent in 1994 and 39 percent in 2004. China has played a major role in this growth as it represents more than 60 percent of world aquaculture production (FAO, 2016).

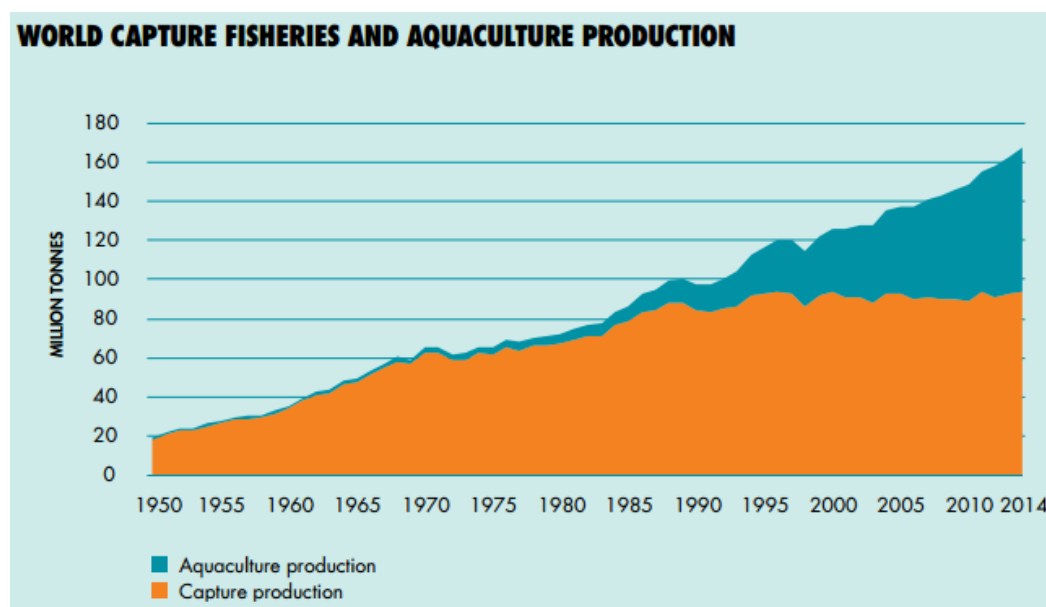


Figure 2. World capture fisheries and aquaculture production between 1950 and 2014. From (FAO, 2016).

Demersal species are defined as those species living at or near the bottom of the water column, such as cod, haddock, hakes, Norway lobster and shrimps (i.e. Merrett & Haedrich, 1997; European Commission, Directorate-General for Maritime Affairs and Fisheries, 2016). This means that they live and feed on or near the bottom occupying the sea floors consisting of mud, sand, gravel or rocks. The split into demersal and pelagic taxa is obviously simplistic, however, in marine waters, demersal species are those usually found on or near the continental shelf, and on or near the continental slope or along the continental rise. The word demersal comes from the Latin *demergere*, which means “to sink”.

Globally, pelagic species comprise the largest proportion of the global marine catches. In 1950, they contributed for the 41 percent of total marine fisheries production while demersal species (i.e. flounders, halibuts, soles, cods, hakes, haddocks and other miscellaneous demersals) for 35 percent. The remaining 24 percent of the total catch came from other species - which also includes demersal species – such as shrimps, prawns, crabs, clams, mussels, and marine fishes not identified. While the total marine fish landings increased with the development of the fishing industry, landings of demersal species reached - and

in some cases exceeded - the limit of potential production in the early 1970s. Subsequently, catches of demersal species levelled off below 20 million tonnes (Figure 3) (FAO, 2011).

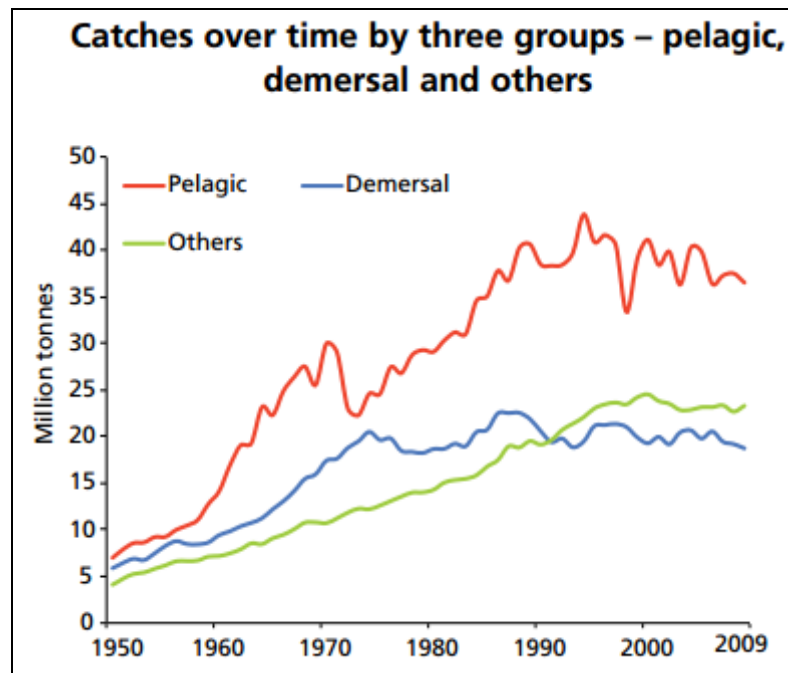


Figure 3. Catch over time by three groups, i.e. pelagic, demersal and other species between 1950 and 2009. From (FAO, 2011).

Most abundant demersal species ordered in terms of average annual landings from 1950 to 2009 were Alaska pollock, Atlantic cod, largehead hairtail, blue whiting, sandeels, haddock, saithe, Cape hakes, Atlantic redfishes, and flatfishes. These ten species produced 37 percent of the total demersal landings in 2009 with a common pattern of decreasing trend in catch. Most of these species had a peak catch in the 1960s or 1970s. Stocks condition vary with country or region. While the Western and Eastern Central Atlantic (FAO Areas 31 and 34) had the highest proportion of overfished stocks (about 54 percent in 2009), the lowest proportion of overfished stocks was about 10 percent, seen in the Eastern Central Pacific (Area 77), Northeast Pacific (Area 67) and Southwest Pacific (Area 81). The Southeast (Area47), Southwest Atlantic (Area41), and Mediterranean and Black Sea (Area 37) had 50percent of fish stock overfished (FAO, 2011).

In terms of distribution, the variation of demersal species by depth appears to be dominant followed by a secondary latitudinal variation and a clustering of sites related to both depth and latitude (McClatchie, et al., 1997; Bergstad, et al., 2008; Mahon & Smith, 1989; Magnussen, 2002). There are similar bathymetric and latitudinal trends in overall fish biomass and abundance. ECO expedition showed also a relationship among surface chlorophyll concentration, zooplankton abundance, and meso- and bathypelagic nekton density (Sutton, et al., 2008; Gaard, et al., 2008; Opdal, et al., 2008). Spatial patterns of demersal fish species diversity and the associated causal factors are less clear and vary greatly from one study to the other (Gaertner, et al., 2005).

Annual per capita consumption of demersal species has stabilized at about 2.9 kg. Demersal fish remain among the main species favoured by consumers in Northern Europe and in North America (annual per capita consumption of 9.2 and 4.3 kg, respectively, in 2013). Cephalopods are mainly preferred by Mediterranean and East Asian countries (FAO, 2016).

In European non-Mediterranean waters, such as the North Sea and adjacent areas a wide range of different fish and shellfish species (including round fish, flat fish, shellfish, crabs, shrimps, lobsters, and skates and

rays) are exploited, among them many demersal species. To catch demersal species, vessels use a variety of techniques and fishing gear, the most important being demersal trawls and seines, as well as beam trawls. Many of these fisheries do not only catch specimens of one single targeted species, but simultaneously catch several species present in the fished area, in varying proportions. Hence, such fisheries are called 'mixed fisheries'. North Sea demersal fishing represents over 70 percent of the sector in this area, involving several thousand of vessels. Demersal catches were worth more than €850 million in 2012, with the highest total value of landings by species for sole, followed by plaice, Norway lobster, cod, saithe, haddock, turbot, anglerfish, whiting and lemon sole (Weissenberger, 2016).

Demersal species life history traits

Living species exhibit a great diversity of patterns of life-history features that correspond to a determined set of population consequences which would ultimately result from adherence to the specified life history. The birth rate, the death rate, the age composition of the population and its ability to grow may be related in numerous ways to the ability of the species to survive in a changed physical environment or in competition with other species. Therefore, the energy available for distribution through trophic levels and driven by natural selection will be influential in shaping life-history patterns to correspond to efficient populations (Cole, 1954).

Studies on life history parameters such as age and growth, along with basic information on distribution, abundance, movements, feeding, reproduction and genetics, are essential for scientists to understand and predict how populations will evolve and how they will respond to different stimuli.

Due to the broad definition of the term “demersal”, different life history traits are shown in this group. Generally, demersal species show relatively restricted adult movements. Their pelagic juvenile stages represent their most important dispersal mechanism (Cowen, et al., 2006) although genetic evidences show that pelagic stages often fail to fully achieve their dispersal potential (Jin-Xian, et al., 2007).

Early-life-histories vary greatly among demersal species. Some species may spawn benthic eggs from which pelagic larvae hatch while others may display life cycles where both the eggs and the larvae are pelagic. In other cases, peculiar forms of parental care evolved (Riginos & Victor, 2001). Pelagic larval duration as well as the spatial distribution of pelagic stages also shows great variability among marine species. In the Mediterranean, the Common two-banded bream (*Diplodus vulgaris*), the Striped red mullet (*Mullus surmuletus*), and the Comber (*Serranus cabrilla*) have an extended pelagic larval duration. An intermediate condition is shown by the Saddled bream (*Oblada melanura*), which spawns pelagic eggs and has offshore larvae but with a shorter pelagic duration. The Blackfaced blenny (*Tripterygion delaisi*) and the Cardinal fish (*Apogon imberbis*) are species with low potential for dispersal, producing benthic or mouth-brooded eggs, inshore larvae, and having shorter pelagic larval duration. The Peacock wrasse (*Symphodus tinca*) releases benthic eggs (Galarzaa, et al., 2009).

Understandably, direct withdrawal of fish individuals due to fishing activities may induce changes in the demographic characteristics of populations, including genetic variations (Rochet, 1998). Several Authors, such as Pauly (1979), Gulland & Garcia (1984), Sharp & Csirke (1984), Greenstreet & Hall (1996), Sainsbury, et al (1997), Haedrich & Barnes (1997), Bianchi, et al. (2000) documented changes in the structure of demersal fish communities. However, the understanding of how fishing activities affect demersal fish communities is still unclear. There is the evidence that the size structure of demersal fish communities is affected by fishing with an overall trend of reduction in large fish and relative increase in small fish (Bianchi,

et al., 2000). Data from more than 230 populations reveal a median reduction of 83 percent in breeding population size from known historic levels. Few populations recover rapidly; most exhibit little or no change in abundance up to 15 years after a collapse (Hutchings & Reynolds, 2004). Reductions in fishing pressure, although clearly necessary for population recovery, are often insufficient. Unprecedented reductions in abundance and surprisingly low rates of recovery draw attention to scientists' limited understanding of how fish behavior, habitat, ecology, and evolution affect population growth at low abundance.

Mediterranean Demersal species

In terms of economic relevance, the most important demersal species are European hake (*Merluccius merluccius*), red mullets (*Mullus* spp.), blue whiting (*Micromesistius poutassou*), whiting (*Merlangius merlangus*), anglerfishes (*Lophius* spp.), pandoras (*Pagellus* spp.), bogue (*Boops boops*), picarels (*Spicara* spp.) striped venus (*Chamelea gallina*), octopus (*Octopus* spp.), cuttlefish (*Sepia officinalis*), red shrimps (*Aristeus antennatus* and *Aristaeomorpha foliacea*), Norway lobster (*Nephrops norvegicus*) and deep-water rose shrimp (*Parapenaeus longirostris*). These species represent about 30 percent of total reported catches in the Mediterranean and Black Sea. In this area, total catches showed a steady increase from about 0.7 million tonnes in 1950 to about 2 million tonnes in the period 1982–88. They then suddenly declined to about 1.3 million tonnes following the collapse of the Black Sea fishery for sprat and anchovy, and have since recovered slightly to about 1.5 million tonnes. Meanwhile, declared catches of most demersal and semi-pelagic fish and crustaceans increased steadily until the period between the 1980s and the end of the 1990s. This has been followed by declines in several species in the last few years (FAO, 2011).

Cephalopods are important catches from trawl fisheries and there are also directed fisheries in some regions especially with smaller vessels (Bas Peired, 2005). The onset of deep-water trawling off the slope areas of the Mediterranean in the mid- 1980s appears to explain the sharp rise in catches of deep-water rose shrimp and aristaedae shrimp (FAO, 2011). The decrease in catches of rose shrimp observed in the mid-1990s is most probably the result of overexploitation of the main fishing grounds (GFCM, 2011). Its recovery in the last three years is probably associated with a period of good recruitment. The declared catches of Norway lobster follow a similar – still less sharp - pattern.

Also in the Mediterranean, depth plays the main role in the group differentiation, indicating the existence of two quite distinct bathyal faunal assemblages, which are separated by the 400–500 m bathymetric zone, e.g. Pérès & Picard (1964); Biagi, et al. (1989); Mura & Cau (1994); Stefanescu, et al. (1994); Abella & Serena (1995); D'Onghia, et al. (1998); D'Onghia, et al. (2003). Common demersal shelf species (*Mullus barbatus*, *Pagellus acarne*, *Loligo vulgaris*, etc.) and slope species (*Merluccius merluccius*, *Phycis blennoides*, *Parapenaeus longirostris*, etc.) perform ontogenetic migration along the depth gradient (Colloca, et al., 2003). They have their nursery grounds (Morfin, 2013), respectively, on the coastal shelf and shallow slope (Ardizzone & Corsi, 1997), contributing this way to their increased dominance in these regions. Morfin et al. (2016) found that adults were generally more densely concentrated than juveniles and occupied areas included in the distribution of juveniles.

According to Bradai, et al. (2012), the Mediterranean is home to a total of 86 species of elasmobranchs, 49 shark species from 17 families and 37 batoids species from 9 families. Only 4 batoid species (*Leucoraja melitensis*, *Raja polystigma*, *R. radula* and *Mobula mobular*) could be considered endemic (Serena, 2005) with *Leucoraja melitensis* considered endemic threatened (Dulvy, et al., 2014). Chondrichthyes, by nature of their K-selected life-history strategies and high position in trophic food webs, are more likely to be

affected by intense fishing activity than most teleosts. There is sufficient evidence from the history of fisheries around the world, both targeting these fishes and taking them as by-catch, of major declines in population size (Stevens, et al., 2000).

Mediterranean Demersal species fisheries and threats

Mediterranean fisheries are dominated by small-scale vessels, dispersed across a large number of landing places in most countries (FAO, 2011). A characteristic of the Mediterranean fisheries is the capability to exploit a variety of demersal species while generally lacking large monospecific stocks. As a result, Mediterranean fisheries have developed a multitude of métiers and scales of investments. Production is essentially concentrated on the continental shelf and capture fishing on the coasts. Yearly volumes are limited (1.5 to 1.7 million tons/year), representing less than 1 percent of global catches (UNEP/MAP-Plan Bleu, 2009). There is serious cause for concern as regards the status of economically and commercially important species (hake, red mullet, common prawn, sole, sardine and tuna), victims of unsustainable overexploitation.

The sustainability of Mediterranean fisheries is also dramatically affected by the effects of increased pollution from human coastal activities, habitat degradation, the introduction of non-indigenous species (NIS), and the impacts of climate-driven changes. Aquaculture has also undergone significant growth (seawater fish farming for sea bass, sea bream, and « fattening up » of tuna) with a two-folded result: on the one hand an increase of production with a reduced impact in terms of fishing effort, on the other this produced a degradation of the quality of the marine environment and habitats.

Up to 85 percent of stocks for which a validated assessment exist are fished outside biologically sustainable limits. European hake stocks show the highest fishing pressure, with a fishing mortality rate that is an average of 5 times higher than the target while only a few stocks of demersal species, such as whiting, some shrimp species, picarel and red mullet, are estimated to be fished at or below the reference point for fishing mortality (FAO, 2016).

Introductions of non-indigenous species (NIS) have caused major changes, particularly in the eastern Mediterranean where a growing number of Indo-pacific species are settling breeding populations. Some of these species have a commercial relevance, however others are negatively affecting fishing economy as well as marine environment. The silver-cheeked toadfish (also known as puffer fish) *Lagocephalus sceleratus* is wide spreading over eastern Mediterranean waters without natural competitors, creating major problems to the fisheries in the region. It is regarded to be among the most destructive NIS in the Mediterranean Sea with a significant impact on the surrounding ecosystem and on the fisheries sector (Zenetos, et al., 2005; Streftaris & Zenetos, 2006; Ozturk, 2011). It is capable of ripping and damaging fishing nets lines and long lines. *L. sceleratus* is considered to be also a serious hazard to consumers since it contains a strong paralytic marine toxin called TTX (tetrodotoxin), which can be lethal to humans (Sabrah, et al., 2006; Ashkar, et al., 2008; Nader, et al., 2012).

Various management tools for coastal ecosystems

Mediterranean fisheries policies have been developed in order to adjust the fishing effort in relation to the availability of fishery resources and to evaluate the fishing capacity of national fleets. Because of the wide variety of species characterizing Mediterranean fisheries, fishery management in the Mediterranean is not based on catch control via TACs and quotas. With few exceptions (such as the bluefin tuna which is currently subject to a quota system throughout the Mediterranean), regulation of total fishing effort

through limited licenses and technical measures such as time and area closures, gear limitations and limited landed sizes are the pillars of fisheries regulation (Cacaud, 2005). Most countries have also introduced within certain fleet segments a limitation on the number of licenses issued.

In the Mediterranean, the overall management of all fisheries is done within the mandate of the General Fisheries Commission for the Mediterranean (GFCM). European Member States' fishing activities are regulated by the Common Fisheries Policy of the European Union (EU-CFP) while non-EU countries define their own fisheries management measures, generally ensuring consistency with GFCM regulations (GFCM & FAO, 2016). Principal management challenges for Mediterranean fisheries are considered the fight against illegal, unreported and unregulated (IUU) fishing, the implementation of management plans for the sustainable exploitation of all fish stocks, and measures to reduce bycatch, discards and incidental catch of vulnerable species.

To date, a total of 16 management and conservation measures have been adopted by the GFCM to ensure the conservation and sustainable exploitation of living marine resources, while safeguarding habitats and vulnerable species from the impact of fishing activities. In general, these binding decisions include: 1) spatial management measures; 2) mitigation measures for the incidental catch of vulnerable species; and 3) other technical conservation measures. Four areas restricted to fisheries activities have been established covering a total area of 17 678 km², which represents approximately 0.7 percent of the Mediterranean Sea's surface. 58 percent of Mediterranean and Black Sea (1 731 097 km²) deep waters and seafloors, i.e. below 1000 m depth, are also protected. Moreover, recommendations have been adopted to mitigate the incidental catch of marine mammals, seabirds, sea turtles and sharks and to improve monitoring and data collection (GFCM & FAO, 2016).

An ecosystem-based approach to fisheries management (Pikitch, et al., 2004) seems particularly useful for the Mediterranean and can be cost-effective by addressing environmental and economic considerations, and tackling cross-sectoral problems. A mix of instruments and integrated approaches have been encouraged to foster societal changes as well as promoting technical progress and economic development. The need for cooperation and coordination amongst all the countries bordering the Mediterranean has long been recognised. This has resulted in almost 40 years of international efforts to protect this fragile and vulnerable ecosystem: the United Nation Environment Protection - Mediterranean Action Plan (UNEP-MAP), the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean and its Protocols; and the Euro-Mediterranean Partnership (EUROMED). EUROMED is also referred to as the Barcelona Process and was re-launched in 2008 as the Union for the Mediterranean (UfM). In 2005, the Euro-Mediterranean partners committed themselves to substantially reduce pollution in the Mediterranean region by 2020. This became known as the 'Horizon 2020 Initiative' endorsed in Cairo in 2006 (European Environment Agency, 2015).

Key priorities for the sector include the need for strong political commitment, intergovernmental cooperation and the provision of technical assistance to riparian States. Essential prerequisites are a consolidated knowledge base, improved data collection and analysis and the development of management and co-management mechanisms that are integrated with environmental objectives, including marine protected areas (MPAs).

Eastern Mediterranean Demersal species

In the Mediterranean, species richness displays a gradient from west to east, with the Western Mediterranean having the highest values of species richness, likely owing to the influx of Atlantic species and the wide range of physicochemical conditions (Coll, et al., 2010). The Levantine Basin and southeastern

side have in general the lowest species richness, which is due to the unfavorable conditions prevailing in the area, such as high salinity (Por & Dimentman, 2006) and a condition of ultraoligotrophy (eastern Mediterranean is considered as one of the most oligotrophic basins all over the world) (Azov, 1991). However, a lack of data in several eastern and southern regions of the Mediterranean basin may have strongly influenced results and considerations on spatial patterns.

The Levantine basin has been affected by two major human endeavours that influenced its ecosystem: first, the construction of the Aswan High Dam resulted in the cessation of fluvial sedimentation and nutrients to the Mediterranean, leading to a sharp decrease in small pelagics' populations and subsequent fall-off of 90 percent of the Egyptian purse seine fishing industry (Azov, 1991; Golani, 1998). Secondly, the cut of the Suez Canal, completed in 1869, that connected two water bodies with different abiotic characteristics and distinct peculiar biotas. The number of fish species migrating to the Mediterranean, known as Lessepsian migrants (Por, 1971), increased steadily in the decades following the 1920s but accelerated dramatically after the year 2000, reaching 101 species in 2014 (Arndt & Schembri, 2015). Hundreds of other taxa (Galil, 2009; Zenetos, et al., 2012) stepped in the Mediterranean at the same time, giving rise to one of the greatest biogeographic convolutions ever witnessed by the contemporary globe (Por, 2010).

Currently, Lessepsian fish species constitute a large proportion of commercial captures (Goren & Galil, 2005; Carpentieri, et al., 2009; Edelist, et al., 2011), leading many native fishes to be displaced by their exotic counterparts (Galil, 2007). However, according to Golani (2010), no Mediterranean species is known to have disappeared since the opening of the Suez Canal. It is emblematic the case of *Sarpa salpa*, indigenous Mediterranean fish, replaced by the NIS *Siganus rivulatus* along the Lebanese coastal waters (Bariche, et al., 2004). Similar behaviours have been plausibly observed in the competition between *Saurida lessepsianus* and *Synodus saurus*; *Upeneus moluccensis* and *Mullus barbatus*; *Callionymus filamentosus* and *C. pusillus* (Fanelli, et al., 2015).

Summing up, demersal resources of the eastern Mediterranean are a mixture of indigenous and non-indigenous species mainly of Lessepsian origins. Assemblages composition is mainly driven by depth and easternmost sectors are witnessing deadly competitions whereby NIS are competing with native species by occupying similar ecological niches (Edelist, et al., 2013). The overall trophic space is widening out under the increasing redundancy of the novel community in a nutrient-deprived ecosystem. Consequently, eastern Mediterranean demersal communities are far from being in a steady state (Fanelli, et al., 2015).

Lessepsian species and invasions

Definition of non-indigenous species (NIS)

According to [Zenetos et al. \(2012\)](#) alien, non-indigenous, exotic, non-native or allochthones species are defined by their presence in the wild, through introduction outside their natural range and beyond their natural dispersal potential. The creation of canals bridges natural barriers to the distribution of previously separated biomes. The diffusion of aquatic organisms in different geographical areas results in significant changes to the newly colonized ecosystems and their species assemblages ([Gollasch, et al., 2006](#); [Nentwig, 2007](#)). The body of water that is now the Mediterranean Sea went through dramatic changes in its biota. It is a vestige of the Tethys Ocean, meaning that in prehistoric times it was inhabited by tropical biota. Approximately 10 million years ago, after being cut off from the rest of the Indo-Pacific, it had slowly lost its tropical characteristics. It eventually became a warm-temperate to subtropical body of water. Changes in its environmental conditions as well as those to its biota, occurred over timescales of thousands to millions of years ([Rilov & Galil, 2009](#)).

For the past two centuries, due to human-mediated arrival of new species, the Mediterranean biodiversity has altered at an alarmingly high rate, with an apparent acceleration in the rate of recorded invasions over the last fifty years ([Galil, et al, 2017](#)). This alteration of the biodiversity is due to the manmade connection of two semi-closed seas with a high degree of endemism, the Mediterranean and the Red Sea ([Quignard & Tomasini, 2000](#)). Invasions interact with factors altering the integrity of marine ecosystems as well as socio-economic value chains. According to [Mooney, et al. \(2005\)](#) and [Rilov & Galil \(2009\)](#), they can cause loss of native biodiversity, habitat destruction, pollution and economic damages.

In marine systems, the dominant invasion pathway is commercial shipping. Species can be transported on the hulls of vessels, in cargo, or in ballast tanks. Some are also found associated with commercially important species, such as oysters and abalone, whose shells serve as habitats for invertebrates and algae ([Culver & Kuris, 2000](#); [Wasson, et al., 2001](#)). When two points are connected by a given transport pathway, propagules can provide the initial conditions required for the population diffusion and, eventually, establishment in new areas.

Direct transport of species from the Red Sea through the Suez Canal is the main vector/corridor for introductions into the Mediterranean Sea while shipping is of second in importance ([Galil & Zenetos, 2002](#); [Galil, 2000](#)). This process was named by [Por \(1978\)](#) “Lessepsian migration” while [Galil & Zenetos \(2002\)](#) reintroduced the original term, ‘Erythrean’ invasion.

Brief history of the ‘Erythrean’ invasion

In the second half of XIX century, Egypt hosted two remarkable works of civil engineering, which were full of consequences for the Mediterranean in the coming decades:

- The construction of the Aswan Low Dam (initiated in 1899) to control the flooding of the Nile and provide water for irrigation. At that time, nothing of its scale had ever been attempted and, on completion, it was the largest masonry dam in the world. In 1970, Egypt completed the construction of the High Dam just a few kilometers downstream from the old one; and
- The construction of the Suez Canal started in 1859. This artificial canal connecting the Mediterranean and the Red Sea was opened ten years later and rapidly became an essential shortcut to navigate from Europe to Asia without circumnavigating the African continent.

The history of navigating through the Suez Isthmus starts roughly 2,500 years earlier, in the time of the Pharaoh Necho II who, according to the Greek historian Herodotus (Herodotus, 5th Cent. BC), tried to connect the Red Sea to the Nile River and from there to the Mediterranean Sea. The pharaoh reportedly never completed the project of the “Pharaoh Canal,” whereas his successor Darius the Great, did. Later, ancient scribes claimed that Darius also failed in completing the work, as he feared submerging the Nile Valley with saline Red Sea waters.

The difference in level between the Mediterranean and the Red Sea had been debated, studied, and measured for 25 centuries. Still Napoleon’s cartographers and engineers erroneously concluded that the Red Sea level should have been higher than the Mediterranean one, misleading — as also happened in earlier epochs — planners and designers. Napoleon was the last to surrender to this misconception at the end of the eighteenth century. By the 1840s, a consensus was reached that there existed no significant difference in altitude between the two seas. This revelation would have significantly reduced construction costs for a north-south canal, cutting the Suez Isthmus.

In 1854 and 1856, Ferdinand de Lesseps, a French diplomat who also investigated geological and hydrological features of the Suez Isthmus, obtained concessions from Said Pasha¹, authorizing him to form a company for excavating a canal open to ships of all nations. After ten years of excavations, and the involvement of 1.5 million laborers, the first steam made it through the whole length of the canal in the month of September 1869, carrying on-board De Lesseps.

The vast scientific importance of the eventual faunal interchange between the two seas was soon realized and few baseline studies were executed. We have to wait until 1917 when Jordan and Hubbs report the first pelagic fish species, *Atherinomorbus lacunosus* (as *Atherina forskali*) (Gollasch, et al., 2006), in the Mediterranean Sea, in the waters off Port Said, and seven years later when Fox (1924) identifies the pelagic crab *Portunus pelagicus* in Haifa (Gore, 1986). These two tropical species were common in the Indo-Pacific oceans with no prior occurrence whatsoever in the Mediterranean Sea. The biota of the two seas were now given the opportunity to venture out of their respective seas to discover and eventually to invade new territories.

New sightings came after these and new alien species were proved to have settled and established Mediterranean populations. In 1969, it was clear that a unique phenomenon of unidirectional migration of species from the Red Sea to the Mediterranean via the Suez Canal was underway. The Romanian zoologist Dov Por named it “Lessepsian migration” (Por, 1978), specifying that this is a successful biotic advance from the Red Sea to the Eastern Mediterranean. Here, climatic conditions along with impoverished local biota facilitate this displacement making Indo-Pacific species “welcome guests” in the Mediterranean (Golani, 1998; Rilov & Galil, 2009).

Few years before, in 1964 Carl J. George and Victoria A. Athanassiou from the American University of Beirut (AUB) and Ismat Boulos of the Lebanese Ministry of Agriculture published a booklet titled, “The Fishes of the Coastal Waters of Lebanon” (George, et al., 1964), the first systematic experience of data collection on the Lebanese halieutic resources. Through this study, relying almost entirely on commercial fishermen as supplier of the specimens, they were able to describe and report 177 fish species inhabiting Lebanese coastal waters, 19 of Indo-Pacific origins. Two Lessepsian species, the spinefoot fish *Siganus rivulatus* and the goaldband goatfish *Upeneus moluccensis* were by that time already considered as “very common,” clearly affirming how Lebanese waters are a conquered realm for invasive subtropical species, at least since the early 1960s.

¹ Said Pasha had been the governor of Egypt and Sudan from 1854 until 1863, officially owing fealty to the Ottoman Sultan but in practice exercising virtual independence.

By the mid-1960s and then in late 1970s, the canal was deepened to handle laden tankers of 150,000 tons. Those enlargements may be associated with the sharp increase in the number of invaders appearing since the mid-1960s (Rilov & Galil, 2009)(Figure 4). Therefore, the “New Suez Canal” inaugurated on August 6, 2015, adding a new 72-kilometer long second shipping lane in the existing 164-kilometer long canal can facilitate the invasion of more species that were confined as larvae or adults in the Red Sea. Along with other large scale ongoing phenomena, this expansion will affect the Levantine Basin, unfolding a varied range of effects at local and regional scales (Galil, et al., 2017).

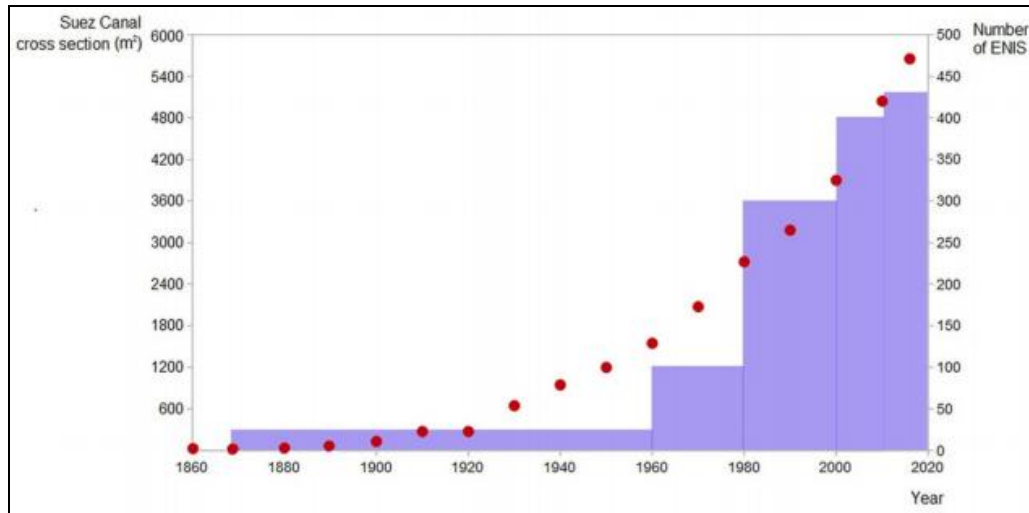


Figure 4. The enlargement of the Suez Canal (cross section, m²) and the numbers of species probably introduced through the Suez Canal. ENIS: Erythraean non-indigenous species. From Galil, et al. (2017).

Description of the main arrivals of NIS in eastern Mediterranean

751 multicellular NIS introduced into the Mediterranean Sea. About two thirds of these species are considered Lessepsian or Erythraean NIS, i.e. introduced through the Suez Canal. Erythraean NIS numbers more than doubled between 1980 and 2016 and are substantially greater in the Levant than in the western Mediterranean (Galil, et al., 2017)(Figure 5). This confirms that the Mediterranean Sea – and more in specific its easternmost shores - is one of the hottest hotspots of marine bioinvasions on earth (Rilov & Crooks, 2009). Due to its proximity to the Suez Canal, its favorable conditions (warmer, saltier waters), dominant currents and the faunal impoverishment, the Eastern Mediterranean shows the greatest occurrence of NIS.

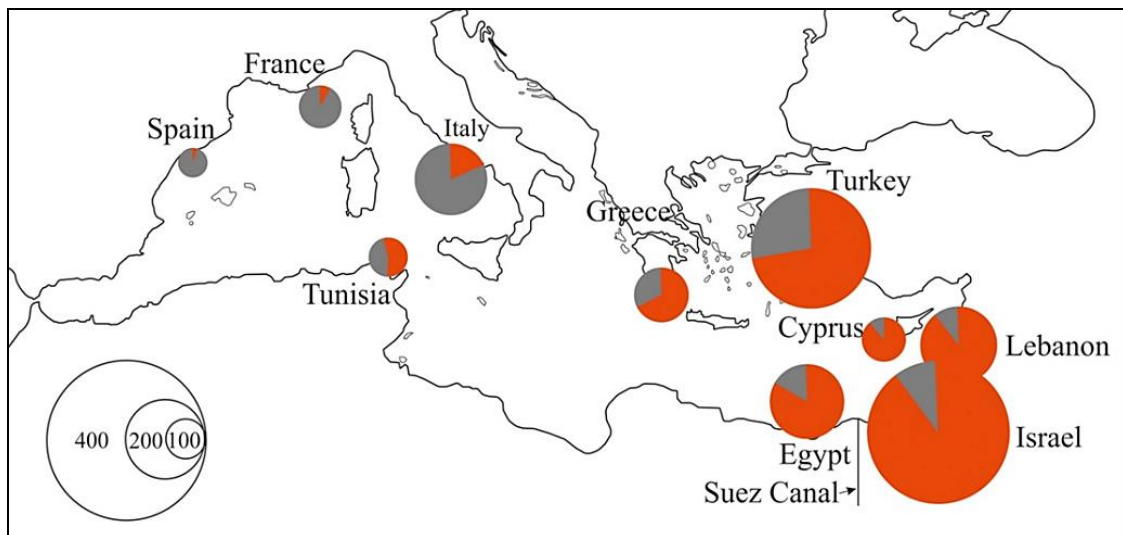


Figure 5. Number of non-indigenous species (NIS) the Mediterranean. In red, the fraction of species probably introduced via the Suez Canal. The circle sizes are proportionate to the total number of NIS recorded in the country. Modified from (Galil, et al., 2017).

Macrophytes, invertebrates and fish of Indo-Pacific origins are prominent in many coastal habitats and have profoundly altered the composition of the biota of the southeastern Mediterranean Sea (Steinitz, 1970; Por, 1978; Galil, 2007). This phenomenon encompasses all major taxa. The dominant groups of alien species in the Mediterranean are Mollusca (215 species, 90 percent of which reported in the Eastern Mediterranean), Crustacea (159, 79 percent in the Eastern Mediterranean), Polychaeta (132, 77 percent in the Eastern Mediterranean), Macrophytae (128, 55 percent in the Eastern Mediterranean) and fish (126, with only two elasmobranchs, i.e. *Himantura uarnak* and *Torpedo sinuspersici*, 83 percent in the Eastern Mediterranean) (Zenetos, et al., 2012) (Figure 6).

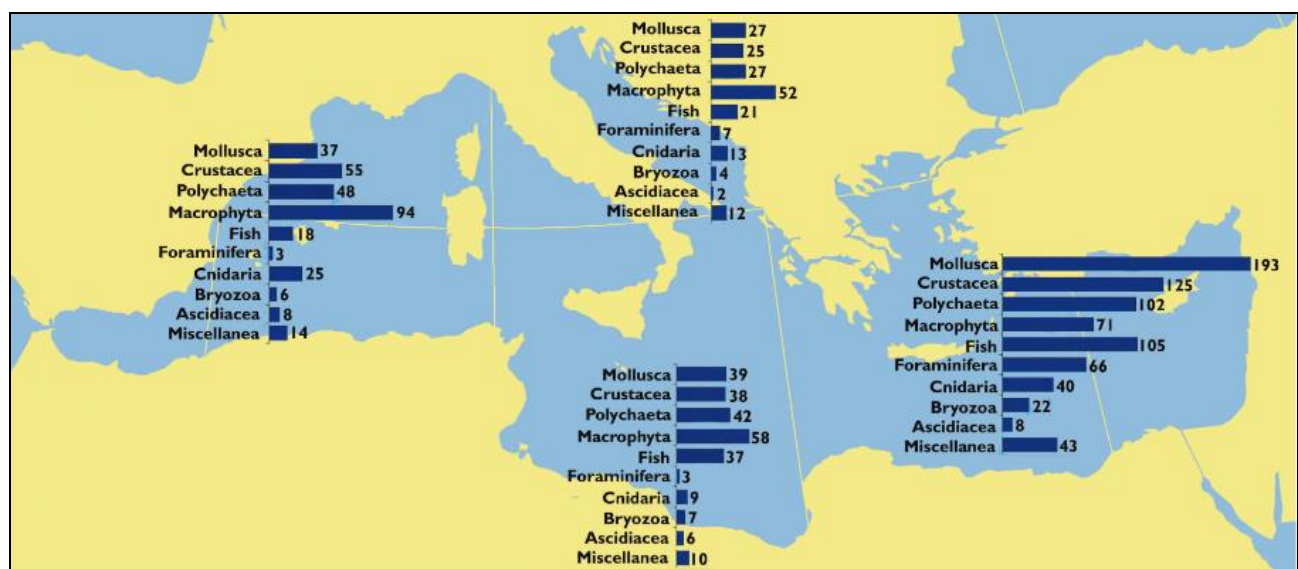


Figure 6. Number of marine alien species per major groups in the MSFD subregions of the Mediterranean Sea. Modified from (Zenetos, et al., 2012).

It is worth noting the dominance of macrophytes among NIS in the Adriatic and the Western Mediterranean due to the introduction of macrophytes in coastal lagoons, whereas in the eastern Mediterranean they hardly add up to 10 percent (Boudouresque, et al., 2011). 84 percent of fish has been reported from the Eastern Mediterranean. In 2012, 70 of those species had not been reported from any other subregion of the basin (Zenetos, et al., 2012). Non-indigenous fish species succeeded in colonizing

almost every available niche, however the majority of fish invaders in the Mediterranean are spawning, shallow water, benthic carnivores (Rilov & Galil, 2009) (Figure 7).

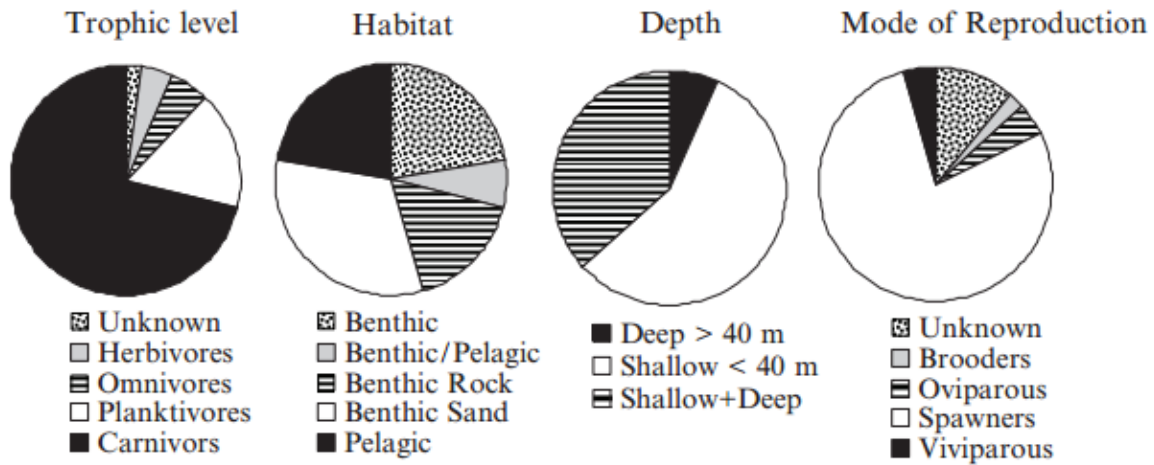


Figure 7. Ecological classifications of non-indigenous fish in the Mediterranean Sea. From (Rilov & Galil, 2009).

In 2003, a survey conducted along the Syrian coastline – whose overall objective was the promotion and improvement of the management of marine and coastal protected areas) – reported rocky banks covered with the NIS *Styopodium schimperi* and the fauna comprised many NIS introduced via the Suez Canal, such as *Strombus decorus*, *Malleus regula*, *Chama pacifica*, *Pinctada imbricata radiata*, *Synaptula reciprocans*, *Fistularia commersonii*, *Pempheris vanicolensis*, *Sargocentron rubrum* and *Siganus rivulatus*. Sandy bottoms were covered with a meadow of the Erythraean seagrass *Halophila stipulacea* (Bitar, et al., 2003) (Figure 8).



Figure 8. Meadow with *Halophila stipulacea* (Cove of the military station of Ras El Bassit – photo: R. D. Grandrive). From: (Bitar, et al., 2003).

In the area of Latakia, the NIS rhodophyte *Galaxaura rugosa* covered almost entirely the rocky substrate, accompanied by many NIS of fish and invertebrates (Bitar, et al., 2003).

In Lebanon, few studies have dealt with the marine flora of Lebanon. (Basson, et al., 1976) listed 190 taxa of macrophytes (including Cyanobacteria), while Bitar (1999) listed 208 taxa including 4 introduced Indo-Pacific NIS. In 2012, 2013 and 2016, several Lebanese localities spread over the Lebanese shores were surveyed within the framework of the international MedMPAnet Program for the establishment of an effective Mediterranean network of marine protected areas (RAC/SPA - UNEP/MAP, 2014). At least 19

Indo-Pacific NIS of macrophytes were identified (Bitar, et al., 2017), while 31 percent and 21 percent respectively of the recorded mollusc and fish species were of Indo-Pacific origin (RAC/SPA - UNEP/MAP, 2014). Influence of some Lessepsians species (as Siganidae, *Chama/Spondylus* bioconstructions) is considered relevant on the habitat; and the seasonal changes are very pronounced in the flora composition (RAC/SPA - UNEP/MAP, 2014). Furthermore, other Lessepsian NIS have established large populations such as: the mytilid *Brachidontes pharaonis*, the stinging feathery hydroid *Macrorynchia philippina*, the bivalve *Malleus regula* and the echinoderm *Synaptula reciprocans* (RAC/SPA - UNEP/MAP 2014). Carpentieri, et al. (2009) evidenced the importance of Lessepsian species in terms of diversity and abundance in the catch composition of Tyre fishing fleet, characterizing the fish community of south Lebanon coasts as a mixed Mediterranean–Red Sea composition. The weight percentage of Lessepsian species observed in the study area was approximately 37 percent. Most common Lessepsian fish species were *Siganus rivulatus*, *S. luridus*, *Etrumeus teres*, *Sargocentron rubrum*, *Scomberomorus commerson*, *Pempheris vanicolensis* and *Lagocephalus* spp.

Ramos Esplá & Pérez (2004) documented the overwhelming presence of NIS from the littoral to the depth of 40 m along the Israeli coast. The mytilid *B. pharaonis* formed a marked belt in the lower part of the mid-littoral. Shallow rocky reefs (1–22 m) were covered by *S. spinosus* and *C. pacifica* formations, overgrown with the stinging Erythraean hydrozoan *M. philippina*. Other common nonindigenous molluscs were *P. imbricata radiata*, *M. regula*, *Strombus persicus*, *Trochus erythraeus*. *Stipopodium schimperi* was pervasive. The abundance of non-indigenous fish such as *F. commersonii*, *P. vanicolensis*, *S. rubrum*, *S. luridus*, *S. rivulatus*, and *Stephanolepis diaspros* was relevant, comprising 37.3 percent of the total number of fish observed (Ramos Esplá & Pérez, 2004).

Ecological and economic impacts of invasions in general.

The opening of the Suez Canal in 1869 allowed entry of Indo-Pacific and Erythraean biota. Some NIS have outcompeted or replaced native species locally, some are considered pests or cause nuisance, whereas other invaders became of commercial value. The rate of marine biotic invasions has increased in recent decades; collectively they have significant ecological and economic impacts in the Mediterranean (UNEP/MAP, 2007). Introduced demersal species have the potential to drastically affect sensitive Mediterranean coastal ecosystems (Sala, et al., 2011) and, if not deeply understood and mitigate, the ecological risks associated with the expansion of the Suez Canal may jeopardize the integrity of a large part of the Mediterranean ecosystem (Samaha, et al., 2016).

Crossing the Suez Canal does not guarantee successful settlement and dispersal of populations. Hydrological conditions are important in understanding the successful spreading of many NIS (Mavruk & Avsar, 2008). Additionally, species ecology is a key determinant for settlement and dispersal success (Galil, et al., 2017; Rilov & Galil, 2009): according to Ben Rais Lasram, et al. (2008), only 30 percent of the Lessepsian species have succeeded in establishing colonizing populations in the Mediterranean Sea. These species have affected the structure and functioning of the sea and the consequent provision of goods and services (Micheli, et al., 2013; European Environment Agency, 2015; Galil, et al., 2016). And complex and fundamental alterations to the Mediterranean Sea are underway (Galil, et al., 2017; Samaha, et al., 2016).

In the last decades, due to their impact on human activities including significant economic impacts and drastic changes in the fishing landing composition, some species took the role of emblematic species.

Starting mid 1980s showing an increasing presence in the last decade, swarms of the invasive Indo-pacific jellyfish, *Rhopilema nomadica*, have appeared along the Levantine coast (Galil, et al., 1990; Lakkis &

Zeidane, 1991) (Figure 9). They frequently draw nearer to the shore negatively affecting tourism, fisheries and coastal installations. Coastal trawling and purse-seine fishing were disrupted.



Figure 9. A specimen of *Rhopilema nomadica* observed in Lebanese waters, during routine sampling activities implemented by the CNRS-Lebanon along the Lebanese coastal waters. Photo: Ghazi Bitar.

Jellyfish-blocked water intake pipes pose a threat to engine cooling systems of ships and coastal power plants: in the summer of 2001 (Rilov & Galil, 2009) and 2015 (<http://www.bbc.com/news/av/world-middle-east-14038729/jellyfish-threaten-israeli-power-plant>), Israel Electric removed tons of jellyfish from its seawater intake pipes at largest power plants. It has recently spread to Pantelleria Island (Crocetta, et al., 2015) and to Tunisia (Galil, et al., 2017). Between April 2013 and April 2017, the interactive web-tool on jelly blooms (<http://www.ciesm.org/gis/JW/build/JellyBlooms.php>) reports 22 swarms (more than 1,000 individuals) all concentrated in the South of Lebanon.

The swimming crab *Portunus pelagicus*, was firstly recorded in the Mediterranean in Port Said in 1898, where it soon became abundant and sold in Egyptian and Palestinian ports (Fox, 1924; Calman, 1927). In the whole Levant basin, it is considered commercially valuable since the early 1920s (Galil, et al., 2002), constituting nearly half of the trawl catches along the Israeli coast in mid 1990s (Golani & Ben-Tuvia, 1995).

The silver-cheeked toadfish *Lagocephalus sceleratus* is a widely distributed species inhabiting the tropical Indian and Pacific Oceans, from which it originated. Through the Suez Canal, it made its way to the Mediterranean where was firstly recorded in February 2003 in the southern Aegean coast of Turkey (Akyol, et al., 2005). *L. sceleratus* has shown a rapid expansion: it reached the North Aegean Sea in 2006 (Bilecenoglu, et al., 2006), the southern end of the Gulf of Gabès in Tunisia (central Mediterranean) in 2010 (Jribi & Bradai, 2012) and for the first time the Italian waters in October 2013, off Lampedusa island (Azzurro, et al., 2014). Today, it is regarded to be among the most destructive NIS in the Mediterranean Sea with a significant impact on the surrounding ecosystem and on the fisheries sector (Streftaris & Zenetos, 2006; Ozturk, 2011). In the Mediterranean, this fish was found to be voracious and carnivorous, feeding mainly on shrimps, crabs, fish—including individuals of its own species—and cephalopods (EastMed, 2010; Aydin, 2011). *L. sceleratus* is considered a serious hazard to consumers since it contains a strong paralytic marine toxin called TTX (tetrodotoxin), which can be lethal to humans (Sabrah, et al., 2006; Nader, et al., 2012). In the eastern Mediterranean, many cases of TTX poisoning have been reported (Ashkar, et al., 2008). In 2005, two cases of human intoxication due to the consumption of pufferfish were recorded in Lebanon (Khalaf, et al., 2014).

At present, the relatively low winter water temperatures (14–15 °C) in the eastern Mediterranean are probably the main obstacle for the establishment of many tropical species in the Levant basin, also considering the recent expansion of the Suez Canal. An increase of a few degrees in winter water temperatures may lift this barrier as well unveiling a probable scenario for the not so distant future when global warming may facilitate even further Lessepsian migration (Rilov & Galil, 2009).

Objectives of the study

The aim of this study was to contribute to a better knowledge of demersal species in the Lebanese coastal waters, Eastern Mediterranean. Various aspects related to the distribution, diversity and biology of these species were studied. More in specific, this gave us the chance to:

1. Investigate the biodiversity of Lebanese demersal species
2. Collect information on biological traits, relative abundance and distribution of demersal species
3. Widen the knowledge on demersal communities exploited by Lebanese artisanal fisheries
4. Investigate the ecological traits of the redcoat, a key demersal Lessepsian fish species

Some chapters of the thesis are presented under the form of articles. Following the present general introduction, constituting **Chapter I**, the thesis is divided as follows:

Chapter II describes “Materials and Methods”, which includes a description of the studied area, sampling design, sampling gears, protocols set for sampling activities and data collection and statistical tests and analyses employed throughout the present thesis. The present thesis also comprises a description of the Lebanon’s fisheries sector that includes socioeconomic characteristics, environmental context and governance-related aspects (**Chapter III**), and a short essay on main traits, history, causes and effect of the so called Lessepsian migration (in Chapter I) both based on original contents and bibliographic review. **Chapter IV** is dedicated to the study of the pattern of distribution and structure of demersal species exploited by artisanal fisheries in the eastern Mediterranean Sea. The second part describes and analyzes the biological assemblages of demersal species along the Lebanese continental shelf and upper slope. **Chapter V** reports the estimation of Weight-Length relationships (WLRs) of 30 coastal species captured in Lebanese waters using data collected in the framework of a multiannual fisheries-independent data collection for the assessment of demersal coastal species. **Chapter VI** presents the biology and ecology of the Lessepsian species *Sargocentron rubrum* in Lebanese waters. Aiming at providing information for sound population dynamic based models and the general discussion, conclusion, and perspectives of this work are presented in the last chapter (**Chapter VII**).

Following annexes are included at the end of the thesis to complement and improve its contents:

- Annex 1 is dedicated to the presentation of a communication in the 45th congress of Italian Society of Marine Biology, May 9-23, 2014 (La porta et al., 2014²) and Annex 2 to a 2014's communication in the 20th LAAS International Science Conference - Advanced Research for Better Tomorrow, March 27-29 (Lelli et al., 2014)³;
- Annex 3 presents two 2014's written communications to the 'Watch Letter' (CIHEAM) (Hamzé et al, 2014⁴; Zuccaro et al., 2014⁵) ;
- Annex 4 presents the first pages of the CANA book of 2014 and 2015 (Khalaf et al, 2014⁶; Lelli 2016⁷);
- Annex 5 presents the first page of a 2014's publication in the Journal of earth Science and Engineering (Khalaf et al. 2014)⁸ and Annex 6 to the first page of a 2017's publication in the New Medit revue (Mulazzani et al., 2017)⁹ ;
- Finally, Annex 7 is dedicated to the presentation of the first page of a 2017's publication in the Journal of applied Ichthyology (Lelli et al., 2017)¹⁰.

² LA PORTA B., NICOLETTI L., MOUAWAD R., TARGUSI M., LA VALLE P., LATTANZI L., LELLI S. (2014). Benthic assemblages along the highly urbanised coasts of Lebanon (eastern Mediterranean Sea). *45° Congresso della Società Italiana di Biologia Marina Venezia, 19-23 maggio 2014*. 166-167.

³ LELLI S., LTEIF M., JEMAA S. and KHALAF G. (2014) - First information on abundance, biology and distribution of the red giant shrimp (*Aristaeomorpha foliacea*) in Lebanese waters. *20th LAAS International Science Conference - Advanced Research for Better Tomorrow. March 27-29, 2014*.

⁴ HAMZÉ M., KHALAF G., FAKHRI M., SURSOCK A., LELLI S. (2014). Research Vessel CANA-CNRS. Five years of research activities in the Eastern Mediterranean Sea. *The Mediterranean Sea. Fisheries and Beyond Paris: CIHEAM, December 2014 - Watch Letter n°31*.

⁵ ZUCCARO M., TREVISI R., GALLI D., LELLI S., UGOLINI R., DI TERLIZZI B., MALORGIO G. (2014). Fishery and aquaculture cooperation for the development of Mediterranean coastal communities. *The Mediterranean Sea. Fisheries and Beyond Paris: CIHEAM, December 2014 - Watch Letter n°31*.

⁶ KHALAF G., FAKHRI M., LELLI S. (2014). Marine Hydrobiology: Hydrology, Coastal Pollution, Fishery and Cetacean. In: CANA-CNRS. A SCIENTIFIC VESSEL FOR LEBANON 2013-2014. 66-95.

⁷ LELLI S. (2016). An Unlikely Mediterranean Sea: Invasive Fish Species in Lebanese Waters. In: CANA-CNRS. A SCIENTIFIC VESSEL FOR LEBANON 2009-2015. 55-58.

⁸ KHALAF G., SAAD A., JEMAA S., SABOUR W., LTEIF M. AND LELLI S. (2014) - Population Structure and Sexual Maturity of the Pufferfish *Lagocephalus sceleratus* (Osteichthyes, Tetraodontidae) in the Lebanese and Syrian Marine Waters (Eastern Mediterranean). *Journal of Earth Science and Engineering* (4).

⁹ MULAZZANI L., ZANASI C., ERRICO A., PUGLIESE P., ZUCCARO M., ZERROUKI R., MEDANI M., OUAZZANI TNACHERI M., MOHANNA C., HAMZA H., LELLI S. (2017) - The comparative analysis of Mediterranean coastal communities: six case studies. *NEW MEDIT N. 2/2017*. 27-37.

¹⁰ LELLI S., LTEIF M., JEMAA S. and KHALAF G., VERDOIT-JARRAYA M. (2017). Weight-length relationships of 3 demersal fish species from Lebanese marine waters, eastern Mediterranean. *J Appl Ichthyol. 2017*; 1-4 (early version).

Chapter 2

Material and Methods

Chapter

2

Materials and Methods

Characteristics of the study area

Situated in the central part of the Levantine Basin (Eastern Mediterranean), Lebanon is geographically limited by latitude 33°- 35°N and longitude 35° 30'-36° 20' E (Figure 10). Its coastal stretch is about 225 km long (Central Intelligence Agency, 2013) from Aarida (north) to Ras el Naqoura (south) on the Levantine Basin of the Mediterranean Sea. Mount Lebanon (3083 m high) is located on a 160-km-long transpressional bend of the left-lateral Levant (Dead Sea) Fault System (LFS). Seaward from Mount Lebanon, the Levantine margin of the Mediterranean basin is particularly steep, reaching water depths of approximately 1500 m only 8 km from shore (Carton, et al., 2009).



Figure 10. Map of study area in Lebanon.

The continental shelf is relatively wide in the north, offshore of the Akkar plain (about 20 km), and in the south, offshore of Saida and Tyre (Nabatiyeh plateau), whereas between Beirut and Batroun, the shelf is extremely narrow. Here the margin exhibits its steepest slope, with the water depth abruptly increasing from 100 to 1500 m in less than 5 km (Carton, et al., 2009). Along the entire margin the continental slope is incised by canyons, most of them connected to rivers flowing from the mountains (Sursock, et al., 2014).

Sea cliffs made out of limestone border most of the shores and sometimes descend directly into the sea. They are separated by gravel or sand beaches, composed partly of shell fragments and mostly of detrital sand (Emery & George, 1963). There is a minimal variation in tides (JRC – Institute for the Protection and

Security of the Citizen (IPSC), 2017). The general circulation along the coast of Lebanon is dominant northwards during most of the year along with the general counter clockwise current gyre of the Eastern Mediterranean. This current is locally modified by the configuration of the coastline and the topography of the narrow continental shelf. This results in a series of clockwise directed eddies and small gyres associated with bays and headlands as well as with numerous submarine canyons incised in the continental shelf (Goedicke, 1972). Water movements along the coast are also strongly related to surface currents and seasonal meteorological factors. Offshore areas of Lebanon are characterized by peculiar oceanographic conditions that may enhance the accumulations of larvae and juveniles and create favourable habitats for

their growth and survival. The Modified Atlantic Water (MAW) enters the Levant Basin through the Cretan Passage and the core of the jet branches southwest of Cyprus. Part of it bypasses Cyprus to the south and reaches the eastern boundary of the basin. In some years, the mainstream flow is blocked off at the Latakia basin, between Cyprus and Syria. In these years, the drift of eggs and larvae eastward could be blocked in the SE Levantin. Moreover, increased retention of eggs and larvae could be associated with the Shikmona mesoscale anticyclonic eddy, generated offshore Lebanese-Israeli coasts. It should feature a predominately convergent flow pattern in the surface layer of the interior of the eddy, with attendant biological implications somewhat similar to those described for ocean surface fronts ([Bakun, 2006](#)).

Lebanon has a typical Mediterranean climate, with an average annual temperature of 20°C and about 300 sunny days each year. It is also characterised by a relatively high average rainfall, ranging from 700 to 1000 mm along the coast to 1,400 mm on Mount Lebanon. Surface water temperatures show high seasonal variation and range from 15°C in winter to 30°C in summer. The water in the upper 50 m is well mixed in winter and becomes stratified during the rest of the year ([Greenpeace, 2010](#)).

The Lebanese coastal waters are characterized by thermophilic biota of Mediterranean and Indo-Pacific origin ([Abboud-Abi Saab et al, 2013](#); [Bitar et al, 2007](#)). The local biodiversity is undergoing rapid alteration under the combined pressures of climate change and anthropogenic impacts. Protection measures, for either species or ecosystems, are still rare. Native marine flora and fauna are competing with invading species originating from the Indo-Pacific and Atlantic oceans. More in specific, for the past two centuries, the biodiversity has been altering at an alarmingly high rate due to human-mediated arrival of new species, with an apparent acceleration in the rate of recorded invasions in the last decades ([Rilov & Galil, 2009](#)). The features of the Lebanese coastline with no closed bays or gulf consent to coastal waters to continuously mix thus preventing conditions of eutrophication and to disperse nutrients and pollutants ([Abboud – Abi Saab, 2012](#)).

Data collection

Background

International organizations and donors have granted funds and capacity building to develop adequate research programmes to support the capability of the Lebanese Government to define new measures towards an appropriate and sustainable management of fishing resources. The idea of an overall Country data collection to gain information on abundance and distribution of Lebanese fisheries resources stemmed from a series of meetings that took place in 2012 aiming at coordinating the efforts of international organizations (i.e. FAO, CIHEAM, Italian Cooperation) and Lebanese stakeholders such as public institutions and academia.

Financed by the Italian Cooperation in Lebanon, in 2012 the project CIHEAM-PESCA LIBANO “Technical Assistance to the Ministry of Agriculture in the field of fishery development” aimed at providing the Lebanese Ministry of Agriculture (MoA) with advanced tools designed for a proper management of marine and fisheries resources. This was achieved by strengthening capabilities of the MoA staff and assessing the potentialities of marine coastal resources. The project gathered scattered data fisheries related from different concerned institutions, on the one hand. On the other, it actively collected data that emerged to be important for a correct management of the sector and still missing. The project had been working on the land to map infrastructures and activities linked to fisheries, and at sea to assess the distribution and abundance of demersal species exploited by the Lebanese artisanal fleet. The National Council for Scientific Research, Lebanon (CNRS-L), in charge of the implementation of the fishing surveys through its Marine Centre, gave follow up executing seasonal data collection at sea in the North Lebanon.

With the aim of assessing the distribution and abundance of fisheries resources along the Lebanese coasts in order to deliver scientific advice to MoA for an enhanced fisheries management, the CNRS-L organized surveys in 2012, 2013 and 2014. Experimental fishing gears were lowered in 62 sites along the coast of Lebanon, at depths ranging from 10 to 600 m. The following sampling stations by year were considered and analyzed for the purpose of this thesis:

- in 2012, a total of 47 hauls carried out in the period June 9 to September 4, 2012 for a total of 35.25 Km of nets deployed.
- In 2013, 49 hauls executed between January 3 and August 29, 2013. A total of 36.75 Km of nets had been lowered up to 150 meters depth.
- Between September 24 and October 13, 2014, 13 sampling stations located in the Akkar Shelf and Tripoli-Beirut regions surveyed by means of 13 Km of nets. 12 sampling stations located in deeper waters (165-300 m depth) surveyed between April 2013 and October 2014.

Sampling design

We deemed fishery-independent survey as the most appropriate tool to provide valuable measures of relative abundance, rates of population change and size and sex composition for a wide range of species. In fact, fishery-independent surveys form the cornerstone of many stock assessments for bony fishes and shellfish species, they are less subject to the unknown and often confounding factors that complicate the interpretation of fishery-dependent indices of stock status. Thus fishery-independent surveys strike a balance between the ability to make inferences about one or more populations versus the usage of a specific area by one or more species (Rago, 2005).

The predominantly used approach for the definition of a fishery-independent survey sampling design is stratification where the total survey area is broken down into strata possessing common features regarding the species composition and their densities and length structures. If the strata are well selected, i.e. characterised by a low variability within the strata and clear differences between strata, the stratification is a convenient way of increasing the precision of the abundance estimates (Cochran, 1977). Survey effort may be allocated between strata according to their size or may be optimised if a priori knowledge on the variability of interest is known (Sparre & Venema, 1992). Within each stratum, the fishing stations are chosen randomly.

It is therefore clear that the stratification scheme depends on the objective established for the survey. Since, the ultimate aim of the abundance survey in Lebanese waters was to obtain an estimate of the relative abundance and spatial distribution of main commercial stocks, it was necessary to adopt a stratification that could allow sampling a relative large array of species with different depth ranges. At the same time, it was required to cover the entire Lebanese coast in order to gather enough data to map the spatial distribution of the stocks. Table 1 and figure 11 summarise the stratification approach adopted for the surveys based on the definition of four coastal regions from North to South (Akkar shelf, Tripoli-Beirut; Beirut-Saida; Saida-Naqoura) and 2 depth strata (0-100 m; 101-150 m). The total number of sampling stations was 48, spatially allocated randomly but proportionally to the extension of each area.

Table 1. Survey areas according to regions and bathymetric strata over the Lebanese continental shelf.

REGION	Area in the bathymetry 0-100m (km ²)	n. hauls	Area in the bathymetry 100-150m (km ²)	n. hauls
1. AKKAR SHELF	473.6	12	124.4	3
2. TRIPOLI-BEIRUT	183.3	5	92.05	3
3. BEIRUT-SAIDA	189.8	5	99.6	3
4. SAIDA-NAQOURA	386.4	11	221.7	6
total	1233.1	33	539.7	15

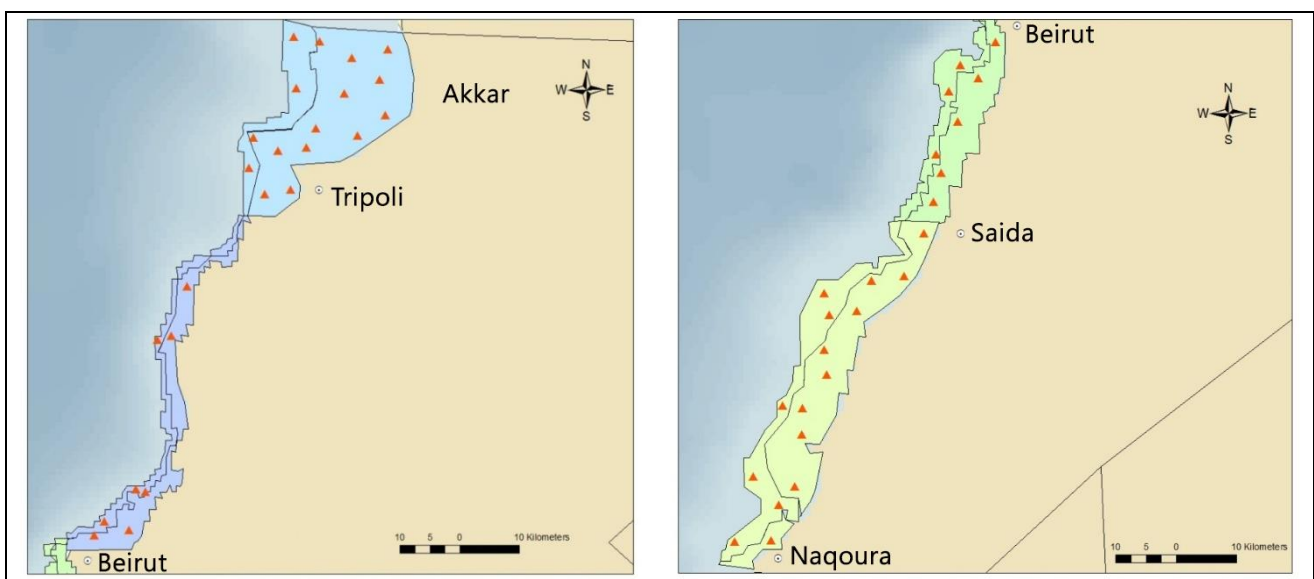


Figure 11. Maps of investigated area showing the randomised distribution of sampling stations along the Lebanese continental shelf. Left: northern sectors (Akkar shelf and Tripoli-Beirut). Right: southern sectors (Beirut-Saida and Saida-Naqoura).

Repercussions of the Syrian conflict and related safety measures forced us to shift southward or to delete sampling stations closer to the Syrian border. Other sampling points were slightly shifted due to technical impediments arisen during sampling activities at sea. Table 2 shows final locations of identification codes of the sampling points.

Table 2. Location of the sampling stations and their identification code.

REGION	Haul n.	Haul name	Depth (-m)	Coord N	Coord E	
AKKAR SHELF	2	North Aabde	40	34°33.116'	35°57.196'	
	3	Nabi Kzaiber	80	34°32.050'	35°53.155'	
	4	Aabde	10	34°30.993'	35°55.562'	
	5	Nahr el Bared	50	34°29.430'	35°52.435'	
	6	El Minie	30	34°28.812'	35°53.151'	
	7	Deir Aamar	30	34°29.416'	35°52.517'	
	8	Nahr Abu Ali	70	34°30.431'	35°53.705'	
	9	Tripoli	30	34°30.030'	35°48.836'	
	10	Palm Islands	30	34°29.876'	35°47.086'	
	12	Qalamoun	60	34°23.305'	35°45.789'	
	14	Beddawi	110	34°31.020'	35°50.165'	
	15	Dedde	140	34°23.502'	35°45.130'	
	TRIPOLI - BEIRUT	16	Enfeh	20	34°21.131'	35°42.733'
		17	Madfoun	40	34°13.186'	35°37.100'
		18	Jounieh	70	33°59.839'	35°36.997'
19		Antelias	10	33°55.133'	35°34.680'	
20		B.Hammoud	90	33°55.266'	35°34.309'	
20-ter		Beirut-Biel	150	33°55.170'	35°32.000'	
21		Chekka	110	34°20.883'	35°42.169'	
22		Fidar	120	34°06.240'	35°37.923'	
22-bis		Jbeil	30	34°06.831'	35°38.254'	
23		Jounieh 2	140	34°00.431'	35°37.085'	
TRIPOLI - BEIRUT	24	Ramlet Al Baida	30	33°51.861'	35°28.229'	
	25	Khaldeh	90	33°50.319'	35°27.137'	
	26	Aramoun	50	33°44.450'	35°24.300'	
	27	Nahr Damour	50	33°40.400'	35°23.300'	
	28	Jiyeh	10	33°40.030'	35°24.610'	
	29	Airport	140	33°48.444'	35°25.240'	
	29-bis	Ouzai	10	33°50.334'	35°28.584'	
	30	Naameh	100	33°44.750'	35°23.935'	
	31	Borj Barajne	130	33°51.891'	35°26.871'	
	SAIDA - NAQOURA	32	Nahr el Awali	70	33°35.465'	35°22.300'
33		Nahr Sainiq	30	33°33.736'	35°21.075'	
35		Sarafand	15	33°31.385'	35°19.807'	
36		Khaizarane	80	33°32.380'	35°20.033'	
37		Aadloun	30	33°24.264'	35°11.918'	
38		Mazraat Bsaile	22	33°19.974'	35°11.345'	
39		Bourghliye	50	33°19.991'	35°11.284'	

40	Sour	50	33°14.056'	35°07.899'
40-bis	Sour2	100	33°14.804'	35°07.001'
41	Rachidiye	30	33°15.019'	35°09.399'
42	Naqoura	10	33°07.216'	35°07.519'
43	Saida	120	33°35.700'	35°22.685'
44	El Aaddoussiye	140	33°32.540'	35°20.190'
45	Sari	140	33°24.993'	35°11.912'
46	Qasmiye	150	33°20.603'	35°10.691'
47	El Bass	130	33°18.996'	35°08.954'
48	Chabriha	100	33°19.521'	35°08.799'

Sampling gears

In Lebanon, the most important commercial species are typically coastal and distributed over areas where standard trawling cannot be carried out. In this situation, other fishing gears (e.g. longlines, gillnets and traps) had to be used to survey untrawable areas and species. Moreover, trawling activities are interdicted in the Lebanese territorial waters ([University of Balamand, 2016](#)). Following the good results obtained in the exploratory fishing survey implemented in March-May 2012 ([Colloca & Lelli, 2012](#)), gillnets were selected as sampling gear for data collection. Moreover, taking into consideration the relatively high CPUEs observed in Lebanese waters when compared with other Mediterranean areas, the dimension of each patch of net was limited to about 250 m length, for a total of 750-1000m of nets employed during each sampling haul. Gillnets with mesh sizes of 26, 30 and 40 mm were lowered at depths less than 100 m; trammel nets with mesh sizes of 22, 24, 26, 28 and 30 mm were lowered at depths greater than 100 m. Longlines of size 5 hooks were lowered at randomly specified depths (results obtained using longlines are not reported in this study). Specifications of technical characteristics of the gillnets used during the fishing surveys are summarised in [Table 3](#).

Table 3. Technical characteristics of gillnets and trammel nets used for the implementation of the fishing surveys.

	Gillnets	Trammel Nets
Net yarn		
Material	PA mono-filament	PA multi-filament
Diameter	0.26/0.30/0.30 mm	0.28/0.28/0.30/0.30 mm
Stretched mesh size	52/60/80 mm	22/24/26/30 (internal wall) 44/48/52/60 (external wall)
Panel height	4.4/3.9/3.9 m	3.0 m
Panel length	500/472/500 m	180/240/240/300 m
Colour	light green	light green/ light green/ light yellow/ light yellow
Bolsh twin		
Material	Twisted PE	Twisted PE
Diameter	1.2 mm	6 mm
Float rope		
Material	Twisted PE	Twisted PE
Diameter	12/14/16 mm	6 mm
Length	250 m	180/240/240/300 m
N. bolshes	1920/1560/1250	
Bolsh size	0.13/0.16/0.20 m	
N. meshes per bolsh	5	
Hanging ratio	0.50/0.53/0.5	0.50/0.53/0.50/0.50
Floats		
Material	PVC	PVC
Size	6.7x4.0 cm	8.0x5.0 cm
N. floats	390	
Lead rope		
Material	Twisted PE	Twisted PE
Diameter	12/14/16 mm	4/5/5/6 mm
Length	250 m	180/240/240/300 m
N. bolshes	192/156/125	
Bolsh size	0.13/0.16/0.20 m	
N. meshes per bolsh	5	2
Lead weight	140 g/m	260/666/666/666 g/m
Hanging ratio	0.5/0.53/0.50	0.50/0.53/0.50/0.50

After the conclusion of the first survey (2012), it appeared clear the need of a fine tuning of the sampling gear in order to reduce the still-too-high selectivity of the gillnets and their fragility especially in deeper waters where the materials undergo serious stresses due to the high pressure and the tractions in the phase of retrieving. During the second survey (2013), after the completion of the activities in the region of Akkar Shelf, gillnets suffered a major rupture and the loss of part of the nets. Damaged patches of nets were re-assembled and raw materials were used to manufacture a new set of multi-mesh trammel nets compatible with the use in deeper waters (specifications summarised in [table 3](#)). The mesh sizes included in net series used for stocks surveying were selected to enable full coverage of the potential size distribution of fish that may be encountered. Due to the incompleteness of the information on the size composition of demersal resources in Lebanon, different mesh sizes covering a wide range and rigged with a hanging ratio around 0.5 had been used.

Protocols for sampling activities

Nine artisanal fishermen from eight different ports in Lebanon distributed in the north, south and central regions of the country were hired to lower the gear at the hauls with the specified coordinates in order to benefit from knowledge and familiarity of the fishermen with their usual fishing grounds ([Table 4](#)). Vessels with minimum requirements were selected to carry out fishing operations without endangering crew and staff. The length of the vessels ranged from 8.75 to 11 m and their gross tonnage ranged from 3.10 to 5.01 tons ([Table 4](#)). A global positioning system (GPS) was used to reach the right haul and depth was confirmed using a sonar. Species collected from hauls were identified and date, type of gear, net meshes, coordinates and depth in each catch were noted.

Table 4. Characteristics of the fishing vessels used in the surveys.

Port	Vessel Nr.	Vessel Name	Vessel Owner	Length LOA (m)	Gross Tonnage	Engine power (hp)
Tripoli	1957	Mouhammed Nouri	Issam Sidawi	10.21	5.01	27.6
Batroun	1945	Bou Nassif	Toufic Assal	8.83	4.57	20.88
Jbeil	1399	Roberto	George Abi Saad	11.00	3.10	85.00
Jounieh	2228	Aida	Joseph Attieh	8.75	3.85	36.00
Beirut/Dora	531	J	Fadel Attieh	8.75	3.75	24.00
Beirut/Ouzaii	9495	Princess Leila	Yehya Yassine	9.00	5.00	60.00
Saida	1960	Rabih	Rabih Sombol	8.80	3.50	24.00
Tyre	1494	Abou Elie	Nicholas Rahmé	9.75	4.76	48.49
Tyre	1212	Jeannette	Nicholas Rahmé	8.80	2.67	24.61

Fishermen lowered the nets in the afternoon and retrieved them 12 hours later at the sunrise. The catch was collected and stored in boxes or bins divided according the mesh size of the net that captured the specimen. Operations of extraction of the catch from the nets were usually completed at the port (except for days with poor catch) where researchers collected and reported on *ad hoc*

sheets. Species collected from the survey were identified using the identification guides of [Fischer et al. \(1987\)](#) and the three CIESM Atlases on Fishes ([Golani et al, 2002](#)), Crustaceans ([Galil et al, 2002](#)) and Molluscs ([Zenetos et al, 2003](#)). All specimens collected regardless the species were measured and weighed. Sex and maturity stage were determined for all the individuals. When the catch of a given species was too abundant to be wholly measured, representative sub-samples of the catch were taken. For fish (bony fishes and Elasmobranches), the total length with the tail fully extended was recorded. The measurement unit was the lower half centimetre. For crustaceans, the cephalothoracic length at the lower millimetre was measured, whereas for cephalopods, the dorsal mantle length at the lower half centimetre was noted down. For octopods, the measure was taken along the line passing through the eyes. Standardised protocols and minimum requirements adopted during the surveys were based on the MEDITS programme protocols ([MEDITS Working Group, 2013](#)) and are summarised in [table 5](#).

Table 5. Protocols and minimum requirements adopted.

Nets management	
Soak time	Approximate 12 hours, overnight
Lowering time	Afternoon
Retrieving time	Dawn
Operators	Professional fishermen
Vessels' minimum requirements	
LOA	> 7m
Engine Power	> 16 hp
Winch	Hydraulic or Motorised
Available equipments	GPS, Fishfinder, Safety equipments
Biological data collection	
Biometric: length	Lower half centimetre (fish)
Biometric: weight	Nearest 1 gram
Biological: sex & maturity stages	MEDITS programme protocols (CODES OF SEXUAL MATURITY FOR FISH, CRUSTACEANS AND CEPHALOPODS)
Biometric & Biological Parameters	Collected on all the specimens

Biological indices and sexual maturity

Biological indices were used for the in-depth study of the collected species and in particular of the redcoat, the fish species *Sargocentron rubrum*. Length and weight measurements were taken as part of the standard data collection performed in the framework of the surveys. Dissection of the specimens was performed and additional measurements were taken, including the weight of the stomach and its content (see the paragraph on stomach contents analysis), collection of the otoliths (see dedicated paragraph) and the macro-examination of the gonads.

Weight-length relationship

Length and weight data are useful in fisheries management and standard results of fish sampling programs. Weight-length relationships (WLRs) are used for estimating the weight corresponding to a given length, and condition factors are used for comparing the condition, fatness, or well-being (Tesch, 1968) of fish, based on the assumption that heavier fish of a given length are in better condition. The equation to relate weight and total length following (Le Cren, 1951) is as follows:

$$W = aL^b$$

The coefficient of determination (r^2) was also used to evaluate the quality of the model.

The type of growth of the fish studied is determined by parameter 'b'. This parameter is the exponent of the arithmetic form of the weight-length relationship. If $b = 3$, growth is isometric and the weight increases at the same rate as the length of the fish, indicating that smaller specimens are in the same condition and form as larger ones. If $b > 3$, growth is positively allometric and the weight increases at a faster rate than the length of the fish, indicating that larger specimens have grown in height or width more than in length. If $b < 3$, growth is negatively allometric and the length increases at a faster rate than the weight of the fish, indicating that large specimens became more elongated or small specimens were in better nutritional condition at the time of sampling (Froese, 2006).

Condition factor

The condition factor (K) was calculated for *Sargocentron rubrum* as it reflects fish 'condition', 'fatness', and 'well-being' (Tesch, 1968). It can indicate periods of physiological stress or phenomena, such as, spawning, mating, population density alterations, feeding conditions, and temperature variations (Le Cren, 1951; Braga, 1986; Loefer & Sedberry, 2003). It was defined by (Fulton, 1904) as:

$$K = \frac{W_T}{L_T^3} \times 100$$

Sexual maturity

Sex and sexual maturity stages of fish, crustaceans and cephalopods were identified according to MEDITS programme protocols (MEDITS Working Group, 2013). For bony fish species, a scale from 1

to 4 was adopted. Additionally, the class zero was added to identify undetermined specimens, the class 2 and 4 were divided into 3 and 2 subclasses respectively. Maturity stages for males and females were as follows: 1) Immature=Virgin; 2a) Virgin Developing; 2b) Recovering; 2c) Maturing; 3: Mature/Spawner; 4a) Spent; 4b) Resting. In [table 6](#), it is detailed different gonad aspects, sexual maturation states and maturity stages for bony fishes, cephalopods, crustaceans and elasmobranchs oviparous.

Table 6. Gonad aspects, sexual maturation states and maturity stages for bony fishes (a), cephalopods (b), crustaceans(c) and elasmobranchs oviparous (d) as used in this study.

a)

Stages	Maturation state	Reproductive apparatus aspect	
0	UNDETERMINED	Sex not distinguished by naked eye. Gonads very small and translucent, almost transparent. Sex undetermined.	
		<i>Females</i>	<i>Males</i>
1	IMMATURE-VIRGIN	Small pinkish and translucent ovary shorter than 1/3 of body cavity. Eggs not visible to naked eye.	Thin and whitish testis shorter than 1/3 of body cavity.
2a	VIRGIN-DEVELOPING	Small pinkish/reddish ovary shorter than 1/2 of body cavity. Eggs not visible to naked eye.	Thin whitish testis shorter than 1/2 of body cavity.
2b	RECOVERING	Pinkish-reddish/reddish-orange and translucent ovary; length about 1/2 of body cavity. Blood vessels visible. Eggs not visible to naked eye.	Whitish/pinkish testis, more or less symmetrical; length about 1/2 of body cavity.
2c	MATURING	Ovary pinkish-yellow in colour with granular appearance; length about 2/3 of body cavity. Eggs are visible to naked eye through the <i>ovarian tunica</i> , which is not yet translucent. Under light pressure, eggs are not expelled.	Whitish to creamy testis; length about 2/3 of body cavity. Under light pressure, sperm is not expelled.
3	MATURE/SPAWNER	Ovary orange-pink in colour, with conspicuous superficial blood vessels; length from 2/3 to full length of body cavity. Large transparent, ripe eggs are clearly visible and could be expelled under light pressure. In more advanced conditions, eggs escape freely.	Whitish-creamy soft testis; length from 2/3 to full length of body cavity. Under light pressure, sperm could be expelled. In more advanced conditions, sperm escapes freely.
4a	SPENT	Reddish ovary shrunk to about 1/2 length of body cavity. Flaccid ovarian walls; ovary may contain remnants of disintegrating opaque and/or translucent eggs.	Bloodshot and flabby testis shrunk to about 1/2 length of body cavity.
4b	RESTING	Pinkish and translucent ovary; length about 1/3 of body cavity. Eggs not visible to naked eye.	Whitish/pinkish testis, more or less symmetrical; length about 1/3 of body cavity.

b)

Stages	Maturation state	Reproductive apparatus aspect	Sex
0	Undetermined	Sex not distinguished by naked eye. Sex undetermined.	U
1	Immature-Virgin	Small and translucent Nidamental glands (NG)/Oviducal glands (OG). Ovary is semi-transparent, stringy and lacking granular structure. Small semi-transparent NG/OG. Oviduct meander not visible. Total absence of spermatophores.	F
		Testis small. Spermatophoric complex (SC) semi-transparent; Vas deferens not visible. Penis appears as a small prominence of SC.	M
2a	Developing	NG/OVG enlarged. NG covering some internal organs. Whitish ovary with granular structure clearly visible, not reaching the posterior half of the mantle cavity. Oviduct meander clearly visible. Eggs very small. Absence of spermatophores.	F
		Enlarged testis with structure not clearly visible. Vas deferens is whitish or white and the spermatophoric organ has white streak.	M
2b	Maturing	Large NG covering the viscera below. Ovary occupies the whole posterior half of mantle cavity, containing reticulated oocytes of all sizes tightly packed and probably a few ripe ova at its proximal part. Oviducts fully developed but empty. Maturing eggs visible to naked eye. Few spermatophores.	F
		Vas deferens is white, meandering, enlarged. Needham's sac (SS) with structure less whitish particles inside. Normally the Needham's sac is without functional spermatophores, but sometimes some immature/abortive ones could occur. Testis tight, crispy, with visible structure.	M
3a	Mature	Large NG as previously. Ovary containing higher percentage of large reticulated eggs and some large ripe ova with smooth surface. In Teuthoidea ripe ova in oviducts. Eggs medium and big, and visible both in oviducts and in the ovary. Well-developed spermatophores.	F
		Testis as before. Spermatophores packed in the Needham's sac.	M
3b	Spent	NG/OG large but soft and running. Ovary shrunk and flaccid, with only immature oocytes attached to the central tissue and a few loose large ova in the coelom. In Teuthoidea, oviduct may contain some mature ova but are no longer packed.	F
		Disintegrating spermatophores in the Needham's sac and the penis.	M

c)

Stages	Maturation state	Reproductive apparatus aspect			
		Colouring of fresh ovary	<i>Parapenaeus longirostris</i>	<i>Aristaeomorpha foliacea</i>	<i>Aristeus antennatus</i>
1	Immature	whitish or translucent	Ovaries not visible without dissection. The ovaries are thin and translucent with a tubular appearance adherent to the dorsal portion of the stomach, not extending to the abdomen.	Ovaries not visible without dissection. The ovaries are thin and translucent with a tubular appearance adherent to the laterals of the stomach, not extending to the abdomen.	Ovaries not visible without dissection. The ovaries are thin and translucent with a tubular appearance adherent to the laterals of the stomach, not extending to the abdomen.
2	Developing/Resting /Recovering	<i>A. foliacea</i> : flesh coloured; <i>A. antennatus</i> : ivory coloured with orange pink-violet dotting; <i>N. norvegicus</i> : cream; <i>P. longirostris</i> : cream orange;	Ovaries are barely visible without dissection. The cephalic lobes start to cover the sides while the abdominal extensions occupy all somites.	Ovaries barely visible without dissection. Cephalic lobes small but distinguishable. The gonad generally extends up to 3rd abdominal somite.	Ovaries barely visible without dissection. Cephalic lobes small but distinguishable. The gonad extends to the full length of the abdomen.
3	Maturing	<i>A. foliacea</i> : light and dark grey; <i>A. antennatus</i> : lilla; <i>N. norvegicus</i> : light green; <i>P. longirostris</i> : light green or grey green;	Ovaries are clearly visible through integument. Ovaries developed and turgid, with cephalic lobes and abdominal extensions occupying the entirely the dorsal portion. The gonads appear granular.	Ovaries are clearly visible through integument. Ovaries developed and turgid, with evident cephalic lobes. The gonad generally extends to the 4th abdominal somite	Ovaries are clearly visible through integument. Cephalic and abdominal extensions are well developed and turgid.
4	Mature	<i>A. foliacea</i> : black; <i>A. antennatus</i> : violet; <i>N. norvegicus</i> : dark grey; <i>P. longirostris</i> : brightgreen or olive green;	Turgid ovaries extending to the whole dorsal area. Lobes and extensions well developed. Eggs well visible.	Turgid ovaries extending to the whole dorsal area. Lobes well developed and abdominal extensions may reach the 5th somite. Eggs well visible.	Turgid ovaries occupying the whole dorsal area. Lobes and abdominal extensions well developed. Eggs well visible.
5	Spent	uncoloured	Ovaries after spawning are fully extended but loose turgidity becoming flaccid.	Ovaries large but flaccid with blackish spots.	Ovaries large but flaccid with purple spots.

d)

Oviparous elasmobranchs		Females		Males	
MATURATION STATE	STAGES	MATURATION STATE	REPRODUCTIVE APPARATUS ASPECT	MATURATION STATE	REPRODUCTIVE APPARATUS ASPECT
IMMATURE	1	IMMATURE	Ovaries: small and whitish. Undistinguishable ovarian follicles. Oviducal gland often not visible. In some species a thickening of the uteri where the gland will develop may be visible. Uteri: thread-like and narrow.	IMMATURE	Claspers: flexible, non-calcified and shorter than pelvic fins. Testes: small and undeveloped (in skates, sometimes with visible lobules). Ducts: straight and thread-like.
	2	DEVELOPING	Ovaries: follicles of different stages of development. Some small and medium-sized yolked follicles may be present. Oviducal gland: distinguishable and developing. Uteri: enlarging.	DEVELOPING	Claspers: flexible, partially calcified and usually as long as or longer than pelvic fins. Testes: developing (in skates, lobules clearly visible but not fully developed). Ducts: developing and beginning to coil.
MATURE	3a	CAPABLE OF REPRODUCTION	Ovaries: presence of large yolked follicles ready to be ovulated. Oviducal glands: fully developed. Uteri: fully developed.	CAPABLE OF REPRODUCTION	Claspers: rigid, fully calcified, and longer than pelvic fins (in some sharks they may only be as long as the pelvic fins). Testes: fully developed (in skates, with fully formed lobules). Ducts: tightly coiled and filled with sperm.
	3b	EGG LAYING	Uteri: presence of egg capsules.	ACTIVE	Claspers: similar to stage 3a, however with clasper glands dilated, sometimes swollen and reddish. Sperm may be present in clasper groove or glands. Testes: similar to stage 3a. Ducts: sperm observed inside (after a cut) or flowing out of the cloaca on pressure.
	4a	POST-LAYING	Ovaries: flaccid with few follicles of different sizes. Few large vitellogenic follicles entering atresia. POFs and atretic follicles may be visible. Oviducal glands: fully developed but may be reduced in size. Uteri: enlarged and flaccid.	REGRESSING	Claspers: fully formed, similar to stage 3. Testes shrunken and flaccid, (in skates, with few visible lobules). On pressure sperm does not flow. Sperm ducts: empty and flaccid.
	4b	REGENERATING	Ovaries: large with small and medium-sized yolked follicles. Pre-ovulatory follicles absent. Oviducal glands: fully developed but may be reduced in size. Uteri: enlarged.	-	-

Stomach contents analysis

The total weight of the stomach (W_s) was measured. Stomachs with food contents were preserved in 70% alcohol until identification. The stomach contents were then rinsed under tap water. Their weight was measured if possible to the nearest gram, counted and identified to the lowest possible taxon. The total weight of each prey group was measured if possible to the nearest gram. Several indices were then calculated to analyse the diet of the target species studied, reflecting its diet composition and feeding strategy.

Diet composition

According to [Hyslop \(1980\)](#), two indices were calculated. The coefficient of vacuity (C_v) was calculated to reflect the richness or lack of food in the environment:

$$C_v = E_v \times N^{-1} \times 100$$

where E_v is the number of empty stomachs and N is the total number of stomachs examined.

The percentage of fullness (F_i) was also calculated for each stomach:

$$F_i = W_p \times W_s^{-1} \times 100$$

where W_p is the weight of the prey items in each stomach. Stomach fullness was classed based on a five-point scale estimated by the percentage of fullness:

empty, partially empty (1-25%), slightly full (26-50%), partially full (51-75%), and full (76-100%).

Moreover, three indices were used to show the significance of different prey items. The frequency of occurrence ($O_{\%}$), the coefficient of prey numerical abundance ($N_{\%}$), and the percentage of weight ($W_{\%}$) ([Hynes, 1950](#) ; [Hyslop, 1980](#) ; [Bowen, 1983](#)):

$$O_{\%} = N_p \times M^{-1} \times 100$$

$$N_{\%} = n \times n_p^{-1} \times 100$$

$$W_{\%} = m \times m_p^{-1} \times 100$$

where N_p is the number of stomachs containing a specific prey group, M is the number of stomachs with prey remains, n is the number of prey of each taxonomic group, n_p is the total number of prey items, m is the mass of prey of each taxonomic group, and m_p is the total mass of prey items. Out of these indices, the importance of each food item in the diet was obtained by the Index of Relative Importance (I_{RI}) ([Pinkas et al., 1971](#)) modified by ([Hacunda, 1981](#)):

$$I_{RI} = O_{\%} \times (N_{\%} + W_{\%})$$

Feeding strategy

The feeding strategy of the target species was analysed according to the graphical method proposed by (Costello, 1990). This graph displays the relationship between the frequency of occurrence ($O\%$) (abscissa) and the coefficient of prey numerical abundance ($N\%$) (ordinate). It particularly illustrates the dominance and the rarity of each group of prey in both seasons and the specialized or generalized feeding strategy as shown in Figure 12.

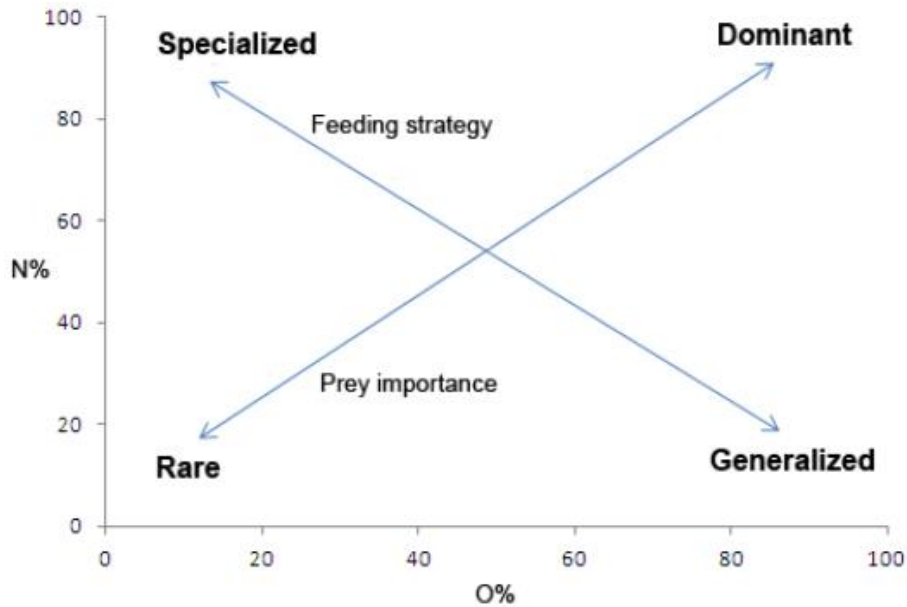


Figure 12. The graph of Costello (1990) and its interpretation concerning feeding strategy and prey importance (with $O\%$ as the frequency of occurrence and $N\%$ as the coefficient of prey numerical abundance).

The most dominant prey items in the diet of the target species are situated to the upper right of the graph (high $N\%$ and $O\%$), whereas the rare prey items are situated to the bottom left (low $N\%$ and $O\%$).

Ageing fish and growth curves

A large number of fish species living in subpolar and temperate regions show a periodicity in the deposition of layers composing calcified structures. This periodicity can appear quite clear in the otoliths where the opaque zone corresponded to a rapid growth and the translucent zone to a slow growth of the fish (Beckman & Wilson, 1995).

In this study, otoliths of *Sargocentron rubrum* were collected by entering the brain cavity from the ventral side of the fish to expose the otoliths. The sagittae were extracted and stored in small plastic bags after before reading. For interpretation, the otoliths were immersed in water and read with a binocular microscope under reflected light (Williams & Bedford, 1974). Slow growth rings (hyaline) appeared dark through the dark transparent background, whereas fast or opaque growth rings (opaque) appeared lighter under reflected light. The technique of otolith sectioning as described by Bedford (1983) was not followed because whole otoliths were considered better for measuring the marginal increments and because of the fragility of the sections.

Once the rings were considered to be annual, each specimen was assigned to a year class, taking into account the data of capture, the annuli counts, their formation period, and the reproductive biology of the species in the area. In the centre of each otolith a hyaline nucleus could be clearly distinguished, surrounded by an opaque area. A narrow hyaline ring borders the area, representing the first annual ring. It is assumed that the margin of the nucleus was formed at the end of the pelagic stage at the beginning of the first winter. The first hyaline ring represents the second winter in the fish's life (age approximately 16 months); each consecutive winter an additional ring is formed. (Golani & Ben-Tuvia, 1985) place the spawning season in July-August.

Growth curves and growth parameters

Analysis of length-at-age data was performed in the statistical software 'R' (R Development Core Team, 2014) to estimate growth parameters K and L . This allows non-linear estimation of growth parameters from length at-age data. The Von Bertalanffy's plot is used to estimate t_0 from the known age/length data and estimated L_∞ and K . The method is based on the regression analysis of the following formula:

$$-\ln (1-L_t / L_\infty) = -K \times t_0 + K \times t$$

Where: the age t is the independent variable (x) and $(-\ln (1-L (t)/ L))$ is the dependent variable (y) of the linear regression. L_∞ is the asymptotic L_T , L_t the L_T at age t , K the growth curvature parameter, and t_0 is the theoretical age when fish would have been at zero L_T .

Data analysis

Catch per unit effort (CPUE)

The catch per unit effort (CPUE) is an indirect measure of the abundance of a target species. Standardized CPUE analysis is widely used to evaluate trends in population density. However, while analyzing data, it has to be taken in mind that mechanism modifying the catchability coefficient or overdispersion of some pelagic species (Fonteneau et al., 1999), can bias our results and lead to relevant mistakes in their interpretation. To reduce the incidence of the catchability factor, we used different types of experimental gears whereas we focused our study on demersal species underexposing our results to bias due to big schools highly dispersed pelagic species. The CPUE was calculated per each species. Each year was calculated separately to standardize the effort (as Km² of nets used) using the statistical software 'R' (R Development Core Team, 2014) in kilogram and in number according to the following:

1. CPUE in kilograms considered by year:

$$CPUE_{Kg, Y} = \frac{\sum W_{i, Y}}{E_{Km^2, Y}}$$

where $W_{i, Y}$ is the weight in Kg per species considered by year, $E_{Km^2, Y}$ is the effort reported as Km² of nets deployed by year.

2. CPUE in number considered by year:

$$CPUE_{Kg, Y} = \frac{\sum N_{i, Y}}{E_{Km^2, Y}}$$

Where $N_{i, Y}$ is the number of individual per species considered by year, $E_{Km^2, Y}$ is the effort reported as Km² of nets deployed by year.

Biodiversity indices

Seasonal and spatial biodiversity were assessed by calculating several diversity indices considering S as the total number of species recorded in the sample and N as the total number of individuals in the same sample (Magurran, 2004). All these indices were calculated using the 'vegan' package on the statistical software 'R' (R Development Core Team, 2014).

The Shannon Index

One of the most used of all diversity measures is the Shannon Index. This index assumes that individuals are randomly sampled from an infinitely large community (Pielou, 1975) and that all species are represented in the sample. It accounts for both abundance and evenness of the species present where a higher index value represents higher diversity with a maximum value equivalent to $\ln S$. The Shannon Index was calculated using the *diversity* function and choosing "Shannon" for index as:

$$H' = -\sum p_i \ln p_i$$

where p_i is the proportion of individuals found in the i th species and calculated as (Pielou, 1969):

$$p_i = \frac{n_i}{N}$$

where n_i is the total number of individuals in the i th species.

The Shannon Index takes into account the degree evenness of species abundances; however, no separate value is given. It is thus possible to calculate the Shannon evenness measure separately as (Pielou, 1969; Pielou, 1975):

$$J' = \frac{H'}{H_{max}}$$

where $H_{max} = \ln S$ represents the maximum diversity where all species had equal abundances.

Simpson's Index

The Simpson index is one of the most meaningful and robust diversity measures indicating the variance of a species abundance distribution and emphasizing the species richness component of diversity (Magurran, 2004). In fact, the probability of any two individuals picked randomly from an infinitely large community belonging to the same species was defined by (Simpson, 1949) as:

$$D = \sum p_i^2$$

where p_i is the proportion of individuals found in the i th species.

However, the appropriate form for a finite measure was defined as:

$$D = \sum \left(\frac{n_i[n_i - 1]}{N[N - 1]} \right)$$

where n_i is the total number of individuals in the i th species. This form gives an index D which is inversely proportional to the diversity. As D increases, the diversity decreases. Therefore, a better expression for Simpson's Index, as recommended by (Lande, 1996) is:

$$1 - D$$

where the value of this index ranges between 0 and 1, which represents the maximum diversity. It was also calculated using the *diversity* function and choosing the index "Simpson". Simpson's diversity measures emphasize dominance, as opposed to the richness component of diversity, and does not purely measure evenness (Magurran, 2004).

Taxonomic diversity

Two or more assemblages can have the same number of species and an equivalence in species abundance, but vary in the diversity of the taxa to which the species belong (Magurran, 2004).

Therefore, measures of taxonomic diversity should be used. One development was Clarke and Warwick's taxonomic distinctness measure (Clarke and Warwick, 1998; Warwick and Clarke, 1998). This measure describes the taxonomic distance between two randomly chosen organisms using the phylogeny of all species in an assemblage. It is in two forms: Δ or 'taxonomic diversity' and Δ^* or 'taxonomic distinctness'. Δ considers species abundances as well as taxonomic relatedness and measures the path between two randomly chosen individuals that might belong to the same species. Δ^* purely measures taxonomic relatedness considering each individual coming from different species. When such data is used, these measures are reduced to a single measure, Δ^+ , indicating the average taxonomic distance between two randomly selected species and can be calculated as:

$$\Delta^+ = \frac{[\sum \sum_{i < j} \omega_{ij}]}{[s(s-1)/2]}$$

where s is the number of species in the study and ω_{ij} is the length between species i and j . The taxonomic distances were first calculated using the function *taxa2dist* from a table containing all the species classified up to their class. The taxonomic diversity was then calculated using the function *taxondive*.

Statistical analyses and regressions

Statistics

The need for comparison and interpretation of data urges the use of several statistical tests and analyses and has long been used in biology. In this context, several statistical analyses were performed in this study using the statistical software 'R project' (R Development Core Team, 2014) aiming to aid the analysis of results. The main analyses performed and application purposes are presented in table 7. It includes inferential statistical tests mainly non-parametric tests (Kruskal-Wallis rank's tests, etc.), descriptive statistical analyses such as Principle Component Analysis and modelisation (regression) as the various approaches are complementary. Descriptive statistics is distinguished from inferential statistics (or inductive statistics), in that descriptive statistics aims to summarize a sample, rather than use the data to learn about the population that the sample of data is thought to represent.

Table 7. The main statistical tests performed in this study as well as their application purposes (LT, WT, FI, IG, IH, and K are total length, total weight, fullness index, and condition factor, respectively. M, F, Imm, and Mat are males, females, immature and mature individuals, respectively.

Statistical R function analysis	Description	Application (Chapter)
Inferential statistic		
Shapiro-Wilk test Function: <i>shapiro.test</i>	Tests that the population is normally distributed.	Tested the normality of the samples in this study. (Chapter VI)
Kruskal-Wallis rank sum test Function: <i>kruskal.test</i>	A nonparametric test efficient for non-normal distributions and/or when variances are not equal. It compares means of two or more independent samples that may have different sizes.	Tested the difference in LT and WT of a species according to the sexual maturity stages. (Chapter VI) Tested the difference in IG, IH, and K of a certain species according to season. (Chapters VI)
Pairwise Test for Multiple Comparisons of Mean Rank Sums (Post Hoc; Nemenyi-Tests) Package: PMCMR Function: <i>posthoc.kruskal.nemenyi.test</i>	Calculates pairwise multiple comparisons between group levels. It is performed after A nonparametric ANOVA.	Used after significant differences in the Kruskal-Wallis rank sum tests for pairwise multiple comparisons of the ranked data. (Chapter VI)
Pearson's chi-square test (goodness-of-fit or chi-square test for independence) Function: <i>chisq.test</i>	Tests if there is a significant difference between expected and obtained results in one or more categories. Tests any association between two categorical variables from a single population.	Tested the correlation between depth and different taxa's distribution. (Chapters IV)
Analysis of covariance (ANCOVA) Function: <i>anova</i>	Compares two or more regression lines by testing the effect of a categorical factor on a dependent variable while controlling for the effect of a continuous covariable.	Performed a statistical comparison of length-weight relationships between sexes of the same species. (Chapters IV & VI)

Linear regressions

The analysis of reproductive organs growth can determine the size or age at maturity. The presence of a relationship between the development of secondary sexual characteristics and reproductive organs and maturity urged the use of clasper length measurements to estimate the size at maturity (Conrath, 2005). Therefore, a linear regression model was used to evaluate the relationship between total length and clasper length. A steeper slope corresponds to the range of lengths at which the elasmobranch is becoming mature. A linear model function in the statistical software 'R project' (R Development Core Team, 2014), *lm*, was used to fit the linear model and estimate the parameters 'a' and 'b' of the equation relating clasper length to total length:

The coefficient of determination (r^2) was used to evaluate the quality of the model.

Nonlinear regressions

Length-weight relationship

Length-weight relationships for fish populations help to a better knowledge of the growth rate, age, and other constituents of population dynamics (Kolher et al., 1995). A nonlinear least squares function, *nls*, on the statistical software 'R project' (R Development Core Team, 2014) was used to estimate of the parameters 'a' and 'b' of the nonlinear power equation between gonad weight and total length following Le Cren (1951):

$$W_T = aL_T^b$$

The start values of these parameters were also derived from the log transformation of the two variables using the linear model function (*lm*) into:

$$\log W_T = a + b \log L_T$$

The coefficient of determination (r^2) was also used to evaluate the quality of the model.

Logistic regressions

Size at maturity is also determined by the length at which 50% of the fish sample is mature (L_{50}). The proportion of mature elasmobranch specimens in each length group is determined. This data is then fitted in a logistic regression and the length at the point of the curve corresponding to 50% mature ($P=0.5$) indicates the size at which these fish mature. The logistic equation takes the following form:

$$P = \frac{1}{1 + e^{(a+bL_T)}}$$

where P is the proportion of mature elasmobranch specimens in each determined length class, and 'a' and 'b' are parameters estimated by fitting the data to the logistic curve. The length at which 50% of the individuals of specific elasmobranch species are mature was estimated for both sexes using a logistic curve from a generalized linear model (GLM) with logit link using the function *glm* in the statistical software 'R' (R Development Core Team, 2014)

Maps

All maps were created on the Quantum Geographic Information System (qGIS) software (Quantum GIS Development Team, 2012).

Chapter 3

Fisheries sector in Lebanon: a context analysis

Chapter

3

Fisheries sector in Lebanon: a context analysis

Country profile

Lebanon is a small (10,452 km²) upper-middle income country, with a GDP per capita of USD 9,928 (World Bank, 2013). In July 2016, its population was estimated at 6,237,738 (Central Investigation Agency, 2017), of which 88 percent is urban. More than one third of the population is concentrated in its capital, Beirut. It ranks 12 out of 21 in the Mediterranean in terms of GDP and Human Development Index (HDI). Lebanon is characterized by a service-oriented economy with a weak agriculture sector. Major sub-sectors are commerce, tourism and financial services (Pinello & Dimech, 2013).

Coastal zone is considered the richest but at the same time the most endangered area of Lebanon. The majority of industrial, commercial and financial activities of the country as well as the largest cities are concentrated in this area. In a corridor of 500 meters wide along the coastline, 40 % of the surface is absorbed by urbanization and 41 % by agricultural uses, while 19 % remain natural areas (beaches, dunes, etc.) (DAR-IAURIF, 2010).

Creeping political paralysis has rendered the three branches of government either vacant or ineffective. Moreover, the collapse of public services, such as electricity, water supply and a visually powerful garbage crisis that has left piles of it uncollected on the streets, led to sizable popular demonstrations. Lebanon continues to face momentous challenges emanating from the war in Syria, including hosting the largest assembly of Syrian refugees, in proportion to the population (Government of Lebanon & United Nations, 2017).

Notwithstanding the political dysfunctionality, improved security conditions have provided a boost for economic activity in 2015. Growth has been driven by a resurgent tourism sector and continued expansion in private lending as Banque du Liban (BdL) renewed its stimulus package in the amount of \$1 billion this year; tourist arrivals increased by 16.6 percent, year-on-year, in the first eight months of 2015, compared to a mere increase of 0.7 percent during the corresponding period in 2014. On the other hand, the real estate sector has acted as a drag on growth, with construction permits and cement deliveries contracting by about 18.8 percent and 16.7 percent, respectively, during the first seven months of 2015 (World Bank, 2015).

The agriculture and fisheries production sector play a minor role in the economy. It contributes to about 5 percent of GDP and 8 percent of the effective labour force, meeting an estimated 30 % of the domestic food demand and it has been constant in the past ten years (FAO, 2017).

Socioeconomic Context

Infrastructures: Transports

Lebanon had about 22,000km of roads in 2001 of which 30 percent are classified and fall under the authority of the MOPWT, while the remaining 70 percent (about 15,400km) are non-classified roads governed by municipalities. International roads make up less than 10 percent of the “Classified road network,” which has increased in length by about 5 percent from 1995 to 2001. “Rural roads” account for over 70 percent of the Non-classified road network, which totals about 15,269 km (Darwish & Timberlake, 1999). Internal roads, town roads, and village roads are the other categories of non-classified roads. The main cities of Lebanon are notorious for persistent traffic delays and high noise levels. Currently, Lebanon has one of the highest car/people ratios in the world with one car for every three people (WFP Logistics, 2008).

Beirut and Tripoli host Lebanon’s two largest commercial ports. The total number of cargo vessels and tankers docking at these two ports has steadily declined from 3,887 ships in 1996 to 3,054 ships in 2000. At the same time, the Tripoli port has been receiving a larger proportion of the total number of ship arrivals (ECODIT/MoE/LEDO, 2001).

Land, sea, and air transport cause significant and diverse impacts on the environment. Most transport infrastructure (in particular roads and harbours) was built without any regard for the protection of landscape and natural resources. Over time, people build residential and commercial facilities with direct access to the roads, causing increased traffic congestion, travel delays, accident fatalities, noise and additional air pollution. The maintenance and renewal of the transport fleet generate each year thousands of tonnes of used oils, old tires, and ballast waters that are often dumped indiscriminately into the environment (ECODIT/MoE/LEDO, 2001).

Infrastructures: Energy

Lebanon currently faces a serious energy challenge associated with fulfilling its social and economic development goals because of a lack of domestic energy resources, reduced generation capacities and the growing demand for energy. The demand for electricity in the country for 2008 was around 2,300 MW and Electricité du Liban (EDL), the public establishment generating, transmitting and distributing electricity to all Lebanese territories, is incessantly struggling to ensure the continuous delivery of power with its maximum in the range of 1,500 MW (World Bank, 2009). The energy sector suffers from years of overall poor governance, weak management of the sector's agencies and high inefficiencies in its infrastructures including power plants and transmission and distribution networks. Despite the efforts, the electricity network does not represent a reliable source for the industrial and commercial sectors, where most end users have been compelled to install and use their own generation systems to overcome the electricity shortages and ensure the continuity of their operations.

The electrification rate in Lebanon is about 99.9%, but this high rate is not reflected in the continuity of power supply and the services provided. The low quality of the country's electricity services as well as supply shortages and hazards have forced many consumers to meet their needs through other generation sources especially in the industrial sector where for each 1 MW supplied by EDL a 2 MW backup generator has been installed (ALI/LCEC, 2006). Energy sector constitutes a heavy burden on

the country's economy and, because this situation persists, many consumers have considerably invested in backup generators, which have significantly affected the country's efficiency in terms of power generation ([World Bank, 2009](#)).

Lebanon does not produce oil or coal and most of its energy needs, i.e. mainly petroleum products, are imported. Renewable energy options are available including tides and waves, geothermal energy, solar energy, wind energy, hydropower, biomass and energy from non-separated waste; however, these resources are not widely used. Altogether, hydro, combustion/renewable/waste (CRW) and geothermal/solar/wind power only represented 4% of the country's energy balance in 2006 ([World Bank, 2009](#)).

EDL supplied electricity to 23 ports/landing sites. Four ports had standby electrical generators, which were enough for the whole port in Jbeil and Beirut-Dalieh Ports, for the fish auction at Ouzai Port, and for the Syndicate building at Dora Port ([CANA-CNRS, 2011](#)).

Population

The cultural and linguistic heritage of the Lebanese people is a blend of both indigenous elements and the foreign cultures that have come to rule the land and its people over the course of thousands of years. About 93% of the population of Lebanon includes numerous Muslim sects and Christian denominations. Because the matter of religious balance is a sensitive political issue, a national census has not been conducted since 1932, before the founding of the modern Lebanese state. Consequently, there is an absence of accurate data on the relative percentages of the population of the major religions and groups ([Department of State. U.S. Government, 2005](#)). The only recent (post-war) statistics available are estimates based on studies made by private organizations. There are from 8.6 to 14 million Lebanese and descendants of Lebanese worldwide ([Rolland, 2003](#)).

The biggest study made after the independence on the Lebanese Population was made by the Central Administration of Statistics under the direction of Robert Kasparian and Mgr. Grégoire Haddad's Social Movement: "L'enquête par sondage sur la population active au Liban en 1970" ("The survey on the active population in Lebanon in 1970"). It was conducted on a sample of 130,000 individuals. Lebanon demographic profile according to the CIA World Factbook ([Central Investigation Agency, 2017](#)) are shown in [table 8](#).

Lebanon, already struggling under complex political and socioeconomic fragility, is currently hosting 1.5 million Syrians who have fled the conflict in Syria (including 1.017 million registered as refugees with the United Nations High Commissioner for Refugees (UNHCR), along with 31,502 Palestine Refugees from Syria, 35,000 Lebanese returnees, and a pre-existing population of more than 277,985 Palestine Refugees in Lebanon ([Government of Lebanon & United Nations, 2017](#)).

Table 8. Lebanon demographic profile (Central Investigation Agency, 2017).

Population	6,237,738 (July 2016 est.)
Age structure	0-14 years: 24.65% (male 786,842/female 750,449) 15-24 years: 16.73% (male 534,040/female 509,663) 25-54 years: 44.44% (male 1,401,857/female 1,370,462) 55-64 years: 7.54% (male 220,020/female 250,288) 65 years and over: 6.64% (male 181,627/female 232,490) (2016 est.)
Dependency ratios	total dependency ratio: 47.3 youth dependency ratio: 35.4 elderly dependency ratio: 12 potential support ratio: 8.3 (2015 est.)
Urbanization	urban population: 87.8% of total population (2015) rate of urbanization: 3.18% annual rate of change (2010-15 est.)
Literacy	definition: age 15 and over can read and write total population: 89.6% male: 93.4% female: 86% (2007 est.)

Employment

In Lebanon, social protection interventions include social insurance and labour market interventions (including contributory schemes such as pensions), social services (access to services such as health and education), and narrowly targeted social assistance programs (Le Borgne & Jacobs, 2016). However, these programs reach only a small share of the population, which typically does not include fishers' communities. There is neither a contract of employment in Lebanon nor any social security cover, which could protect fishers in case of disability, loss of employment and retirement (PescaMed, 2011). Thus, fishers remain heavily reliant on their earnings, possibly on private safety nets (such as remittances) or the credit system (see the paragraph Credit system).

In recent years, the supply of low-skilled workers has grown rapidly also due to the Syrian crisis (resulted in a large influx of refugees into Lebanon), lowering incomes for low-income and poor Lebanese. The jobs that have been created have typically been of low quality (for example, low skills, often informal) and gone predominantly to foreign workers (e.g. labourers in the construction sector) (Le Borgne & Jacobs, 2016). In 2012, the marine fisheries sector employed 3,200 people (Pinello & Dimech, 2013) with the bulk of the sector operators being Lebanese (Majdalani, 2005).

Credit system

Although Lebanon performs well regionally in lending to small and medium enterprises (SMEs), the country's conservative lending culture limits access to credit, although this is partially mitigated by incentive programs of the government and the Banque du Liban (BdL). Lebanese firms depend significantly on the banking sector for their financing, as 53 percent of all firms, 50 percent of small firms, and 63 percent of medium-size firms report having received a bank loan. Overall, domestic commercial banks provide 24 percent of firms' working capital finance and 39 percent of their investment finance. Notwithstanding, access to credit remains among the top constraints to business and growth as identified by Lebanese SMEs (World Bank, 2016). In addition, accessing credit remains a challenge because the value of required collateral is significantly high. In Smaller firms are facing

major difficulties obtaining business loans from banks, resulting in a reduced amount of bank lines of credit and loans, less bank financing of investment and working capital, and more internal sources of financing (World Bank, 2016). Some bank credit facilities are virtually available also for microenterprises and fishers. Few banks offer small credit and none does it without any collateral. Therefore, only those fishers who own a boat or some other valuable good, can afford to ask for a loan. The interest rates vary between 25% and 30% according to the length of the repayment period (normally 16/18 months) and the amount of the instalments (PescaMed, 2011).

The most common credit facility serving fishing communities is the one provided by the fish sellers. Besides the yearly grant that some of them usually give to fishermen, they are often available to lend them extra money during the year. In 2010, the amount was generally limited to 300-400 USD and normally with no interest charged (PescaMed, 2011). Repayment schemes are very flexible, but the only obligation fishermen have is to sell their fish to their moneylenders (Ricerca e Cooperazione NGO, 2005). Several micro credit programmes have been started in some fishing ports by local NGO and International Cooperation Agencies, with alternate results. Other credit facilities available for the fishing communities are Micro-Credit in such as Al Hasan and Al Majmoua. They usually rely in strong commitments and high rate of repayment (Ricerca e Cooperazione NGO, 2005).

Environmental Context

Physical environment

Lebanon is one of the smallest countries in the world having area of 10452 km² (United Nations Statistics Division, 2016). It is a predominantly mountainous country located in the Levantine basin of the Mediterranean Sea, bordered by Syria from the north and east. Lebanon has also a large hydrological network of 2000 rivers including a dozen running through the Lebanese coast and which consequently play an important role in the quality of marine coastal waters. The Lebanese coastline is relatively short - about 225 km (Central Intelligence Agency, 2013) - with the coastal zone showing high population density. 55 percent of the total population lives there, across a territory that hosts 33% of all built-up areas (GFCM, 2014). The Lebanese continental shelf is relatively narrow rarely extending beyond an 8 kilometers strip from the coast, with the exception of the wider shelf in North Lebanon (GFCM, 2014)(Figure 13). Along the entire margin the continental slope is incised by an intricate system of canyons, most of which being associated to rivers flowing from the mountains (Sursock, et al., 2014).

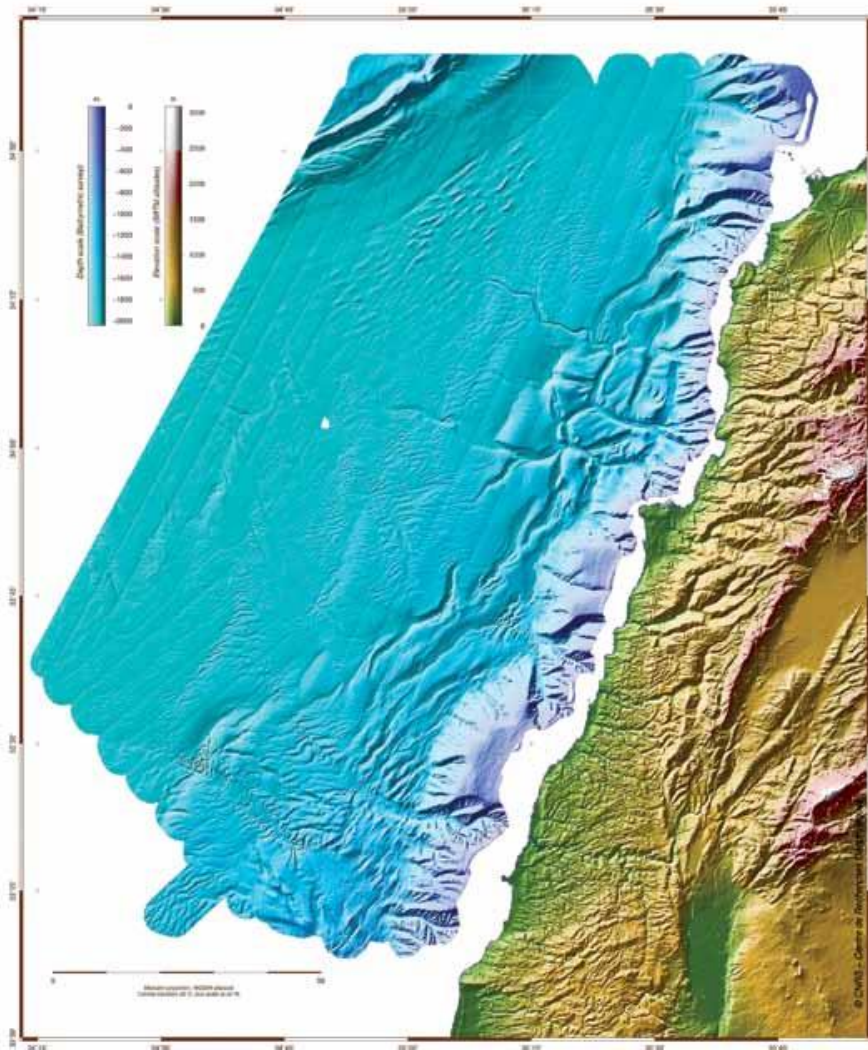


Figure 13. Bathymetric mapping of the Lebanese coast at depths greater than 200 meters. Sea Floor Relief Map Scale 1:200.000 The Shalimar Cruise IFREMER-IPGP-CNRS (2003). Modified from (CANA-CNRS, 2012).

In general, Lebanon enjoys a typical Mediterranean climate with two very contrasting seasons: a winter that is cold and heavily wet and a summer that is long, hot and dry and two intermediate seasons (spring and autumn). Along the coast, winters are relatively mild and rainy where the annual temperature is relatively low, around 13 to 15°C (Abboud Abi Saab, et al., 2012). In some cases, this temperature can decrease up to 30°C or 4°C especially in December and January. During summer, temperatures are relatively high and can reach 30 to 35°C and even a 38°C temperature was observed in July and August (Administration Centrale de la Statistique, 2006; Abboud Abi Saab, et al., 2012). Moreover, according to (Abboud Abi Saab, et al., 2013) the mean monthly variation of sea surface temperature between 2000 and 2012 varied between a minimum of 17.82°C in March and a maximum of 29.71°C in August, and the mean monthly variation of air temperature varied between a minimum of 12.4°C in January and a maximum of 27.59°C in August (Figure 14). The diurnal range remains close to 7°C throughout the year (Abboud Abi Saab, 1985).

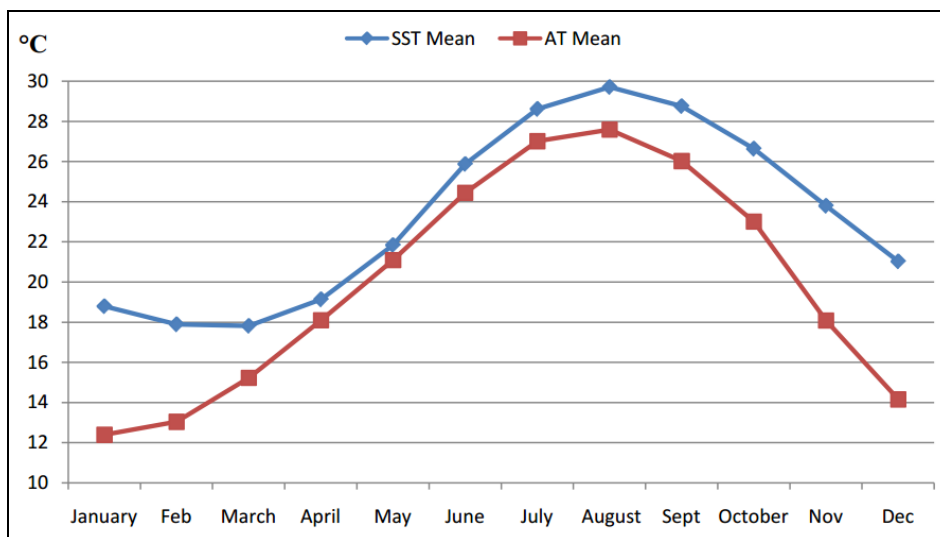


Figure 14. Mean monthly variations for 2000-2012 period of Sea Surface Temperature (SST) and Air Temperature (AT) in Lebanese marine waters (eastern Mediterranean) (Abboud Abi Saab, et al., 2013).

Biodiversity

The Lebanese coastal waters are characterized by thermophilic biota of Mediterranean and Indo-Pacific origin (Abboud-Abi Saab, et al., 2013; Bitar, et al., 2007). The local biodiversity is undergoing rapid alterations under the combined pressures of climate change and human impact. Native marine flora and fauna are competing with invading organisms originating from the Indo-Pacific and Atlantic oceans (Abboud – Abi Saab, 2012). The features of the Lebanese coastline with no closed bays or gulf consent to coastal waters to continuously mix thus preventing conditions of eutrophication and to disperse nutrients and pollutants.

The status of marine biodiversity in Lebanon was assessed in 1996 within the Biological Diversity of Lebanon - Country Study Report (BDL-CSR) (Hamadeh, et al., 1996) and then reviewed through several published and unpublished papers. According to the (Hamadeh, et al., 1996), the country's coastal sea comprising 1685 species, including 367 fish species, 50 of which are of commercial interest. Phytoplankton encompasses 580 species whilst the zooplankton accounts for the largest share of marine faunal diversity with more than 747 species recorded (Hamadeh, et al., 1996). The microzoobenthos is represented with 12 known species whereas the macrozoobenthos is diversified and encompass 662 species (Bitar & Kouli-Bitar, 2001).

Other families of marine organisms include seven species of cephalopods (octopuses, cuttlefish and squids), at least three species of reptiles (loggerhead, green and leather-back marine turtles) and five species of mammals (dolphins and porpoises and, less common in local waters, whales and seals). The information on the conservation status is mainly available for selected species (turtles and cetaceans). The Biodiversity Country Study identified submerged rocky, sandy and grassy habitats as well as sciaphile, photophile, endofauna and epifauna communities, including 68 threatened species (MoE/ECODIT, 2010).

In 2012 and 2013, within the context of the MedMPAnet research project, commissioned by UNEP and carried out by the Regional Activity Centre for Specially Protected Areas (RAC-SPA), approximately 436 six low taxa (at the level of species, genus or family) of megabenthic organisms

and nekton, belonging to 21 high taxa (phyla, classes) were observed and reported (RAC/SPA - UNEP/MAP, 2014) (Figure 15).

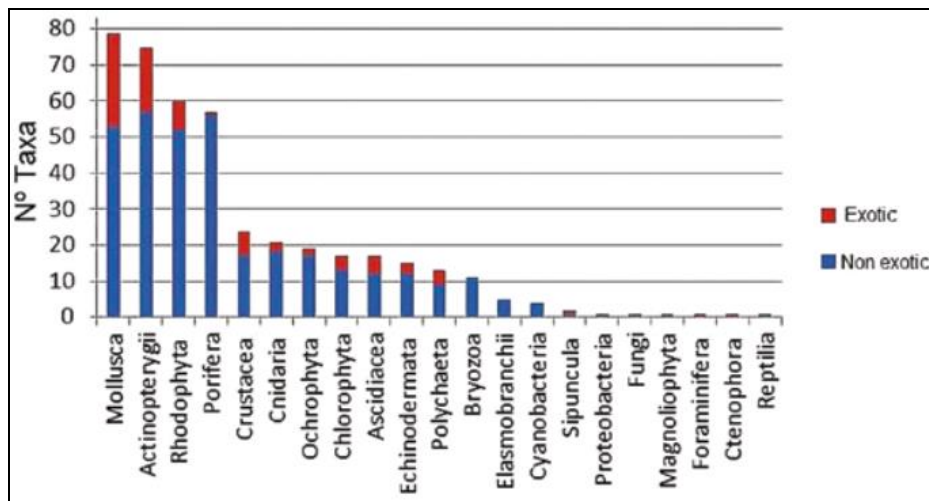


Figure 15. Number of species/taxon observed in the two Lebanon missions (06/2012, 08-09/2013) (RAC/SPA - UNEP/MAP, 2014).

77 non-indigenous species were reported (17.6 percent), 75 of Indo-Pacific origin and 2 of Atlantic origin (*Oculina patagonica* and *Percnon gibbesi*); 24 species (31 percent) were molluscs, 16 species (21 percent) bony fishes and 7 species (9 percent) Rhodophyta (RAC/SPA - UNEP/MAP, 2014). The number of newly reported species continues to increase also due to the contribution of newcomers of Mediterranean origins (Mamish, et al., 2012). In fact, the fine jellyfish *Aequorea forskalea* was reported in 2016 in the waters facing Beirut (CANA-CNRS, 2016)(Figure 16).



Figure 16. A new arrival in Lebanese waters, the jellyfish *Aequorea forskalea*, observed in the coastal area of Beirut on April 2016. First record in Lebanese coastal waters. (Photo Ali Baddreddine). Source (CANA-CNRS, 2016).

Protected areas

Two marine natural reserves have been established in Lebanon: the Palm Islands Nature Reserve (Decree 121, 09/03/1992) in the north and the Tyre Coast Nature Reserve (Decree 708, 05/11/1998) in the south ([Lebanese Ministry of Environment / IUCN, 2012](#)).

Palm Islands Nature Reserve (PINR) is located in the proximity of the city of Tripoli. It is made up of 3 islands: Sanani, Ramkine and Palm. PINR covers an area of nearly 4.2 km² ([Lebanese Ministry of Environment / IUCN, 2012](#)) and it is a resting place for sea-crossing migratory birds and the only site in Lebanon for sea bird breeding. It has been designated a Mediterranean Specially Protected Area under the Barcelona Convention, an Important Bird Area by Birdlife Convention as well as Wetland of Special International Importance ([MOE Ministry of Environment, 2017](#)).

Tyre Coast Nature Reserve (TCNR) is a Nature reserve and a Ramsar acknowledged site. Expanding over 380 ha, the reserve includes the largest sandy beach in Lebanon. Tyre Coast Nature Reserve hosts many species of plants, animals and insects. It is a nesting site for the endangered Loggerhead and green sea Turtle and the shelter of the Arabian spiny mouse and many other important creatures. The TCNR is also located on major migratory routes where internationally important bird species have been identified. It is a Ramsar site (No. 980) since 16/04/1999 ([Lebanese Ministry of Environment / IUCN, 2012](#)). Management plans aiming at the protection and the conservation of the reserve were prepared by the MoE ([Peillen, et al., 2012](#)).

A “national maritime protected zone at the Oceanographic & Fishing Institute in Batroun” was established by Minister of Agriculture by Decision 129/1 of 1991.

Fisheries Sector

Lebanese Fisheries Overview

Lebanon’s fisheries sector is composed of a little artisanal fishing fleet, namely 2,005 licensed vessels (in 2015 according to the DFW) predominantly operated by rather aged fishers using old boats with dated equipment ([Pinello & Dimech, 2013](#)). Most of the boats are motorized and below 12 m in length using fishing techniques mostly based on passive gears such as gillnets, trammel nets, longlines, and purse seines. Fishing operations are mostly carried out at depths of up to 50 m ([Sacchi & Dimech, 2011](#); [Brême, 2004](#); [Lelli, et al., 2007](#)). Few vessels are equipped with GPS, while the rest have very limited navigational or safety equipment ([Majdalani, 2004](#); [Sacchi & Dimech, 2011](#)). Lebanese coastal waters contain a significant richness of marine organisms with more than 80 fish species being of commercial importance ([Nader, et al., 2012](#)). Illegal fishing behaviours and harmful or unsustainable practices such as the use of small mesh nets and explosives thrive as a result of an outdated legislation and the lack of its enforcement ([Sacchi & Dimech, 2011](#)). Lack of urban and industrial waste management along with the absence of an effective sanitation network are contaminating marine and fresh waters. Coastal areas are subject to uncontrolled urban sprawl and increasing processes of artificialisation. It is widely agreed that human activities are affecting in a worrying manner the narrow coastal area environment leading to a critical increase in its exposure to geological hazards. Human pressure on the coastal area, along with the low public investment in the sector during the past decades have narrowed the economic value of the sector and therefore negatively affected fishers’ lives ([DAR-IAURIF, 2010](#); [UNDP, 2012](#); [World Bank, 2011](#); [MoE/UNDP/ECODIT, 2011](#)).

Despite its chaotic management, the Lebanese fishing sector represents a unique case in the Mediterranean, being the only one solely composed by small-scale artisanal vessels. Due to its geographical location, Lebanon represents also an outpost for a comprehensive understanding of the dynamics driving the colonization of the Mediterranean by Indo-Pacific and Red Sea species. The knowledge on the impact of Lebanon's fleet on fisheries coastal resources – both non-indigenous and endemic - is still very limited though, being available only scattered information on distribution, abundance and biological characteristics of few fish and shellfish stocks (Colloca & Lelli, 2012; Lelli, 2007; Carpentieri, et al., 2009; Bariche, et al., 2006; Bariche, 2003; Nader, et al., 2014; Nader, et al., 2012; George, et al., 1964).

Lebanon is moving its first steps in the fulfilment of international requirements in terms of data collection on its halieutic resources through stocks, catch and effort assessments (FAO EastMed, 2014). International organizations and donors have granted funds and capacity building to develop adequate research programmes to support the capability of the Lebanese Government to define new measures towards an appropriate and sustainable management of fishing resources.

Fishing fleet, gears and grounds

The bulk of the fishing fleet is made up by multipurpose artisanal vessels known locally as *flouka*, a small 3 - 15 m fishing craft, customarily made of wood, generally undecked; and with/without inboard or outboard engines (Majdalani, 2005). In 2015, the DFW reports the average fishing vessel length of licensed fishing vessels as 7.2 m with 546 vessels smaller than 6 m LOA, 1,420 vessels 6 to 12 m LOA and 39 vessels bigger than 12 m LOA.

Fishing grounds are bounded by law between 500 m to 6 nm from the shoreline and outings are limited to 24 hours per fishing trip. 78 percent of fishermen fish within 3 nm of the coast with less than 10 vessels operating beyond the 6 nm (Majdalani, 2004; Sacchi & Dimech, 2011). Fishing techniques in Lebanon consist mainly of passive gears such as gillnets, trammel nets, longlines, purse seine nets, lampara nets and beach seines. Table 9 summarizes major characteristics of the gears in use in Lebanese fisheries.

Table 9. Fishing gears in Lebanon. Modified from (University of Balamand, 2016).

GEAR	DESCRIPTION	SPECIES TARGETED
Small mesh size gillnet	Has a 32 mm stretched mesh size and is made of a 0.33 mm diameter PA monofilament. The length of each net is about 50 m and the stretched height is 3 m. Gillnets are set between 10 and 50 m depth for a short soaking time (less than 12 hrs)	Demersal species and small pelagic
Medium mesh size gillnets	These gears have a stretched mesh size ranging between 48 and 120 mm built with a single wall of monofilament net. Their length ranges between a few hundred meters to more than 1,000 m	Demersal species and small pelagic
Large mesh size gillnet	The nets are made of a mesh size ranging between 140 and 180 mm with 1.5 mm diameter built from a single wall of monofilament or multifilament net. Their length is from 300 to 1,000 m and height up to 13 m	Large pelagic species
Encircling gear	Trammel nets are used with an inner panel mesh size of 28 to 40 mm and of 150 to 1,000 m in length and 1.2 to 2 m in height, at depth between 5 to 50 m, are used for bottom species. The nets are generally made of PA multifilament or monofilament of 210/1 to 210/2 (approx. 40.000 m/Kg)	Demersal species and small pelagic
Longlines	Bottom longlines consist of blue PA monofilament mainline to monofilament snoods with hooks of about 1 m long, attached at regular intervals (around 5-6 m)	Demersal species
Traps	Have triangular meshes and have 30 mm bar mesh size	Demersal species
Lampara net	Is a part of surrounding nets not having a purse line system in order to close the bottom part of the bag. The net is made up of PA multifilament panel of 10 to 14 mm stretched meshes and it is composed of two lateral wings framing a central "bunt", made of the smallest meshes and thickest twine. The total length can reach up to 200 m and the height not more than 25 m	Small pelagic species
Purse "shincholas" seines	Used at a maximum depth of 50 m. The nets are made up of PA multifilament of 210/2 to 210/6 and of 10 to 14 mm mesh sizes	Small pelagic species
Handline "Boulis"	Line with several hooks at its end, rolled on a small wooden piece	Demersal species
Drifting "Jarjaras" Longlines	Uses large hooks 83 mm in length and 30 mm in width. Not commonly used between fishermen	Large pelagic species

Source: [Sacchi & Dimech \(2011\)](#)

Halieutic resources

Fish stocks in Lebanon have not been regularly assessed. However, private universities, the National Council for Scientific Research - Lebanon (CNRS-L) and FAO in coordination with the Ministry of Agriculture are putting the bases for a steady data collection to allow sound stock assessments. A sole systematic experience of data collection on the Lebanese halieutic resources was performed by (George, et al., 1964). Their study relied almost entirely on commercial fishermen as supplier of the specimens. They described 177 species, 19 of which Lessepsians.

Significant and recent studies on small pelagic fishery indicated that a relevant fraction of landed specimens were juveniles (Bariche, et al., 2006; Sacchi & Dimech, 2011). Small pelagic fisheries constitute about two thirds of the Lebanese landings. Fishing practices targeting juvenile fishes are partially driven by the market since it favours the smallest fishes, which are consumed whole. Furthermore, all the effort of the fleet is concentrated mainly within the 6 nautical miles leading to a high fishing pressure on the coastal fisheries resources particularly within the 3 nautical miles zone (Lelli, et al., 2007; Bariche, et al., 2006; Sacchi & Dimech, 2011; Colloca & Lelli, 2012). The status of halieutic resources between 6 and 12 nautical miles is not known, but it can be considered as virgin stocks as nearly no fishing activities are conducted in the said area.

A short offshore survey carried out by (Colloca & Lelli, 2012), set off a preliminary evaluation of the potentiality of offshore fishing grounds for local artisanal fishery in South Lebanon. This survey showed good yields (CPUEs higher than those of European Mediterranean countries) for the European hake (*Merluccius merluccius*) and the small shrimp *Plesionika edwardsii* (Colloca & Lelli, 2012).

The outcomes of visual census observations carried out in 2012 and 2013 showed typical characteristics of overexploited fish populations (RAC/SPA - UNEP/MAP, 2014). Observed abundances and biomasses were lower in the South (Nakoura and Tyre) than those in the Central-North Lebanon (Raouché, Ras Chekaa and Enfeh). However, the high heterogeneity of habitats that occurs in the study area makes it possible to host a high diversity of fish species (RAC/SPA - UNEP/MAP, 2014).

Marine Fish Catch Profile

In Lebanon, landing is composed by a great number of species, many of which are Lessepsian migrants. MOA catch data for 2015 indicated that 20 species accounted for 80 % of catch and that sardines (Clupeidae) and anchovies are the most important species representing more than 25% of production¹¹ (DFW, 2016, personal communication)(Table 10).

¹¹ It should be noted that these figures are the result of a pilot activity conducted by FAO EastMed Project, which is undergoing review for possible amendment; thus, the figures might not be accurate and presented for indicative purposes only (DFW, personal communication).

Table 10. Lebanon estimated catch data for 2015 (DFW 2016, personal communication).

Species / Taxa	Annual Catch (tons)	Percent of catch
<i>Clupeidae</i> [Herrings, Sardines nei]	1,033.20	14.1
<i>Euthynnus alletteratus</i> [Little tunny]	687.4	9.4
<i>Pagellus acarne</i> [Axillary seabream]	607.9	8.3
<i>Diplodus sargus</i> [White seabream]	514.1	7.0
<i>Siganus rivulatus</i> [Marbled spinefoot]	463	6.3
<i>Pagellus erythrinus</i> [Common pandora]	302	4.1
<i>Liza aurata</i> [Golden grey mullet]	256.1	3.5
<i>Pagrus caeruleostictus</i> [Blue spotted seabream]	242.3	3.3
<i>Lithognathus mormyrus</i> [Sand steenbras]	213.1	2.9
<i>Sardinella aurita</i> [Round sardinella]	210.1	2.9
<i>Oblada melanura</i> [Saddled seabream]	201.3	2.8
<i>Seriola dumerili</i> [Greater amberjack]	191.5	2.6
<i>Sphyraena sphyraena</i> [European barracuda]	191.2	2.6
<i>Sphyraena chrysotaenia</i> [Yellowstripe barracuda]	147.3	2.0
<i>Siganus luridus</i> [Dusky spinefoot]	139.4	1.9
<i>Boops boops</i> [Bogue]	130.7	1.8
<i>Caranx crysos</i> [Blue runner]	119.6	1.6
<i>Trachinotus ovatus</i> [Pompano]	110.7	1.5
<i>Portunus pelagicus</i> [Blue swimming crab]	105.5	1.4

In 1978, purse seine catches were estimated at 67 percent (4,000 tonnes) of the total fish landings in Lebanon (Mouneimné, 1978). In the experimental survey carried out by (Bariche, et al., 2006), *Sardina pilchardus* and *Sardinella aurita* composed 28% each of the total biomass while *Engraulis encrasicolus* and *Scomber japonicus* represented 22 and 10%, respectively. The remaining 12% was made up of twenty-eight other fish species. Between 2006 and 2011 the total fish catch in North Lebanon was estimated between a maximum of 3,457 tons in 2006) and a minimum of 1,704 tons in 2009. It has to be taken into account that the fishing effort in North Lebanon is directly dependent on weather conditions, market status and the political situation of the country (Nader, et al., 2012).

As far as demersal species are concerned, Lelli (2007) in the short survey implemented in South Lebanon in 2006, reported the relatively high abundance of *Sargocentron rubrum*, *Siganus rivulatus* and *Fistularia commersoni* over the continental shelf and the dominance of *Merluccius merluccius*, *Phycis blennoides* and *Centrophorus granulosus* in the upper slope. (Carpentieri, et al., 2009) reported in South Lebanon relatively high catches for *Siganus* spp., *Pagellus* spp., *Dentex* spp. and *S. rubrum*. It has been also substantiated the presence of deeper waters assemblages particularly abundant in red giant shrimps (Lelli, 2014).

Economic traits

The Lebanese fishing sector compromise about 0.06 % of GDP (Pinello & Dimech, 2013). The fishing industry generated a net profit of USD 4.6 million. The revenue of the fleet provided an average annual salary of about USD 4,300 (on a full-time equivalent basis) which is below the Lebanon's minimum wage for the manufacturing sector (FAO EastMed, 2016). In 2011 the annual salary was

approximately USD 3,000/fisher to about 3,229 fishers and a gross income of USD 7,400/fisher-owner (Pinello & Dimech, 2013). The sector employs in Lebanon a minimum of 4,475 fishermen operating in the fishing fleet, while the average number is 6,480 and increases to 9,575 fishermen during the peak season (Majdalani, 2005). 2012 data indicated that the marine fisheries sector employed 3,200 people (Pinello & Dimech, 2013). In 2011, the Lebanese fleet landed an estimated 4,850 t with a value of 26.98 Million USD (Pinello & Dimech, 2013). According to DFW, in 2014, Lebanon started reporting to FAO, fisheries catch data (2,998 tons in 2014 and 3,483 tons in 2015) based on the system developed by FAO EastMed Project.

Considering the local consumption of about 35.000 tons, more than 75% of the consumed fish is imported from abroad. Marine capture fisheries compromise about 0.06 % of the Lebanese GDP (Pinello & Dimech, 2013). The fishing industry is reliant on the exploitation of small pelagic species. Fisheries in Lebanon are small-scale fisheries and are based on bottom stationary gear (trammel nets and longlines), purse seine nets (lampara) and beach seines. Fishing operations, with the exception of longlines, are mostly carried out at depths of up to 50 m (University of Balamand, 2016). Most of the fishing nets have small mesh sizes i.e. less than 2x2 cm (Majdalani, 2005).

The fish production is marketed, besides auctions, on port stalls, by licensed and/or unlicensed shops and fish stalls, directly by fishermen, as well as by street vendors. Local production is sold fresh for human consumption. A shrimp farm is the only business that freezes its products (Majdalani, 2013). In 2005 there were fish halls for sorting, packing, selling and icing fish at 16 port/landing sites along the Lebanese coast. The only canning plant in Lebanon was decommissioned due to lack of supply of sardines and tuna (Majdalani, 2005). The Central Fish Market (Quarantina-Beirut) attracts fish from all over Lebanon and most imported fishes.

67% of the first-sales occur through indirect sales (mainly the auction markets), while 23% through a direct transaction (about two third through fishmongers and the rest sold directly to the final consumer). Ten percent of the production was sold using so-called 'other' channels, and in most cases, they were related to self-consumption (Pinello & Dimech, 2013). Purse seiners, which are the biggest and most productive vessels, sold most part of their production through indirect sales whereas the fleet segment minor gear < 6 m LOA sold one third of its production through direct transactions, which include also the sale to restaurants (FAO EastMed, 2016).

In 2005, there were fish auctions at the ports of Dora, Ouzaii, Saida, Tripoli and Sour. With respect to cold storage facilities, seven fish halls were equipped with chill rooms/refrigerators and twelve with ice (PescaMed, 2011). The ice was mainly present as crushed, being ready made from commercial suppliers. No fish hall had iceboxes for sale to fishermen, processors, and households, thus, fishermen had to resort to buy such items from local vendors. Only the ports of Qalamoun, Saida, and Naqoura Ports were equipped with ice crusher machines (Majdalani, 2004; PescaMed, 2011).

Within fishers, planning and forecasting capabilities are limited, as the immediate needs are a matter of mere survival. Let aside the minimum spent for food and few other necessary items, the priority is given to the expenditures related to the income generating activities (in this case nets, baits, etc). Schooling can be an arduous issue and health a burden that only few families can afford without any external support. Therefore, many fishermen integrate their incomes through different occupations that are usually not related to the fishing sector. Indeed, for some of them, fishing activities become secondary income generating occupations (Pinello & Dimech, 2013).

According to figures published by the Lebanese customs administration combined with the figures produced by (Pinello & Dimech, 2013), Lebanon imports 78% of the consumed seafood products. The

export versus import is negligible, which means that the domestic production accounts for about 22% of the seafood products consumed in the country, makes the country highly dependent on the import. In 2011, the average value of the seafood import was 4.2 \$/Kg, while the average value of the animal products in general was 3.0 \$/Kg. The annual production from marine capture fisheries is evaluated at 4,632 tonnes and 803 from aquaculture. For the same year, the apparent per capita seafood consumption was 6.03 Kg, which is about one third of the average figure for the Mediterranean in 2005 ([Pinello & Dimech, 2013](#)).

Fisheries management

The management of the Lebanese fisheries and aquaculture sectors is the responsibility of MoA, which includes a Department of Fisheries & Wildlife. At local and professional level, the fisheries sector in Lebanon is represented by 34 fishermen cooperatives under the General Cooperatives Union grouping around 43% of vessel owners/operators ([University of Balamand, 2016](#)). In general, they do not function as a collective according to a defined plan but mainly based on the initiatives of individuals. This makes such cooperatives unable of making proper decisions for the benefit of fishermen ([CANA-CNRS, 2011](#)). As for fishermen syndicates, five are active in the country (North, Beirut, Ouzaii, Saida and South) ([University of Balamand, 2016](#)). The role of syndicates is to lobby for the improvement and development of the sector within Government.

There is no national collective labor agreement in force for the operators of the sector.

Fisheries management measures and institutional arrangements applied to main fisheries ([Majdalani, 2013](#)) at first glance:

- Technical measures
 - Closed season:
 - Purse seines: January 1 - April 15
 - Fyke nets: May 15-September 15
 - Closed areas:
 - Ban of fishing within 500m from coastline.
 - Fishing gear
 - Beach seines: banned
 - Air compressors: banned
 - Mesh size control: minimum mesh size 2 x 2 cm except for purse seine nets that can be of lower mesh size.
- Nature reserves:
 - Palm Islands (North Lebanon)
 - Tyre Coast:
 - Establishing fisheries restricted area at Oceanographic & Fishing Institute in North Lebanon
- Economic incentives:

- Taxes: no taxes levied on fisheries products
- Other measures:
 - Establishing "minimum landing size" for many commercial species.
 - Regulation of Fyke Nets
 - Ban on fishing, sale and consumption of Lagocephalus species

The main ministries dealing with the fishery sector are the following:

Ministry of Agriculture (MOA): it was created in 1943, is mandated to regulate and supervise duties related to agricultural wealth and soil preservation, control of hunting (in collaboration with Ministry of Environment), fishing, use of pesticides, conservation of protected forests, reforestation of state and private lands and the implementation of laws and regulations such as the Forests and Fisheries laws. Within it, the Department of Fisheries & Wildlife (DFW) is responsible for the management of the fisheries sector. Decree No. 5246 "Organization of Ministry of Agriculture" issued on 30/6/1994 defined the role of DFW ([University of Balamand, 2016](#)) as:

- Marine and freshwater fisheries and game hunting affairs.
- Applied research on aquaculture and establishment of training centres in different locations and at its Institute of Oceanography and Fisheries at Batroun.
- Fishing licenses.
- Establishing and modernizing fishing ports and fish handling facilities in coordination with the Ministry of Transportation.
- Regulating the fishing sector by assigning fishing seasons and protected areas.
- Organizing and regulating diving clubs and protected areas.
- Improving the livelihood of fishermen by organizing cooperatives and syndicates.
- Carrying applied research on aquaculture.
- Developing and modernizing fishing techniques.
- Providing training on fishing boats.
- Preparing extension programs.
- Hatching and distributing adaptable fish species.
- Running trials on local and introduced fish species.
- Surveying game species.
- Preparing general guidelines to preserve game species and regulate its hunting in coordination with the Ministry of Environment (MOE).
- Growing of game species and running trials on them.
- Enforcing fishing and game hunting laws and regulations.

The first law the fisheries sector is Law No. 1104 (issued by Decision) promulgated on 14/11/1921:

- Prevents fishing inside harbors and docks except fishing with rods and lines with a maximum of two-hook.
- Bans dumping all materials that would spoil the water or agitate, intoxicate and/or poison the fish in the coast or in the harbors designated for fishing.
- This ban applies also to the industrial plants on the coast regarding disposing their wastes into the sea except in accordance with the terms of the permission that they request.
- Forbids the use of explosives in fishing.
- Bans the use of firearms for fishing without special permission and every firearm found in fishing vessels will be impounded.
- Forbids pushing the fish into the nets by muddying the waters by any means.

Since 1921, several laws, decrees and decisions related directly to fisheries were promulgated with the most relevant being Law No. 2775 “Monitoring of coastal marine fishing” passed in 1929. This law manages the fishing sector by:

- Identifying fishing – Delimiting Coastal Fisheries – Monitoring Coastal Fisheries – Designated staff.
- Various Prohibitions – Prohibited places- Prohibited times - Types of overfishing.
- Fishing gears – prohibited gears.
- Measures related to the organization and monitoring of fisheries and fishing by several vessels.
- Special provisions related to safeguarding juvenile fish and conservation of fish and shellfish - Minimum sizes of fish and shellfish to be fished, transported and sold.
- Prohibited baits – various prohibitions.
- Arrangements and precautions related to fishing operations.
- Measures for practicing fishing by rod and line.
- Fees for fishing licenses and fishing gears.
- Aquaculture Institute.
- Penalties.

It is noteworthy to mention that, since 1921, a number of laws were passed by parliament e.g. Law of 19/11/1947 “Subjecting river fishing to licensing”, decrees e.g. Decree 9924 of 20/2/2013 “Organization of Technical Troupe to monitor and control Forests, hunting and fisheries” and minister decisions e.g. Decision 346/1 of 15/7/2010 “Regulating and defining some fishing types and gears” in response to technological changes and binding international agreements e.g. GFCM recommendations. Currently there is a national policy for fisheries management aiming at the enforcement of laws, decrees and ministerial decisions, notwithstanding the overlapping in related public authorities. A new Lebanon Draft Fisheries Law was formulated by FAO, GFCM and MOA to replace Law No. 2775 of 1929. This draft law is a framework law aiming to cover most developments

in fisheries and aquaculture sectors and respond to present international legal instruments. This draft law is still to be passed by Lebanese parliament.

Ministry of Public Works and Transport (MOPWT): MOPWT was given the authority to protect maritime public domains and territorial sea, and to fight all forms of pollution caused by shipping operations, air and noise pollution produced by vehicular traffic. The lack of instrumental and financial resources is considered as a burden towards enabling the Ministry to undertake its duties. MOPWT is responsible for giving permits for the construction and rehabilitation of fishing ports or harbours. It is also responsible for authorizing building of local fishing and recreational vessels. It is also mandated with vessel registration, annual seaworthiness check-ups and sailing licensing for fishing vessels. MOPWT practises its mandate through a number of legal instruments like:

- Maritime Trade Law issued on 02/18/1947
- Decree number 16225 issued on 13/6/1957: Definition of marine navigation
- Decision of 31/1 26/1/1966 “Ratification of Lebanese Ports System”
- Decision 77/N/96 issued on 10/7/1996: Organization of sailing of fishing and recreational vessels within the Lebanese territorial waters
- Decree 12841 of 7/8/1998 “Organization of fishing and leisure ports, and regulation of their use and safeguarding”
- Law 163 of 18/8/2011 “Determination and announcement the maritime areas of the Lebanese Republic”
- Decree 6433 of 1/10/2011 “Delimitation of the Lebanese Exclusive Economic Zone”

Ministry of Environment (MOE): MOE is mandated to formulate policies and strategies, fight pollution from various sources, establish protected areas, and issue conditions for permitting the establishment of industrial plants. Law 444 of 29/7/2002 “Protection of the Environment” specifies the mandate of MOE. Moreover, Decree No 5591, issued on 30 August 1994, organises the Ministry of Environment and it specifies its responsibilities and duties. In specific, Article 11 pointed out to the presence of the Department for the protection of the Natural Reserves, including the fishery sector and states the following: “To protect all that is natural and to monitor the environment through the protection of all the natural resources such as water, soil, air, forests, the seashore, the river and all its aquatic and terrestrial organisms”. Lebanese legislators has also ratified several legal instruments like the Law of the Seas.

Ministry of Labour (MOL): Labour Law of 23/9/1946 and its associated legal laws and decrees prohibits child labour i.e. people under the age of 15 years old are not allowed to practice fishing or other careers or professions.

The Lebanese legislation concerned with the organization of the fishery sector relates mainly to monitoring coastal fishing, providing license for fishing in rivers, banning the fishing activity for certain types of marine species and the use of specific types of fishing nets. [Table 11](#) provides a summary of the existing laws and regulations related to fisheries and fishing.

Table 11. Laws and regulations related to the fisheries sector in Lebanon. Modified from (University of Balamand, 2016).

REGULATION	No	YEAR	TITLE
Law	1104	14/11/1921	The determination of the coastal zone scope and penalties related to the infringement of fishing rules
Law	144/S	10/6/1925	Definition of Public Domain

Law	372	25/6/1926	Regulations relating to navigation, fishermen and fishing boats
Law	2775	28/9/1929	Monitoring of coastal marine fishing
Law	3178	18/6/1930	The wandering of foreign fishing vessels not covered by the French Mandate
Law	70/L.R	5/5/1937	Regulation of Coastal Fishing
Law	86/L.R.	3/5/1939	Safety of maritime navigation and conditions in ships
Law	95/L	9/5/1939	Regulating sponge fishing
Law	153/L.R.	14/7/1939	Prevention of docking, trawling, use of fixed or dredge nets in the area where the marine cable wire between Tunisia and Beirut reach land
Law		23/9/1946	Labor Law
Law		02/18/1947	Maritime Trade Law
Law		19/11/1947	Subjecting river fishing to licensing
Decree	11882	3/6/1948	Regulation of fishing in rivers
Decree	7993	3/4/1952	Syndicates Regulations
Decree	16225	13/6/1957	Definition of maritime navigation
Decree	6349	16/3/1961	Organization of Technical Troupe to monitor and control forests, hunting and fisheries (Repealed by Decree No. 9924 of 20/2/2013)
Decree	8371	30/12/1961	The organization of the Ministry of Agriculture and identifying its Cadre
Law		25/5/1962	Amendment of Article 2 of Law of 5/5/1954 related to marine fishing
Decree	10121	20/7/1962	Zoning and licensing requirements for extracting gravel and sand from the Maritime Public Domain.
Decree	17199	18/8/1964	Putting in effect the draft law for cooperative associations.
Decree	17614	18/9/1964	Exploitation of Maritime Public Domain not presently exploited.
Decree	3401	11/12/1965	Cooperatives (Repealed by Decree 2989 of 17/3/1972)
Decision	31/1	26/1/1966	Ratification of Lebanese Ports System.
Decree	4809	24/6/1966	Regulating the occupation of the public maritime domain
Decree	4810	24/6/1966	System of occupation of maritime public domain
Decree	9791	4/5/1968	Putting into practice the draft law aimed at monitoring the beaches
Decree	11541	23/12/1968	Organization of the special service responsible for monitoring the coast within the Internal Security Forces
Decree	11618	4/1/1969	Establishment of Cooperation Division within the Ministry of Agriculture
Decree	15649	21/9/1970	Regulation for extraction of sand and other materials from Maritime Public Domain and from seabed
Decision	93/1	16/6/1971	The conditions imposed on the use of buoys in the field of marine fishing, swimming and docking
Decree	2989	17/3/1972	Repealing Decree 3401 of 11/12/1965 regarding Cooperatives and replacing it with new provisions
Decision	347/1	11/12/1972	Regulation of free diving fishing
Legislative Decree	138	16/9/1983	Determining the breadth of the territorial sea areas and the Forbidden Maritime Zones
Law	64	12/8/1988	Conservation of the environment against pollution from harmful wastes and dangerous materials.
Law	89	7/9/1991	Determination of Marine Fishing Licenses fees – 1991 Government Fiscal Budget Law (Annex 9)
Decision	108/1	11/9/1991	Creating a protected fishing and hunting area within the premises of Anjar Centre
Decision	129/1	23/10/1991	Establish a national maritime protected zone at the Oceanographic & Fishing Institute in Batroun
Decision	281/1	19/11/1991	Ban on fishing of sponge for 5 years
Decision	209/1	21/11/1991	Organization of maritime navigation, functioning of the ports, the equivalence of vocation certificates and services required by the Ministry of Public Works and Transport for Maritime Navigation.

Law	121	9/3/1992	Establishment of two nature reserves (in some of the islands in front of Tripoli Beach)
Decision	62/1	16/3/1993	Ban of Sardines nets within specific conditions
Decision	63/1	16/3/1993	Ban on fishing of sponge for 5 years
Decision	229/1	13/10/1993	Regulating the use, under certain conditions, of the newly introduced Kerkari nets to Lebanon
Decision	32/N	24/3/1994	Organization of sailing of fishing and recreational vessels within the territorial waters and beyond.
Decree	5246	20/6/1994	The organization of the Ministry of Agriculture and identifying its Cadre and conditions of employment in some of the functions for this Cadre and the ranks and salaries of its professional staff (Article 100 – Department of Fisheries & Wildlife)
Decision	183/1	27/10/1994	Ban of fishing in Lake Qaraoun
Decision	226/1	14/12/1994	Distribution of fishing nets and gear among fishermen cooperatives along the Lebanese coast
Decision	47/1	13/3/1995	Distributing fishing nets and gear among fishermen co-operatives along the Lebanese coast.
Decision	98/1	19/5/1995	Distribution of nets and fishing gear to development committees in the places that could not set up cooperatives to date.
Decision	60/1	31/7/1995	Defining the specific conditions for the use of Kirkai (Cianciolo) nets
Decision	61/1	31/7/1995	Defining the specific conditions for the use of Sardine nets (Lux)
Decision	254/1	8/12/1995	Regulating fishing-diving sport
Decision	255/1	8/12/1995	Regulating fishing-diving sport institutes
Decision	261/1	20/12/1995	Distribution of fishing nets and gear donated by FAO among fishermen cooperatives
Decision	131/1	15/3/1996	Organizing work at Oceanographic and Fishing Institute at Batroun in collaboration with the National Council for Scientific Research (CNRS)
Decision	156/1	20/3/1996	Forming the Examination Committee to settle the situations of amateur scuba divers
Decision	234/1	20/5/1996	Defining medical form needed to practice scuba diving
Decision	71/N/96	3/7/1996	Establishment of marine fishing port in the region of Halat
Decision	77/N/96	10/7/1996	Organization of sailing of fishing and recreational vessels within the Lebanese territorial waters.
Decision	324/1	22/7/1996	Amending Decision No. 156/1 of 1996 & Decision 254/1 of 8/12/1995
Decision	119/N/96	8/10/1996	Considering the area of maritime beach a fishing and recreational port
Decision	202/1	14/4/1997	Amending Decision 254/1 of 8/12/1995 regarding regulating fishing-diving sport
Decision	381/1	25/11/1997	The activities Programme of the Oceanographic and Fisheries Institute in Batroun.
Decision	385/1	26/11/1997	Prohibition of fishing in river estuaries along the Lebanese coast
Decision	397/1	28/11/1997	Creation of a Fishing and Hunting Guidance Centre at the Institute of Oceanography and Fisheries in Batroun- Governorate of North Lebanon
Decision	398/1	28/11/1997	Creation of a Fishing and Fisheries Centre at the Institute of Oceanography and Fisheries in Batroun- Governorate of North Lebanon
Decision	1/18	2/2/1998	Establishment of Fisheries & Wildlife Extension Services Centers
Decision	50/1	6/3/1998	Settlement of situations for scuba divers holding diving certificates
Decision	115/1	23/6/1998	Organization of work at the Institute of Oceanography and Fisheries and defining the basis for cooperation with the National Centre for Scientific Research (CNRS)
Decree	12841	7/8/1998	Organization of fishing and leisure ports, and regulation of their use and safeguarding
Law	708	5/11/1998	Creation of Tyr Coast Nature Reserve in Jaftlak Ras Al Ain – Tyr Real

			Estate Zone
Decision	279/1	19/11/1998	Ban on catching sea turtles
Decision	280/1	19/11/1998	Prohibiting to fish with beach seines along the Lebanese coast.
Decision	281/1	19/11/1998	Ban on fishing of sponge for 5 years
Decision	290/1	23/11/1998	Defining the use of the sardine nets within specific conditions
Decision	291/1	23/11/1998	Restricting the use of Kirkari nets (purse seine) to specific conditions
Decision	42/1	24/3/1999	Organization of the hobby of underwater fishing
Decision	43/1	24/3/1999	Restricting the use of Sardine and "Cianciolo" nets to specific conditions
Decision	78/1	29/6/1999	Amending article 4 of Decision No. 43/1 of 24/3/1999 regarding restricting the use of the sardine and Cianciolo nets to specific conditions.
Decision	122/1	21/9/1999	Stop-work for Decision No. 280/1 of 19/11/1998 Prohibiting to fish with beach seines along the Lebanese coast
Decision	125/1*	23/9/1999	Prohibiting fishing of whales, seals and marine turtles
Decision	179/1	1/12/1999	Assigning classrooms at the disposal of official vocational agricultural school at the Oceanographic Institute
Decision	19/1	11/1/2000	Creation of a center for fishing, nursery and forestation in Abdeh in the Governorate of North Lebanon
Decision	267/1	27/11/2000	Stop-work for Decision No. 280/1 of 10/11/1998 - Prohibiting to fish with beach seines along the Lebanese coast until 15/5/2001
Decision	126/1	23/5/2001	Regulating scuba diving sport
Decision	147/1	18/6/2001	Delegation of signing of the amateur scuba diving licenses
Law	444	29/7/2002	Protection of the Environment
Decision	88/1	14/3/2003	Prohibition of fishing by beach seines along the Lebanese coast
Decision	127/1	9/5/2003	Stop work for Decision 88/1 of 14/3/2003 that prohibits fishing by beach seines along the Lebanese coast, until 15/5/2005
Decision	165/2T	23/7/2003	Establishing a Cooperative for coast protection and fishing & shellfish fishing in the province of Mount Lebanon.
Decision	199/2T	19/8/2003	Establishing a cooperative for fishermen in the Governorate of Mount Lebanon.
Decision	321/1	31/10/2003	Stop work for Decision 88/1 of 14/3/2003 that prohibits fishing by beach seines along the Lebanese coast
Decision	15/1	21/1/2004	Legal sizes relating to fishing, transporting, buying and importing fish, shellfish and crustaceans in Lebanon
Law	571	11/2/2004	Permitting the Government to join the Agreement to preserve cetaceans in the Black Sea, Mediterranean and the Contiguous Atlantic Area
Law	613	20/11/2004	Permitting the Government to ratify the amendments to the Agreement establishing the General Fisheries Commission for the Mediterranean
Decision	54/1	24/2/2005	Permission for Department of Fisheries & Wildlife to catch marine organisms to conduct research
Decision	352/1	3/10/2005	Stop work for Decision 88/1 of 14/3/2003 that prohibits fishing by beach seines along the Lebanese coast for three years
Decision	104/FO	17/11/2005	Repeal of decisions regarding occupying riverine public domain
Decision	130/2T	13/6/2007	Establishing a cooperative for fishermen in the Governorate of Mount Lebanon.
Decision	408/1	2/11/2007	Defining types of marine fishing gears
Decision	1/1	1/1/2008	Stop-work for Decision No. 408/1 of 2/11/2007 concerned with defining types of marine fishing gears
Decision	93/1	14/3/2008	Regulating scuba diving
Decision	459/1	14/8/2008	Establishing a port for marine fishing and excursion in the zone of Jall Al Bahr-Ain Almraysah
Law	34	16/10/2008	Permission to the government to join the Convention on the Protection of the Marine Environment and the Coastal Region of the Mediterranean; which are the amendments made to the Protection

			of the Mediterranean Sea against Pollution.
Decision	20/1	15/1/2009	Defining types of marine fishing gears
Decision	35/2T	5/3/2009	Establishment of a cooperative for the development of fishing in the Governorate of the North Lebanon
Decision	229/1	12/5/2009	Prohibiting the use of remains of slaughterhouses as feed for fish
Decision	346/1	15/7/2010	Regulating and defining some fishing types and gears
Decision	676/1	27/7/2011	Prohibiting fishing, transporting, selling and consuming of some fish species
Law	163	18/8/2011	Determination and announcement the maritime areas of the Lebanese Republic
Decree	6433	1/10/2011	Delimitation of the Lebanese Exclusive Economic Zone
Decision	952/1	26/10/2011	Hygienic regulations for fresh, chilled and frozen fish transport vehicles
Decision	8/1	4/1/2012	Regulating and defining some fishing types and gears (Fyke nets)
Decree	8633	7/8/2012	Fundamentals of Environmental Impact Assessment
Decree	9924	20/2/2013	Organization of Technical Troupe to monitor and control Forests, hunting and fisheries
Decision	792/1	16/8/2013	Amending Decision No. 108/1 of 1991 (Creating a protected fishing and hunting area within the premises of Anjar Centre)
Decision	1154/1	9/12/2013	General conditions to protect cetaceans (repealed by Decision 215/1 of 16/3/2015)
Decision	1160/1	10/12/2013	General conditions for fishing sharks (repealed by Decision 215/1 of 16/3/2015)
Decision	1163/1	12/12/2013	Ban on catching seabirds
Decision	396/1*	12/5/2014	Ban on catching seabirds
Decision	482/1	9/6/2014	Correction of Article 2 of Decision 396/1 of 15/5/2014 (Ban on catching seabirds)
Decree	639	18/9/2014	Joining the Integrated Coastal Zone Management Protocol in the Mediterranean emanating from the amendments to the Convention for the Protection Of The Mediterranean Sea Against Pollution which was approved in Barcelona on 06/10/1995 and ratified by Law No. 34 Date 16/10/2008
Decision	1044/1*	25/11/2014	General conditions to protect cetaceans
Decision	1045/1*	25/11/2014	General conditions to catch sharks
Decision	215/1	16/3/2015	Repeal of Decision 1154/1 of 9/12/2013 and Decision 1160/1 of 10/12/2013
Decision	1234/1	31/12/2015	Amending Decision 952/1 of 26/10/2011 regarding hygienic regulations for fresh, chilled and frozen fish transport vehicles

* In accordance with GFCM recommendations

The main Fisheries Law (Law No. 2775-Monitoring of Coastal Fishing. 28/9/1929) is outdated and goes back to 1929 during the French mandate for Lebanon. FAO, GFCM and MOA drafted a new law that was finalised in December 2014 and sent to the Cabinet of Ministers for approval and forwarding to the Parliament for discussion, amendments and eventual ratification. This Draft Fisheries & Aquaculture Law contains the following sections:

- Section 1 - Terminology
- Section 2 - General Provisions on Management of Living Aquatic Resources
- Section 3 - Common Provisions for Marine and Inland Fishing
- Section 4 - Marine Fishing
- Section 5 - Inland Fishing

- Section 6 - Biodiversity Conservation & Preservation of the Aquatic Environment
- Section 7 - Aquaculture Establishments
- Section 8 - Handling and Marketing of Living Aquatic Resources
- Section 9 - Fees
- Section 10 - Law Enforcement and Penalties
- Section 11 - Establishment and Competence of the Division of Fisheries
- Section 12 - Final and Transitional Provisions
- Annexes 1 & 2: Minimum landing size of marine and freshwater species

With respect to the fishing gears and their technical characteristics there are currently very limited number of gear regulations and restrictions in the Lebanese fisheries legislation. The legislation concerns the size of the gear and the mesh and the practices of bottom trawling, static and surface nets and surrounding gears for small pelagic fishes. The current legislation specifies the following:

- Trawling is banned in Lebanese territorial waters and currently there are no trawlers registered in the Lebanese fishing fleet register.

- Surrounding gears (purse seine and lampara): Decision 43/1 of 1999 limited the mesh size to a minimum of 6x6 mm for sardine (lux) nets. Moreover, Decision 20/1 of 2009 defined net height to be 35 fathoms for Cianciolo/Kerkari nets and 20 fathoms for Sardine nets. The regulation currently in effect, Decision 346/1 of 2010 that describes the gear (height, light, depth) and defines the legal season for fishing with purse seine sardine (lux) nets, is summarized in [Table 12](#).

Table 12. Management measures for purse seines fishery. Modified from (University of Balamand, 2016).

MANAGEMENT MEASURES	DESCRIPTION	EFFECTIVENESS
Needed documents	<ul style="list-style-type: none"> • Boat registration deed • Navigation license • Fishing license • Fishermen ID 	The major fishing ports are under the control of the Lebanese Army where fixed points are positioned
Spatial restrictions (e.g. closed areas, MPAs, etc.)	<ul style="list-style-type: none"> • Forbidden in depth above 25 fathoms • Fishing activities are allowed beyond 500 m from coastline 	Fishing is allowed beyond 500 m from shoreline. Deep water is a major challenge as continental shelf is narrow
Temporal restrictions (e.g. closed seasons)	<ul style="list-style-type: none"> • Forbidden from January 1st till April 15th • Forbidden during the day 	Fishermen requested to reconsider the closure period
Gear restrictions (e.g. forbidden gears, limits to mesh size, etc.)	<ul style="list-style-type: none"> • Net cannot be higher than 25 fathoms • Mesh: > 20x20mm (for non-migratory species) • Maximum four lights holders can be used (500 Watt each) • Forbidden to use generators 	Purse seines with large mesh size do not catch targeted species
Minimum fish size	<ul style="list-style-type: none"> • 15 cm (Decision 15/1 of 2004) 	Sardine in Lebanon is commercialized and appreciated in small sizes. Large Sardines are not attractive for consumers
Minimum mesh size	<ul style="list-style-type: none"> • There is no minimum limit for migratory species including Sardines according to Law 2775 of 1929 • Sardine nets minimum mesh size of 6x6 mm is specified in Decision 43/1 of 1999 	
Participatory restrictions (e.g. licensing, TURFs, etc.)	<ul style="list-style-type: none"> • No limits for fishing license number 	
Limits to fishing capacity (e.g. max. number of vessels; fleet reduction etc.)	<ul style="list-style-type: none"> • No limits for boat size and engine power 	
Others	<ul style="list-style-type: none"> • Capture of protected and vulnerable species (Whales, dolphins, marine turtles, sharks and rays, monk seals...) 	By catch is accidental in most of the cases for purse seiners

- For the static gears several regulations exist, which forbid the use of bottom nets for catching pelagic species and give precise definition of these gears. The minimum legal mesh size in Lebanon is larger (20 mm bar mesh) than the legal mesh size in several Mediterranean legislations e.g. the EC regulation n° 1967/2006 for the Mediterranean Sea limits the stretched mesh size of gillnet to a minimum of 16 mm). There is no limitation on net length and height in Lebanese legislation.

- For longlining hook size is not regulated in the Lebanese legislation.

- For traps the Lebanese legislation establishes the mesh size to 20 mm bar mesh size for square mesh and 30 mm for triangle mesh trap. There is no limitation of number of traps and soaking time.

- For other fishing techniques, the Lebanese legislation forbids the use of beach seines and of air compressors; licenses are issued for spear fishing for recreational activities and its use is prohibited with scuba diving breathing apparatus. There is no specific regulation for commercial underwater spear fishing in Lebanon.

- Recreational fisheries: according to existing regulations it is limited to:

- Rod and line: with a maximum of two hooks per rod
- Underwater fishing for amateurs with spear-guns
- Riverine fishing

Scarcity of financial resources and clear and effective policy management have led to neglecting the potential of the fishery and aquaculture sectors and induced a gradual decline in their productivity as well that of the standard of living for fishermen and fish workers involved in ancillary activities. On the other hand, the limited knowledge of market and fish consumption patterns or potentialities in new harvested or cultivated products, together with the lack of a strategic vision to define priorities, hamper the creation of job opportunities.

In the last years, the FAO-EastMed-Project in collaboration with the MoA is supporting the development of regionally consistent fisheries management plans among the Eastern Mediterranean countries. Within this context, the University of Balamand (UOB) developed a web-based utility (based on FAO's ARTFISH software) dubbed FLOUCA Web to collect catch and effort data for the marine fisheries sector. Data are collected and entered locally by MoA staff. FLOUCA Web offers a variety of statistical diagnostics that are in line with the requirements of regional and international fisheries bodies. MOA started reporting catch data to FAO as of 2014. Moreover, the same project spearheaded collecting socio-economic data for the sector since 2011. FAO-Eastmed is also collaborating with the CNRS-L to put in place a system of data collection of biological parameters of some flag species in line with the Data Collection Reference Framework (DCRF) issued by GFCM and it has recently (2016) initiated – in collaboration with MoA and UOB – a bottom-up process for the development of a management plan for the small pelagic fishery in Lebanon.

Threats

According to (Plan Bleu and UNEP, 2000), more than 60 percent of Lebanon's population lives in the coastal zone. The impact of population density and economic activities on marine biodiversity is therefore immense and pose formidable challenges to coastal zone management, including the conservation of marine resources, and the protection of sea-based livelihoods and the Mediterranean Sea. The high population density over the coastal zone and particularly around coastal slums of major cities (MOE & UNDP, 2010), has led to a degradation of the coastal ecosystem due to wastewater effluents, public discharges and uncontrolled management of the coastal zones (Faour, et al., 2004; Khalaf, et al., 2009). In 2007, there are 53 identified wastewater outfalls along the Lebanese coasts and moderately eutrophic areas have been identified (Abboud Abi Saab, et al., 2008). In addition, dumpsites are found in different areas along the coast. High levels of polycyclic aromatic hydrocarbons (PAH) were found in sediments and mollusc bivalves sampled in the area of

Tyre Marine Reserve, few kilometres south of Tyre (UNEP, 2007). Industrial plants (tannery, steel, cement, fertilizers, food processing, etc.), tourism settlements, agricultural effluents and oil shipping (Ricerca e Cooperazione NGO, 2005) are further sources of land-based pollution.

The marine environment has been marginalised for decades and was often managed like an expendable resource. Short of sufficient inland space, extensive facilities are built infringing on the public maritime domain and/or protrude into the sea, including wastewater treatment plants, highways, and sports stadiums. The private sector has also implemented oversized sea-filling projects for real estate development. These practices are not sustainable and have immeasurable and irreversible impacts on marine biodiversity and coastal habitats such as altering wave patterns, preventing sand replenishment, destructing nursery coastal areas and reducing public access (UNDP, 2012).

Fortunately, some particularly destructive such as bottom drifting nets and bottom trawls are not practiced in Lebanon (Greenpeace, 2010). However, the concentration of fishing effort in a narrow coastal strip (see paragraphs Lebanese Fisheries Overview and Fishing fleet, gears and grounds), coupled with the use of harmful practices has led to a likely overexploitation of many coastal commercial species.

According to (UNDP, 2012), the cost of environmental degradation in Lebanon linked to land and wildlife resources is estimated at \$100 million per year, or 0.6% of Lebanon's GDP. On the other hand, the limited knowledge of market and fish consumption patterns or potentialities in new harvested or cultivated products, together with the lack of a strategic vision to define priorities, hamper the creation of job opportunities (Samir Majdalani (DWF) personal communication).

Chapter 4

**Distribution, abundance, diversity
and structure of demersal species
exploited by Lebanon's artisanal
fisheries**

Chapter 4

Part I: Analysis of structure and distribution of demersal species exploited by Lebanon's artisanal fisheries

Part II: Short Communication

Pattern of distribution and diversity of demersal assemblages in the eastern Mediterranean Sea

Analysis of structure and distribution of demersal species exploited by Lebanon's artisanal fisheries

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ABSTRACT

Lebanon's fisheries sector is composed of a little artisanal fishing fleet, namely 2,005 licensed vessels below 12 m in length using fishing techniques mostly based on passive gears. Due to its geographical location, Lebanon represents an outpost for a comprehensive understanding of the dynamics driving the colonization of the Mediterranean by Indo-Pacific and Red Sea species. A 3-year experimental fishing surveys program was conducted. Sampling stations were surveyed by means of experimental nets lowered up to 300 m depth aiming at assessing the distribution and abundance of fisheries resources along the Lebanese continental shelf and mid-upper slope. We deemed fishery-independent survey as the most appropriate tool to provide valuable measures of relative abundance, rates of population change and size and sex composition for a wide range of species.

A diversified mix of teleostean, selacean, cephalopod and crustacean species composes catches of Lebanese demersal fisheries. In three years of data collection, a total of 121 hauls were executed and 97 Km of nets (0.351 Km²) were lowered. 3,579 specimens belonging to 129 species and 73 families were collected with an overall weight of 601 Kg. The catch was composed by 18 crustaceans, 8 cephalopods, 91 teleosteans and 12 elasmobranchs. *Sargocentron rubrum* was the most abundant species, with the highest numerical occurrence, overall weight and CPUE. *Dentex macrophthalmus* was the second species in terms of numerical abundance and occurrence, whereas *Phycis phycis*, *Merluccius merluccius* and *Lagocephalus sceleratus* were reported relatively high in weight. Among

12 species of elasmobranchs caught in this study, 6 are considered threatened with extinction by the IUCN Red List. Among those, *Gymnura altavela* and *Squatina aculeata* are considered critically endangered, facing an extremely high risk of extinction in the wild. In our study, 17 non-indigenous species (NIS) of Indo-Pacific origin – 13 fish and 4 crustacean species - were recorded over the Lebanese coastal waters, 15 of which demersal, one pelagic (the herring *Etrumeus teres*) and one with a mixed benthic-pelagic behaviour (the portunid crab *Charybdis longicollis*).

Data showed the depth to cause a general decrease in the numerical abundance and biomass (beyond 150 m depth) probably related to a general reduction in food availability that affects epibenthic and demersal assemblages on the slope. This pattern was due to a reduction of the abundance of teleosts, which decreased with depth, while decapod crustaceans and elasmobranchs showed an opposite trend increasing from the coastal shelf to the middle slope.

Keywords: fishing impact; Levantine basin; spatiotemporal variations, small-scale fishery, fauna; species composition

INTRODUCTION

Marine capture from fisheries provides food and offers livelihood opportunities for world's population. Therefore, assessing their state of conservation and the efficiency at which they are exploited is a major societal objective for natural scientists worldwide (Pauly, et al., 2002; Branch, et al., 2011).

In the Mediterranean basin, demersal species account for roughly 30% of total landings from the region, and represent therefore an important resource for the fishery sector (Leonart & Maynou, 2003). However, strong concern exists regarding the long-term sustainability of demersal fisheries. Indeed, according to recent assessments, most Mediterranean demersal stocks are overexploited (see Colloca, et al. (2013) for a recent review and GFCM's recommendation 34/2010/1) and approximately 75% of demersal Mediterranean species are not assessed. Indeed, the Mediterranean demersal stocks have been subject to trawling at least since 1700 (Osio G. C., 2012), one of the longest trawl fishery exploitation in the Western world. Mediterranean demersal fisheries are multispecific, with more than a hundred species of fish, crustaceans and mollusks being targeted (Leonart & Maynou, 2003). The few stocks considered to be exploited sustainably are either short-lived small pelagics or crustaceans (Osio, et al., 2015). In addition to overexploitation, there is evidence of biodiversity threats, habitat loss and degradation of ecosystem functioning caused by fishing practices (Coll, et al., 2010).

The overexploitation of fishery resources has led to a major fisheries crisis. In this context, artisanal fisheries, and in particular small-scale coastal fisheries, appear as relevant alternatives for a sustainable use of coastal resources.

The artisanal fishing sector provides direct employment to tens of millions of people, and indirect employment to tens of millions more (UNEP, 2005). Artisanal fishing comprises 90% of all fishing jobs worldwide, approximately 45% of the world's fisheries, and nearly a quarter of the world catch (UNEP, 2004). They provide critical income and edible protein to hundreds of millions of people across the globe. They employ twenty-four times more fishers than large-scale fisheries, for an equivalent annual catch for human consumption (Jacquet & Pauly, 2008). Total annual fuel oil consumption by these fisheries is much lower and discards are small compared to large-scale

fisheries (Kelleher, 2005; Jacquet & Pauly, 2008). In addition, bottom trawling has an impact on the habitats whose extent and duration vary depending on local conditions (Jones, 1992). Artisanal fisheries in the Mediterranean Sea represent roughly 86% of the approximately 42 000 fishing boats exploiting coastal and offshore stocks (Maynou, et al., 2013). In the Mediterranean Sea, small-scale coastal fisheries (SSF) mainly operate on the continental shelf (0–200m depth), in areas which can be reached within a few hours from the home ports (Farrugio & Le Corre, 1993; Colloca, et al., 2004; Tzanatos, et al., 2006; Forcada, et al., 2010; Maynou, et al., 2011; FAO, 2015). Foremost characteristics of the sector are the high diversification of gears and techniques, the multitude of species exploited, the changing patterns of gears use in time and space and the varying degree of fishermen's dependence on fishing (Tzanatos, et al., 2006). Boats can be active fully or part-time of the year, and their activity is characterized by a diverse array of métiers which can be defined as target species, fishing gears, grounds and techniques, with frequent seasonal and spatial changes to adapt to varying resource availability (Colloca, et al., 2004; Lelli, et al., 2007; Forcada, et al., 2010).

Lebanon's fisheries sector is composed of a little artisanal fishing fleet, namely 2,005 licensed vessels (in 2015 according to the Department of Fisheries and Wildlife (DFW) of the Lebanese Ministry of Agriculture) predominantly operated by rather aged fishers using old boats with dated equipment (Pinello & Dimech, 2013). Most of the boats are motorized and below 12 m in length using fishing techniques mostly based on passive gears such as gillnets, trammel nets, longlines, and purse seines. Fishing operations are mostly carried out at depths of up to 50 m (Sacchi & Dimech, 2011; Brême, 2004; Lelli, et al., 2007). Few vessels are equipped with GPS, while the rest have very limited navigational or safety equipment (Majdalani, 2004; Sacchi & Dimech, 2011). Lebanese coastal waters contain a significant richness of marine organisms with more than 80 fish species being of commercial importance (Nader, et al., 2012).

Illegal fishing behaviors and harmful or unsustainable practices such as the use of small mesh nets and explosives thrive as a result of an outdated legislation and the lack of its enforcement (Sacchi & Dimech, 2011). Lack of urban and industrial waste management along with the absence of an effective sanitation network are contaminating marine and fresh waters. Coastal areas are subject to uncontrolled urban sprawl and increasing processes of artificialization. It is widely agreed that human activities are affecting in a worrying manner the narrow coastal area environment leading to a critical increase in its exposure to geological hazards. Human pressure on the coastal area, along with the low public investment in the sector during the past decades have narrowed the economic value of the sector and therefore negatively affected fishers' lives (DAR-IAURIF, 2010; UNDP, 2012; World Bank, 2011; MoE/UNDP/ECODIT, 2011). Despite its chaotic management, the Lebanese fishing sector represents a unique case in the Mediterranean, being the only one solely composed by small-scale artisanal vessels.

Due to its geographical location, Lebanon also represents an outpost for a comprehensive understanding of the dynamics driving the colonization of the Mediterranean by Indo-Pacific and Red Sea species. The knowledge on the impact of Lebanon's fleet on fisheries coastal resources – both non-indigenous and endemic - is still very limited though, being available only scattered information on distribution, abundance and biological characteristics of few fish and shellfish stocks (Colloca & Lelli, 2012; Lelli, 2007; Carpentieri, et al., 2009; Bariche, et al., 2006; Bariche, 2003; Nader, et al., 2014; Nader, et al., 2012; George, et al., 1964).

Lebanon is moving its first steps in the fulfilment of international requirements in terms of data collection on its halieutic resources through stocks, catch and effort assessments (FAO EastMed, 2014). International organizations and donors have granted funds and capacity building to develop

adequate research programmes to support the capability of the Lebanese Government to define new measures towards an appropriate and sustainable management of fishing resources. The idea of an overall Country data collection to gain information on abundance and distribution of Lebanese fisheries resources stemmed from a series of meetings that took place in 2012 aiming at coordinating the efforts of international organisations (i.e. FAO, CIHEAM, Italian Cooperation) and Lebanese stakeholders such as public institutions and academia.

Financed by the Italian Cooperation in Lebanon, in 2012 the project CIHEAM-PESCA LIBANO “Technical Assistance to the Ministry of Agriculture in the field of fishery development” aimed at providing the Lebanese Ministry of Agriculture (MoA) with advanced tools designed for a proper management of marine and fisheries resources. This was achieved by strengthening capabilities of the MoA staff and assessing the potentialities of marine coastal resources. The project gathered scattered data fisheries related from different concerned institutions, on the one hand. On the other, it actively collected data that emerged to be important for a correct management of the sector and still missing. The project had been working on the land to map infrastructures and activities linked to fisheries, and at sea to assess the distribution and abundance of demersal species exploited by the Lebanese artisanal fleet. The National Council for Scientific Research, Lebanon (CNRS-L), in charge of the implementation of the fishing surveys through its Marine Centre, gave follow up executing seasonal data collection at sea in the North Lebanon.

The objective of this paper is to address part of the aforementioned gaps, describing composition, spatial distribution, depth and relative abundance of demersal communities exploited by the Lebanese small-scale fisheries. It allows also to highlight the portion of Lessepsian species in the catches by analyzing CPUE (in number and weight) data from the surveys. We also intend to contribute to widen the arrays of available methodologies for fisheries independent data collections especially in areas where trawling is not possible or convenient. As eastern Mediterranean halieutic species are poorly studied and very little information is available for most of the commercially relevant species, this set of information can represent a valid tool to improve the management of coastal habitats also with the aim to ensure the long-term sustainability of fishery resources.

MATERIALS AND METHODS

Study area

Situated in the central part of the Levantine Basin (Eastern Mediterranean), Lebanon is geographically limited by latitude 33°- 35°N and longitude 35° 30'-36° 20' E. Its coastal stretch is about 225 km long from Arida (north) to Ras el Naqoura (south) on the Levantine Basin of the Mediterranean Sea.



Figure 17. Map of study area: Lebanon, eastern Mediterranean.

The continental shelf is relatively wide in the north, offshore of the Akkar plain (about 20 km), and in the south, offshore of Saida and Tyre (Nabatiyeh plateau). Between Beirut and Batroun, the shelf is extremely narrow and the margin exhibits its steepest slope, with the water depth abruptly increasing from 100 to 1500 m in less than 5 km. Along the entire margin the continental slope is incised by canyons, most of them connected to rivers flowing from the mountains.

Sea cliffs made of limestone border most of the shores and sometimes descend directly into the sea. They are separated by gravel or sand beaches, composed partly of shell fragments and mostly of detrital sand (Emery & George, 1963).

There is a minimal variation in tides.

Lebanon has a typical Mediterranean climate, with an average annual temperature of 20°C and about 300 sunny days each year. It is also characterised by a relatively high average rainfall, ranging from 700 to 1000 mm along the coast to 1,400 mm on Mount Lebanon. Surface water temperatures show high seasonal variation and range from 15°C in winter to 30°C in summer. The water in the upper 50 m is well mixed in winter and becomes stratified during the rest of the year (Greenpeace, 2010).

The Lebanese coastal waters are characterized by thermophilic biota of Mediterranean and Indo-Pacific origin (Abboud-Abi Saab, et al., 2013; Bitar, et al., 2007). The local biodiversity is undergoing rapid alteration under the combined pressures of climate change and anthropogenic impacts. Protection measures, for either species or ecosystems, are still rare. Native marine flora and fauna are competing with invading species originating mainly from the Indo-Pacific oceans. The features of the Lebanese coastline with no closed bays or gulf consent to coastal waters to continuously mix thus preventing conditions of eutrophication and to disperse nutrients and pollutants (Abboud – Abi Saab, 2012).

Sampling Design

Description of the scientific surveys. The CIHEAM-Pesca Libano Project and the CNRS-L planned and implemented a 3-year experimental fishing surveys program. Sampling stations were surveyed by means of experimental gillnets, trammel nets and lowered up to 300 m depth aiming at assessing the distribution and abundance of fisheries resources along the Lebanese. We deemed fishery-independent survey as the most appropriate tool to provide valuable measures of relative abundance, rates of population change and size and sex composition for a wide range of species. In fact, fishery-independent surveys form the cornerstone of many stock assessments for bony fishes and shellfish species, they are less subject to the unknown and often confounding factors that complicate the interpretation of fishery-dependent indices of stock status. Thus fishery-independent surveys strike a balance between the ability to make inferences about one or more populations versus the usage of a specific area by one or more species (Rago, 2005).

Spatial stratification. The predominantly used approach for the definition of a fishery-independent survey sampling design is stratification where the total survey area is broken down into strata possessing common features regarding the species composition and their densities and length structures. If the strata are well selected, i.e. characterised by a low variability within the strata and clear differences between strata, the stratification is a convenient way of increasing the precision of the abundance estimates (Cochran, 1977). Survey effort may be allocated between strata according to their size or may be optimised if a priori knowledge on the variability of interest is known (Sparre & Venema, 1992). Within each stratum, the fishing stations are chosen randomly.

It is therefore clear that the stratification scheme depends on the objective established for the survey. As the ultimate aim of the abundance survey in Lebanese waters was to obtain an estimate of the relative abundance and spatial distribution of main commercial stocks, it was necessary to adopt a stratification that could allow sampling a relative large array of species with different depth ranges. At the same time, it was required to cover the entire Lebanese coast in order to gather enough data to map the spatial distribution of the stocks. Table 13 and figure 18 summarise the stratification approach adopted for the surveys based on the definition of four coastal regions from North to South (Akkar shelf, Tripoli-Beirut; Beirut-Saida; Saida-Naqoura) and 2 depth strata (0-100 m; 100-150 m). The total number of sampling stations was 48, spatially allocated randomly but proportionally to the extension of each area.

Table 13. Survey areas according to regions and bathymetric strata over the Lebanese continental shelf.

REGION	Area in the bathymetry 0-100m (km ²)	n. hauls	Area in the bathymetry 100-150m (km ²)	n. hauls
1. AKKAR SHELF	473.6	12	124.4	3
2. TRIPOLI-BEIRUT	183.3	5	92.05	3
3. BEIRUT-SAIDA	189.8	5	99.6	3
4. SAIDA-NAQOURA	386.4	11	221.7	6
total	1233.1	33	539.7	15

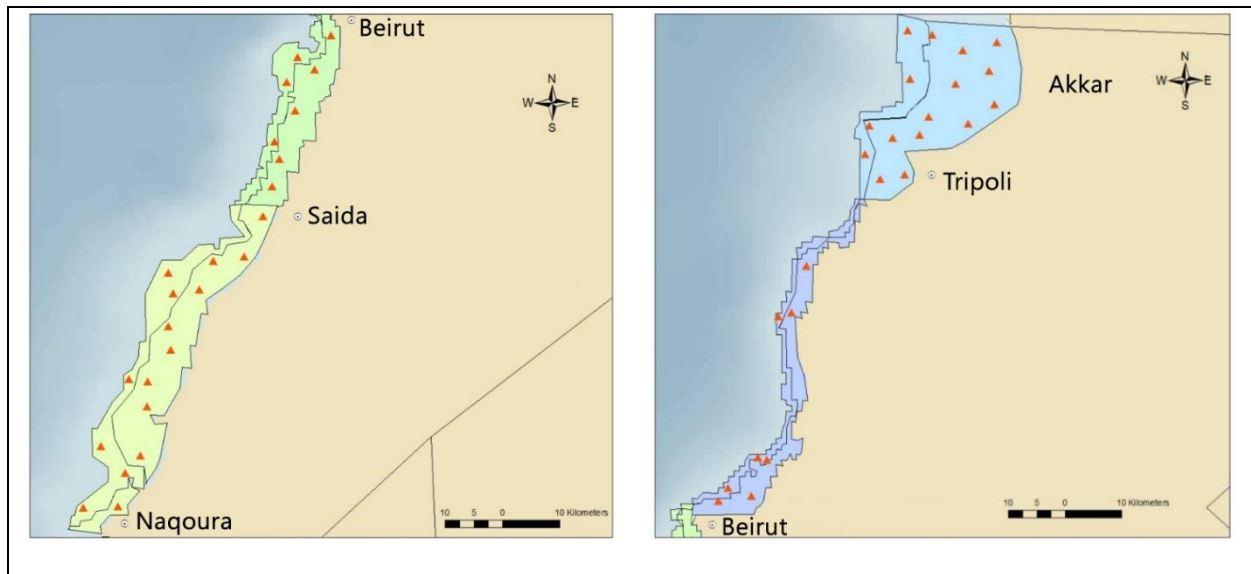


Figure 18. Maps of investigated area showing the randomised distribution of sampling stations along the Lebanese continental shelf. Left: Akkar shelf and Tripoli-Beirut regions. Left: northern sectors (Akkar shelf and Tripoli-Beirut). Right: southern sectors (Beirut-Saida and Saida-Naqoura).

Repercussions of the Syrian conflict and related safety measures led us to shift southward or to delete sampling stations closer to the Syrian border. Other sampling points were slightly shifted due to technical impediments arisen during sampling activities at sea. Minor differences in mean depth registered at the same stations between years were due to minor differences in the route undertaken during the haul. With the aim of broadening the spectrum of information collected both in terms of better definition of the distribution of demersal species inhabiting the upper sector of the continental slope, a total of 12 sampling stations were added at depths ranging between 165 and 300 meters. Hauls were distributed along the whole coast-line, trying to evenly cover major Lebanese fishing fields (2 hauls in Akkar Shelf, 3 in the Tripoli-Beirut region, 3 in Beirut-Saida, 4 in Saida-Naqoura).

Protocols Set for Sampling Activities and Data Collection

Nine artisanal fishers from nine different ports in Lebanon distributed in the north, south and central regions of the country were chartered to lower the gear at the sampling stations with the specified coordinates in order to benefit from knowledge and familiarity of the fishermen with their usual fishing grounds. Vessels with minimum requirements were selected to carry out fishing operations without endangering crew and staff. The length of the vessels ranged from 8.75 to 11 m and their gross tonnage ranged from 3.10 to 5.01. A global positioning system (GPS) was used to reach the right haul and depth was confirmed using a sonar. Date, type of gear, net meshes, coordinates and depth for each haul were noted.

Sampling gears

In Lebanon, the most important commercial species are typically coastal and distributed over areas where standard trawling cannot be carried out. In this situation, other fishing gears (e.g. longlines, gillnets and traps) had to be used to survey untrawlable areas and species. Moreover, trawling activities are interdicted and no licenses are issued by the Lebanese Government (University of Balamand, 2016). Following the good results obtained in the exploratory fishing survey implemented

in March-May 2012 (Colloca & Lelli, 2012), gillnets were selected as sampling gear for data collection. Moreover, taking into consideration the relatively high CPUEs observed in Lebanese waters when compared with other Mediterranean areas, the dimension of each patch of net was limited to about 250 m length, for a total of 750-1000m of nets employed during each sampling haul.

Gillnets with mesh sizes of 26, 30 and 40 mm were lowered at depths less than 100 m; trammel nets with mesh sizes of 22, 24, 26, 28 and 30 mm were lowered at depths greater than 100 m. The mesh sizes included in net series used for stocks surveying were selected to enable full coverage of the potential size distribution of fish that may be encountered. Due to the incompleteness of the information on the size composition of demersal resources in Lebanon, different mesh sizes covering a wide range and rigged with a hanging ratio around 0.5 had been used. Specifications of technical characteristics of nets used during the fishing surveys are summarised in table 14.

Table 14. Technical characteristics of gillnets and trammel nets used for the implementation of the fishing surveys.

	Gillnets	Trammel Nets
Net yarn		
Material	PA mono-filament	PA multi-filament
Diameter	0.26/0.30/0.30 mm	0.28/0.28/0.30/0.30 mm
Stretched mesh size	52/60/80 mm	22/24/26/30 (internal wall) 44/48/52/60 (external wall)
Panel height	4.4/3.9/3.9 m	3.0 m
Panel length	500/472/500 m	180/240/240/300 m
Colour	light green	light green/ light green/ light yellow/ light yellow
Bolsh twin		
Material	Twisted PE	Twisted PE
Diameter	1.2 mm	6 mm
Float rope		
Material	Twisted PE	Twisted PE
Diameter	12/14/16 mm	6 mm
Length	250 m	180/240/240/300 m
N. bolshes	1920/1560/1250	
Bolsh size	0.13/0.16/0.20 m	
N. meshes per bolsh	5	
Hanging ratio	0.50/0.53/0.5	0.50/0.53/0.50/0.50
Floats		
Material	PVC	PVC
Size	6.7x4.0 cm	8.0x5.0 cm
N. floats	390	
Lead rope		
Material	Twisted PE	Twisted PE
Diameter	12/14/16 mm	4/5/5/6 mm
Length	250 m	180/240/240/300 m
N. bolshes	192/156/125	
Bolsh size	0.13/0.16/0.20 m	
N. meshes per bolsh	5	2
Lead weight	140 g/m	260/666/666/666 g/m
Hanging ratio	0.5/0.53/0.50	0.50/0.53/0.50/0.50

Sampling period

In 2012, a total of 47 hauls were carried out in the period June 9 to September 4, 2012 for a total of 35.25 Km of nets deployed. In 2013, 49 hauls were executed between January 3 and August 29, 2013. A total of 36.75 Km of nets had been lowered up to 150 meters depth. Between September 24 and October 13, 2014, 13 sampling stations located in the Akkar Shelf and Tripoli-Beirut regions were surveyed by means of 13 Km of nets. 12 sampling stations located in deeper waters (165-300 m depth) were surveyed between April 2013 and October 2014.

Measures and biological parameters recorded after collection.

Fishermen lowered the nets in the afternoon and retrieved them 12 hours later at the sunrise. The catch was collected and stored in boxes or bins divided according the mesh size of the net that captured the specimen. Operations of extraction of the catch from the nets were usually completed at the port (with the exception of days with poor catch) where researchers collected and reported on *ad hoc* sheets. Species collected from the survey were identified using the identification guides of (Fischer, et al., 1987) and the three CIESM Atlases on Fishes (Golani, et al., 2002), Crustaceans (Galil, et al., 2002) and Molluscs (Zenetos, et al., 2003). All the individuals collected - irrespective the species - were measured and weighed. Sex and maturity stage were determined for all the individuals. When the catch of a certain species was too abundant to be wholly measured, representative sub-samples of the catch were taken. For fish (bony fishes and Elasmobranches), the total length with the tail fully extended was recorded. The measurement unit is the lower half centimetre. For crustaceans, the cephalon-thoracic length at the lower millimetre was measured, while for cephalopods, the dorsal mantle length at the lower half centimetre was noted down. For octopods, the measure is taken along the line passing through the eyes. Standardised protocols and minimum requirements adopted during the surveys are summarised in [table 15](#).

Table 15. Protocols and minimum requirements adopted.

Nets management	
Soak time	Approximate 12 hours, overnight
Lowering time	Afternoon
Retrieving time	Dawn
Operators	Professional fishermen
Vessels' minimum requirements	
LOA	> 7m
Engine Power	> 16 hp
Winch	Hydraulic or Motorised
Available equipments	GPS, Fishfinder, Safety equipments
Biological data collection	
Biometric: length	Lower half centimetre (fish)
Biometric: weight	Nearest 1 gram
Biological: sex & maturity stages	MEDITS programme protocols (CODES OF SEXUAL MATURITY FOR FISH, CRUSTACEANS AND CEPHALOPODS)
Biometric & Biological Parameters	Collected on all the specimens

Statistical analyses

The catch per unit effort (CPUE) is an indirect measure of the abundance of a target species. Standardized CPUE analysis is widely used to evaluate trends in population density. However, while analyzing data, it has to be taken in mind that mechanism modifying the catchability coefficient or overdispersion of some pelagic species (Fonteneau et al., 1999) can bias our results and lead to relevant mistakes in their interpretation. To reduce the incidence of the catchability factor, we used different types of experimental gears whereas we focused our study on demersal species underexposing our results to bias due to big schools highly dispersed pelagic species. The CPUE was calculated per each species. Each year was calculated separately to standardize the effort (as Km² of nets used) using the statistical software 'R' (R Development Core Team, 2014) in kilogram and in number according to the following:

3. CPUE in kilograms considered by year:

$$CPUE_{Kg, Y} = \frac{\sum W_{i, Y}}{E_{Km^2, Y}}$$

where $W_{i, Y}$ is the weight in Kg per species considered by year, $E_{Km^2, Y}$ is the effort reported as Km² of nets deployed by year.

4. CPUE in number considered by year:

$$CPUE_{Kg, Y} = \frac{\sum N_{i, Y}}{E_{Km^2, Y}}$$

Where $N_{i,y}$ is the number of individual per species considered by year, $E_{Km^2,y}$ is the effort reported as Km² of nets deployed by year.

We used the Pearson's chi-square test (goodness-of-fit or chi-square test for independence) to test the correlation between depth and different taxa's distribution.

Maps were realized and performed on the Quantum Geographic Information System (qGIS) software ([Quantum GIS Development Team, 2012](#)) for the scientific survey data.

RESULTS

2012 survey

A total of 47 hauls using 0.75 km net with three mesh sizes (24, 30, 40 mm) were carried out in the period June 9 to September 4, 2012 between 10 and 150 m depth. 35.25 Km of gillnets were deployed. 583 individuals belonging to 67 species and 46 families were collected with an overall weight of approximately 100 Kg. The catch was composed by:

- 11 crustaceans
- 3 cephalopods
- 51 teleosteans
- 2 elasmobranchs (*Squatina aculeata*, *Raja clavata*)

The catch was generally very poor in most of the sampling points with an average yield lower than 1 specimens/km net for most of the species. The most abundant species was *Sargocentron rubrum*, a by-catch species of gillnets and trammel nets fisheries, with 1,148.93 specimens/km² net, followed by the common pandora (*Pagellus erythrinus*, 283.69 specimens/km² net) and juveniles of amberjack (*Seriola dumerili*, 255.32 specimens/km² net).

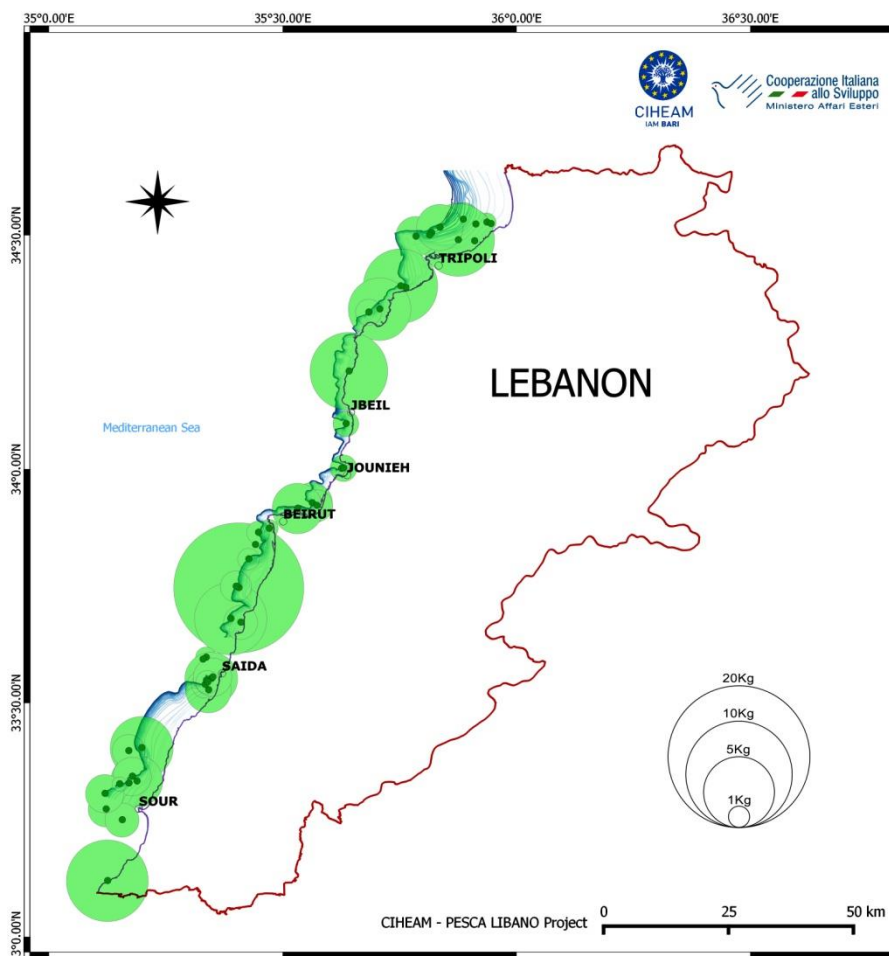


Figure 19. The map representing the total catch per haul (bubble plots of the observed abundances) in 2012 survey.

The entire surveyed area had been broken in two strata. 32 hauls were performed in the shallower one (0-99 meters depth) and 15 in the deeper one (100-150 m). Within the first stratum, bathymetries up to 49 meters were surveyed by means of 19 sampling stations in which 40.8 Kg of overall landings were harvested. This represents 40% of the overall weight of the species caught. 13 sampling points were placed between 50 and 99 meters depths. These resulted to provide the highest yields with 3.2 Kg per haul and 41.2 Kg for the whole substratum. As a result of the hauls carried out in the first stratum, 443 individuals were collected, 36.6% were belonging to the species *S. rubrum*, 7.7% to *S. dumerili*, 4.7% to *P. erythrinus* and 4.1% to *L. sceleratus* (see table 16). Deepest waters ranging from 100 to 150 m counted 15 hauls that provided 20 kg of catches, less than 20% of the overall sampled specimens.

Table 16. Catch per strata in the 2012 survey.

Stratum	Substratum	N. of Hauls	N. of Individuals	Catch (Kg)	Avrg Catch (Kg/haul)	St.dev. σ (Kg)
0 - 99		32	443	82.0	2.64	3.53
	0 - 49	19	262	40.8	2.26	2.25
	50 - 99	13	181	41.2	3.17	4.72
100 - 150		15	122	20.0	1.33	1.38
Total		47	565	102.0		

As a result of the hauls carried out in the second stratum, 122 individuals were collected, 15.6% were belonging to the species *P. erythrinus*, 13.1% to *C. linguatula*, 10.7% to *M. goltziana*, 5.7% to *D. macrophthalmus* and *M. merluccius*.

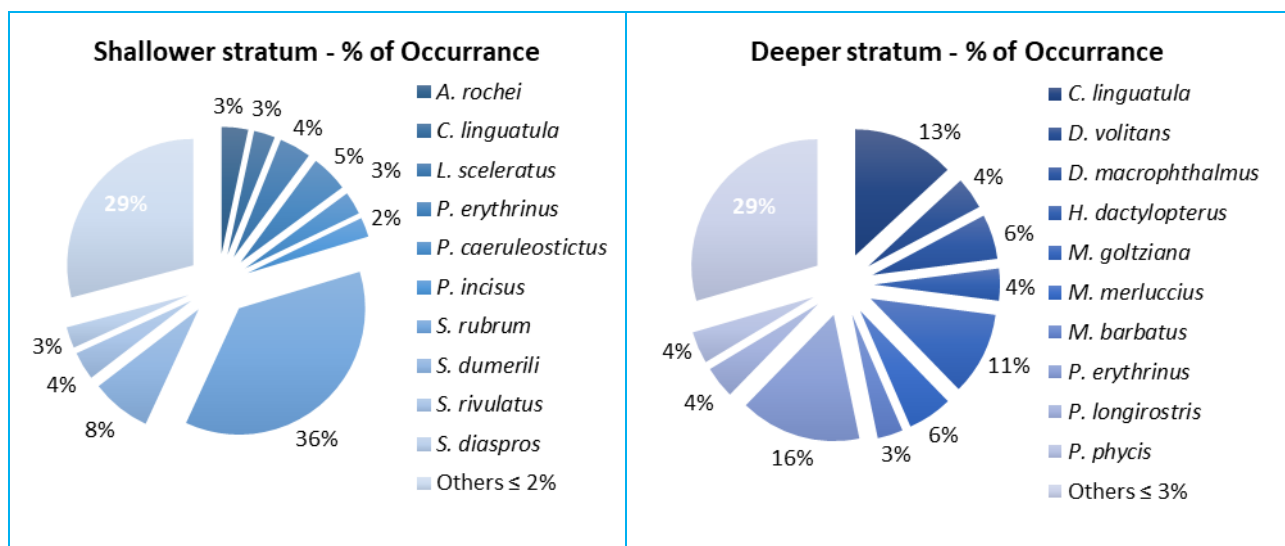


Figure 20. Catch composition (percentage of occurrence) per stratum.

2013 survey

A total of 49 hauls using 0.75 km of gillnets up to 100 meters depth and trammel nets between 100 and 150 m were executed between 10 and 150 m depth. 24.75 Km of gillnets in 33 hauls and 12.0 Km

of trammel nets in 16 hauls had been lowered. 2104 individuals belonging to 100 species and 57 families were collected with an overall weight of approximately 365 Kg. The catch was composed by species belonging to the following groups:

- 15 crustaceans
- 5 cephalopods
- 71 teleosteans
- 9 elasmobranchs

15,585.19 individuals had been collected per Km² of nets. As in the first survey, *S. rubrum* resulted to be by far the most abundant species with yields almost five times higher than the previous survey, i.e. 5444.44 specimens/km² nets. Due to the higher efficiency and reduced selectivity of the nets used in deeper waters, *Aristaeomorpha foliacea* and *Dentex macrophthalmus* showed relatively high yields (1,392.59 and 1200.00 specimens/Km² of nets respectively).

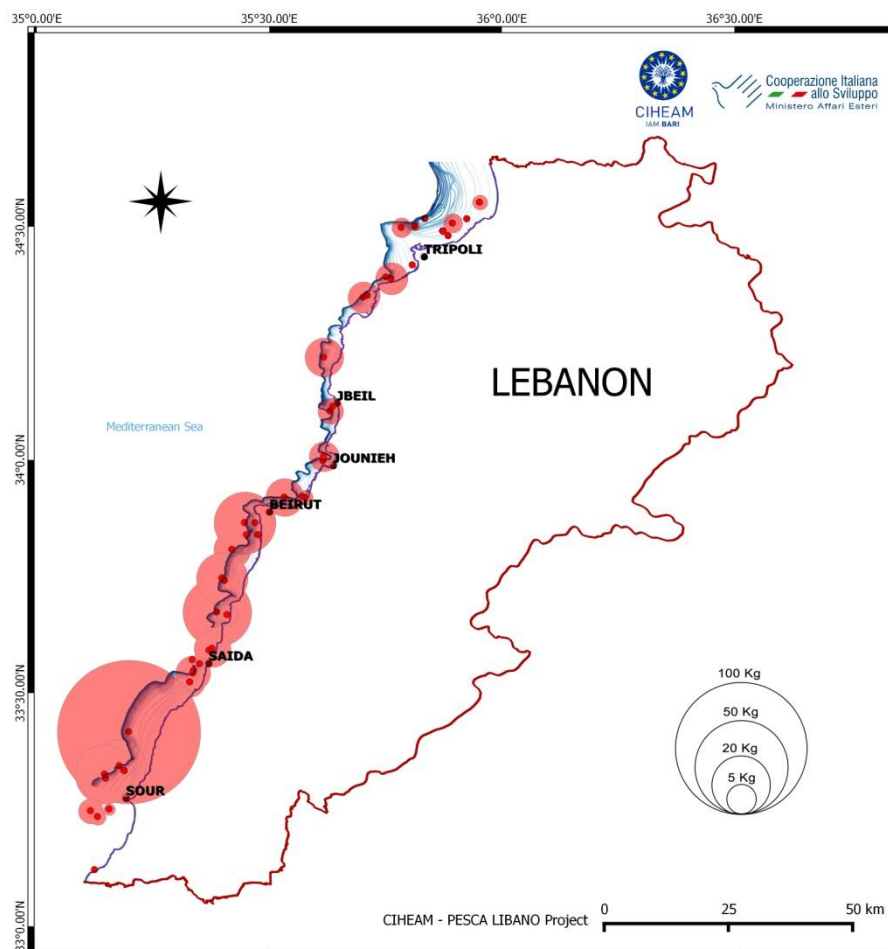


Figure 21. The map representing the total catch per haul (bubble plots of the observed abundances) in survey 2013.

33 hauls were performed in the shallower stratum (0-99 meters depth) and 16 in the deeper one (100-150 m). Within the first stratum, bathymetries up to 49 meters were surveyed by means of 19 sampling stations that returned an overall catch of less than 40 Kg. 13 sampling points were placed between 50 and 99 meters depths providing 73.5 Kg of catch; more than 5 Kg each survey tow (Table 17).

Table 17. Catch per strata in 2013 survey.

Stratum	Substratum	Nr. of Hauls	Nr. of Individuals	Catch (Kg)	Avrg Catch (Kg/haul)	St.dev. σ (Kg)
0 - 99		33	903	112.1	3.40	6.11
	0 - 49	19	343	38.6	2.03	2.12
	50 - 99	14	560	73.5	5.25	8.72
100 - 150		16	1188	250.9	15.68	28.06
Total		49	2091	363.0		

As a result of the hauls carried out in the first stratum, 903 individuals were collected, 73.3% were belonging to the species *S. rubrum*, 3.0% to the crab *P. pelagicus* and 2.9% to *D. vulgaris*. Deepest waters ranging from 100 to 150 m counted 16 hauls that provided 251 kg of catches, more than 69% of the overall sampled specimens. 1188 individuals were collected in this stratum, 15.7% were belonging to the species *A. foliacea*, 13.6% to *D. macrophthalmus*, 6.44% to *M. merluccius* and *P. phycis*.

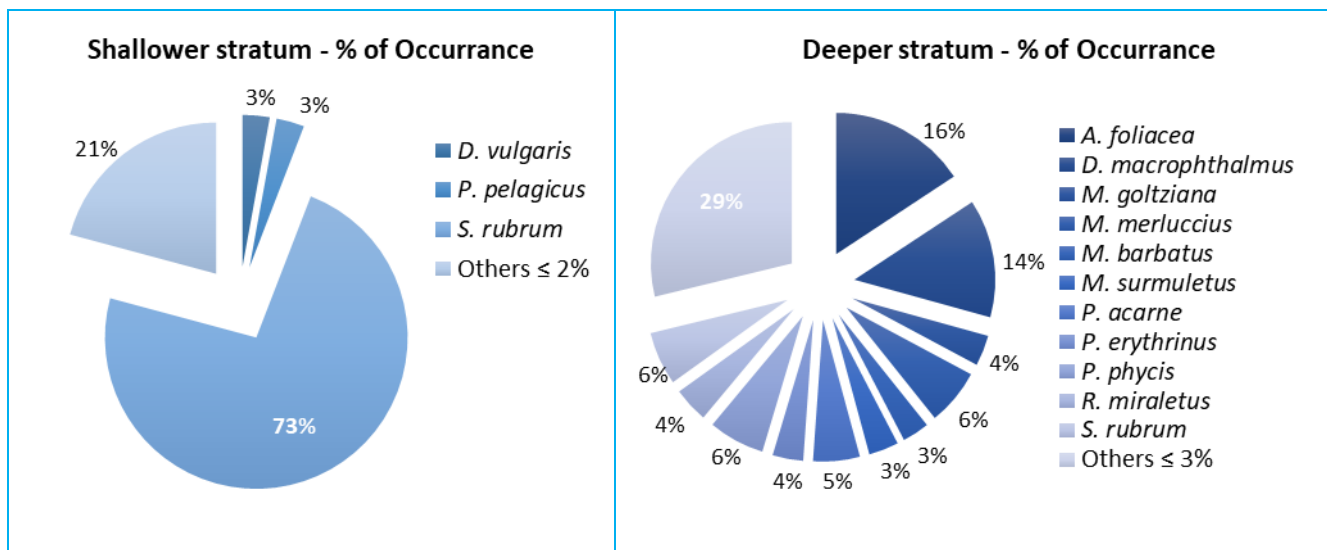


Figure 22. Percentage of occurrence of the most collected species in relation to strata.

2014 survey

A total of 13 hauls using 1 km of trammel nets between 10 and 150 m were carried out in the period September 24 to October 13. 10 Km of nets in 10 hauls in the bathymetric range 0-99 m and 3 Km of in 3 hauls between 100 and 150 m depth had been lowered in the water off Tripoli and the Akkar shelf. 354 individuals belonging to 37 species and 25 families were collected with an overall weight of approximately 38 Kg (Figure 23). The catch was composed by species belonging to the following groups:

- 1 cephalopod (*Sepia officinalis*)
- 34 teleosteans
- 2 elasmobranchs (*Dasyatis pastinaca* and *Rhinobatos rhinobatos*)

9,076.92 individuals had been collected per Km² of nets. As in the previous surveys, *S. rubrum* resulted to be by far the most abundant species, i.e. 5,435.90 specimens/km² nets. Another Lessepsian species, *Siganus rivulatus*, showed relatively elevated yields (871.79 specimens/Km² of nets).

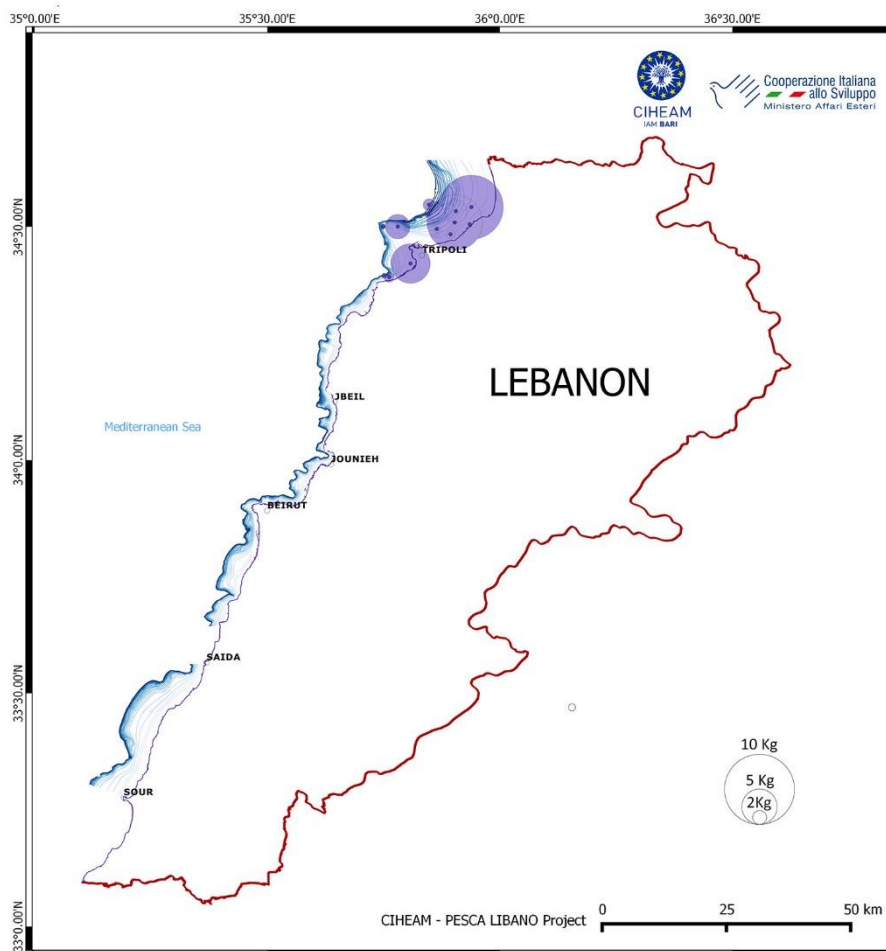


Figure 23. The map representing the total catch per haul (bubble plots of the observed abundances) in survey 2014.

10 hauls were performed in the shallower stratum (0-99 meters depth) returning 33.5 Kg and 3 in the deeper one (100-150 m) providing 4.5 Kg of catch (Table 18).

Table 18. Catch per strata in 2014 survey.

Stratum	Nr. of Hauls	Nr. of Individuals	Catch (Kg)	Avrg Catch (Kg/haul)	St.dev. σ (Kg)
0 - 99	10	325	33.4	3.35	3.02
100 - 150	3	29	4.6	1.52	0.64
Total	13	354	38.1		

As a result of the hauls carried out in the first stratum, 325 individuals were collected, 60.0% were belonging to the species *S. rubrum*, 10.5% to the marbled spinefoot *S. rivulatus* and 2.8% to *F. commersonii*.

Deepest waters ranging from 100 to 150 m counted 3 hauls that provided 4.6 Kg. *S. rubrum* accounted for 58.6% of the collected specimens (all collected at 100 m depth) whereas the bathy-demersal species *Helicolenus dactylopterus* for 31.3%.

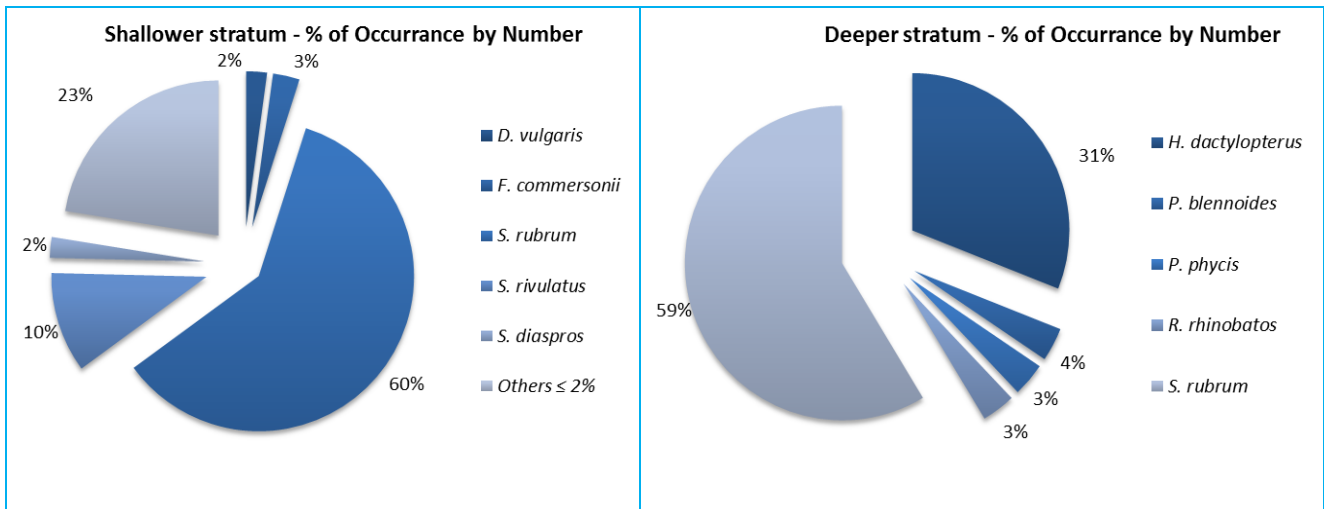


Figure 24. Percentage of occurrence of the most collected species according to stratum.

Deeper waters survey, i.e. beyond 150 meters depth

Twelve sampling stations had been surveyed by means of a total of 12 km of trammel nets at depths ranging between 165 and 300 m depth. Sampling stations were located 2 in the Akkar shelf region, three in the Tripoli-Beirut, three in the Beirut-Saida, four in the Saida-Naqoura region.

538 individuals belonging to 52 species and 36 families were collected with an overall weight of approximately 98.5 Kg. The catch was composed by species belonging to the following groups:

- 10 crustaceans
- 5 cephalopods
- 30 teleosteans
- 6 elasmobranchs

This means that 13,794.87 individuals and had been collected each Km² of nets.

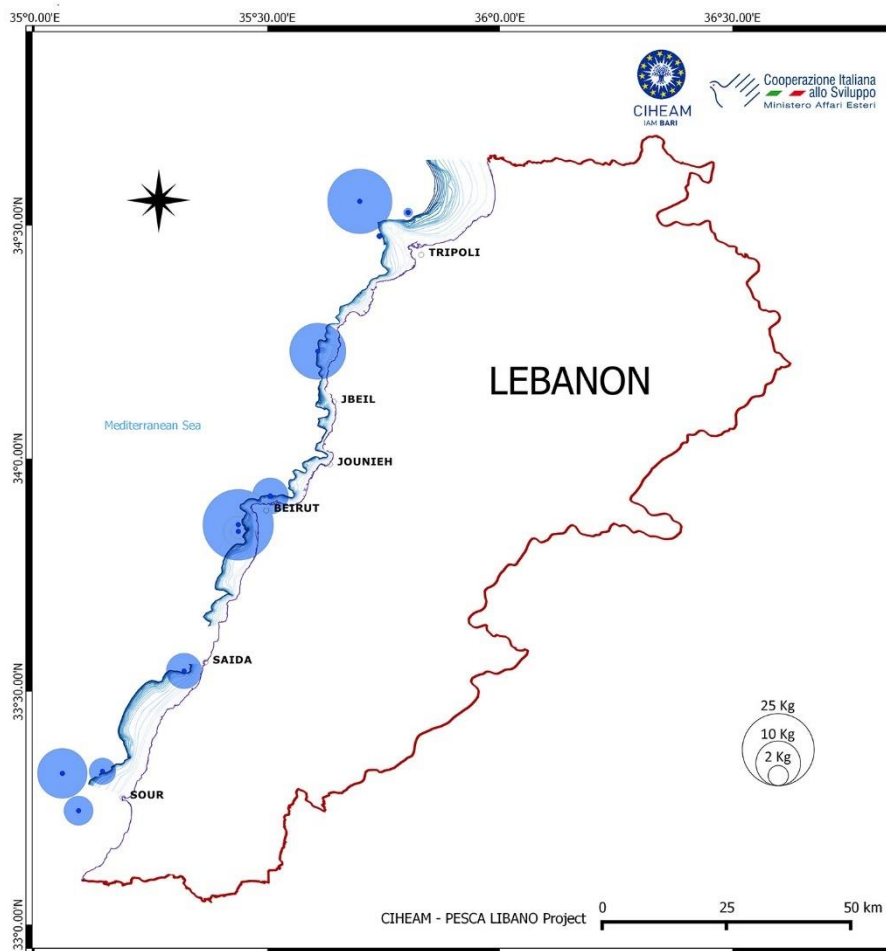


Figure 25. The map representing the total catch for each haul (bubble plots of the observed abundances).

As far as the weight of the resources collected is concerned, the two elasmobranchs *Heptanchias perlo* and *Centrophorus granulosus* were the most abundant species, respectively 13.0 Kg (three individuals) and 10.9 Kg (two individuals). 54 individuals and 10.9 Kg of *Phycis phycis* were pulled aboard. In terms of number of specimens collected, *D. macrophthalmus* resulted to be the most numerous with 2435.90 specimens/km² nets (17.66% of all collected specimens), followed by *A. foliacea* 1923.08 specimens/km² nets with an occurrence of 13.94%.

Aggregated dataset

In three years of data collection, a total of 121 hauls were executed and 97 Km of nets (0.351 Km²) were lowered. 3,579 specimens belonging to 129 species and 73 families were collected with an overall weight of 601 Kg. The catch was composed by species belonging to the following taxa:

- 18 crustaceans
- 8 cephalopods
- 91 teleosteans
- 12 elasmobranchs

Sargocentron rubrum is the most abundant species, with the highest numerical occurrence, overall weight and CPUE, i.e. 3159.54 specimens/km² nets. Species composition, abundance and depth distribution is shown in Table 19.

Among the bony fish species, six (*Dentex dentex*, *Epinephelus aeneus*, *E. marginatus*, *Merluccius merluccius*, *Sardinella maderensis*, and *Sciaena umbra*) are included in the IUCN Red List as considered threatened to a certain extent with extinction. *Dentex macrophthalmus* was the second species in terms of numerical abundance and occurrence (CPUE=754.986 specimens every Km² of nets), whereas *Phycis phycis*, *M. merluccius* and *Lagocephalus sceleratus* were reported relatively high in weight (27.334 Kg, 24.902 Kg and 24.584 Kg respectively collected). Neither crustaceans nor cephalopods species reported in this study were included in the IUCN Red List. The giant red shrimp *Aristaeomorpha foliacea* was found relatively abundant in the lower part of the continental shelf and upper slope (754.986 specimens/Km² nets) while the spiny spider crab *Maja goletziana* was the most abundant crustacean in weight (15.351 Kg). *Sepia officinalis* (16 specimens and 2.150 Kg collected) was the most abundant cephalopod. Among 12 species of elasmobranchs caught in this study, 6 are considered threatened with extinction by the IUCN Red List. Among those, *Gymnura altavela* and *Squatina aculeata* are considered critically endangered, facing an extremely high risk of extinction in the wild. *Raja miraletus* was the most abundant in terms of number of specimens collected (N=52, 148.148 specimens/Km² nets) whereas *Centrophorus granulosus* was the second most abundant species in weight of the whole study (105.000 Kg).

Table 19. List of species collected in the 4 surveys 2012, 2013, 2014 and deeper waters in the eastern Mediterranean. Total weight per species stated in grams (*Tot Weight (g)*), number of specimens collected (*No Specs*), percentage of occurrence in sampling stations (*O%*, and by year) CPUE (number of specimens by Km² of nets and kg/Km² of nets) percentage of specimens (number of specimens over the total number of specimens collected). Last four columns report the species' occurrence by depth stratum (*SSh*=shallow shelf, < 50 m depth; *MSh*=medium shelf, 50 to 99 m depth; *DSh*=deep shelf, 100 to 150 m depth; *CSl*=upper continental slope, 151 to 300 m depth). *=1 to 10 specimens; **=10 to 50 specimens; ***= >50 specimens.

In the column "species", in [] the International Union for the Conservation of Nature (IUCN) Red List Category for each species caught: no mentions=no assessment or data deficiency or least concern; *CR*=Critically Endangered; *EN*=Endangered; *VU*=Vulnerable; *NT*=Near Threatened. When categorization differs, Mediterranean category is reported as "*in Med*". (*L*)=Lessepsian migrant.

Species	Family	Tot Weight (g)	No Specs	O%	O% 2012	O% 2013	O% 2014	CPUE (Specs/ Km ² nets)	CPUE (Weight/ Km ² nets)	% (No Specs/ Specs Tot)	SSh	MSh	DSh	CSl
<i>Aulopus filamentosus</i>	Aulopidae	466	3	2.479	0.000	5.085	0.000	8.547	1.328	0.08				*
<i>Auxis rochei</i>	Scombridae	7957	23	19.008	34.043	11.864	0.000	65.527	22.670	0.64	**	*	*	*
<i>Balistes capriscus</i>	Balistidae	90	1	0.826	0.000	0.000	6.667	2.849	0.256	0.03	*			
<i>Boops boops</i>	Sparidae	27	1	0.826	0.000	1.695	0.000	2.849	0.077	0.03			*	
<i>Bothus podas podas</i>	Bothidae	23.9	1	0.826	2.128	0.000	0.000	2.849	0.068	0.03		*		
<i>Capros aper</i>	Caproidae	16	1	0.826	0.000	1.695	0.000	2.849	0.046	0.03			*	
<i>Caranx crysos</i>	Carangidae	311	1	0.826	2.128	0.000	0.000	2.849	0.886	0.03	*			
<i>Chauliodus sloani</i>	Stomiidae	3	1	0.826	0.000	1.695	0.000	2.849	0.009	0.03			*	
<i>Chelidonichthys lucerna</i>	Triglidae	358	5	4.132	0.000	8.475	0.000	14.245	1.020	0.14			*	
<i>Chlorophthalmus agassizii</i>	Chlorophthalmidae	17	1	0.826	0.000	1.695	0.000	2.849	0.048	0.03				*
<i>Citharus linguatula</i>	Citharidae	2480	61	50.413	59.574	55.932	0.000	173.789	7.066	1.70	*	*	**	*
<i>Coelorinchus caelorhincus</i>	Macrouridae	1040	33	27.273	0.000	55.932	0.000	94.017	2.963	0.92			**	**
<i>Conger conger</i>	Congridae	8903	12	9.917	0.000	20.339	0.000	34.188	25.365	0.34	*		*	*
<i>Dactylopterus volitans</i>	Dactylopteridae	7423.6	16	13.223	29.787	3.390	0.000	45.584	21.150	0.45		*	*	
<i>Dentex dentex</i> [VU]	Sparidae	1539.2	4	3.306	0.000	6.780	0.000	11.396	4.385	0.11	*	*	*	
<i>Dentex macrophthalmus</i>	Sparidae	11714.3	265	219.008	17.021	435.593	0.000	754.986	33.374	7.40		*	***	***
<i>Dentex maroccanus</i>	Sparidae	374	7	5.785	0.000	11.864	0.000	19.943	1.066	0.20			*	
<i>Diplodus annularis</i>	Sparidae	34	1	0.826	0.000	1.695	0.000	2.849	0.097	0.03	*			
<i>Diplodus sargus sargus</i>	Sparidae	1138.5	16	13.223	12.766	13.559	13.333	45.584	3.244	0.45	**	*		
<i>Diplodus vulgaris</i>	Sparidae	2286.9	36	29.752	6.383	44.068	46.667	102.564	6.515	1.01	*			
<i>Echelus myrus</i>	Ophichthidae	249	1	0.826	0.000	1.695	0.000	2.849	0.709	0.03			*	
<i>Echeneis naucrates</i>	Echeneidae	288.7	2	1.653	2.128	0.000	6.667	5.698	0.823	0.06		*	*	
<i>Epinephelus aeneus</i> [NT]	Serranidae	7343.1	4	3.306	6.383	1.695	0.000	11.396	20.921	0.11		*	*	
<i>Epinephelus marginatus</i> [EN]	Serranidae	560	2	1.653	4.255	0.000	0.000	5.698	1.595	0.06		*		
<i>Epinephelus sp.</i>	Serranidae	340	1	0.826	0.000	1.695	0.000	2.849	0.969	0.03		*		
<i>Etrumeus teres</i> (L)	Dussumieriidae	737.5	11	9.091	14.894	0.000	26.667	31.339	2.101	0.31		**		

<i>Euthynnus alletteratus</i>	Scombridae	2795.6	9	7.438	2.128	13.559	0.000	25.641	7.965	0.25	*	*		
<i>Fish (NOT IDENTIFIED)</i>	NA	16	1	0.826	0.000	1.695	0.000	2.849	0.046	0.03			*	
<i>Fistularia commersonii</i> (L)	Fistulariidae	10120.3	26	21.488	8.511	22.034	60.000	74.074	28.833	0.73	*	**	*	
<i>Helicolenus dactylopterus</i>	Sebastidae	6230.1	73	60.331	29.787	79.661	80.000	207.977	17.750	2.04	*	*	**	**
<i>Hoplostethus mediterraneus</i>	Trachichthyidae	349	15	12.397	0.000	25.424	0.000	42.735	0.994	0.42			*	*
<i>Lagocephalus sceleratus</i> (L)	Tetraodontidae	24583.6	28	23.140	44.681	6.780	20.000	79.772	70.039	0.78	**	**	*	*
<i>Lagocephalus spadiceus</i> (L)	Tetraodontidae	1551.5	6	4.959	0.000	1.695	33.333	17.094	4.420	0.17	*	*		*
<i>Lepidorhombus boscii</i>	Scophthalmidae	142.2	1	0.826	2.128	0.000	0.000	2.849	0.405	0.03			*	
<i>Lepidorhombus whiffiagonis</i>	Scophthalmidae	1327.9	3	2.479	2.128	3.390	0.000	8.547	3.783	0.08	*		*	*
<i>Lithognathus mormyrus</i>	Sparidae	677.9	7	5.785	6.383	6.780	0.000	19.943	1.931	0.20	*			
<i>Liza ramada</i>	Mugilidae	496.9	2	1.653	0.000	0.000	13.333	5.698	1.416	0.06	*			
<i>Lophius budegassa</i>	Lophiidae	4640	3	2.479	0.000	5.085	0.000	8.547	13.219	0.08			*	*
<i>Merluccius merluccius</i> [VU] in Med	Merlucciidae	24902	103	85.124	14.894	162.712	0.000	293.447	70.946	2.88		*	***	**
<i>Microchirus ocellatus</i>	Soleidae	129.9	5	4.132	2.128	6.780	0.000	14.245	0.370	0.14		*	*	
<i>Mullus barbatus</i>	Mullidae	4373.9	45	37.190	12.766	66.102	0.000	128.205	12.461	1.26		*	***	*
<i>Mullus sp.</i>	Mullidae	190	1	0.826	0.000	1.695	0.000	2.849	0.541	0.03		*		
<i>Mullus surmuletus</i>	Mullidae	6648	50	41.322	0.000	84.746	0.000	142.450	18.940	1.40			***	*
<i>Muraena helena</i>	Muraenidae	5669	6	4.959	0.000	10.169	0.000	17.094	16.151	0.17		*	*	
<i>Mycteroperca rubra</i>	Serranidae	2221.2	11	9.091	8.511	11.864	0.000	31.339	6.328	0.31	*	*	*	
<i>Nemipterus randalli</i> (L)	Nemipteridae	864.4	13	10.744	2.128	15.254	20.000	37.037	2.463	0.36		*	*	
<i>Oblada melanura</i>	Sparidae	454.2	4	3.306	2.128	1.695	13.333	11.396	1.294	0.11	*			
<i>Ophidion barbatum</i>	Ophidiidae	30	1	0.826	0.000	1.695	0.000	2.849	0.085	0.03			*	
<i>Pagellus acarne</i>	Sparidae	6363.8	125	103.306	6.383	203.390	13.333	356.125	18.130	3.49	*	*	***	***
<i>Pagellus erythrinus</i>	Sparidae	8755.3	97	80.165	85.106	86.441	40.000	276.353	24.944	2.71	**	**	***	*
<i>Pagrus auriga</i>	Sparidae	298.5	1	0.826	2.128	0.000	0.000	2.849	0.850	0.03			*	
<i>Pagrus caeruleostictus</i>	Sparidae	5303.1	30	24.793	27.660	23.729	20.000	85.470	15.109	0.84	**	*	*	*
<i>Pagrus pagrus</i>	Sparidae	5118.8	30	24.793	17.021	37.288	0.000	85.470	14.583	0.84	*	*	**	*
<i>Pegusa impar</i>	Soleidae	74	1	0.826	0.000	1.695	0.000	2.849	0.211	0.03	*			
<i>Pempheris vanicolensis</i> (L)	Pempheridae	653.2	13	10.744	19.149	6.780	0.000	37.037	1.861	0.36	*	*	*	
<i>Phycis blennoides</i>	Phycidae	2885.5	23	19.008	0.000	37.288	6.667	65.527	8.221	0.64			**	*
<i>Phycis phycis</i>	Phycidae	27334.7	145	119.835	14.894	232.203	6.667	413.105	77.877	4.05	*	*	***	***
<i>Pomadasys incisus</i>	Haemulidae	1939.7	18	14.876	23.404	8.475	13.333	51.282	5.526	0.50	**	*		
<i>Pomadasys stridens</i> (L)	Haemulidae	65.1	1	0.826	0.000	0.000	6.667	2.849	0.185	0.03		*		
<i>Pseudocaranx dentex</i>	Carangidae	190	1	0.826	2.128	0.000	0.000	2.849	0.541	0.03	*			
<i>Sardinella aurita</i>	Clupeidae	405.9	6	4.959	8.511	3.390	6.667	17.094	1.156	0.17	*		*	
<i>Sardinella maderensis</i> [VU]	Clupeidae	139.3	1	0.826	0.000	0.000	0.000	2.849	0.397	0.03	*			

<i>Sargocentron rubrum</i> (L)	Holocentridae	108189	1109	916.529	344.681	1245.763	1413.333	3159.544	308.231	30.99	***	***	***
<i>Saurida lessepsianus</i> (L)	Synodontidae	17	1	0.826	0.000	1.695	0.000	2.849	0.048	0.03			*
<i>Sciaena umbra</i> [NT]-[VU] in Med	Sciaenidae	738.6	6	4.959	10.638	1.695	0.000	17.094	2.104	0.17	*		
<i>Scomber japonicus</i>	Scombridae	1493.2	21	17.355	25.532	10.169	20.000	59.829	4.254	0.59	**	*	*
<i>Scomber scombrus</i>	Scombridae	1056	7	5.785	0.000	11.864	0.000	19.943	3.009	0.20			*
<i>Scorpaena elongata</i>	Scorpaenidae	7116	31	25.620	0.000	52.542	0.000	88.319	20.274	0.87		*	** **
<i>Scorpaena notata</i>	Scorpaenidae	1279	10	8.264	0.000	16.949	0.000	28.490	3.644	0.28			* *
<i>Scorpaena porcus</i>	Scorpaenidae	814.6	5	4.132	0.000	3.390	20.000	14.245	2.321	0.14	*	*	
<i>Scorpaena scrofa</i>	Scorpaenidae	1051.4	11	9.091	4.255	11.864	13.333	31.339	2.995	0.31	*	*	* *
<i>Seriola dumerili</i>	Carangidae	8413.5	42	34.711	76.596	10.169	0.000	119.658	23.970	1.17	**	*	*
<i>Serranus cabrilla</i>	Serranidae	975.7	17	14.050	0.000	20.339	33.333	48.433	2.780	0.47	*	*	* *
<i>Serranus scriba</i>	Serranidae	109	1	0.826	0.000	0.000	6.667	2.849	0.311	0.03	*		
<i>Siganus luridus</i> (L)	Siganidae	2032.1	21	17.355	14.894	22.034	6.667	59.829	5.789	0.59	**	*	*
<i>Siganus rivulatus</i> (L)	Siganidae	4640.5	67	55.372	34.043	28.814	226.667	190.883	13.221	1.87	***	**	*
<i>Solea solea</i>	Soleidae	346	2	1.653	0.000	3.390	0.000	5.698	0.986	0.06			*
<i>Sparisoma cretense</i>	Scaridae	316.7	5	4.132	2.128	0.000	26.667	14.245	0.902	0.14	*	*	
<i>Sphoeroides pachygaster</i>	Tetraodontidae	2659	3	2.479	0.000	5.085	0.000	8.547	7.575	0.08			* *
<i>Stephanolepis diaspros</i> (L)	Monacanthidae	2513	26	21.488	27.660	10.169	46.667	74.074	7.160	0.73	**	*	*
<i>Synodus saurus</i>	Synodontidae	82	1	0.826	2.128	0.000	0.000	2.849	0.234	0.03	*		
<i>Trachinotus ovatus</i>	Carangidae	416.6	4	3.306	0.000	1.695	20.000	11.396	1.187	0.11	*	*	
<i>Trachinus draco</i>	Trachinidae	540.6	1	0.826	2.128	0.000	0.000	2.849	1.540	0.03		*	
<i>Trachinus radiatus</i>	Trachinidae	162	1	0.826	0.000	1.695	0.000	2.849	0.462	0.03		*	*
<i>Trachinus sp.</i>	Trachinidae	319	1	0.826	0.000	1.695	0.000	2.849	0.909	0.03	*		
<i>Trachurus picturatus</i>	Carangidae	5805.9	21	17.355	0.000	33.898	6.667	59.829	16.541	0.59			**
<i>Trachurus trachurus</i>	Carangidae	200.7	4	3.306	0.000	0.000	26.667	11.396	0.572	0.11		*	
<i>Trichiurus lepturus</i>	Trichiuridae	254	3	2.479	2.128	3.390	0.000	8.547	0.724	0.08			* *
<i>Trigloporus lastoviza</i>	Triglidae	1313.5	18	14.876	14.894	18.644	0.000	51.282	3.742	0.50	*	*	* *
<i>Trygla lyra</i>	Triglidae	157.3	5	4.132	10.638	0.000	0.000	14.245	0.448	0.14			*
<i>Umbrina cirrosa</i>	Sciaenidae	1077	4	3.306	0.000	6.780	0.000	11.396	3.068	0.11	*		*
<i>Upeneus moluccensis</i> (L)	Mullidae	54	2	1.653	0.000	3.390	0.000	5.698	0.154	0.06			*
<i>Uranoscopus scaber</i>	Uranoscopidae	1411.6	8	6.612	2.128	8.475	13.333	22.792	4.022	0.22	*	*	*
<i>Xyrichthys novacula</i>	Labridae	83.6	2	1.653	2.128	0.000	6.667	5.698	0.238	0.06	*		
<i>Aristaeomorpha foliacea</i>	Aristeidae	8059.6	265	219.008	4.255	445.763	0.000	754.986	22.962	7.40		*	*** **
<i>Aristeus antennatus</i>	Aristeidae	383.1	12	9.917	2.128	18.644	0.000	34.188	1.091	0.34			* *
<i>Calappa granulata</i>	Calappidae	4312.3	26	21.488	6.383	38.983	0.000	74.074	12.286	0.73		*	** **
<i>Charybdis longicollis</i> (L)	Portunidae	343.8	17	14.050	0.000	28.814	0.000	48.433	0.979	0.47	*	*	* *

<i>Goneplax rhomboides</i>	Goneplacidae	4	1	0.826	0.000	1.695	0.000	2.849	0.011	0.03				*
<i>Homola barbata</i>	Homolidae	29	3	2.479	0.000	5.085	0.000	8.547	0.083	0.08				* *
<i>Liocarcinus depurator</i>	Portunidae	156	5	4.132	8.511	1.695	0.000	14.245	0.444	0.14	*	*		*
<i>Maja goltziana</i>	Majidae	15351.3	107	88.430	40.426	149.153	0.000	304.843	43.736	2.99		*	***	**
<i>Marsupenaeus japonicus</i> (L)	Penaeidae	24.3	3	2.479	2.128	3.390	0.000	8.547	0.069	0.08	*			
<i>Medorippe lanata</i>	Dorippidae	15	1	0.826	0.000	1.695	0.000	2.849	0.043	0.03				*
<i>Myra subgranulata</i> (L)	Leucosiidae	104	3	2.479	0.000	3.390	0.000	8.547	0.296	0.08				*
<i>Parapandalus narval</i>	Pandalidae	14	2	1.653	0.000	3.390	0.000	5.698	0.040	0.06				*
<i>Parapenaeus longirostris</i>	Pandalidae	236.1	19	15.702	12.766	22.034	0.000	54.131	0.673	0.53	*		**	*
<i>Parthenope sp.</i>	Parthenopidae	259	9	7.438	0.000	15.254	0.000	25.641	0.738	0.25				* *
<i>Plesionika edwardsi</i>	Pandalidae	20	2	1.653	0.000	3.390	0.000	5.698	0.057	0.06				*
<i>Portunus pelagicus</i> (L)	Portunidae	2633.1	39	32.231	25.532	45.763	0.000	111.111	7.502	1.09	**	*		
<i>Scyllarides latus</i>	Scyllaridae	449.7	2	1.653	2.128	1.695	0.000	5.698	1.281	0.06				*
<i>Squilla mantis</i>	Squillidae	41.6	1	0.826	2.128	0.000	0.000	2.849	0.119	0.03				*
<i>Illex coindetii</i>	Ommastrephidae	1181	7	5.785	6.383	6.780	0.000	19.943	3.365	0.20				* *
<i>Loligo vulgaris</i>	Loliginidae	180	1	0.826	2.128	0.000	0.000	2.849	0.513	0.03	*			
<i>Octopus vulgaris</i>	Octopodidae	1165	2	1.653	0.000	3.390	0.000	5.698	3.319	0.06	*			*
<i>Sepia elongata</i>	Sepiidae	85	1	0.826	0.000	1.695	0.000	2.849	0.242	0.03				*
<i>Sepia officinalis</i>	Sepiidae	2150.4	16	13.223	0.000	22.034	20.000	45.584	6.126	0.45	*	*	*	*
<i>Sepia orbignyana</i>	Sepiidae	701	9	7.438	0.000	15.254	0.000	25.641	1.997	0.25		*	*	*
<i>Sepia sp.</i>	Sepiidae	136	1	0.826	0.000	1.695	0.000	2.849	0.387	0.03				*
<i>Todarodes sagittatus</i>	Ommastrephidae	622	2	1.653	4.255	0.000	0.000	5.698	1.772	0.06				*
<i>Todaropsis eblanae</i>	Ommastrephidae	120	1	0.826	0.000	1.695	0.000	2.849	0.342	0.03				*
<i>Centrophorus granulosus</i>	Centrophoridae	105000	21	17.355	0.000	35.593	0.000	59.829	299.145	0.59			**	*
<i>Dalatias licha</i> [NT] – [VU] in Med	<i>Dalatiidae</i>	13200	2	1.653	0.000	3.390	0.000	5.698	37.607	0.06				*
<i>Dasyatis marmorata</i>	Dasyatidae	2780	4	3.306	0.000	6.780	0.000	11.396	7.920	0.11	*	*		*
<i>Dasyatis pastinaca</i>	Dasyatidae	4071	4	3.306	0.000	3.390	13.333	11.396	11.598	0.11			*	*
<i>Gymnura altavela</i> [VU] – [CR] in Med	Gymnuridae	453	1	0.826	0.000	1.695	0.000	2.849	1.291	0.03				*
<i>Heptranchias perlo</i> [NT]	Hexanchidae	13000	3	2.479	0.000	5.085	0.000	8.547	37.037	0.08				*
<i>Raja clavata</i> [NT]	Rajidae	18340	21	17.355	2.128	33.898	0.000	59.829	52.251	0.59			*	* **
<i>Raja miraletus</i>	Rajidae	11717	52	42.975	0.000	88.136	0.000	148.148	33.382	1.45			*	** *
<i>Rhinobatos rhinobatos</i> [EN]	Rhinobatidae	2180	3	2.479	0.000	0.000	20.000	8.547	6.211	0.08			*	*
<i>Squatina aculeata</i> [CR]	Squatinae	12000	1	0.826	2.128	0.000	0.000	2.849	34.188	0.03			*	
<i>Torpedo marmorata</i>	Torpedinidae	7646	22	18.182	0.000	37.288	0.000	62.678	21.783	0.61	*		**	*
<i>Torpedo nobiliana</i>	Torpedinidae	2635	7	5.785	0.000	11.864	0.000	19.943	7.507	0.20				*

Depth distribution

The relationship between depth and catch per unit of effort (CPUE) is shown in Figure 26. Net surface was calculated separately according to depth to normalize abundance results. Numerical abundance was significantly correlated with depth. Teleosteans (bony fishes) showed highest CPUE over the coastal shelf. Crustaceans and elasmobranchs showed highest abundances in deeper waters, over the deeper shelf and the upper slope. Cephalopods showed an unclear trend with bulk of abundance in the medium-deeper shelf and a sharp peak at 250 m depth.

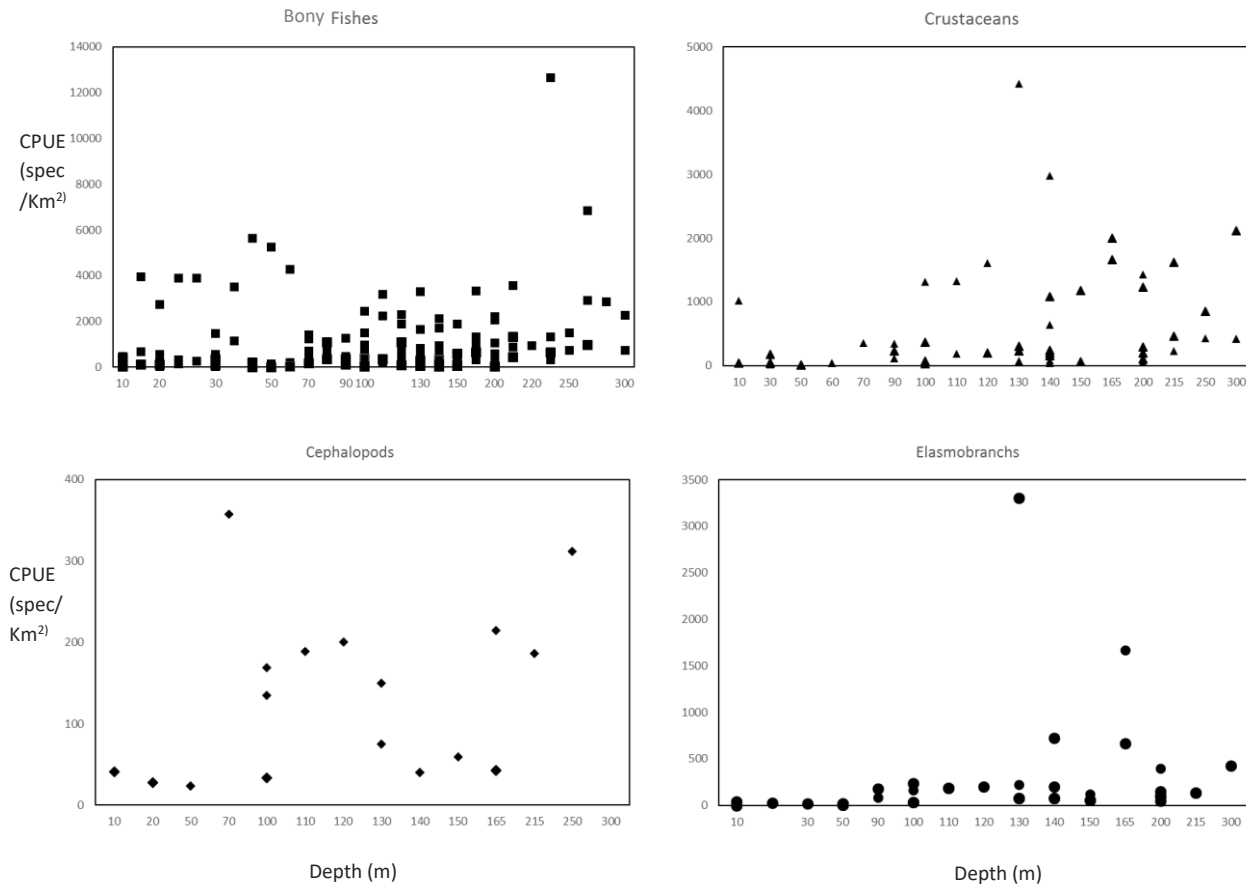


Figure 26. Relationship between sampling depth and CPUE in specimens/Km² of nets for the main taxa of demersal organisms obtained in the eastern Mediterranean Sea.

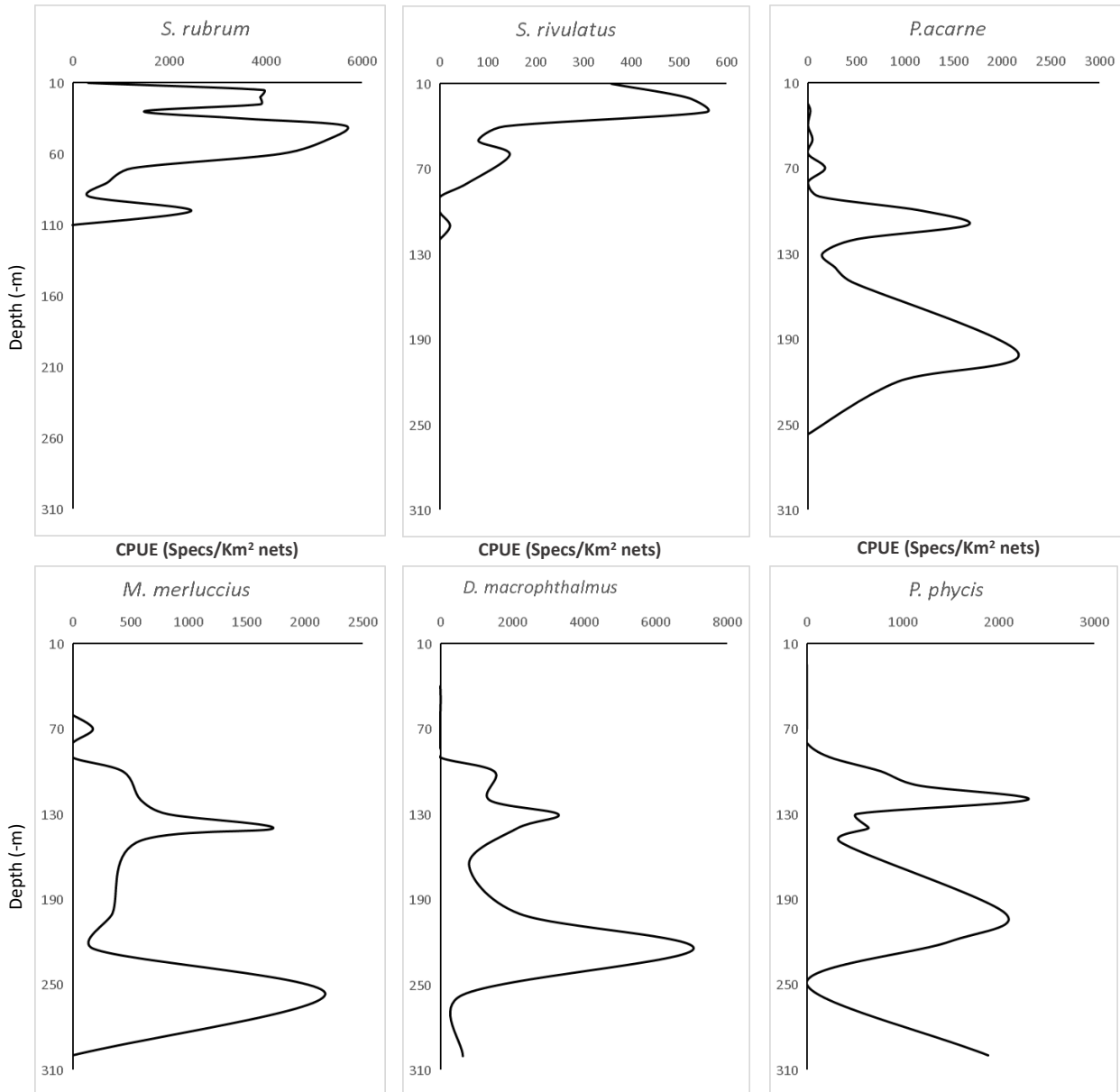
The relationships between depth and CPUE for some of the most abundant demersal species according to this study is shown in Figure 27. A variety of patterns of the bathymetric distribution of the studied species was found:

S. rubrum and *Siganus rivulatus* exhibited a distribution restricted to the coastal shelf with bulk of abundance set between 30 and 40 m depth. *Pagellus acarne* showed a wide distribution with few specimens collected between 30 and 80 meters, a bulk at 200 meters with a decreasing trend down to 220 meters depth.

Four species (*Merluccius merluccius*, *Dentex macrpphthalmus*, *Phycis phycis* and *Maja goltziana*) showed an increasing trend of population density with depth, within the depth range of this study. For *P. phycis* and *M. goltziana*, we can assume that there was a peak in population density deeper than the maximum depth surveyed. These species also reveal a bulk of abundance at 120-140 meters.

A. foliacea showed the highest abundance between 130 and 140 meters followed by a decreasing trend of population density with depth. At the deepest limit of the depth distribution of this study, this species showed a growing trend that make us presume a peak in population density deeper than the maximum depth surveyed.

Raja miraletus showed a narrow depth distribution mainly limited to 130 meters; 85% of the specimens were collected at this depth.



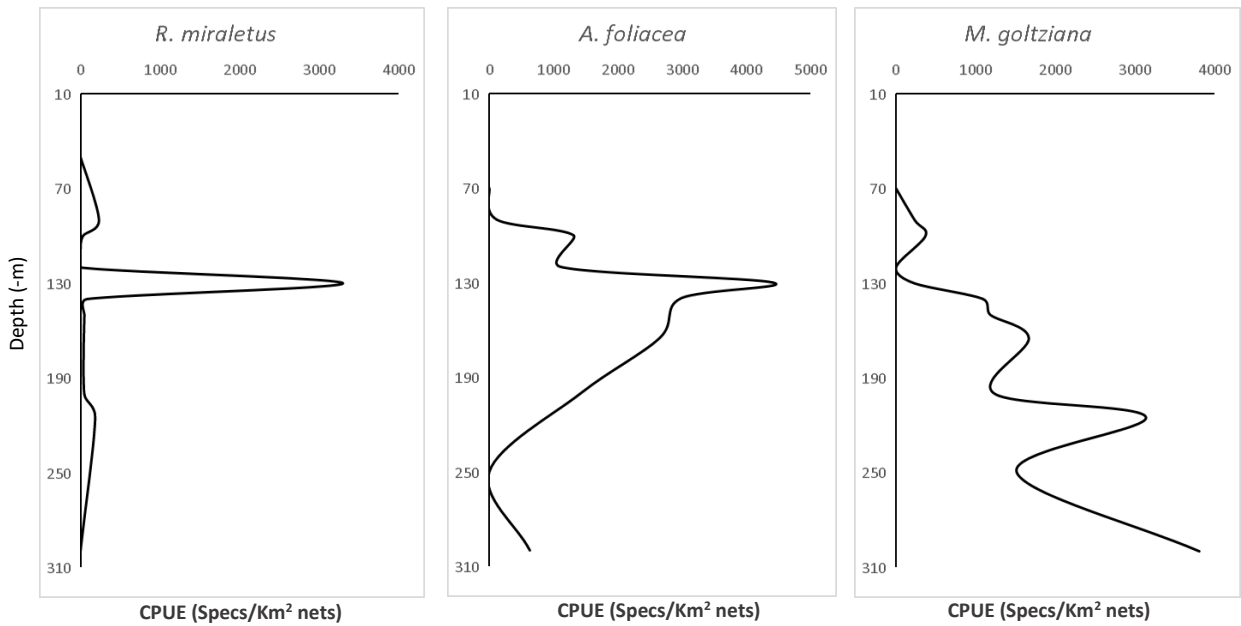


Figure 27. Depth distribution between 10 and 300 meters depth for nine species in the eastern Mediterranean.

Lessepsian species. As shown in [table 19](#), a total of 17 Lessepsian species (distributed in 14 families), 13 teleosteans and 4 crustaceans were collected in our study. They amounted to almost 160 Kg and 1386 specimens collected: this represents 26.47% of the total weight and 38.73% in number of specimens collected. Only 4 individuals (315 g) belonging to the three Lessepsian species, *Charybdis longicollis*, *Lagocephalus sceleratus* and *L. spadiceus* were collected over the upper slope, representing 0.29% of the total number of Lessepsian specimens collected for this study.

DISCUSSION

Coastal, demersal stocks are subject to various threats worldwide, especially in the Mediterranean Sea, which is considered a hotspot of biodiversity but at the same time a hotspot of threat for demersal species (Coll, et al., 2010; Ben Rais Lasram, et al., 2008). Overfishing, bycatch, introduction of non-indigenous species (NIS), pollution, habitat loss and climate change are the foremost sources of stress affecting this fish group (Coll, et al., 2010). Presence and status of demersal populations has been described for most regions of the Mediterranean (e.g. Colloca, et al., 2003; Gaertner, et al., 2007; Quignard & Tomasini, 2007; Ben Rais Lasram, et al., 2009; Coll, et al., 2010; Gaertner, et al., 2013; Granger, et al., 2015) with the exception of the eastern basin and notably along the Lebanese coast where information on abundance, distribution and assemblages of demersal species is still deficient. As such, the Levantine Basin is described as low in species richness, due to the unfavourable conditions prevailing in the area - such as high salinity (Por & Dimentman, 2006) - but also, most likely to a reduced sampling effort. A lack of data in several eastern and southern regions of the Mediterranean basin may have strongly influenced results and considerations on spatial patterns.

This study represents the only evaluation of demersal resources, distribution and diversity along the Lebanese coast, Eastern Mediterranean since around 50 years. This paper shows results obtained from landings obtained by fisheries independent scientific surveys carried out in Lebanese coastal waters.

Sampling protocol

We deemed fishery-independent survey as the most appropriate tool to provide valuable measures of relative abundance, rates of population change and size and sex composition for a wide range of demersal species. In fact, fishery-independent surveys form the cornerstone of many stock assessments for bony fishes and shellfish species, as they are less subject to the unknown and often confounding factors that complicate the interpretation of fishery-dependent indices of stock status (Rago, 2005). Thus fishery-independent surveys strike a balance between the ability to make inferences about one or more populations versus the usage of a specific area by one or more species (Rago, 2005).

For the selection of the sampling gear, we considered took into consideration that mechanisms modifying the catchability coefficient or overdispersion of some pelagic species (Fonteneau, et al., 1999), can bias our results and lead to relevant mistakes in their interpretation. To reduce the incidence of the catchability factor, we used different types of experimental gears and we focused our study on demersal species underexposing our results to bias due to big schools highly dispersed pelagic species. Nonetheless, In the case of Lebanon, the most important commercial species are typical coastal and distributed over areas where standard trawling cannot be carried out (Brême, 2004; Carpentieri, et al., 2009). For this reason, backed by fishermen and scientists, we finally developed an experimental trammel net suitable for operating over the continental shelf and upper slope, with poor selectivity properties to catch a variety of species and sizes of fish and other organisms. In fact, if compared to gillnets, trammel nets of different mesh sizes ensure similar mechanisms of capture in terms of snagging (the fish is caught by twine entangling with the fish oral area), gilling (caught with the mesh behind the gill cover); wedging (caught by the largest part of the body) (Karlsen & Bjarnason, 1986; Grati, et al., 2015), whereas the entangling factor increases due to the presence and configuration of additional two sheets of netting (Cochrane, 2002).

Variation of abundance index

The analysis of the Catch Per Unit Effort (CPUE) and total weight variation of the demersal fish observed during this study provided indications of the spatio-temporal variation of their distribution and abundance.

Although the causes for the spatial distribution of a fish population are still poorly understood, density-dependent processes are often suggested as a possible explanation (Myers & Stokes, 1989; MacCall, 1990; Casini, et al., 2005), as well as environmental factors (Corten & van de Kamp, 1996; Heessen, 1996; Rose & Kulka, 1999), pollution, habitat loss induced by anthropogenic activities including degree of stock exploitation (Winters & Wheeler, 1985) and recent warming of the climate system (Gray, et al., 2005; Poulard & Blanchard, 2005; Rochet, et al., 2010). Factors affecting fish abundance and distribution often operate at regional scales (Heessen & Daan, 1996; Rose & Kulka, 1999). However, the nature of Lebanese water, availability of prey, daily and seasonal movements for breeding and feeding, as well as fishing techniques and the depths at fishing can explain to a certain extent, the variation in distribution and abundance (Bianchi, 1992; Koslow, 1993; Gordon, et al., 1995). Due to the uniqueness of this study in the region, no trend could be estimated concerning the variation in abundance and biomass of demersal fish inhabiting the coastal waters.

Spatial and depth variation

The survey of the year 2012 resulted in an overall low CPUE without relevant differences among sector. With the exception of one haul carried in out in region 'Beirut-Saida', all the sampling stations provided less than 10 Kg of samples. Instead, in 2013 the yields in the northern sectors ('Akkar Shelf' and 'Tripoli-Beirut') remained similar to the previous year whilst 'Beirut-Saida' and 'Saida-Naqoura' sectors gave an average for the two areas of more than 10 Kg per haul.

Data showed the depth to cause a general decrease in the numerical abundance and biomass (beyond 150 m depth) probably related to a general reduction in food availability that affects epibenthic and demersal assemblages on the slope (Peres, 1985; Sanders & Hessler, 1969). This pattern was due to a reduction of the abundance of teleosts, which decreased with depth, while decapod crustaceans and elasmobranchs showed an opposite trend increasing from the coastal shelf to the middle slope. This trend is similar to the one described by Colloca, et al. (2003) as a result of the MEDITS campaign run in Italian Central Mediterranean Sea. Abundant shelf species (*Mullus barbatus*, *Pagellus erythrinus*, *Sargocentron rubrum*, *Siganus rivulatus*) and slope species (*Dentex macrophthalmus*, *Merluccius merluccius*, *Phycis phycis*, *Aristaeomorpha foliacea*, etc.) have their nursery grounds, respectively, on the coastal shelf and shallow slope (Ardizzone & Corsi, 1997; Golani & Ben-Tuvia, 1985; Bariche, 2012) and contributed to the increased dominance in these regions. The most abundant elasmobranchs were *Raja miraletus* and *Centrophorus granulosus*. The latter is a demersal shark caught in large individuals probably as a result of the selectivity of the trammel nets that usually intercept bigger individuals (Lteif, et al., 2017; Coelho, et al., 2005). Lteif et al (2017) also reported that the Levantine area along the coast of Lebanon is a reproductive area for *C. granulosus* (reported as *C. uyato*).

Biodiversity and Lessepsian species.

One only previous systematic experience of data collection on the Lebanese halieutic resources was performed by (George, et al., 1964). Their study relied almost entirely on commercial fishermen as supplier of the specimens. A few specimens were obtained through limited shore seining and the poisoning of coastal pot holes. They described 177 fish species inhabiting Lebanese coastal waters. It is worth mentioning the inclusion in the list of species not directly collected but reported from adjacent waters, adding a non-empirical element to this report (Golani, 1996).

In our study, 17 NIS of Lessepsian origin – 13 fish and 4 crustacean species - were recorded over the Lebanese coastal waters, 15 of which demersal, one pelagic (the herring *Etrumeus teres*) and one with a mixed benthic-pelagic behaviour (the portunid crab *Charybdis longicollis*). George, et al. (1964) reported 19 Lessepsian species over the 177 collected. This means that in 50 years the ratio of the autochthon fishing resources remained steady, with an apparent slight decrease from 89% to 87%. Although in terms of

biomass (not mentioned in the study of [George, et al., 1964](#)) we can assume that 50 years ago this was considerably poorer than today, in terms of number of species, the trend, at this stage, is not so evident. As a result of 7 years of data collection carried out with various fishing gears over the Syrian waters, [Saad \(2005\)](#) reported 224 species of Osteichthyes (bony fishes), 37 of which were NIS migrant from the Red Sea (16.5%). In an extended work realised by [Carpentieri, et al. \(2009\)](#) in South Lebanon, a total of 25 Lessepsian species over 110 identified (23%) were recorded. This indicates that back then 77% of the total catch was made up by Mediterranean species.

In absolute terms, in 2012, [Zenetos, et al. \(2012\)](#) reported 193 NIS species of Molluscs, 125 of Crustaceans and 105 of fishes in the eastern Mediterranean. NIS numbers more than doubled between 1980 and 2016 and are substantially greater in the Levant than in the western Mediterranean ([Galil, et al., 2017](#)). This confirms that the Mediterranean Sea – and more in specific its easternmost shores - is one of the hottest hotspots of marine bioinvasions on Earth ([Rilov & Crooks, 2009](#)). The success of Lessepsian migrants in the colonization of the eastern Mediterranean has been probably the result of occupation of an unsaturated niche and of out-competing local species on resources such as food and shelter. NIS, in fact, may have altered the evolutionary pathway of native species by competitive exclusion, niche displacement, predation, and other ecological and genetic mechanisms ([Mooney & Cleland, 2001](#)).

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Part II. Short Communication

Pattern of distribution and diversity of demersal assemblages in the eastern Mediterranean Sea

Pattern of distribution and diversity of demersal assemblages in the eastern Mediterranean Sea

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ABSTRACT

The understanding of patterns of spatial distribution of fish populations is a critical consideration particularly in the eastern Mediterranean Sea, where the faunal composition has been drastically altered by the migration of numerous Indo-Pacific species from the Red Sea following the construction of the Suez Canal in 1869. This migration can cause loss of native biodiversity, habitat destruction, pollution and economic damages. Additionally, the eastern Mediterranean displays peculiar environmental characteristics such as high temperature, high salinity, extreme oligotrophy and high anthropogenic pressure with relevant effects on coastal ecosystems. Specimens were collected in the framework of a three-year fishery-independent survey from June 2012 to October 2014 in the Lebanese marine waters, Levantine Sea (eastern Mediterranean). Species assemblages occurring along the Lebanese continental shelf and exploitable using gillnets and trammel nets were investigated. The analysis of the data collected shows the occurrence of 6 clusters of stations with a different species composition that can configure 4 major assemblages along the Lebanese continental shelf and the upper slope.

Keywords: fishing impact; Levantine basin; spatiotemporal variations, small-scale fishery, fauna; species composition

INTRODUCTION

Mediterranean small-scale fishing fleet are made up of approximately 65 000 vessels run by 130 000 fishers (Sacchi & Dimech, 2011). These small-scale fisheries are characterized by the use of more than 50 types of fishing gears to target species according to the fishing season (FAO, 2015). In Lebanon, the fishing fleet is entirely composed of artisanal vessels using fixed gear (i.e. trammel nets, gillnets, longlines, traps) and purse seiner nets for small pelagics. Fishing gears are fairly diversified and designed to exploit a wide range of species in the coastal area with landings characterized by a great number of species (Carpentieri, et al., 2009). In relation to these characteristics, understanding and future management of these fisheries should require a multispecies approach, which considers the community (i.e. assemblages) and not the single species as the basic unit of the analysis (Pitcher, 2000).

Numerous Authors analyzed faunal changes and the establishment of certain assemblages that occur in the areas targeted by small-scale fisheries, i.e. continental shelf and upper slope. They proved that the spatial distribution of demersal species is mainly influenced by depth, type of substratum and physical characteristics (such as temperature and salinity) of the water masses, e.g. Mahon & Smith (1989); Bianchi (1992); Fujita, et al. (1995); McClatchie, et al. (1997); Magnussen (2002); Gaertner, et al. (2005); Maravelias, et al. (2007). Some species appear to be widely distributed independently of the environmental gradients (Colloca, et al., 2003) even though biotic interactions among assemblage members seem to be of less importance (Mahon & Smith, 1989; Sale, et al., 1994).

The understanding of patterns of spatial distribution of fish populations is a critical consideration particularly in the eastern Mediterranean, where the faunal composition has been drastically altered by the migration of numerous Indo-Pacific species from the Red Sea following the construction of the Suez Canal in 1869 (Por, 1978; Galil & Zenetos, 2002). According to Mooney, et al. (2005) and Rilov & Galil (2009), this migration can cause loss of native biodiversity, habitat destruction, pollution and economic damages. Additionally, the eastern Mediterranean displays peculiar environmental characteristics such as high temperature, high salinity, extreme oligotrophy and high anthropogenic pressure with relevant effects on coastal ecosystems (Coll, et al., 2010).

The objective of the present study is to investigate and describe composition and spatial distribution of demersal communities occurring on the Lebanese continental shelf and upper slope, in the Levantine Basin, with a view of creating sound baseline for future protection and management measures of demersal species along the Lebanese coast.

MATERIALS AND METHODS

Specimens were collected from June 2012 to October 2014 in the Lebanese marine waters, Levantine Sea (eastern Mediterranean). Lebanese coastal line is about 225 km and the continental shelf is relatively wide in the north, offshore of the Akkar plain (about 20 km), and in the south, offshore of Saida and Tyre (Nabatiyeh plateau). Between Beirut and Batroun however, the shelf is extremely narrow and the margin exhibits its steepest slope, with the water depth abruptly increasing from 100 to 1500 m in less than 5 km. Along the entire margin the continental slope is incised by canyons, most of them connected to rivers flowing from the mountains.

Lebanese coastal waters were broken down into 4 regions (Figure 28) to allow geographical-based analysis. Total number of sampling stations was 48, spatially allocated randomly but proportionally to the extension of each area. Specimens were sampled using trammel and gill nets with different mesh sizes lowered by artisanal fishing vessels. The species were then identified using the identification guides of Fischer, et al. (1987) and the three CIESM Atlases on Fishes (Golani, et al., 2002), Crustaceans (Galil, et al., 2002) and Molluscs (Zenetos et al., 2003). All the individuals collected - irrespective the species - were measured and weighed, additionally sex and maturity stage were determined. Collected specimens were stored on board and returned to the laboratory. In the laboratory, each specimen collected was measured and weighed. A measuring tape was used to measure fish total lengths (L_T) to the nearest 0.1 centimeter (cm). Total weights (wet weight, W) were measured to the nearest 0.01 gram (g) using a digital balance. For crustaceans, the cephalothoracic length (CL) at the lower millimeter (mm) was measured.

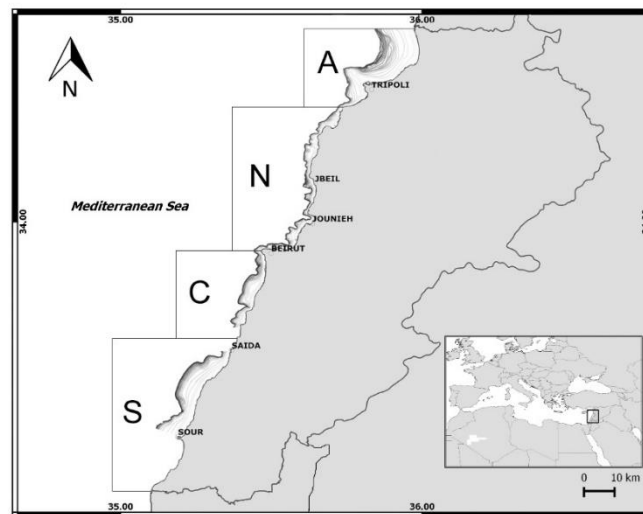


Figure 28. Location of the sampling area in Lebanese marine waters, eastern Mediterranean. Lebanese coastal waters were break down into 4 regions based mainly on the conformation of the continental shelf (A: Akkar shelf; N: North; C: Center; S: South). Bathymetries up to 100 meters depth are shown.

Statistical analyses

To evaluate dissimilarity patterns among assemblages, we used:

1. nonmetric multidimensional scaling (nMDS) based on Bray–Curtis similarity
2. maps of clusters
3. clusters by depth

A nMDS was performed on the matrix of CPUE in kilograms and number separately of the different demersal species caught according to the scientific survey factors (gear, region, depth, and season). The data (CPUE in kilograms and number or total weight) were log transformed before the analyses into $\log(x+1)$ in order to homogenize the variances and normalize the distributions. Both nMDS analyses were performed using the metaMDS function of the 'vegan' package on the statistical software 'R project' ([R Development Core Team, 2014](#)) on 2012 and 2013 combined datasets.

RESULTS

Species assemblages occurring along the Lebanese continental shelf and exploitable using gillnets and trammel nets have been investigated. The analysis of the data collected shows the occurrence of 6 clusters of stations with a different species composition that can configure 4 major assemblages along the Lebanese continental shelf and the upper slope., as shown in [figures 29 and 30](#).

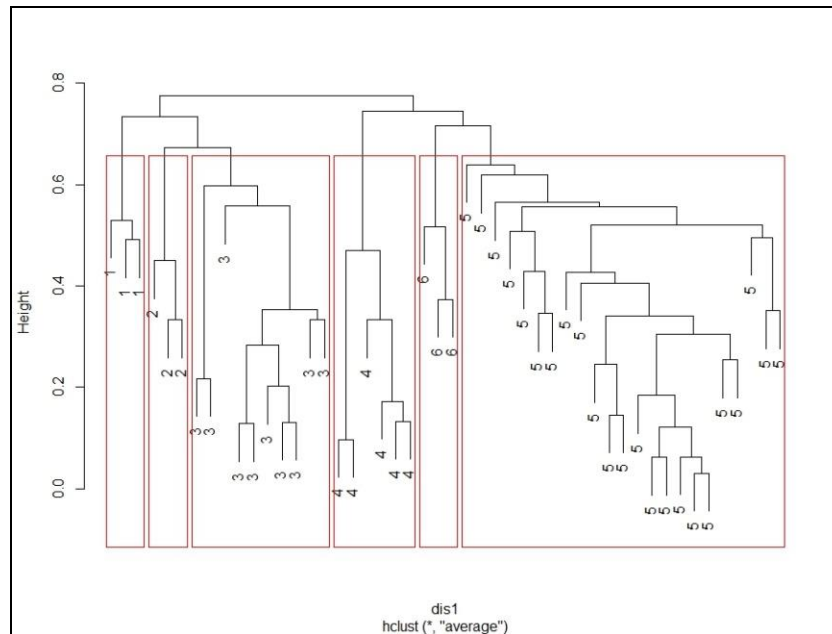


Figure 29. Cluster dendrogram of surveyed stations along the Lebanese coast.

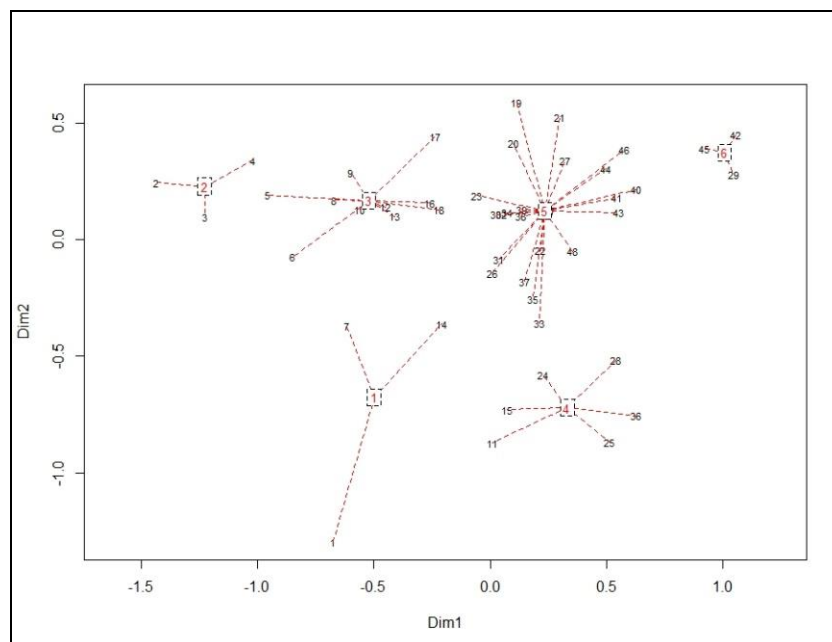


Figure 30. Multidimensional scaling of sampling stations along the Lebanese coast.

DISCUSSION

In the present work, structure and distribution of demersal fish assemblages were examined on the continental shelf and upper slope of Lebanese waters, eastern Mediterranean Sea.

Clusters 1, 2 and 3 (including 16 sampling stations) feature poor catches located in north Lebanon and more frequently in shallow waters. A small number of individuals of *Sargocentron rubrum*, *Portunus pelagicus* characterised some of the hauls belonging to these clusters. In general, it is impossible to identify any pattern.

Cluster 4 (6 sampling stations) reports stations located between Tripoli and Tyre at depths comprised between 40 and 100 m. All the stations are characterised by the redcoat *S. rubrum* as dominant species of the catches. This is typically a species inhabiting rocky bottoms, in coastal reefs or hidden in caves and cracks of rocks especially during the day. This species was usually associated with *Fistularia commersoni*, *Pagellus acarne* and siganids (species inhabiting bottoms of different nature) and the benthopelagic species *Trachurus picturatus*.

Cluster 5 (26 sampling stations) is quite complex to examine as it includes hauls located over three sectors (N, C, S), i.e. between Chekka (north Lebanon) and Naqoura (south) at all depths surveyed. To define a pattern ecologically driven, the cluster may be divided into two sub-clusters that are easily detectable in the multidimensional scaling shown in [Figure 30](#). Hauls indicated as 40, 41, 43, 44 and 21, 27, 46 are all located at depths between 100 and 150 m. Thus, they appear to be closely related to Cluster 6 showing an assemblage typical of mobile bottoms in the deeper continental shelf. Teleosts (bony fishes) as *Dentex macrophthalmus*, *Phycis phycis*, *Merluccius merluccius*, *Pagellus* spp., and the Crustaceans *Maja goletziana* and *Aristaemorpha foliacea* resulted the most common species for this sub-cluster. It is interesting to notice that the stations 40, 41, 43, 44 and those belonging to cluster 6 are all located in the Southern Lebanese waters, defining a cluster of stations with common geographical location. The rest of the cluster returned species found in mixed bottoms (sand/rocks) and caves in shallower waters (10 to 90 meters depth) such as *Diplodus vulgaris* and *S. rubrum*.

Cluster 6 (3 sampling stations) comprises hauls located in the southern deeper continental shelf. The group of species identified in this cluster is typical of sandy/muddy bottoms in the deeper continental shelf and upper slope. The red giant shrimp *A. foliacea* is particularly abundant being associated with *D. macrophthalmus*, *M. merluccius*, *Mullus* spp., the hollowsnout grenadier *Coelorinchus caelorhincus*, *Helicolenus dactylopterus*, *P. acarne*, *Phycis* spp. and the selacean *Centrophorus granulosus*.

ACKNOWLEDGEMENT

This study could not have been completed without the support of the Lebanese fishermen, their bravery and tough job in the sea. The communities of fishermen are the ultimate beneficiaries of all our efforts aimed at creating new and sustainable sources of income and improving their quality of life. Data and financial funding for this study was provided in the framework of the CIHEAM-PESCA Libano project, of the CANA project on “Establishing Monitoring and Sustainable Development of the Lebanese Sea” (both financed by the Italian Cooperation) and within the Grant Research Programme of the CNRS-L.

Chapter 5

Weight-length relationships

Chapter

5

Weight-length relationships

Information on weight-length relationships (WLR) of demersal species was almost absent along the Lebanese coast. In Chapter 5, WLRs have been presented for thirty demersal species in Lebanese marine waters, eastern Mediterranean. Some of these species are commercially relevant and/or NIS.

Part I. Weight-length relationships of 3 demersal fish species from Lebanese marine waters, eastern Mediterranean

The WLRs of 3 demersal fish species (constituting Part 1 of chapter 5) had been submitted to the revue 'Journal of Applied Ichthyology' and accepted on July 4th, 2017, with the title "Weight-length relationships of 3 demersal fish species from Lebanese marine waters, eastern Mediterranean" (DOI: 10.1111/jai.13459). These species were selected because no WLRs had previously been published in the Mediterranean for these species.

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Part II. Weight-length relationships of 27 demersal species from Lebanese marine waters, eastern Mediterranean

It is envisaged to publish the WLRs of the other species in the revue 'Egyptian Journal of Aquatic Research' and they are presented following the previous article (Part 2 of chapter 5).

Weight-length relationships of 3 demersal fish species from Lebanese marine waters, eastern Mediterranean

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ABSTRACT

Weight-length relationships (WLRs) were estimated for 3 demersal species, from the Lebanese marine waters, eastern Mediterranean, namely *Coelorinchus caelorhincus* (Risso, 1810), *Scorpaena elongata* Cadenat, 1943 and *Stephanolepis diaspros* Fraser-Brunner, 1940. The specimens were collected using trammel and gill nets from June 2012 to October 2014. The values of parameter b of the WLRs $W=aL^b$ ranged from 2.922 to 3.708. Pronounced sexual dimorphism in WLR was observed for *S. diaspros* and none showed a WLR-based geographical pattern of distribution. WLRs reported in this study should be applied only within the observed length ranges.

Keywords: Lebanon, weight-length regressions, fishes

INTRODUCTION

Length and weight data are useful in fisheries management and standard results of fish sampling programs. Weight-length relationships (WLRs) are used for estimating the weight corresponding to a given length, and condition factors are used for comparing the condition, fatness, or well-being (Tesch, 1968) of fish,

based on the assumption that heavier fish of a given length are in better condition. Both concepts have been used in fisheries research since the beginning of the 20th century (Froese, 2006). WLRs are only known for a restricted number of species, which hampers efforts to model aquatic ecosystems. On the one hand WLRs are used to predict the weight from the length of a fish, which is particularly useful for computing the biomass of a sample of fish from the length-frequency of that sample. On the other, WLR for a given population can be compared to average parameters taken from other regions, in different years in order to identify the relative condition or robustness of the population (Le Cren, E. D. 1951). Hence, WLR is considered an important tool in fisheries management (Froese et al., 2011).

Eastern Mediterranean halieutic species are poorly studied and very little biological information is available, notably for most of the commercially relevant species. There is an urgent need to manage and regulate small-scale coastal fisheries in the region to ensure the long-term sustainability of fishery resources, and this requires basic population dynamics information for the target species (Santos et al., 1995). In Lebanon, Colloca & Lelli (2012) and Khalaf et al. (2014) characterized WLRs for the striped soldier shrimp *Plesionika edwardsii*, the puffer fish *Lagocephalus sceleratus*.

In this paper, WLRs were estimated for 3 coastal species, i.e. *Coelorhynchus coelorhynchus*, *Scorpaena elongata*, *Stephanolepis diaspros*. We are providing wider size ranges than those found in science literature and to the best of our knowledge, this study presents the first estimation of WLRs for *S. elongata*. Specimens were captured in Lebanese waters in the framework of a multiannual fisheries-independent data collection for the assessment of demersal coastal species. Sex and geographic distribution effects on WLRs was also examined.

MATERIALS AND METHODS

The specimens were collected from June 2012 to October 2014 in the Lebanese marine waters, Levantine Sea (eastern Mediterranean). Lebanese coastal line (220 km) was broken down into 4 regions (Figure 31) to allow geographical-based analysis. Specimens were sampled using trammel and gill nets with different mesh sizes lowered by artisanal fishing vessels. All the individuals collected - irrespective the species - were measured and weighed; additionally sex and maturity stage were determined. Collected specimens were stored on board and returned to the laboratory where they were measured and weighed. A measuring tape was used to measure fish total lengths (*TL*) to the nearest 0.1 centimeter (cm). Total weights (wet weight, *TW*) were measured to the nearest 0.01 gram (g) using a digital balance. Biological data were collected following the *Medit Handbook, Version 7 (2013)*.

The parameters *a* and *b*, of the WLR curve ($W = aL^b$) were estimated using a nonlinear least squares function *nls* in the statistical software R (R Development Core Team, 2014). The start values of these parameters were derived from the log transformation of the two variables ($\ln W = \ln a + b \ln L$) using the linear model function *lm*. The coefficient of determination (r^2) aids in determining the accuracy of the model prediction skills. Finally, statistical comparison of WLR between sexes (*tests were only performed for species with sample size for each sex modality upper than 5 individuals*) and geographical sectors was performed by applying ANCOVA tests (Zar, 1996). When significant differences were observed, WLR was estimated for each sex; when no significant differences were observed, one WLR was estimated for the sexes combined (comprising Non-determined individuals). Standard deviations of *b* were calculated to

detect substantial deviation from isometric growth ($b=3$). Significant difference of b values from 3, which represent isometric growth, was tested with the T-test (Pauly, D., 1993).

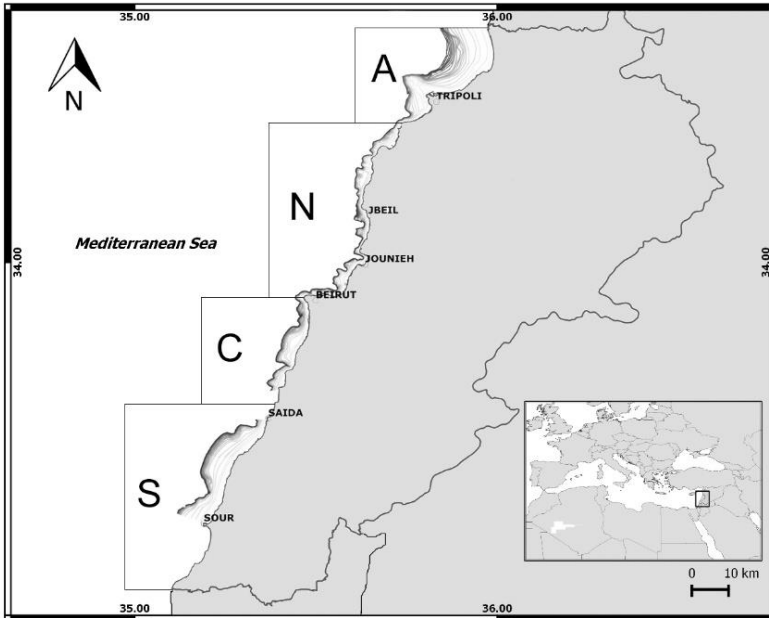


Figure 31. Location of the sampling area in Lebanese marine waters, eastern Mediterranean. Lebanese coastal waters were break down into 4 regions based mainly on the conformation of the continental shelf (A: Akkar shelf; N: North; C: Center; S: South). Bathymetries up to 100 meters depth are shown.

RESULTS

A total of 90 individuals belonging to three species were examined in this study. Among them, *Stephanolepis diaspros* is an early Red Sea immigrant in the Mediterranean Sea firstly reported by Steinitz (1927) in Palestinian waters. The length and weight characteristics, as well as the sample size and parameters of the WLRs are represented in table 20. The sample sizes ranged from a minimum of 26 individuals for *S. diaspros* to a maximum of 33 for *C. caelorhincus*. Pronounced sexual dimorphism in WLR was observed for *S. diaspros* with significant differences in the slopes of WLR between males and females (ANCOVA; $P < 0.05$). The values of the allometric coefficient (b) ranged from a minimum of 2.922 for *S. diaspros* (all individuals) to a maximum of 3.708 for male specimens of *S. diaspros* (Table 20). The three species evidenced a nearly isometric growth with a mean b value of 3.027 (SD. 0.096). All relations were highly significant ($P < 0.001$), the most accurate model was shown to be that of *S. elongata* ($r^2 = 0.990$) and the least one was that of *C. caelorhincus* ($r^2 = 0.560$).

No WLR-based geographical pattern of distribution were found.

Estimated WLR parameters should be considered only as mean annual values for most of these species since the data were collected over an extensive period of time and are not representative of any particular season.

Table 20. The length and weight characteristics as well as the parameters of the length-weight relationships ($W=aL^b$) for 3 species caught in the Lebanese waters, eastern Mediterranean. When significant differences between sexes were observed, WLR was estimated for each sex; when no significant differences were observed, one WLR was estimated for the sexes combined (comprising non-determined individuals). Sex (F = female; M = male; All = includes F, M and non-determined individuals); N is the sample size; W is the weight; SD is the standard deviation; a and b are the parameters of the length-weight relationships; r^2 is the coefficient of determination. Meaning of the letters and symbol in exponent in the first column: L for Lessepsian species, * for species for which it is the first information available on WLRs. In the first column, number of individuals in each sex modalities are specified. P-value, significance between male and female [in bold, significant differences ($P<0.05$)], with tests only performed for species with sample size for each sex modality upper than 5 individuals.

Species	Sex	N	Samples characteristics		Relation parameters				P-value
			TL min–TL max (mm)	W min–W max (g)	a (10^{-3})	b (10^{-3})	SD (b)	r^2	
<i>Coelorhynchus coelorhynchus</i> (Risso, 1810) 20 F; 8 M; 5 ND	All	33	11.0-24.0	9.0-125.0	0.004	3.110	0.618	0.56	0.78
<i>Scorpaena elongata</i> Cadenat, 1943 * 18 F; 9 M; 4 ND	All	31	14.0-41.5	36.0-1124.0	0.013	3.050	0.046	0.99	0.44
<i>Stephanolepis diaspros</i> Fraser-Brunner, 1940 L, 7 F; 15 M; 4 ND	All	26	10.5-25.0	14.0-244.0	0.020	2.922	0.251	0.84	0.01
	M	15	13.5-22.0	14.0-190.0	0.002	3.708	0.350	0.87	

DISCUSSION

Information related to the WLR of demersal species is almost absent along the Lebanese coast. Froese (2006) and Froese et al. (2014) had analyzed the WLR of all fishes available on the Fishbase website (www.fishbase.org) using meta-analysis and Bayesian methods. A few studies carried out by Turkish Authors (Başusta et al., 2013; Ergüden et al., 2009; Ergüden et al., 2017; Gündoğdu et al., 2016; Özvarol, 2014; Sangun et al., 2007; Taskavak and Bilecenoglu, 2001) bring together information on WLRs for demersal species in the northern part of the eastern Mediterranean. This information allowed us comparisons only with *S. diaspros*, whose WLR shows corresponding negative allometric pattern in Sangun et al., 2007. *C. coelorhynchus* showed different allometric patterns as those reported in other Mediterranean sub-regions (Aegean and Adriatic Sea) by Ungaro et al. 2001; Filiz, & Bilge 2004 and Filiz et al. 2006, whereas no references are available in the eastern Mediterranean. No references whatsoever are reported on Fishbase website (Froese & Pauly 2017) on *S. elongata*.

As pointed out by Petrakis and Stergiou (1995), use of the WLR should be limited to the sizes in the estimation of the parameters. However, this may act as a tool to support fisheries management measures by establishing a minimum catch weight limit when lengths are estimated at sea. In Lebanon, where management measures are limited or outdated and the fishing pressure is high on coastal fisheries resources while fishing practices targeting juvenile fishes are partially driven by the market (Bariche et al., 2006; Sacchi & Dimech., 2011; Colloca & Lelli 2012), the use of basic but powerful descriptive tools of halieutic populations such as WLRs is highly recommended.

ACKNOWLEDGEMENTS

This study could not have been completed without the support of the Lebanese fishermen, their bravery and tough job in the sea. The communities of fishermen are the ultimate beneficiaries of all our efforts aimed at creating new and sustainable sources of income and improving their quality of life. Data and financial funding for this study was provided in the framework of the CIHEAM-PESCA Libano project, of the CANA project on “Establishing Monitoring and Sustainable Development of the Lebanese Sea” (both financed by the Italian Cooperation) and within the Grant Research Programme of the CNRS-L.

Conflict of interest

The author certifies that there is no conflict of interest.

Part II. Weight-length relationships of 27 demersal species from Lebanese marine waters, eastern Mediterranean

Weight-length relationships of 27 demersal species from Lebanese marine waters, eastern Mediterranean

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ABSTRACT

Weight-length relationships (WLRs) were estimated for 27 demersal species, from the Lebanese marine waters, eastern Mediterranean (21 teleost fish, 3 elasmobranch fish and 3 crustaceans), namely *Aristaeomorpha foliacea*, *Auxis rochei*, *Citharus linguatula*, *Dentex macrophthalmus*, *Diplodus vulgaris*, *Fistularia commersonii*, *Helicolenus dactylopterus*, *Lagocephalus sceleratus*, *Maja goltziana*, *Merluccius merluccius*, *Mullus barbatus*, *Mullus surmuletus*, *Pagellus acarne*, *Pagellus erythrinus*, *Pagrus caeruleostictus*, *Pagrus pagrus*, *Phycis blennoides*, *Phycis phycis*, *Portunus pelagicus*, *Raja clavata*, *Raja miraletus*, *Sargocentron rubrum*, *Seriola dumerili*, *Siganus luridus*, *Siganus rivulatus*, *Torpedo marmorata*, *Trachurus picturatus*. Among these species, 6 were Lessepsian migrants, 13 were commercially important and 22 were described for the first time in this area. The specimens were collected using trammel and gill nets from June 2012 to October 2014. The values of parameter b of the WLRs $W=aL^b$ ranged from 1.818 to 3.494. Pronounced sexual dimorphism in WLR was observed for *M. barbatus*, *P. erythrinus*, *P. phycis*, *S. rubrum*, and *T. marmorata*. *S. rubrum* also showed a WLR-based geographical pattern of distribution. WLRs reported in this study should be applied only within the observed length ranges.

Keywords: Lebanon, weight-length regressions, fishes

INTRODUCTION

Length and weight data are useful in fisheries management and standard results of fish sampling programs. Weight-length relationships (WLRs) are used for estimating the weight corresponding to a given length, and condition factors are used for comparing the condition, fatness, or well-being (Tesch, 1968) of fish, based on the assumption that heavier fish of a given length are in better condition. Both concepts have been used in fisheries research since the beginning of the 20th century (Froese, 2006). WLRs are only known for a restricted number of species, which hampers efforts to model aquatic ecosystems. On the one hand WLRs are used to predict the weight from the length of a fish, which is particularly useful for computing the biomass of a sample of fish from the length-frequency of that sample. On the other, WLR for a given population can be compared to average parameters taken from other regions, in different years in order to identify the relative condition or robustness of the population (Le Cren, E. D. 1951). Hence, WLR is considered an important tool in fisheries management (Froese et al., 2011).

Eastern Mediterranean halieutic species are poorly studied and very little biological information is available, notably for most of the commercially relevant species. There is an urgent need to manage and regulate small-scale coastal fisheries in the region to ensure the long-term sustainability of fishery resources, and this requires basic population dynamics information for the target species (Santos et al., 1995). In Lebanon, Colloca & Lelli (2012), Khalaf et al. (2014) and Lteif et al. (2016) characterized WLRs for the striped soldier shrimp *Plesionika edwardsii*, the puffer fish *Lagocephalus sceleratus* and 8 cartilaginous fish species respectively. Furthermore, since 2015, the Lebanese National Council for Scientific Research (CNRS-L) with the support of the FAO EastMed project is running a monthly-based biological data collection on 3 species (*Pagellus erythrinus*, *Lithognathus mormyrus* and *Sardinella aurita*), which includes also the estimation of their WLRs (data not yet published).

In this paper, WLRs were estimated for 27 coastal species captured in Lebanese waters using data collected in the framework of a multiannual fisheries-independent data collection for the assessment of demersal coastal species. It represents the first information available on WLRs for 22 of these species along the Libano-Syrian coast, namely *Aristaeomorpha foliacea*, *Auxis rochei*, *Citharus linguatula*, *Dentex*

macrophthalmus, *Diplodus vulgaris*, *Fistularia commersonii*, *Helicolenus dactylopterus*, *Maja goletziana*, *Merluccius merluccius*, *Mullus barbatus*, *Mullus surmuletus*, *Pagellus acarne*, *Pagrus caeruleostictus*, *Pagrus pagrus*, *Phycis blennoides*, *Phycis phycis*, *Portunus pelagicus*, *Sargocentron rubrum*, *Seriola dumerili*, *Siganus luridus*, *Siganus rivulatus*, *Trachurus picturatus*. Also, to the best of our knowledge, this study presents the first estimation of WLRs for *Auxis rochei* and *Maja goletziana*.

It aims at providing information for sound population dynamic based models reporting data on the most common demersal species and those that are mostly targeted by local artisanal fisheries. Sex and geographic distribution effects on WLRs was also examined.

MATERIALS AND METHODS

The specimens were collected from June 2012 to October 2014 in the Lebanese marine waters, Levantine Sea (eastern Mediterranean). Lebanese coastal line (220 km) was break down into 4 regions (Figure 32) to allow geographical-based analysis. Specimens were sampled using trammel and gill nets with different mesh sizes lowered by artisanal fishing vessels.

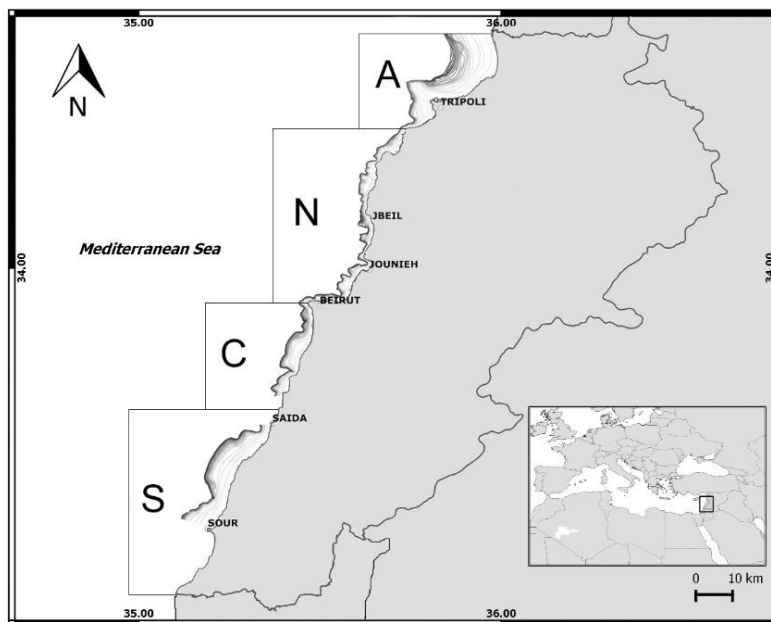


Figure 32. Location of the sampling area in Lebanese marine waters, eastern Mediterranean. Lebanese coastal waters were break down into 4 regions based mainly on the conformation of the continental shelf (A: Akkar shelf; N: North; C: Center; S: South). Bathymetri es up to 100 meters depth are shown.

The species were then identified using the identification guides of Fischer et al. (1987) and the three CIESM Atlases on Fishes (Golani et al., 2002), Crustaceans (Galil et al., 2002) and Molluscs (Zenetos et al., 2003). All the individuals collected - irrespective the species - were measured and weighed, additionally sex and maturity stage were determined. Collected specimens were stored on board and returned to the laboratory. In the laboratory, each specimen collected was measured and weighed. A measuring tape was used to measure fish total lengths (TL) to the nearest 0.1 centimeter (cm). Total weights (wet weight, TW) were measured to the nearest 0.01 gram (g) using a digital balance. For crustaceans, the cephalothoracic

length (CL) at the lower millimeter (mm) was measured. Standardized protocols and minimum requirements adopted during the surveys are summarized in [table 21](#).

Table 20. Protocols and minimum requirements adopted for nets management, vessels minimum requirements and biological data collection. *Medit's Handbook, 2013.

Nets management	
Soak time	Approximate 12 hours, overnight
Lowering time	Afternoon
Retrieving time	Dawn
Operators	Professional artisanal fishermen
Vessels' minimum requirements	
LOA	> 7m
Engine Power	> 16 hp
Winch	Hydraulic or Motorised
Available equipment	GPS, Fishfinder, Safety equipment
Biological data collection	
Biometric: length	TL, nearest 0.1 cm (fish) CL, lower mm (crustaceans)
Biometric: weight	Nearest 0.01 grams
Biological: sex & maturity stages	MEDITS programme protocols* (Codes of sexual maturity for Fish, Crustaceans and Cephalopods)
Biometric & Biological Parameters	Collected on all the specimens

The parameters a and b , of the WLR curve ($W = aL^b$) were estimated using a nonlinear least squares function nls in the statistical software R ([R Development Core Team, 2014](#)). The start values of these parameters were derived from the log transformation of the two variables ($\ln W = \ln a + b \ln L$) using the linear model function lm . The coefficient of determination (r^2) aids in determining the accuracy of the model prediction skills. Finally, statistical comparison of WLR between sexes (*tests were only performed for species with sample size for each sex modality upper than 5 individuals*) and geographical sectors was performed by applying ANCOVA tests ([Zar, 1996](#)). When significant differences were observed, WLR was estimated for each sex; when no significant differences were observed, one WLR was estimated for the sexes combined (comprising Non-determined individuals). Standard deviations of b were calculated to detect substantial deviation from isometric growth ($b=3$). Significant difference of b values from 3, which represent isometric growth, was tested with the T-test ([Pauly, D., 1993](#)).

RESULTS

A total of 2931 individuals, comprising 21 bony fish species, 3 selaceans (3 batoids) and 3 crustaceans were examined in this study. Among them, 6 species (22.2%) were Lessepsian migrants (*Fistularia commersonii*, *Lagocephalus sceleratus*, *Portunus pelagicus*, *Sargocentron rubrum*, *Siganus luridus* and *Siganus rivulatus*).

Table 22. The length and weight characteristics as well as the parameters of the length-weight relationships ($W=aLb$) for 27 species caught in the Lebanese waters, eastern Mediterranean. When significant differences between sexes were observed, WLR was estimated for the sexes combined (comprising non-determined individuals). Taxonomy corresponds to classification of the species collected (P = bony fishes; S = selaceans; K = crustaceans); Sex (F = female; M = male; All = includes F, M and non-determined individuals); N is the sample size; $\overline{TL} / \overline{CL}$ is the mean of total length or carapace length; W is the weight; SD is the standard deviation; a and b are the parameters of the length-weight relationships; r² is the coefficient of determination; Growth type (A+ = positive allometry; A- = negative allometry; I = isometry). Meaning of the letters and symbol in exponent in the first column: L for Lessepsian species, * for species for which it is the first information available on WLRs, and C for commercially important species for the Lebanese coast. In the first column, number of individuals in each sex modalities are specified. P-value, significance between male and female [in bold, significant differences (P<0.05)], with tests only performed for species with sample size for each sex modality upper than 5 individuals.

Species	Taxonomy	Sex	N	Samples characteristics				Relation parameters				P-value	Growth type
				\overline{TL} (cm)/ \overline{CL} (mm)		\overline{W} (g)		a (10 ⁻³)	b (10 ⁻³)	SD (b)	r ²		
				(min-max)	SD	(min-max)	SD						
<i>Aristaeomorpha foliacea</i> (Risso, 1827)*, C 205 F ;55 M; 5 ND	K	All	265	4.74 (2.4-5.8)	0.47	30.41 (6.0-65.0)	8.20	0.700	2.414	0.119	0.72	0.95	A-
<i>Auxis rochei</i> (Risso, 1810)** 6F; 3 M; 13 ND	P	All	22	28.84(16.0-47.0)	7.14	361.68 (60.0-1166.0)	298.27	0.054	2.595	0.316	0.95	0.95	A-
<i>Citharus linguatula</i> (Linnaeus, 1758)* 46 F; 10M; 5 ND	P	All	61	16.43 (11.0-22.0)	2.37	40.66 (12.7-97.0)	21.47	0.004	3.248	0.279	0.74	0.15	A+
<i>Dentex macrophthalmus</i> (Bloch, 1791)* 139 F; 72M; 54 ND	P	All	265	13.93 (8.0-23.0)	2.24	44.20 (9.0-195.0)	22.56	0.022	2.868	0.042	0.92	0.80	A-
<i>Diplodus vulgaris</i> (Geoffroy Saint-Hilaire, 1817) *, C 5 F ; 17 M ; 14 ND	P	All	36	15.50 (11.5-19.5)	1.99	63.52 (26.9-130.0)	24.11	0.016	3.012	0.194	0.91	0.12	I
<i>Fistularia commersonii</i> (Rüppell, 1838) L,* 18 F ; 8 M	P	All	26	84,98 (56.0-112.0)	10.75	389.24 (128.0-578.0)	116.62	0.120	1.818	0.293	0.68	0.17	A-
<i>Helicolenus dactylopterus</i> (Delaroche, 1809)* 16 F ; 20 M ; 37 ND	P	All	73	16.01 (8.0-27.5)	4.16	85.34 (7.0-384.0)	77.15	0.012	3.134	0.103	0.97	0.14	A+
<i>Lagocephalus sceleratus</i> (Gmelin, 1789) L, 11 F; 15 M ; 2 ND	P	All	28	39.36 (23.0-71.0)	10.90	877.99 (139.0-3375.0)	825.23	0.118	2.400	0.261	0.89	0.64	A-

<i>Maja goitziana</i> d'Olivera, 1888 ** 32 F ; 69 M	K	All	101	8.10 (3.2-11.8)	2.21	151.99 (6.0-554.0)	114.21	0.420	2.746	0.229	0.92	0.64	A-
<i>Merluccius merluccius</i> (Linnaeus, 1758) *, C 28 F ; 49 M ; 26 ND	P	All	103	30.95 (18.0-51.0)	6.48	241.77 (60.0-938.0)	158.49	0.022	2.679	0.087	0.86	0.92	A-
<i>Mullus barbatus</i> (Linnaeus, 1758) *, C 25 F ; 6 M ; 14 ND	P	All	45	19.94 (13.0-27.0)	3.28	97.20 (23.0-230.0)	47.34	0.017	2.869	0.138	0.93	0.04	A-
		F	25	20.90 (13.0-27.0)	3.27	113.90 (26.2-230.0)	50.39	0.012	2.993	0.122	0.96	A-	
<i>Mullus surmuletus</i> (Linnaeus, 1758) *, C 30 F ; 11 M ; 9 ND	P	All	50	22.08 (16.5-27.0)	2.70	132.96 (57.0-244.0)	48.75	0.021	2.813	0.170	0.88	0.71	A-
<i>Pagellus acarne</i> (Risso, 1827)*, C 39 F; 35 M ; 51 ND	P	All	125	15.75 (9.0-21.0)	2.38	50.91 (8.0-106.7)	20.68	0.018	2.856	0.120	0.92	0.33	A-
<i>Pagellus erythrinus</i> (Linnaeus, 1758), C 37 F ; 30 M ; 30 ND	P	All	97	17.96 (10.0-30.0)	3.47	90.26 (13.0-370.7)	56.56	0.021	2.870	0.070	0.93	0.03	A-
		F	37	17.74 (14.0-27.0)	2.82	82.64 (38.0-265.7)	43.15	0.019	2.887	0.113	0.92	A-	
		M	30	18.75 (14.0-30.0)	3.92	108.45 (37.0-370.7)	70.33	0.033	2.729	0.102	0.95	A-	
<i>Pagrus caeruleostictus</i> (Valenciennes, 1830)*, C 11 F, 9 M; 10 ND	P	All	30	20.40 (14.5-48.0)	7.73	176.77 (60.0-1600.0)	295.15	0.068	2.521	0.245	0.94	0.46	A-
<i>Pagrus pagrus</i> (Linnaeus, 1758) *, C 20 F ; 7 M; 3 ND	P	All	30	21.30 (16.0-40.0)	4.92	170.63 (61.0-936.0)	164.26	0.018	2.951	0.050	0.96	0.62	A-
<i>Phycis blennoides</i> (Brünnich, 1768) * 2 F ; 18 M ; 3 ND	P	All	23	24.57 (22.5-39.5)	3.49	125.46 (81.0-516.5)	88.09	0.005	3.138	0.067	0.93	-	A+
<i>Phycis phycis</i> (Linnaeus, 1766) * 53 F ; 42 M ; 50 ND	P	All	145	25.54 (14.0-42.0)	4.96	188.52 (40.0-868.0)	153.78	0.003	3.343	0.066	0.90	0.05	A+
		F	53	26.60 (20.0-42.0)	4.78	213.32 (77.0-868.0)	145.11	0.006	3.145	0.107	0.87	A+	
		M	42	26.27 (14.0-40.0)	5.80	205.19 (40.0-783.0)	184.04	0.002	3.515	0.142	0.91	A+	
<i>Portunus pelagicus</i> (Linnaeus, 1758) L, *, C 18 F ; 12 M ; 1 ND	K	All	31	4.79 (3-8.4)	1.26	84.94 (13.1-318.2)	73.86	1.259	2.601	0.099	0.90	0.91	A-
<i>Raja clavata</i> (Linnaeus, 1758) 9 F ; 11 M	S	All	20	48.55 (25.0-70.0)	12.97	906.05 (62.0-2300.0)	739.44	0.004	3.150	0.264	0.98	0.37	A+

<i>Raja miraletus</i> (Linnaeus, 1758) 22 F ; 29 M ; 1 ND	S	All	52	34.69 (25.0-44.0)	3.46	225.33 (72.0-490.0)	88.84	0.001	3.494	0.190	0.89	0.71	A+
<i>Sargocentron rubrum</i> (Forsskål, 1775) L,* 432 F ; 314 M ; 363 ND	P	All	1109	17.38 (12.0-22.0)	1.69	97.56 (33.2-248.0)	29.74	0.018	2.993	0.045	0.86	0.03	I
		F	432	17.33 (12.5-21.5)	1.55	96.36 (33.2-216.4)	27.27	0.016	3.035	0.076	0.85	I	
		M	314	17.18 (12.6-22.0)	1.72	92.43 (35.4-248.0)	28.92	0.018	2.995	0.078	0.86	I	
<i>Seriola dumerili</i> (Risso, 1810) *, C 15 F; 11 M; 16 ND	P	All	42	24.93 (17.5-31.0)	3.76	200.32 (86.6-367.1)	80.80	0.031	2.715	0.190	0.88	0.76	A-
<i>Siganus luridus</i> (Rüppell, 1829)L,* , C 9 F; 9 M ; 3 ND	P	All	21	18.45 (14.5-29.0)	3.63	96.77 (41.8-303.3)	63.66	0.029	2.754	0.145	0.93	0.92	A-
<i>Siganus rivulatus</i> (Forsskål & Niebuhr, 1775) L,* , C 33 F ; 14 M ; 20 ND	P	All	67	17.76 (11.0-25.5)	2.63	69.26 (31.8-200.0)	30.68	0.027	2.706	0.110	0.80	0.35	A-
<i>Torpedo marmorata</i> (Risso, 1810) 6 F ; 16 M	S	All	22	25.18 (14.0-30.5)	3.71	347.55 (51.0-550.0)	107.30	0.398	2.093	0.273	0.87	0.03	A-
		M	16	25.00 (14.0-30.0)	3.49	327.69 (51.0-474.0)	95.74	0.352	2.118	0.312	0.95	A-	
<i>Trachurus picturatus</i> (Bowdich, 1825)* 4 F ; 7 M ; 10 ND	P	All	21	31.26 (18.0-35.0)	4.23	276.47 (54.9-432.0)	94.18	0.004	3.254	0.428	0.93	-	A+

The length and weight characteristics, as well as the sample size and parameters of the WLRs are represented in Table 22. These results provide new maximum lengths and weights for these species along the Lebanese coast. The sample sizes ranged from a minimum of 20 individuals for *Raja clavata* to a maximum of 1109 for *S. rubrum*. A minimum of 5 individuals was used to estimate WLR per sexual category. Pronounced sexual dimorphism in WLR was observed for *M. barbatus*, *P. erythrinus*, *P. phycis*, *S. rubrum* and *T. marmorata* with significant differences in the slopes of WLR between males and females (ANCOVA; $P < 0.05$). There were no significant differences in slopes between males and females in any of the other species. The values of the allometric coefficient (b) ranged from a minimum of 1.818 for *F. commersonii* to a maximum of 3.494 for *Raja miraletus* (Table 22) with a mean b value of 2.841 (SD. 0.376). One species evidenced isometric growth (I), 8 species showed positive allometry ($A+$), and 18 species had negative allometry ($A-$). All relations were highly significant ($P < 0.001$) with 59.26% r^2 greater than 0.9. At species level, the most accurate model was shown to be that of *Raja clavata* ($r^2 = 0.98$) and the least one was that of *Fistularia commersonii* ($r^2 = 0.68$).

WLRs patterns by geographical distribution were investigated in species with more than 80 individuals available (i.e. *A. foliacea*, *D. macrophthalmus*, *M. goltziana*, *M. merluccius*, *P. acarne*, *P. erythrinus*, *P. phycis*, *S. rubrum*). Highly significant ($P < 0.001$) differences in WLRs among regions were found only in *S. rubrum* (Table 23) while a significant ($P < 0.05$) difference at regional level was obtained for *M. goltziana*. In both cases, the WLR in the south sector showed a lower rate of growth of the body weight.

Table 21. Test for differences in slopes of the weight-length relationships for fish species caught in four different regions. n_i and b_i are respectively the sample size and the regression slope for each region i . P is the significance of covariance analysis bet ween region for $H_0: b_1 = b_2 = b_3 = b_4$ [in bold, significant differences ($P < 0.05$)].

Species	Akkar shelf		North		Center		South		P
	n_1	b_1	n_2	b_2	n_3	b_3	n_4	b_4	
<i>A. foliacea</i>	0	-	19	2.477	80	2.355	105	2.426	0.927
<i>D. macrophthalmus</i>	4	2.785	63	2.845	48	2.799	150	2.845	0.2843
<i>M. goltziana</i>	13	3.123	18	2.936	25	3.028	51	2.882	0.076
<i>M. merluccius</i>	1	-	9	2.741	6	2.611	86	2.721	0.308
<i>P. acarne</i>	4	2.970	67	2.916	13	3.004	41	2.978	0.147
<i>P. erythrinus</i>	26	2.921	57	2.885	1	2.731	13	2.947	0.247
<i>P. phycis</i>	1	-	62	2.797	17	2.720	65	2.833	0.064
<i>S. rubrum</i>	348	3.027	121	3.040	361	3.047	279	3.108	<2.2e-16

Estimated WLR parameters should be considered only as mean annual values for most of these species since the data were collected over an extensive period of time and are not representative of any particular season.

DISCUSSION

Information related to the length-weight relationships of demersal species is almost absent along the Lebanese coast. Froese (2006) and Froese et al. (2014) had analyzed the length-weight relationships of all fishes available on the Fishbase website (www.fishbase.org) using meta-analysis and Bayesian methods. A few studies carried out by Turkish Authors (Başusta et al., 2013; Ergüden et al., 2009; Ergüden et al., 2017; Gündoğdu et al., 2015; Özvarol, 2014; Sangun et al., 2007; Taskavak and Bilecenoglu, 2001) bring together information on WLRs for demersal species in the northern part of the eastern Mediterranean. This information allowed us comparisons with 15 species examined in the present study, i.e. *C. linguatula*, *D. vulgaris*, *F. commersonii*, *L. sceleratus*, *M. merluccius*, *M. barbatus*, *M. surmuletus*, *P. acarne*, *P. erythrinus*, *P. caeruleostictus*, *P. pagrus*, *S. rubrum*, *S. luridus*, *S. rivulatus*. WLRs show corresponding allometric patterns as those reported in aforementioned studies except for *M. barbatus* and *M. surmuletus* that differ from those reported by Özvarol 2014 and Sangun et al. 2007. In Lebanese waters, *Lagocephalus sceleratus*, *Raja miraletus* and *Torpedo marmorata* showed same allometric patterns as those reported by Khalaf et al. (2014) and Lteif et al. (2016), whilst *Raja miraletus* behavior differ from the one described by the last Authors (Table 24).

Table 22. Weight-length relationships (WLRs) for combined sex samples in Lebanese waters. a and b are the parameters of the WLRs ($W=aL^b$). Growth type: A+ = positive allometry and A- = negative allometry. Comparison between this study and previous ones: K reports data from Khalaf et al. (2004) and L from Lteif et al. (2016).

Species	This study		Previous studies ^{K, L}		This study / Previous studies
	<i>a</i> (10^{-3})	<i>b</i> (10^{-3})	<i>a</i> (10^{-3})	<i>b</i> (10^{-3})	
<i>Lagocephalus sceleratus</i> (Gmelin, 1789)	0.118	2.400	0.014 ^K	2.306 ^K	A- / A- ^K
<i>Raja clavata</i> (Linnaeus, 1758)	0.004	3.150	0.002 ^L	3.327 ^L	A+ / A+ ^L
<i>Raja miraletus</i> (Linnaeus, 1758)	0.001	3.494	0.352 ^L	2.118 ^L	A+ / A- ^L
<i>Torpedo marmorata</i> (Risso, 1810)	0.398	2.093	1.337 ^L	1.752 ^L	A- / A- ^L

The observed difference among regions could be due to the sampling procedure, such as an uneven sampling period. The sample of *S. rubrum* was relatively large (1109 specimens) and covered a reasonable size range, suggesting that the differences in slope could reflect the influence of differences in environmental or habitat factors (Morato et al., 2001). Moreover, according to Bagenal and Tesch (1978) and Gonçalves et al. (1997), the *b* parameters generally do not vary significantly throughout the year, unlike parameter *a* which may vary seasonally, daily and between habitats. As pointed out by Petrakis and Stergiou (1995), use of the WLR should be limited to the sizes in the estimation of the parameters. However, this may act as a tool to support fisheries management measures by establishing a minimum catch weight limit when lengths are estimated at sea. In Lebanon - where management measures are limited or outdated and the fishing pressure is high on coastal fisheries resources while fishing practices targeting juvenile fishes are partially driven by the market (Bariche et al., 2006; Sacchi & Dimech., 2011; Colloca & Lelli 2012), the use of basic but powerful descriptive tools of halieutic populations such as WLRs is highly recommended.

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Chapter 6

Population biology of the Lessepsian migrant *Sargocentron rubrum* (Forsskål, 1775) along Lebanon's coast, eastern Mediterranean

**Population biology of the Lessepsian migrant
Sargocentron rubrum (Forsskål, 1775) along
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Population biology of the Lessepsian migrant *Sargocentron rubrum* (Forsskål, 1775) along Lebanon's coast, eastern Mediterranean

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ABSTRACT

This study focuses on the biology of the Mediterranean population of the redcoat *Sargocentron rubrum*, an Indo-Pacific fish species firstly reported in Palestine in 1946. Between June 2012 and October 2014, 1109 individuals were collected by trammel and gill nets with different mesh sizes lowered by artisanal fishing vessels over coastal Lebanese marine waters at depths ranging from 10 to 100 m. The total length (L_T) of the specimens ranged from 12 to 22 cm, and the mean \pm s.d. was 17.38 ± 1.69 cm. The most common L_T class was 18 cm. Total weight of the specimens ranged from 33 to 248 g, and the mean \pm s.d. was 97.56 ± 29.74 g. A total of 432 males and 314 females were collected, and the sex ratio was significantly different from 1:1. Weight and L_T relationship showed a slightly negative allometric growth ($b=2.993$ and $r^2=0.86$), and the mean \pm s.d. L_T at which 50% of the individuals were sexually mature was 17.62 ± 2.28 cm for females and 17.45 ± 3.87 cm for males. The primary prey items found in the fish stomachs were crabs (infraorder Brachyura) and in particular those belonging to the genus *Thalamita*. *S. rubrum* is an extremely active predator between May and August whereas it feeds lightly in colder seasons. Stomachs gave the highest abundance both in terms of number and weight in the month of August. The lifespan of *S. rubrum* exceeds 6 years old with a maximum attainable size, $L_\infty = 21.315$. The results of this study will help to parameterize models of the population dynamics for this exploited fish stock to better understand its role in the ecosystem functioning and the interactions with other commercially exploited native species.

Key words: Teleostean; non indigenous; Lebanon; life history; fishing, reproductive biology.

INTRODUCTION

Following the cut of the Suez Canal, completed in 1869, that connected two water bodies with different abiotic characteristics and distinct peculiar biotas, the number of fish species migrating from the Red Sea to the Mediterranean, known as Lessepsian migrants (Por, 1971), increased steadily in the decades following the 1920s but accelerated dramatically after the year 2000, reaching 101 species in 2014 (Arndt & Schembri, 2015). Hundreds of other taxa (Galil, 2009; Zenetos, *et al.*, 2012) moved in the Mediterranean at the same time, giving rise to one of the greatest biogeographic convolutions ever witnessed by the contemporary globe (Por, 2010). Currently, Lessepsian fish species constitute a large proportion of commercial captures in eastern Mediterranean countries (Goren & Galil, 2005; Carpentieri, *et al.*, 2009; Edelist *et al.*, 2011).

Demersal resources of the eastern Mediterranean have become a mixture of indigenous and non-indigenous species (NIS) mainly of Lessepsian origins (Galil *et al.*, 2017) but crossing the Suez Canal does not guarantee successful settlement and dispersal of populations. While hydrological conditions are important in understanding the successful spreading of many NIS (Mavruk & Avsar, 2008), species' external morphology (Azzurro, *et al.*, 2014) and their ecology are key determinants for settlement and dispersal success (Galil *et al.*, 2017; Rilov & Galil, 2009). The majority of successful fish invaders in the Mediterranean are spawning, shallow water, benthic carnivores (Rilov & Galil, 2009). Assemblages composition is mainly driven by depth and easternmost sectors are witnessing deadly competitions whereby some native species are being probably replaced by NIS occupying similar ecological niches (Edelist *et al.*, 2013). The overall trophic space is widening out under the increasing redundancy of the novel community in a nutrient-deprived ecosystem. Consequently, Eastern Mediterranean demersal communities are far from being in a steady state (Fanelli *et al.*, 2015).

The redcoat *Sargocentron rubrum* (Forsskål, 1775) belongs to the family Holocentridae (Figure 33). It is an Indo-West Pacific species whose distribution ranges from Tonga (Randall, *et al.*, 2003), Japan and northwestern Australia to eastern Africa (Fiona & Mark, 2002) and the Red Sea (Randall, 1998). From there via the Suez Canal, it moved into the Mediterranean, as one of the earliest Red Sea immigrant. It was firstly reported in Palestine in 1946 (Haas & Steinitz, 1947; Laskaridis, 1948) and only one year later in Greek waters, off the northeast end of Rhodes island (Laskaridis, 1948). In the easternmost waters of the Levantine basin, by mid 1960s, *S. rubrum* is already considered as a 'common' fish species (George *et al.*, 1964; Ben-Tuvia, 1966). It is currently considered as a successful invader (Azzurro *et al.*, 2014) and is reported abundant in its easternmost area of distribution (Golani, 1998; Carpentieri *et al.*, 2009; Colloca & Lelli, 2012; Lelli, 2007; Harmelin-Vivien *et al.*, 2005; Edelist & Spanier, 2009) although its Mediterranean distribution is mainly limited to the eastern part (Zenetos, *et al.*, 2015). It is commonly caught by passive gears and bottom trawls in Egypt, Palestine, Lebanon, Turkey, Cyprus, Greece (Megisti Island, Crete and Rhodes) (EastMed, 2010) and Israel (Golani & Ben-Tuvia, 1985). Due to its hard-scaled body and sharp spines, *S. rubrum* is not appreciated by consumers and thus has a low value on the market (approximately 1 USD per kilogram) (Golani & Darom, 1999; Colloca & Lelli, 2012) or it is not sold, discarded or consumed by fishers and their families.



Figure 31. An embalmed specimen of *Sargocentron rubrum* exposed in the Lebanese fishing port of Ouzaii (Beirut).

It is found in coastal waters up to 85 meters depth (Randall, 1998) commonly between 10 and 40 m (Golani, 1981; Harmelin-Vivien *et al.*, 2005) on rocky grounds, particularly during the day in caves and cracks of rocks. It typically occurs in aggregations, feeding mainly on benthic crabs, shrimps and small fishes (Golani & Ben-Tuvia, 1985). Its eggs and larvae are pelagic (Ben-Tuvia, 1986). Surprisingly, using DNA barcoding techniques, (Bariche, *et al.*, 2015) got to the conclusion that more than one species belonging to the genus *Sargocentron* has entered over time the Mediterranean from the Red Sea, remaining unreported and probably misidentified. The subtropical reef-associated Holocentridae species native to the western Atlantic Ocean *Holocentrus adscensionis* has been recently recorded in Maltese waters by (Vella, *et al.*, 2016).

Rare are the studies performed on the redcoat in the eastern Mediterranean, and none along Lebanese coastal waters. This study essentially reflects the biological aspects of the redcoat fish population in response to the needs for such information. The objectives were to contribute to a better knowledge of the population biology and to increase the knowledge on age determination, growth, sexual maturity, reproduction and nutritional strategy for this species in the Lebanese marine waters. Length and weight data, sex ratio, length-weight relationships, length at which 50% of the individuals matured, condition factor as well as the main prey items found in the stomachs of this species are presented and compared to available data from other areas. This study provides a first evaluation of the population health condition in the Mediterranean Sea habitat and aims, at a longer term, to better understand the role of this species in the ecosystem functioning and the interactions with other commercially exploited native species and to stimulate, in case of necessity, the implementation of regulations to control the spread of this species.

MATERIALS AND METHODS

A total of 1109 specimens of redcoat were collected from June 2012 to October 2014 in the Lebanese marine waters, Levantine Sea (eastern Mediterranean). Lebanese coastal line (225 km) was break down into 4 regions (Figure 34) to allow geographical-based analysis. Specimens were sampled using trammel and gill nets with different mesh sizes lowered by artisanal fishing vessels.

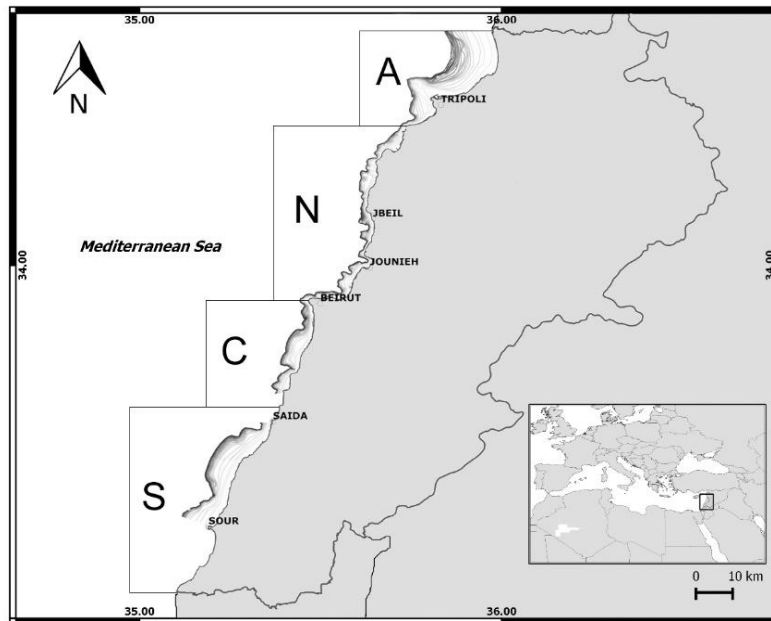


Figure 32. Location of the sampling area in Lebanese marine waters, eastern Mediterranean. Lebanese coastal waters were break down into 4 regions based mainly on the conformation of the continental shelf (A: Akkar shelf; N: North; C: Center; S: South). Bathymetries up to 100 meters depth are shown.

All the individuals collected - irrespective the species - were measured and weighed, additionally sex and maturity stage were determined. Collected specimens were stored on board and returned to the laboratory. In the laboratory, each specimen collected was measured and weighed. A measuring tape was used to measure fish total lengths (TL) to the nearest 0.1 centimeter (cm). Total weights (wet weight, W) were measured to the nearest 0.01 gram (g) using a digital balance. Standardized protocols and minimum requirements adopted during the surveys are summarized in Table 25.

Table 23. Protocols and minimum requirements adopted for nets management, vessels minimum requirements and biological data collection. * MEDITS Working Group, 2013.

Nets management	
Soak time	Approximate 12 hours, overnight
Lowering time	Afternoon
Retrieving time	Dawn
Operators	Professional artisanal fishermen
Vessels' minimum requirements	
LOA	> 7m
Engine Power	> 16 hp
Winch	Hydraulic or Motorised
Available equipment	GPS, Fishfinder, Safety equipment
Biological data collection	
Biometric: length	TL, nearest 0.1 cm (fish) CL, lower mm (crustaceans)
Biometric: weight	Nearest 0.01 grams
Biological: sex & maturity stages	MEDITS programme protocols* (Codes of sexual maturity for Fish, Crustaceans and Cephalopods)
Biometric & Biological Parameters	Collected on all the specimens

Sex determination

Sexual stages were identified on a scale from 1 to 4. Additionally, the class zero was added to identify undetermined specimens, the class 2 and 4 were divided into 3 and 2 subclasses respectively (MEDITS Working Group, 2013). Maturity stages for males and females were as follows: 1) Immature=Virgin; 2a) Virgin Developing; 2b) Recovering; 2c) Maturing; 3: Mature/Spawner; 4a) Spent; 4b) Resting.

Condition fish index

The Fulton's condition factor (CF) (Fulton, 1904) was also computed using total weight (W_T) and total length (L_T), where:

$$CF = W_T \times L_T^{-3} \times 100$$

The K is used to compare the 'condition', 'fatness', or 'well-being' of fish, based on the assumption that heavier fish of a given length are in better condition (Froese, 2006).

Weight-Length Relationship

The parameters a and b , of the Weight-Length Relationship (WLR) curve ($W = aL^b$) were estimated using a nonlinear least squares function nls in the statistical software R (R Development Core Team, 2014). The start values of these parameters were derived from the log transformation of the two variables ($\ln W = \ln a + b \ln L$) using the linear model function lm . The coefficient of determination (r^2) aids in determining the accuracy of the model prediction skills. Finally, statistical comparison of WLR between sexes and geographical sectors was performed by applying ANCOVA tests (Zar, 1996). Standard deviations of b were calculated to detect substantial deviation from isometric growth ($b=3$).

Significant difference of b values from 3, which represent isometric growth, was tested with the T-test (Pauly, 1993).

Ageing fish and growth curves

To assess the annual nature of otolith rings, the seasonal evolution of the marginal ring of the otolith was determined from fish having 2 to 6 rings. Whole otoliths were observed under reflected light against a dark background, so that alternating dark and white rings called hyaline and opaque, respectively, could be seen. The hyaline rings formed at an annual rate (true annuli) were detected. These otoliths were viewed while immersed in water (Williams & Bedford, 1974). The technique of otolith sectioning as described by Bedford (1983) was not followed because whole otoliths were considered better for measuring the marginal increments and because of the fragility of the sections.

Once the rings were considered to be annual, each specimen was assigned to a year class, taking into account the data of capture, the annuli counts, their formation period, and the reproductive biology of the species in the area (Figure 35). Although data on spawning of this species in the Mediterranean is scarce, Golani & Ben-Tuvia (1985) place the spawning season in July-August. Otoliths were read under a light microscope, coupled to a high-resolution video camera and monitor system, following standard procedures.

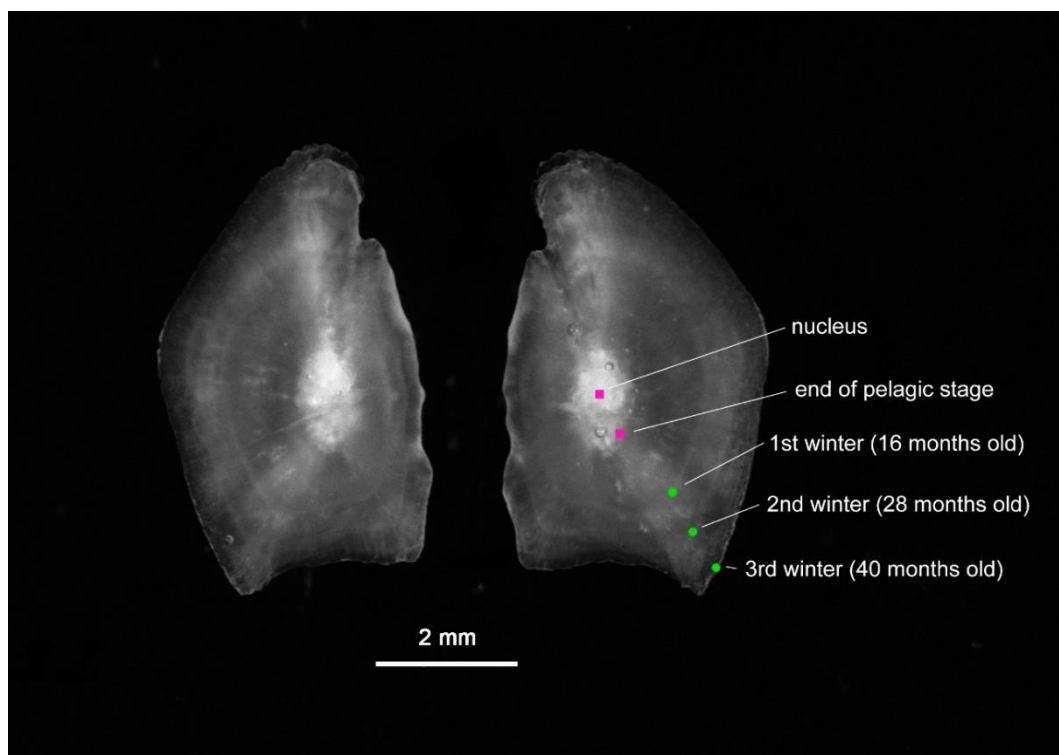


Figure 33. Otoliths of a specimen of *Sargocentron rubrum* collected in the month of February and the interpretation based on the alternation of hyaline areas and opaque, thin annual rings laid winter. (Photo: Salvatore Gancitano).

Analysis of length-at-age data was performed in the statistical software R (R Development Core Team, 2014) to estimate growth parameters K and L . This allows non-linear estimation of growth parameters from length at-age data. The Von Bertalanffy's plot is used to estimate t_0 from the known age/length data and estimated L_∞ and K . The method is based on the regression analysis of the following formula:

$$-\ln(1-L_t/L_\infty) = -K * t_0 + K * t$$

Where: the age t is the independent variable (x) and $(-\ln(1-L(t)/L))$ is the dependent variable (y) of the linear regression. L_∞ is the asymptotic L_T , L_t the L_T at age t , K the growth curvature parameter, and t_0 is the theoretical age when fish would have been at zero L_T .

Stomach content analysis

The total weight of the stomach (W_S) was measured. Stomachs with food contents were preserved in 70% alcohol until identification. The stomach contents were then rinsed under tap water. Their weight was measured if possible to the nearest gram, counted and identified to the lowest possible taxon. The total weight of each prey group was measured if possible to the nearest gram. According to Hyslop (1980), two indices were calculated. The coefficient of vacuity (C_V) was calculated to reflect the richness or lack of food in the environment:

$$C_V = E_V \times N^{-1} \times 100$$

where E_V is the number of empty stomachs and N is the total number of stomachs examined.

The percentage of fullness (F_I) was also calculated for each stomach:

$$F_I = W_P \times W_S^{-1} \times 100$$

where W_P is the weight of the prey items in each stomach. Stomach fullness was classed based on a five-point scale estimated by the percentage of fullness:

empty, partially empty (1-25%), slightly full (26-50%), partially full (51-75%), and full (76-100%).

Moreover, three indices were used to show the significance of different prey items. The frequency of occurrence ($O\%$), the coefficient of prey numerical abundance ($N\%$), and the percentage of weight ($W\%$) (Hynes, 1950; Hyslop, 1980; Bowen, 1983):

$$O\% = N_p \times M^{-1} \times 100$$

$$N\% = n \times n_p^{-1} \times 100$$

$$W\% = m \times m_p^{-1} \times 100$$

where N_p is the number of stomachs containing a specific prey group, M is the number of stomachs with prey remains, n is the number of prey of each taxonomic group, n_p is the total number of prey items, m is the mass of prey of each taxonomic group, and m_p is the total mass of prey items. Out of these indices, the importance of each food item in the diet was obtained by the Index of Relative Importance (I_{RI}) (Pinkas *et al.*, 1971) modified by Hacunda (1981):

$$I_{RI} = O\% \times (N\% + W\%)$$

Statistical analyses

The L_T and W_T were used to generate the WLR using a non-linear power regression ($W_T = aL_T^b$) (LeCren, 1951) where a and b are the parameters to be estimated. A non-linear power regression was also used to determine the relationship between the W_G and L_T of male specimens ($W_G = aL_T^b$). Non-linear regressions were used to represent any regression of weight on length because any weights will scale

to the cubic power of length (Froese, 2006). In addition, the length at which 50% of the fish are mature (L_{50}) was estimated across all length classes using a logistic curve from a generalized linear model (GLM) with logit link using the function *glm* in the statistical software R (R Development Core Team, 2014). Furthermore, statistical comparison of WLRs between the sexes was evaluated with an ANCOVA test. A Shapiro-Wilk normality test was used to test for normality in the sample and the Wilcoxon rank sum test was used to test for differences in length, weight and per cent fullness between the males and females. A Kruskal-Wallis rank sum test was used to examine the differences between L_T and W_T with respect to sexual maturity and between the biological indices (I_G , I_H and K) according to the season. The χ^2 goodness of fit test [$\alpha=0.05$, (Zar, 2010)] was used to examine significant deviations from the expected sex ratio.

To determine the feeding strategy of the species, feeding strategy graphs were plotted following the method of Costello (1990). The feeding strategy graphs illustrate the dominance and rarity of each type of prey in both seasons and whether the feeding strategy is specialized or generalized.

RESULTS

Morphometric measurements and depth distribution

A total of 1109 individuals (432 females, 314 males and 363 undetermined or immature) of redcoat ranging from 12 to 22 cm in TL (mean $TL \pm SD = 17.38 \pm 1.69$ cm, $N=1109$) and from 33.2 to 248.0 g in W (mean $W \pm SD = 97.56 \pm 29.74$ g, $N=1109$) were studied. Specimens were collected at depths ranging from 10 to 100 m, with nearly 80% (884 individuals) of the specimens collected at depths between 30 and 60 m. The sex ratio of males to females was found to be 0.73. Therefore, significant differences between the number of males and females were observed and with a sex ratio significantly different from 1:1 ($P<0.05$).

Separate length–frequency distributions by sex show similar length ranges, i.e. 12.5-22 and 12.5-21.5 cm TL for male and female respectively (Figure 36). Most frequent length classes are 17 and 18 cm TL for male, and 18-19 cm TL for females. For the whole sample, the most frequent length class is 18 cm TL . Most frequent length classes are 17 and 18 cm TL for male, and 18-19 cm TL for females. For the whole sample, the most frequent length class is 18 cm TL . Similar weight ranges were also found, i.e. 35.4-248.0 g and 33.2-216.4 g for male and female respectively, with average values of 101.37 ± 25.559 g and 103.60 ± 24.186 g. Males and females showed no significant differences in length and weight distributions.

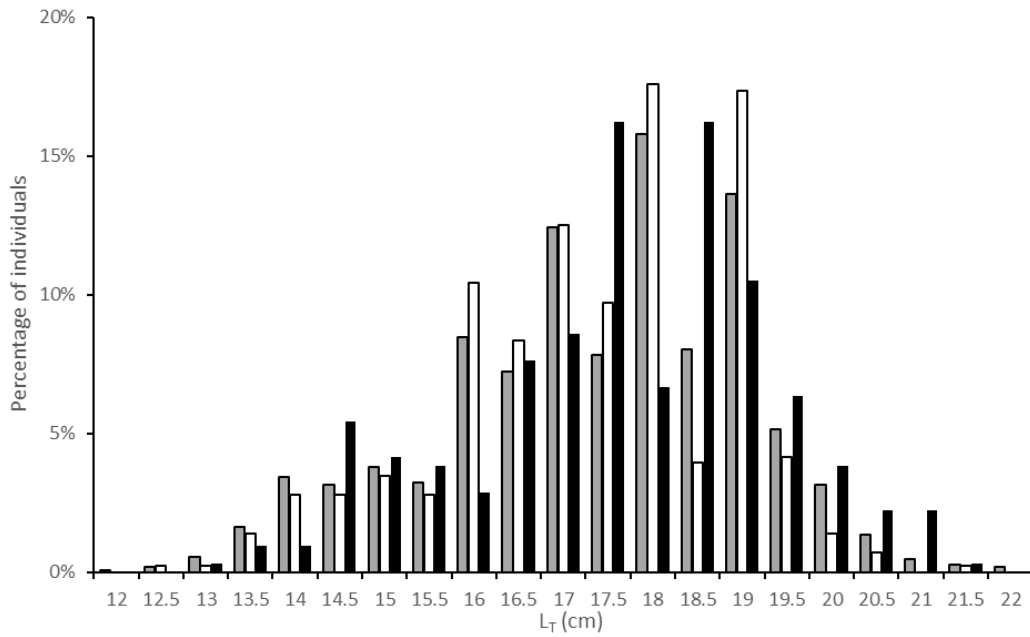


Figure 34. The length frequency distribution of the redcoat *S. rubrum* for the whole sample (■), males (●) and females (□).

Weight-Length relationship (WLR)

WLR for *S. rubrum* evidenced isometric growth (I) for the whole sample and for males and slightly positive allometric growth for females. All relations were highly significant ($P < 0.001$) with r^2 greater than 0.85 for the three groups. Intercepts varied between 0.016 and 0.018. Pronounced sexual dimorphism in WLR was observed with significant differences in the slopes of WLR between males and females (ANCOVA; $P < 0.05$) (Figure 37).

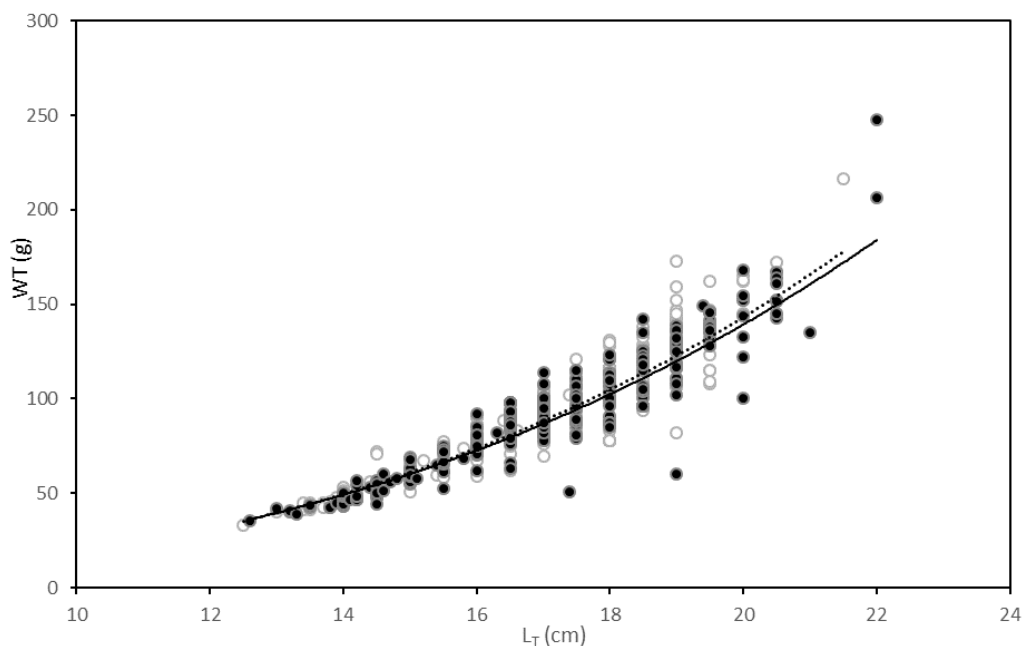


Figure 35. The weight-length relationship of *S. rubrum* for the whole sample ($N=1109$). Males (● and continuous line) and females (○ and pointed line) are displayed separately. For females, the equation of the fitted exponential regression

model with $r^2=0.85$ is: $WT = 0,016 * L_T^{3.035}$. For males: $r^2=0.86$; $WT = 0,018 * L_T^{2.995}$. For whole individuals collected, the equation with $r^2=0.86$ is: $WT = 0,018 * L_T^{2.993}$.

WLR patterns by geographical distribution were investigated and a highly significant ($P < 0.001$) differences in WLRs among regions was found (Table 26). In particular, sector 4 'South' showed a clear positive allometric growth.

Table 24. Test for differences in slopes of the weight-length relationships for *S. rubrum* specimens caught in four different regions. n_i and b_i are respectively the sample size and the regression slope for each region i . P is the significance of covariance analysis between region for $H_0: b_1 = b_2 = b_3 = b_4$ [significant difference ($P < 0.05$)].

Sector 1 - Akkar Shelf		Sector 2 - North		Sector 3 - Center		Sector 4 - South		P
n_1	b_1	n_2	b_2	n_3	b_3	n_4	b_4	
348	3.027	121	3.04	361	3.047	279	3.108	<2.2e-16

Sexual maturity and biological indices

All stages of maturity were observed among the specimens collected during the study period both for males and females. Males and females were equally distributed among all of the observed maturity stages (Figure 38).

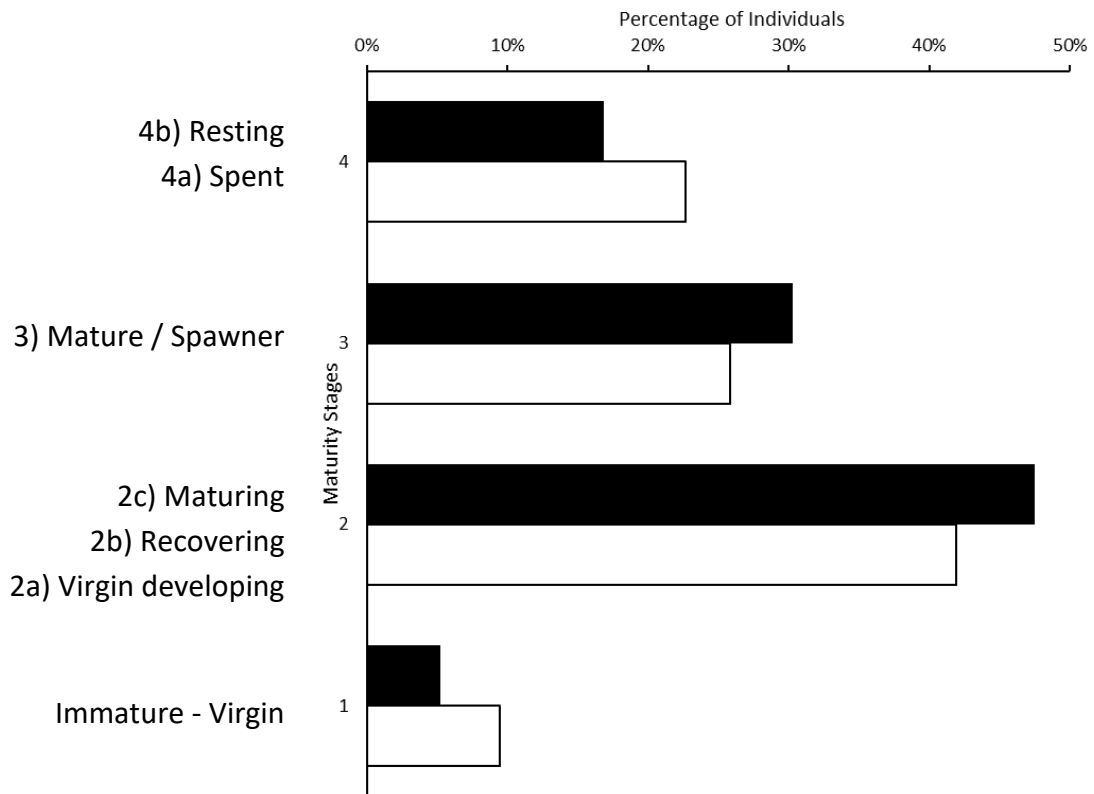


Figure 36. Percentages of *S. rubrum* individuals with respect to the stage of maturity as categorized by MEDITS (2013) and sex (Males ■ ; Females □).

In addition, significant differences were observed among weights and lengths of specimens for each maturity stage regardless of whether the sexes were analysed in combination or separately.

Taking into account substages as defined by MEDITS Handbook (2013), males and females were both predominantly found of substages 2b “Recovering” and 3 “Mature/Spawner”. Females always attained a longer size than males except for maturing/developing category in which average sizes are identical. The smallest mature male was observed at 15 cm L_T and the smallest mature female at 15.5 20 cm L_T .

Spawning season

Mature individuals have been collected for males and females over the four seasons but very few individuals were found in autumn and winter. For females, mature individuals prevail in spring whereas for males, they prevail in summer and spring. For females, immature individuals prevail in autumn and summer and for male, they prevail in winter and fall (Figure 39).

The results of the Kruskal –Wallis test indicates a significant difference between the maturity stages and the season for males and females.

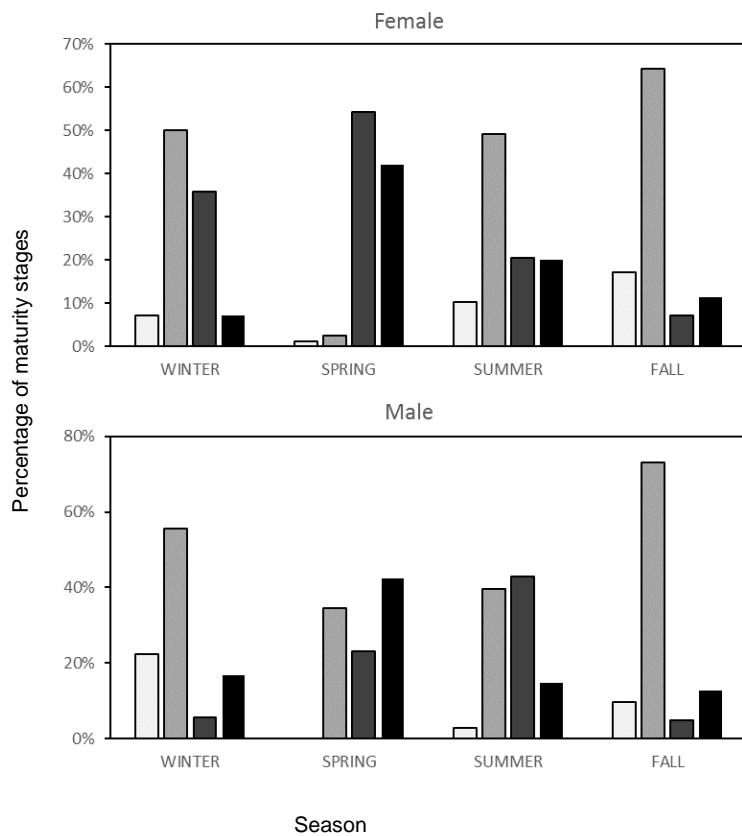


Figure 379. Percentages of maturity stages by seasons females (top) and for males (bottom) of *S. rubrum* in the eastern Mediterranean. □ Immature/vergin; ◻ maturing/developing; ◼ mature/spawner; ◼ resting/spent.

The length at which 50% of males and females attain maturity is estimated by fitting a logistic regression curve. The latter indicated that the length at 50% maturity (L_{50}) was 16.91 ± 2.28 cm for females and 16.46 ± 3.87 cm for males (Figure 40).

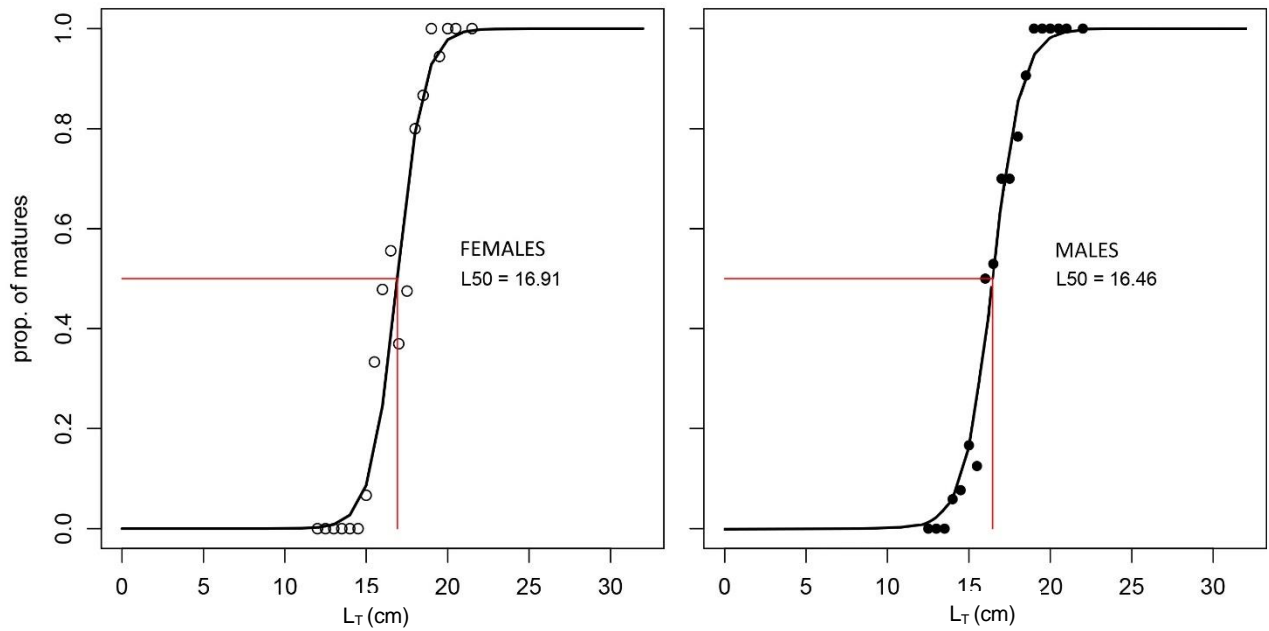


Figure 38. The proportion of mature redcoat, *S. rubrum* to length class to estimate the length at 50% maturity (L50) in logistic regressions. LT is the total length.

Stomach content analysis

A total of 123 *S. rubrum* stomachs were examined. 79 stomachs were found to contain food items, and 44 stomachs were empty or contained non-identifiable food items at any taxonomic level. The coefficient of vacuity was 35.77% for all specimens and 13.82%, 17.07% and 4.88% for female, male and undetermined specimens, respectively. The highest rates of the full stomachs (36.36%) belonged to males of the biggest length classes and males and females of the 16 to 18 cm LT (Figure 41).

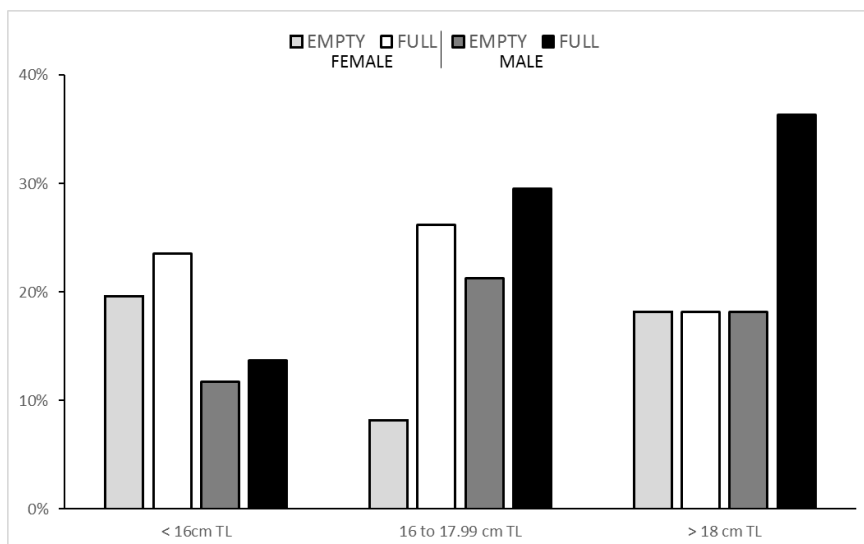


Figure 39. The proportion of full and empty stomachs of *S. rubrum* by sex according to length classes.

The redcoat *S. rubrum* was found to prey upon 8 categories (classes) of preys, namely the red algae Florideophyceae; Polychaetas; Malacostraca (subphylum Crustacea) specifically the orders

Amphipoda, Decapoda and Isopoda; the molluscs polyplacophorans, bivalves, gastropods, cephalopods, and the bony fishes Actinopterygii.

Overall, Malacostraca were the most abundant preys (83.95%). Malacostraca Decapoda alone account for 44.74% of the whole samples. In terms of weight, bony fishes account for 17.61% whereas molluscs reached 13.38% (Table 27).

Table 25. Food items found in the stomach of *S. rubrum* in Lebanese waters. Number of stomachs in which the prey occurs (O), the number of preys (N) and the weight in grams (W) are reported. Also, the frequency of occurrence (O%), coefficient of prey numerical abundance (N%), percentage of weight (W%), and the Index of Relative Importance (IRI) were estimated.

		O (O%)	N (N%)	W (W%)	IRI
Rhodophyta					
	<i>Corallina officinalis</i>	5 (4.07)	5 (0.99)	0.4 (0.94)	0.08%
Polychaeta					
	Eunicidae	30 (24.96)	39 (7.72)	1.6 (3.52)	2.74%
	Goniadidae	1 (0.81)	1 (0.20)	0 (0.23)	0.00%
Crustacea not identified		2 (1.63)	2 (0.40)	0 (0.00)	0.01%
Amphipoda					
	Gammaridea	16 (13.01)	97 (19.21)	1.1 (2.58)	2.57%
Isopoda		3 (2.44)	6 (1.19)	0.2 (0.47)	0.04%
	Sphaeromatidae	26 (21.14)	93 (18.42)	1.6 (3.76)	4.69%
Decapoda		23 (18.70)	44 (8.71)	1.8 (4.23)	2.42%
Dendrobranchiata					
	Penaeidae	1 (0.81)	1 (0.20)	0.1 (0.23)	0.00%
Caridea					
	Alpheidae	14 (11.38)	14 (2.77)	1.1 (2.58)	0.61%
	<i>Alpheus</i> sp.	4 (3.25)	6 (1.19)	2 (4.69)	0.19%
	<i>Synalpheus</i> sp.	2 (1.63)	2 (0.40)	0.5 (1.17)	0.03%
	Pandalidae	1 (0.81)	1 (0.20)	0.2 (0.47)	0.01%
	Processidae	10 (8.94)	22 (4.35)	0.2 (0.47)	0.43%
Anomura					
	<i>Galahtea</i> sp.	3 (2.44)	4 (0.79)	0.3 (0.70)	0.04%
	<i>Pisidia</i> sp.	2 (1.63)	4 (0.79)	0.6 (1.41)	0.04%
Brachyura		27 (21.95)	47 (9.31)	4.9 (11.50)	4.57%
	Epialtidae	2 (1.63)	2 (0.40)	0.2 (0.47)	0.01%
	<i>Acanthonyx lunulatus</i>	8 (6.50)	9 (1.78)	0.6 (1.41)	0.21%
	<i>Ebalia</i> sp.	2 (1.63)	2 (0.40)	0.1 (0.23)	0.01%
	<i>Myra subgranulata</i>	1 (0.81)	1 (0.20)	0.1 (0.23)	0.00%
	Parthenopidae	1 (0.81)	1 (0.20)	0.2 (0.47)	0.01%
	Pilumnidae	7 (5.69)	10 (1.98)	1.4 (3.29)	0.30%
	Portunidae	6 (4.88)	9 (1.78)	1.1 (2.58)	0.21%
	<i>Gonioinfradens paucidentata</i>	4 (3.25)	8 (1.58)	2.7 (6.34)	0.26%
	Thalamita sp.	8 (6.50)	19 (3.76)	2.6 (6.10)	0.64%
	Xanthidae	6 (4.88)	12 (2.38)	1.1 (2.58)	0.24%
	<i>Xantho granulicarpus</i>	6 (4.88)	8 (1.58)	2.7 (6.34)	0.39%
Mollusca					
	Polyplacophora				
	Chitonidae	1 (0.81)	1 (0.20)	0.1 (0.23)	0.06%

Gastropoda	<i>Chiton</i> sp.	3 (2.44)	3 (0.59)	0.8 (1.88)	0.06%
		3 (2.44)	3 (0.59)	0.6 (1.41)	0.05%
	Pyramidellidae	1 (0.81)	1 (0.20)	0.1 (0.23)	0.00%
	Retusidae	1 (0.81)	1 (0.20)	0.1 (0.23)	0.00%
Cephalopoda	Nassariidae	3 (2.44)	4 (0.79)	1 (2.35)	0.08%
		2 (1.63)	2 (0.40)	2.5 (5.87)	0.10%
Cephalopoda	Octopodidae	1 (0.81)	1 (0.20)	0.2 (0.47)	0.01%
Bivalvia		1 (0.81)	1 (0.20)	0.3 (0.70)	0.01%
Actinopterygii not identified		5 (4.07)	5 (0.99)	0.4 (0.94)	0.08%
Atheriniformes	<i>Atherina</i> sp.	1 (0.81)	1 (0.20)	0.9 (2.11)	0.02%
Clupeiformes	Clupeidae	1 (0.81)	1 (0.20)	0.8 (1.88)	0.02%
Clupeiformes	<i>Sardinella aurita</i>	2 (1.63)	2 (0.40)	1.9 (4.46)	0.08%
Clupeiformes	<i>Engraulis encrasicolus</i>	2 (1.63)	2 (0.40)	1 (2.35)	0.04%
Perciformes	Gobiidae	4 (3.25)	4 (0.79)	1.5 (3.52)	0.14%
Perciformes	Labridae	3 (2.44)	3 (0.59)	0.6 (1.41)	0.05%
Perciformes	Serranidae	1 (0.81)	1 (0.20)	0.4 (0.94)	0.01%

The analysis of the weight of prey items in stomachs (W_p) according to the month showed that the heaviest stomach contents were found primarily in August and secondly in June whereas all the stomachs collected in the month of September were empty. No empty stomachs were found in August (Figure 42).

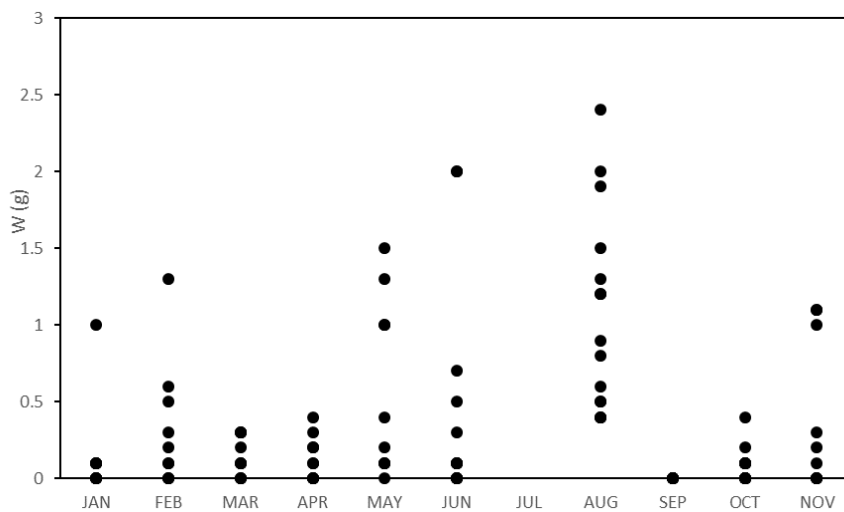


Figure 40. Weight of the prey items in each stomach (W_p) collected for *S. rubrum* in Lebanese waters by month of collection.

Numerical abundance ($N\%$), and the percentage of weight ($W\%$) were also monthly estimated. Both $N\%$ and $W\%$ showed biggest presence in terms of number and weight of preys in the months of August and May whereas the poorest were found in September (no preys whatsoever) and October (Figure 43).

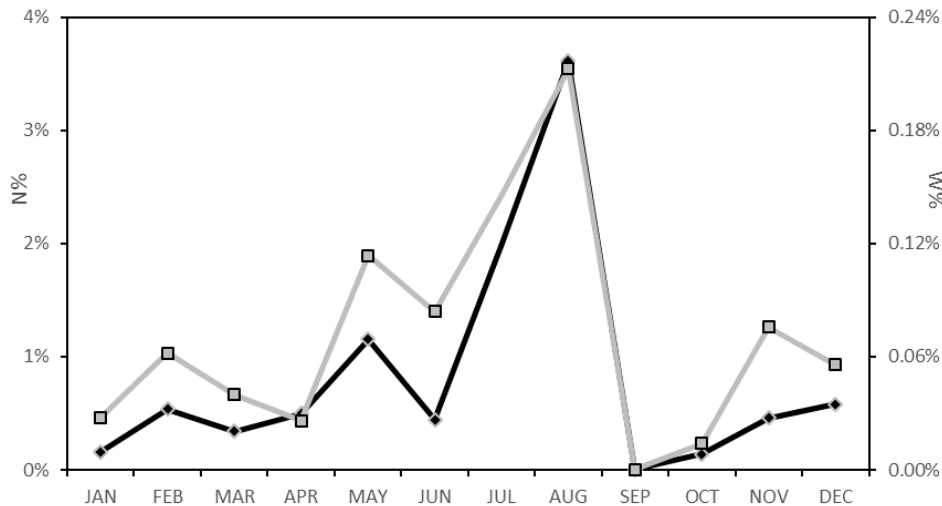


Figure 41. Numerical abundance (N%, grey curve), and the percentage of weight (W%, black curve) of preys in stomach contents of *S. rubrum* collected in Lebanese coastal waters.

In all seasons, according to IRI, Brachyura was the most abundant prey group with a peak value in summer ($I_{RI} = 41.49\%$). Isopoda are remarkably abundant in spring ($I_{RI} = 9.82\%$) and summer ($I_{RI} = 10.80\%$) while in the latter season, polychaeta occurs in more than half of the stomach analysed ($O_{\%} = 51.71$) (Table 28). Rhodophyta and Anomura were found only in summer while Polychaeta were absent from stomach contents in fall. Caridea, whose IRI varies through season between 7.88% in spring and 1.87% in fall, in summer show a high occurrence in stomach contents ($O_{\%} = 41.38$). Mollusca and bony fishes play a limited role in terms of occurrence ($O_{\%}$) and abundance (N%), although their percentage of weight (W%) give higher relevance both for pelagic and demersal species.

Table 26. Variation in the diet of *S. rubrum* in terms of the frequency of occurrence ($O_{\%}$), coefficient of prey numerical abundance (N%), percentage of weight (W%), and Index of Relative Importance (IRI) through seasons.

Prey Group	WINTER				SPRING				SUMMER				FALL			
	N%	O%	W%	IRI	N%	O%	W%	IRI	N%	O%	W%	IRI	N%	O%	W%	IRI
Rhodophyta	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.66%	17.24%	1.81%	0.60%	0.00%	0.00%	0.00%	0.00%
Polychaeta	12.50%	13.33%	4.62%	2.28%	12.75%	36.67%	6.62%	7.10%	5.98%	51.72%	3.25%	4.77%	0.00%	0.00%	0.00%	0.00%
Amphipoda	4.69%	3.33%	0.49%	0.17%	5.88%	16.67%	0.87%	1.12%	29.24%	27.59%	4.50%	9.31%	3.03%	2.86%	0.21%	0.09%
Isopoda	12.50%	16.67%	2.10%	2.43%	26.47%	30.00%	6.25%	9.82%	20.93%	41.38%	5.17%	10.80%	12.12%	5.71%	1.36%	0.77%
"other Decapoda"	12.50%	23.33%	4.88%	4.06%	18.63%	36.67%	10.21%	10.57%	5.65%	17.24%	3.24%	1.53%	0.00%	0.00%	0.00%	0.00%
Caridea	10.94%	16.67%	8.99%	3.32%	13.73%	26.67%	15.83%	7.88%	5.32%	41.38%	6.42%	4.86%	21.21%	5.71%	11.60%	1.87%
Anomura	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.66%	17.24%	4.06%	1.16%	0.00%	0.00%	0.00%	0.00%
Brachyura	39.06%	36.67%	49.94%	32.64%	14.71%	30.00%	26.39%	12.33%	24.58%	58.62%	46.19%	41.49%	42.42%	20.00%	36.08%	15.70%
Mollusca	1.56%	3.33%	4.84%	0.21%	2.94%	10.00%	14.09%	1.70%	1.66%	13.79%	8.33%	1.38%	15.15%	8.57%	34.40%	4.25%
"other Fish"	0.00%	0.00%	0.00%	0.00%	1.96%	6.67%	2.04%	0.27%	0.33%	3.45%	0.36%	0.02%	6.06%	5.71%	2.98%	0.52%
"pelagic fish"	1.56%	3.33%	11.08%	0.42%	0.98%	3.33%	9.76%	0.36%	1.33%	13.79%	13.84%	2.09%	0.00%	0.00%	0.00%	0.00%
"demersal fish"	4.69%	10.00%	13.54%	1.82%	1.96%	6.67%	7.95%	0.66%	0.66%	6.90%	2.82%	0.24%	0.00%	0.00%	0.00%	0.00%

Analysis of feeding strategy according to the Costello graphs showed that the redcoat had a mixed feeding strategy based mainly on crustaceans and particularly brachyurans especially in winter and fall (Figure 43 a, d) when this was particularly evident. Amphipoda is the most abundant (N%) in

summer (Figure 44 c) prey group while Polychaeta were relevant feeding items in spring and summer (Figure 44 b, c).

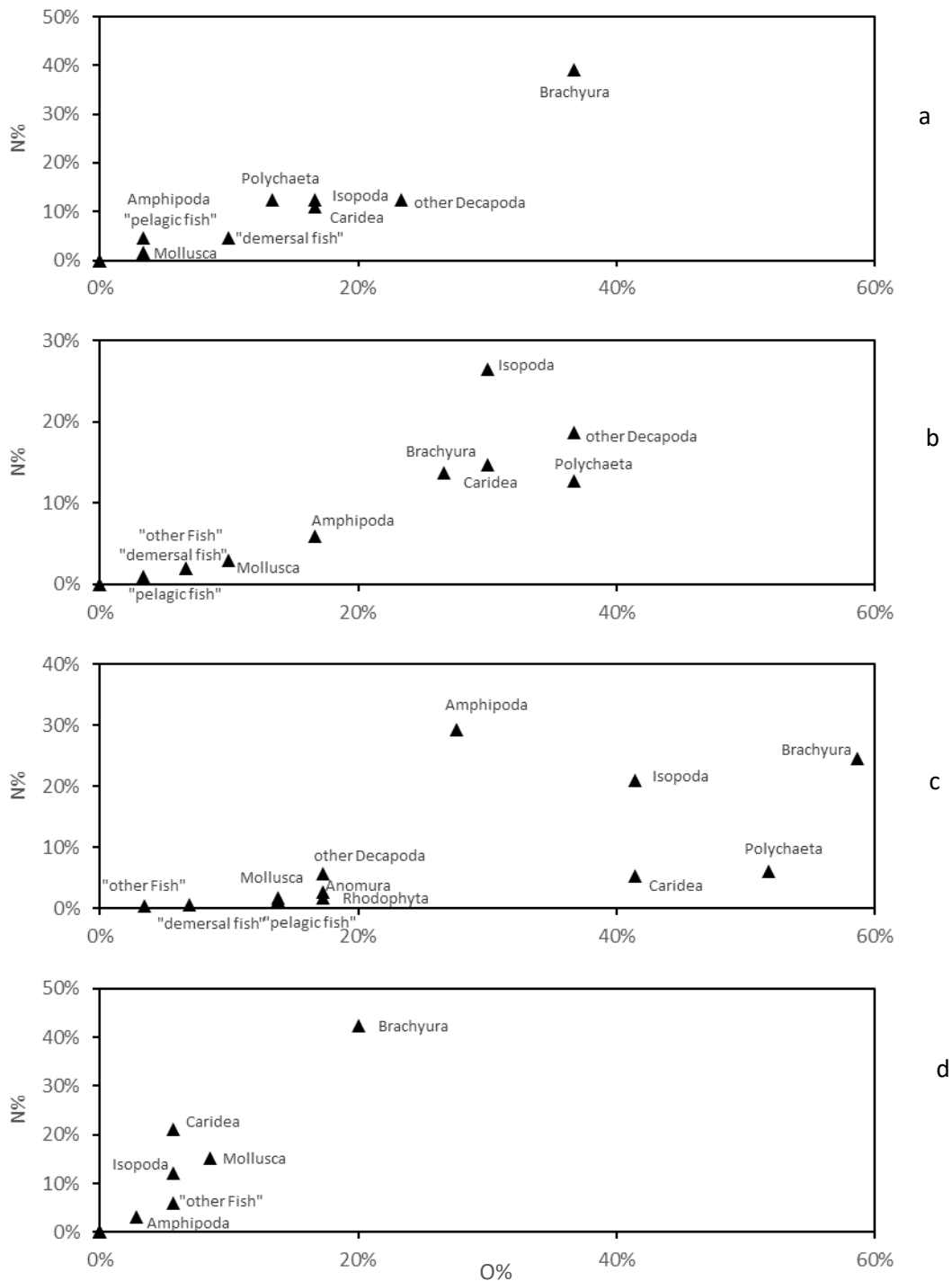


Figure 42. Feeding strategy graphs for *S. rubrum* specimens in the winter (a), spring (b), summer (c) and fall (d) seasons.

The Lebanese coastal waters are characterized by thermophilic biota of Mediterranean and Indo-Pacific origin (Abboud-Abi Saab *et al.*, 2013; Bitar *et al.*, 2007). The local biodiversity is undergoing rapid alterations under the combined pressures of climate change and human impact. Native marine flora and fauna are competing with invading organisms originating from the Indo-Pacific and Atlantic

oceans (MoE/UNDP/ECODIT, 2011) (Abboud – Abi Saab, 2012). The features of the Lebanese coastline with no closed bays or gulf consent to coastal waters to continuously mix thus preventing conditions of eutrophication and to disperse nutrients and pollutants.

Age and growth

The sample consisted of individuals ranging from age 21 to 81 months old individuals, i.e. from the class I to the class VI of age. 104 otoliths were analyzed and used to calculate von Bertalanffy growth function (VBGF)(Figure 45). The number of individuals and length interval at age data according to sexes combined are in Table 29 along with length estimated from the VBGF. Results of direct age reading were only partial matching those obtained from VBGF: for age class I (only one individual analysed) there was no correspondence; age classes II and III showed no correspondence although results from observations clearly move towards VBGF. A good correspondence was found for age classes IV, V and VI.

Table 27. Number of otoliths analyzed (N), total length (LT) range and mean length (\pm standard deviation, SD) at each age group of *S. rubrum*. TLVBGF gives the LT of the fish according to von Bertalanffy growth function.

Age	N	Range (cm)	Mean length (cm)	SD	TL _{VBGF}
1	1	14	14		7.672
2	16	13.0-16.5	14.84	0.83	11.769
3	52	13.5-17.5	15.72	1.07	14.635
4	20	14.5-17.5	16.38	0.87	16.640
5	13	16.0-20.5	17.38	1.50	18.044
6	2	19.0-20.5	19.75	1.06	19.026

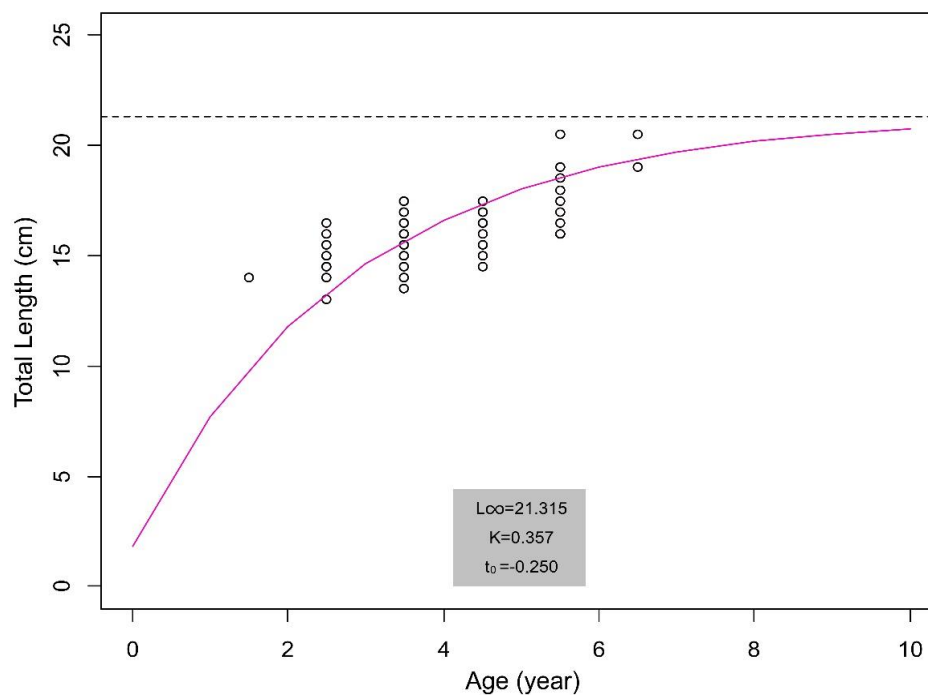


Figure 43. Von Bertalanffy growth curve in length of *S. rubrum* in the eastern Mediterranean.

The parameters of the VBGF were as follows: the maximum attainable size, $L_{\infty} = 21.315$ cm; the growth coefficient $K = 0.357$; the hypothetical time at which the fish would have been zero size $t_0 = 0.250$.

DISCUSSION

The population of redcoat inhabiting the eastern Mediterranean has reached considerable size since more than three decades (Golani & Ben-Tuvia, 1985). According to the CIHEAM-Pesca Libano experimental surveys that provided most of the specimens for the present study, *Sargocentron rubrum* is the most abundant coastal demersal species in Lebanon constituting 31% of the specimen collected (see Chapter 4 of this thesis). The easternmost shores of the Mediterranean Sea are one of the hottest hotspots of marine bioinvasions on earth (Rilov & Crooks, 2009). Due to its proximity to the Suez Canal, its favorable conditions (warmer, saltier waters) but also to the faunal impoverishment and unoccupied niches, the Eastern Mediterranean shows the greatest occurrence of non-indigenous species. *S. rubrum* is a spawning, shallow water, benthic carnivore, which constitutes the profile of the successful fish invader according to Rilov & Galil (2009).

Additionally, *S. rubrum* is a nocturnal predator mainly feeding on macro-zoobenthos, which was an underexploited niche given that only *Apogon imberbis* and the other Red Sea immigrant, *Pempheris vanicolensis* present the same trophic scheme (Golani & Ben-Tuvia, 1985). Despite its successful settlement in coastal waters of the eastern Mediterranean, and its ability to breed over long distances, reproducing in open water or scattering eggs over the substratum (Thresher, 1984), the Mediterranean distribution of *S. rubrum* remains limited westward to the eastern Aegean even though it was reported in the coastal waters of Rhodes (Greece) about 70 years ago (Laskaridis, 1948).

Redcoat specimens were collected mainly over mixed and rocky bottoms at depths ranging from 10 to 100 m - predominantly 30 to 60 m - slightly deeper than 10-40 m depth range previously reported in the Mediterranean by (Riedl, 1966), Golani (1981), Golani, et al., 1983, Golani & Ben-Tuvia (1985), Harmelin-Vivien et al. (2005). However, this depth range matches with the one reported by Randall (1998) for *S. rubrum* over its entire geographical ditribution.

The maximum L_T of the specimens in this study (22 cm) was much smaller than the maximum length observed worldwide (32 cm according to Fischer, et al., 1990) but bigger than previous specimens collected in the Mediterranean (20.0 cm for Mouneimné (1978), 18.0 cm for Golani & Ben-Tuvia, 1985), 16.7 cm for Taskavak & Bilecenoglu (2001), 21.4 cm for Can, et al. (2002), 20.1 in Özvarol & Tatlıses (2017). Maximum weight recorded in this study was correspondingly higher than those previously mentioned. Males and females showed no significant differences in length and weight distributions, suggesting that there is no segregation by size or sex. Gregarious species like *S. rubrum* are better able to exploit resources when living in groups because it is easier to find and catch prey, but when resources are limited, intraspecific competition can become problematic, inducing individuals within a population to spatial and temporal segregation by size and sex. This lack of segregation is a further signal of the healthy condition and apparent availability of resources for *S. rubrum* in Lebanese waters.

The weight - length relationship observed in this study is consistent with the findings in India (Muddula Krishna, et al., 2015) and eastern Mediterranean (Mouneimné, 1978; Taskavak &

Bilecenoglu, 2001; Can et al., 2002; Özvarol & Tatlıses, 2017). Despite the virtually isometric growth of the whole sample, of male and female individuals, the latter highlighted a clearer positive allometric growth. Furthermore, there is a clear indication that weight-length relationship in the region 'South' showed a marked positive growth. This discrepancy may have been caused by differences in the sample size, habitat and physiological status. This variation in size and growth may have been caused by a reduced fishing-related mortality in the region.

S. rubrum showed a partially defined seasonal reproduction with a peak spawning period in spring and a "latent" season in fall. The latter was also highlighted by Golani & Ben-Tuvia (1985) although said latency was stretching over the whole spring season. In our study, in winter we observed an increase of mature individuals leading to the spring peak (particularly evident in female individuals) and a following decline in summer. This behaviour differs from the one described more than three decades ago by Golani & Ben-Tuvia (1985) and Mounéimné (1978). Said Authors got to the conclusion that redcoat is a summer spawner. It is not clear whether the expansion of the spawning period observed in the present study toward the colder season (spring) can be the result of an uneven data collection by season or can suggest an adaptation of the species to the Mediterranean environment or can be the result of the variation of abiotic traits, such as the sea water temperature.

Despite the eastern Mediterranean is known to be an oligotrophic basin (Azov, 1991), Lebanese waters show some moderate inshore eutrophication and heavily eutrophied local systems (Abboud Abi Saab, et al., 2008). Here, low coefficient of vacuity in top predators show a considerable food availability (Lteif, et al., 2016), which is also confirmed by the predominance of full stomachs observed in this study for males, females, and all size categories of *S. rubrum*.

S. rubrum is an extremely active predator between May and August whereas it feeds lightly in colder seasons. This is perfectly in line with the findings of Golani, et al. (1983). Likewise, the composition of the diet is coherent with Golani, et al. (1983) but also with other species of the same genus (Randall, 1967; Vivien, 1973; Woods & Sonoda, 1973; Vivien & Peyrot-Clausade, 1974; Matthey & Reynold, 1979; Arias-González, et al., 2004). Benthic crustaceans, in particular crabs (infraorder Brachyura) are the main component in the diet of *S. rubrum*.

This becomes even more evident in winter and fall when the feeding activity is lower whereas in spring and summer *S. rubrum* diversified more its diet feeding significantly also on amphipods, isopods, other decapods, polychaetas and shrimps belonging to the families Alpheidae, Pandalidae and Processidae. This seasonal shift in diet appears to be related to the availability of each prey item in the study area. The presence in the stomach contents of specimens belonging to the family Processidae, confirms the nocturnal predation habits and based on the analysis of the bulk of the preys, it is evident that the redcoat feeds mainly over rocky bottoms. However, few species are also indicators of predatory activity over soft bottoms (i.e. *Charybdis longicollis* and *Myra subgranulata*) and in the water column (some species clupeiformes) (Figure 46).

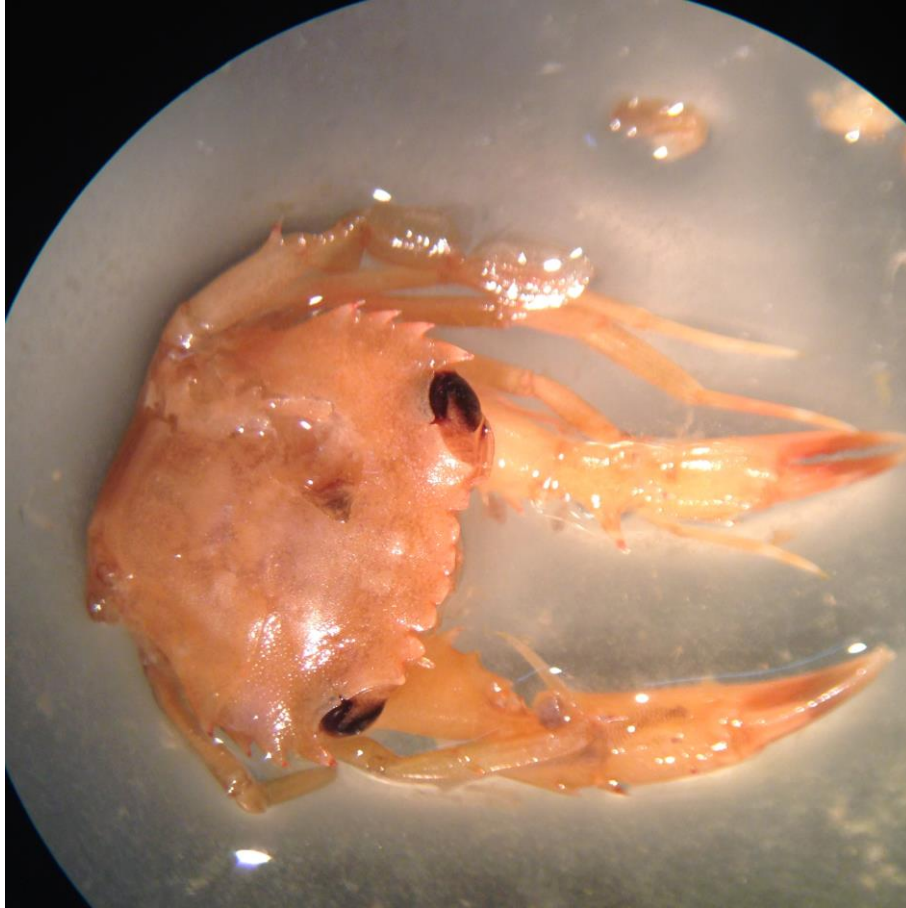


Figure 46. A portunid crab belonging to the genus *Thalamita* observed in stomach contents of a specimen of *S. rubrum* sampled in Lebanese coastal waters.

The life span of most tropical fishes is short and occasionally exceeds 2-3 years (Gulland, 1969). In Indian waters, Anbalagan, et al. (2016) calculated the life span of about 3.5 years for *S. rubrum*. They indicated that *S. rubrum* attains a length of about 18 cm during the first year, 22 cm and 23 cm during the second and third years respectively. In the Mediterranean, Golani & Ben-Tuvia (1985) outlined a much slower growth based on otoliths reading, reporting a total length of 9.5 cm for the first year, 12.8 cm for the second year and 14.4 and 15.5 cm for the third and fourth year. In our study, the age determination does not differ consistently from the latter, suggesting a similar reading pattern. However, the fourth year (last age class in the study of Golani & Ben-Tuvia) was considerably different probably due to an increased number of specimens available for this study. According to our study, the lifespan of *S. rubrum* exceeds age of 6 years old, which is almost double than the value found in Indian waters by Anbalagan, et al. (2016).

Despite the important ecological role of *S. rubrum* in the Mediterranean and in general of the family Holocentridae worldwide, biological traits, abundance and behavior of this species have been scarcely investigated. *S. rubrum* is commonly available for aquariums and is traded from the Pacific and Indian Ocean (Blasiola, 2000), hence levels of exploitation recently increased in some areas (Anbalagan, et al., 2016). In the Mediterranean, it has a scarce commercial value on fishing markets and it is usually discarded (Figure 47).



Figure 44. Two specimens of *S. rubrum* discarded at sea in the port of Sarafand, Lebanon along with various litter.

Three decades after the study of [Golani & Ben-Tuvia \(1985\)](#), the maximum length and thus the lifespan of the population increased. The Lebanese population of *S. rubrum* does not seem to suffer from overfishing or other threats. However, management measures on demersal resources highly affected by fishing activities should take into consideration the ecological role of *S. rubrum* and the ongoing expansion of the presence of the family Holocentridae to other species. Data presented in this study are meant to parameterize models of population dynamics for this fish stock to better understand its role in the ecosystem functioning and the interactions with other commercially exploited native species.

Acknowledgements

This study could not have been completed without the support of the Lebanese fishermen, their bravery and tough job in the sea. The communities of fishermen are the ultimate beneficiaries of all our efforts aimed at creating new and sustainable sources of income and improving their quality of life. Data and financial funding for this study was provided in the framework of the CIHEAM-PESCA Libano project, of the CANA project on “Establishing Monitoring and Sustainable Development of the Lebanese Sea” (both financed by the Italian Cooperation) and within the Grant Research Programme of the CNRS-L. We are particularly grateful to Fabien Morat and Philippe Lenfant for their help in identifying redcoat’s preys from otoliths and Salvino Gancitano (IAMC-CNR) for sharing his knowledge on the art of fish sclerochronology.

Chapter 7

General discussion, conclusion and perspectives

Chapter

7

General discussion, conclusion and perspectives

As an absolute prime in Lebanon, in 2012 the project CIHEAM-Pesca Libano - in coordination with major Lebanese and international actors in the fisheries research - had been implementing experimental fishing surveys to assess the distribution and abundance of fisheries resources along the entire Lebanese coast in order to deliver a scientific advice to the Lebanese Government for an enhanced fisheries management. The idea of an overall Country data collection to gain information on abundance and distribution of Lebanese fisheries resources stemmed from a series of meetings that took place in 2012 aiming at coordinating the efforts of international organizations (i.e. FAO, CIHEAM, Italian Cooperation) and Lebanese stakeholders such as public institutions and academia.

Financed by the Italian Cooperation in Lebanon, the project CIHEAM-Pesca Libano “Technical Assistance to the Ministry of Agriculture in the field of fishery development” aimed at providing the Lebanese Ministry of Agriculture (MoA) with advanced tools designed for a proper management of marine and fisheries resources. This was meant to be achieved by strengthening capabilities of the MoA staff and assessing the potentialities of marine coastal resources. The National Council for Scientific Research, Lebanon (CNRS-L), in charge of the implementation of the fishing surveys through its Marine Centre, gave further follow up executing seasonal data collection at sea in the North Lebanon.

Adopting appropriate methodologies

Abundance surveys are frequently used to gain information on stock size and distribution. In marine areas, demersal fish species are typically surveyed by bottom trawls whereas pelagic species are predominantly surveyed by acoustic methods calibrated by trawl catches. Trawl surveys are aimed at assessing species distributed over soft bottoms (i.e. sandy, muddy bottoms) whereas they cannot be used for those species inhabiting rocky or sandy-rocky habitats (Sparre & Venema, 1992). In the case of Lebanon, the most important commercial species are typical coastal and distributed over areas where standard trawling cannot be carried out. In this situation, other fishing gears (e.g. longlines, gillnets and traps) had to be used to survey untrawable areas and species. Moreover, trawling activities are interdicted in the Lebanese territorial waters (University of Balamand, 2016).

For this reason, backed by fishermen and scientists, we developed an experimental trammel net suitable for operating over the continental shelf and upper slope, with poor selectivity properties to catch a variety of species and sizes of fish and other organisms. In fact, if compared to gillnets, trammel nets of different mesh sizes ensure similar mechanisms of capture in terms of snagging (the fish is caught by twine entangling with the fish oral area), gilling (caught with the mesh behind the gill cover); wedging (caught by the largest part of the body) (Karlsen & Bjarnason, 1986 ; Grati, et al., 2015), whereas the entangling factor increases due to the presence and configuration of additional two sheets of netting (Cochrane, 2002).

We deemed fishery-independent survey as the most appropriate tool to provide valuable measures of relative abundance, rates of population change and size and sex composition for a wide range of demersal species. In fact, fishery-independent surveys form the cornerstone of many stock assessments for bony fishes and shellfish species, as they are less subject to the unknown and often confounding factors that complicate the interpretation of fishery-dependent indices of stock status (Rago, 2005). Thus fishery-independent surveys strike a balance between the ability to make inferences about one or more populations versus the usage of a specific area by one or more species.

DEMERSAL SPECIES

Presence and diversity

Coastal, demersal stocks are subject to various threats worldwide, especially in the Mediterranean Sea, which is considered a hotspot of biodiversity but at the same time a hotspot of threat for demersal species (Coll et al., 2010 ; Ben Rais Lasram et al., 2008). Overfishing, bycatch, introduction of non-indigenous species (NIS), pollution, habitat loss and climate change are the foremost sources of stress affecting this fish groups (Coll et al., 2010). Presence and status of demersal populations has been described for most regions of the Mediterranean (e.g. Colloca et al., 2003; Gaertner et al., 2007; Quignard & Tomasini, 2007; Ben Rais Lasram et al., 2009; Coll et al., 2010; Gaertner et al., 2013; Granger, et al., 2014) with the exception of the eastern basin and notably along the Lebanese coast where information on abundance, distribution and assemblages of demersal species is still deficient. As such, the Levantine Basin is described as low in species richness, due to the unfavourable conditions prevailing in the area - such as high salinity (Por & Dimentman, 2006) - but also, most likely to a reduced sampling effort. A lack of data in several eastern and southern regions of the Mediterranean basin may have strongly influenced results and considerations on spatial patterns. However, some studies are in progress and a recent study focus on demersal species along the depth gradient within the South Aegean and Cretan Seas (Eastern Mediterranean) (Peristeraki et al., 2017).

Fisheries can affect species relationships and, as observed by Pauly et al. (1998), intensive fishing causes larger and long-lived species to disappear (Bianchi et al., 2000), generating a significant selection pressure for early maturation (Stearns, 1992; Uusi-Heikkilä et al., 2015) and creating impoverished ecosystems (Colloca et al., 2003). In the Mediterranean, such effect has been documented for elasmobranchs which have undergone marked reduction of stock abundance and local extinction (Aldebert, 1997). Along the Lebanese coast, recent studies have contributed to the improvement of the knowledge of these cartilaginous fishes (Lteif, 2015; Lteif et al., 2016a & 2016b; Lteif et al., 2017). Small-scale fisheries are known to have a lower environmental impact (FAO, 2015), however Lebanese government is engaged in putting into effect management measures that need sound scientific advice on halieutic resources base on an increased knowledge on:

1. the diversity and distribution patterns of these (and pelagic) species along the Lebanese coast in relation to depth and the occurrence of alien species of Indo-Pacific origin;
2. their life-history traits.

These two main aspects are discussed in order to better understand the causes of underlying diversity patterns and to assist various environmental management actions, particularly those related to the implementation of fisheries management measures in Lebanon. In the long run, the

findings of the study are meant to contribute to the setup of an effective, scientific-based fisheries management in the eastern Mediterranean.

Demersal fish species are demanded worldwide for their highly valuable parts. Annual per capita consumption of demersal species has stabilized at about 2.9 kg. Demersal fish remain among the main species favoured by consumers in Northern Europe and in North America (annual per capita consumption of 9.2 and 4.3 kg, respectively, in 2013). Cephalopods are mainly preferred by Mediterranean and East Asian countries (FAO, 2016).

Worldwide, the most abundant demersal species ordered in terms of average annual landings from 1950 to 2009 were Alaska pollock, Atlantic cod, largehead hairtail, blue whiting, sandeels, haddock, saithe, Cape hakes, Atlantic redfishes, and flatfishes. These ten species produced 37 percent of the total demersal landings in 2009 with a common pattern of decreasing trend in catch. Most of these species had a peak catch in the 1960s or 1970s. Stocks condition vary with country or region. Mediterranean and Black Sea (Area 37) had 50 percent of fish stock overfished (FAO, 2011).

Mediterranean fisheries are dominated by small-scale vessels, dispersed across a large number of landing places in most countries (FAO, 2011). A characteristic of the Mediterranean fisheries is the capability to exploit a variety of demersal species while generally lacking large monospecific stocks. As a result, Mediterranean fisheries have developed a multitude of métiers and scales of investments. Production is essentially concentrated on the continental shelf and capture fishing on the coasts. Yearly volumes are limited (1.5 to 1.7 million tons/year), representing less than 1 percent of global catches (UNEP/MAP-Plan Bleu, 2009). There is serious cause for concern as regards the status of economically and commercially important species (hake, red mullet, common prawn, sole, sardine and tuna), victims of unsustainable overexploitation.

Up to 85 percent of stocks for which a validated assessment exist are fished outside biologically sustainable limits. European hake stocks show the highest fishing pressure, with a fishing mortality rate that is an average of 5 times higher than the target while only a few stocks of demersal species, such as whiting, some shrimp species, picarel and red mullet, are estimated to be fished at or below the reference point for fishing mortality (FAO, 2016).

In the framework of the present study, a total of 129 species were recorded at depths ranging from 10 to 300 m. Most of these species are demersal including the most economically relevant species, i.e. European hake (*Merluccius merluccius*), red mullet (*Mullus* spp.), pandoras (*Pagellus* spp.) and red shrimps (*Aristeus antennatus* and *Aristaeomorpha foliacea*). The high rate of occurrence of the red shrimps –particularly that of *A. foliacea* – was undoubtedly remarkable. The geographically widespread giant red shrimp, *A. foliacea*, is one of the most important exploited crustaceans, having a long traditional and economical significance for the deep fishery of the western and central Mediterranean (Papaconstantinou & Kapiris, 2003). It occurs along the continental slope from 150 m to 1850 m with a peak in abundance between 300 m and 700 m, showing a preference for muddy bottoms, with aggregations mainly in submarine trenches and canyons (Ragonese et al., 1997). The species was rarely recorded in the eastern Mediterranean probably due to a lack of studies implemented in those areas and its stocks are considered pristine in some areas as its exploitation has not yet been developed (Papaconstantinou & Kapiris, 2003; Gönülal et al., 2010). In our experimental surveys *A. foliacea* has been observed at depths ranging from 90 to 200 meters.

Lessepsian species

In our study, 17 NIS of Lessepsian origin (13 fish and 4 crustacean species) were recorded over the Lebanese coastal waters, 15 of which demersal, one pelagic (the herring *Etrumeus teres*) and one with a mixed benthic-pelagic behaviour (the portunid crab *Charybdis longicollis*) (Table 30). Only one previous systematic experience of data collection on the Lebanese halieutic resources over the entire Country's coastal waters was performed by Carl J. George and Victoria A. Athanassiou from the American University of Beirut (AUB) and Ismat Boulos of the Lebanese Ministry of Agriculture in 1964. In the booklet titled, "The Fishes of the Coastal Waters of Lebanon" (George et al., 1964), they described and reported 177 fish species inhabiting Lebanese coastal waters, 19 of Indo-Pacific origins (it is worth to mention the inclusion in the list of species not directly collected but reported from adjacent waters, adding a non-empirical element to this report (Golani, 1996).

Two Lessepsian species, the spinefoot fish *Siganus rivulatus* and the goaldband goatfish *Upeneus moluccensis* were by that time already considered as "very common," clearly affirming how Lebanese waters are a conquered realm for invasive subtropical species, at least since the early 1960s.

Table 28. List of non-indigenous species (NIS) collected in the present study in the eastern Mediterranean. Total weight per species stated in grams (Tot Weight (g)), number of specimens collected (No Specs), percentage of occurrence in sampling stations (O%) CPUE (number of specimens by Km² of nets and kg/Km² of nets) percentage of specimens (number of specimens over the total number of specimens collected). Last four columns report the species' occurrence by depth stratum (SSh=shallow shelf, < 50 m depth; MSh=medium shelf, 50 to 99 m depth; DSh=deep shelf, 100 to 150 m depth; CSI=upper continental slope, 151 to 300 m depth). *=1 to 10 specimens; **=10 to 50 specimens; *= >50 specimens.**

Species	Family	Tot Weight (g)	No Specs	O%	CPUE (Specs/Km ² nets)	CPUE (Weight/Km ² nets)	% (No Specs/Specs Tot)	SSh	MSh	DSh	CSI
<i>Etrumeus teres</i>	Dussumeriidae	737.5	11	9.091	31.339	2.101	0.31	**			
<i>Fistularia commersonii</i>	Fistulariidae	10120.3	26	21.488	74.074	28.833	0.73	*	**	*	
<i>Lagocephalus sceleratus</i>	Tetraodontidae	24583.6	28	23.140	79.772	70.039	0.78	**	**	*	*
<i>Lagocephalus spadiceus</i>	Tetraodontidae	1551.5	6	4.959	17.094	4.420	0.17	*	*		*
<i>Nemipterus randalli</i>	Nemipteridae	864.4	13	10.744	37.037	2.463	0.36		*	*	
<i>Pempheris vanicolensis</i>	Pempheridae	653.2	13	10.744	37.037	1.861	0.36	*	*	*	
<i>Pomadasys stridens</i>	Haemulidae	65.1	1	0.826	2.849	0.185	0.03		*		
<i>Sargocentron rubrum</i>	Holocentridae	108189	1109	916.529	3159.544	308.231	30.99	***	***	***	
<i>Saurida lessepsianus</i>	Synodontidae	17	1	0.826	2.849	0.048	0.03				*
<i>Siganus luridus</i>	Siganidae	2032.1	21	17.355	59.829	5.789	0.59	**	*	*	
<i>Siganus rivulatus</i>	Siganidae	4640.5	67	55.372	190.883	13.221	1.87	***	**	*	
<i>Stephanolepis diaspros</i>	Monacanthidae	2513	26	21.488	74.074	7.160	0.73	**	*	*	
<i>Upeneus moluccensis</i>	Mullidae	54	2	1.653	5.698	0.154	0.06				*
<i>Charybdis longicollis</i>	Portunidae	343.8	17	14.050	48.433	0.979	0.47	*	*	*	*
<i>Marsupenaeus japonicus</i>	Penaeidae	24.3	3	2.479	8.547	0.069	0.08	*			
<i>Myra subgranulata</i>	Leucosiidae	104	3	2.479	8.547	0.296	0.08				*
<i>Portunus pelagicus</i>	Portunidae	2633.1	39	32.231	111.111	7.502	1.09	**	*		

This means that in 50 years the percentage of the autochthon fishing resources remained steady, with an apparent slight decrease from 89% to 87%. Although in terms of biomass (not mentioned in the study of [George et al., 1964](#)) we can assume that 50 years ago this was considerably poorer than today, in terms of number of species, the trend, at this stage, is not so evident. As a result of 7 years of data collection carried out with various fishing gears over the Syrian waters, ([Saad, 2005](#)) reported 224 species of Osteichthyes (bony fishes), 37 of which were NIS migrant from the Red Sea (16.5%). In an extended work realised by ([Carpentieri et al., 2009](#)) a total of 25 Lessepsian species over 110 identified (23%) were recorded. This indicates that back then only 77% of the total catch was made up by Mediterranean species.

In absolute terms, by 2012, ([Zenetos et al., 2012](#)) reported 193 NIS species of Mollusks, 125 of Crustaceans and 105 of fishes in the eastern Mediterranean. NIS numbers more than doubled between 1980 and 2016 and are substantially greater in the Levant than in the western Mediterranean ([Galil et al., 2017](#)). This confirms that the Mediterranean Sea – and more in specific its easternmost shores - is one of the hottest hotspots of marine bioinvasions on Earth ([Rilov & Crooks, 2009](#)). The success of Lessepsian migrants in the colonization of the eastern Mediterranean has been probably the result of occupation of an unsaturated niche and of out-competing local species on resources such as food and shelter. NIS, in fact, may have altered the evolutionary pathway of native species by competitive exclusion, niche displacement, predation, and other ecological and genetic mechanisms ([Mooney & Cleland, 2001](#)). The study of [Parravicini et al. \(2015\)](#) examine the conservatism of the climatic niche by using the example of the invasion by Indo-Pacific tropical fishes into the Mediterranean Sea and showed that tropical invaders may spread far beyond their native niches. Dispersal and establishment success of Lessepsian fish immigrants are influenced by different ecological traits. The accelerated rate of entry was attributed by many authors to an increase in the Mediterranean surface water temperature ([Ben Rais Lasram & Mouillot, 2009](#)). However, the Suez Canal has been repeatedly deepened and widened during the last decades and following the study of [Arndt & Schembri \(2015\)](#) the increased immigration rate of Red Sea fishes might also be related to reduced dispersal barriers. Indeed, by analysing the relationship between dispersal and establishment success and a pool of different traits for 101 Lessepsian fish species using generalized linear models, their models did not reveal a significant relationship between the sea surface temperature in the native range of immigrant fishes and their dispersal or establishment success in the Mediterranean Sea. The minimum depth in which a species was observed was the only significant trait influencing dispersal success. This trait is likely related to the architecture of the Suez Canal since until the 1970s only species with a very low minimum depth were recorded to have entered the Mediterranean, but species occurring in deeper water started to immigrate after 1980 when the canal was deepened to 19.5 m. The establishment success of Lessepsian fishes was also significantly linked to size and spawning type. Benthic spawners and species with adhesive eggs representing successful colonizers. Moreover, successful colonizers were species with a tendency to form schools, whereas solitary species were less successful. The recent extension of the Suez Canal, completed on the 6 of August 2015, may exacerbate the threat of dramatic increase in the introduced number of alien species. It should double vessel traffic within the Canal, with the current average of 49 transits per day expected to increase to 97 passages per day ([SCA, 2015](#)).

Another study of [Belkamer et al. \(2013\)](#), compile data on species traits, geographical distribution, and environmental affinity of the entire pool of reef-associated fish species in the Red Sea and more generally across the Indo-Pacific. They use this extensive data to identify the prime characteristics separating Red Sea species that have become alien in the Mediterranean from those that have not. They find that alien species occupy a larger range of environments in their native ranges, explaining their ability to colonize the seasonal Mediterranean. Red Sea species that naturally experience high

maximum temperatures in their native range have a high probability of becoming alien. Thus, contrary to predictions of an accelerating number of aliens following increased water temperatures, hotter summers in this region may prevent the establishment of many alien species. They further find that additional processes, such as competition, promote ecological diversity among alien species. They use these results to provide a first quantitative ranking of the potential of Red Sea species to become established in the eastern Mediterranean.

However, in deeper waters assemblages, we observed that autochthon species prevail. Those assemblages are mainly characterised by commercially valuable species such as the red mullets (*Mullus surmuletus* and *M. barbatus*), the European hake (*Merluccius merluccius*) and the red giant shrimp (*Aristaeomorpha foliacea*). As shown in Table 1, NIS of Lessepsian origins are more abundant in the shallow continental shelf becoming scarcer in deeper continental shelf and virtually absent over the slope. Shallow water preference of Lessepsian fish previously documented by (Golani & Ben-Tuvia, 1989; Golani, 1996) is confirmed by the outcomes of the present study. In particular, the Mediterranean coralligenous seems to contain several components similar to Red Sea biogenic habitats favouring benthic-demersal species migrating from the Red Sea in the occupation of spatial niches; this may explain the high abundance of these species in the studied area (Spanier et al., 1989). The invasion of fishes into the Mediterranean is combined with the simultaneous invasion of marine mollusks, crustaceans, foraminifera, polychaetas and a host of other invertebrates and algae (Rilov & Galil, 2009; Golani, 2010). According to the present study, the most abundant Lessepsian fish species in Lebanese waters is by far the redcoat, *Sargocentron rubrum*. *S. rubrum* is a nocturnal predator mainly feeding on macro-zoobenthos, which was an underexploited niche given that only *Apogon imberbis* and the other Red Sea immigrant, *Pempheris vanicolensis* present the same trophic scheme (Golani & Ben-Tuvia, 1985). Despite its successful settlement in coastal waters of the eastern Mediterranean, and its ability to breed over long distances, reproducing in open water or scattering eggs over the substratum (Thresher, 1984), the Mediterranean distribution of *S. rubrum* remains limited westward to the eastern Aegean even though it was reported in the coastal waters of Rhodes (Greece) about 70 years ago (Laskaridis, 1948).

Redcoat specimens were collected mainly over mixed and rocky bottoms at depths ranging from 10 to 100 m - predominantly 30 to 60 m - slightly deeper than 10-40 m depth range previously reported in the Mediterranean by (Riedl, 1966 ; Golani, 1981 ; Golani et al., 1983 ; Golani & Ben-Tuvia, 1985 ; Harmelin-Vivien et al., 2005). However, this depth range matches with the one reported by (Randall, 1998) for *S. rubrum* over its entire geographical distribution. Three decades after the study of Golani & Ben-Tuvia (1985), based on our study, the maximum length and thus the lifespan of the population increased in the Mediterranean. The Lebanese population of *S. rubrum* does not seem to suffer from overfishing or other threats. However, management measures on demersal resources highly affected by fishing activities should take into consideration the ecological role of *S. rubrum*, the possible expansion of its geographical boundaries and the ongoing enlargement of the presence of the family Holocentridae in the Mediterranean (Vella et al., 2016).

Weight Length Relationships

Information related to the length-weight relationships of demersal species is almost absent along the Lebanese coast. Froese (2006) and Froese et al. (2014) had analyzed the length-weight relationships of all fishes available on the Fishbase website (www.fishbase.org) using meta-analysis and Bayesian methods. A few studies carried out by Turkish Authors (Başusta et al., 2013 ; Erguden et al., 2009 ; Erguden et al., 2017 ; Özvarol, 2014 ; Sangun et al., 2007 ; Taskavak & Bilecenoglu, 2001) bring together information on WLRs for demersal species in the northern part of the eastern

Mediterranean. This information allowed us comparisons with 15 species examined in the present study, among the others some commercially relevant species (*Merluccius merluccius*, *Mullus barbatus*, *M. surmuletus*, *Pagellus acarne*, *P. erythrinus*) and some Lessepsian migrants (*Fistularia commersonii*, *Lagocephalus sceleratus*, *Sargocentron rubrum*, *Siganus luridus*, *S. rivulatus*, *Stephanolepis diaspros*). Some differences were recorded among different areas surveyed in our study. These could be due to sampling procedures or they could reflect the influence of differences in environmental or habitat factors (Morato et al., 2001). WLRs may act as a tool to support fisheries management measures by establishing a minimum catch weight limit when lengths are estimated at sea. In Lebanon - where management measures are limited or outdated and the fishing pressure is high on coastal fisheries resources while fishing practices targeting juvenile fishes are partially driven by the market (Bariche et al., 2006 ; Colloca & Lelli, 2012 ; Sacchi & Dimech, 2011), the use of basic but powerful descriptive tools of halieutic populations such as WLRs is highly recommended.

Abundance index and spatio-temporal variations

The analysis of the Catch Per Unit Effort (CPUE) and total weight variation of the demersal fish observed during this study provided indications of the spatio-temporal variation of their distribution and abundance. Although the causes for the spatial distribution of a fish population are still poorly understood, density-dependent processes are often suggested as a possible explanation (Myers & Stokes, 1989 ; MacCall, 1990 ; Casini et al., 2005), as well as environmental factors (Corten & van de Kamp, 1996; Heessen, 1996; Rose & Kulka, 1999), pollution, habitat loss induced by anthropogenic activities including degree of stock exploitation (Winters & Wheeler, 1985) and recent warming of the climate system (Jennings & Kaiser 1998; Gray et al. 2005; Poulard & Blanchard 2005; Rochet et al. 2010). Factors affecting fish abundance and distribution often operate at regional scales (Heessen & Daan, 1996; Rose & Kulka, 1999). However, the nature of Lebanese water, availability of prey, daily and seasonal movements for breeding and feeding, as well as, fishing techniques and the depths at fishing can explain to a certain extent, the variation in distribution and abundance (Bianchi, 1992; Koslow, 1993, and Gordon et al., 1995). Due to the uniqueness of this study in the region, no trend could be estimated concerning the variation in abundance and biomass of demersal fish inhabiting the coastal waters.

Communities (assemblages) are dynamic under constantly changing conditions, and in the long term no community is stable with respect to evolutionary change (Williamson, 1987). Hence, whether communities can ever be considered stable is largely dependent upon the temporal scale of any investigation (Connell & Sousa, 1983; Wiens, 1984; Wiens et al., 1986).

Numerous Authors analyzed faunal changes and the establishment of certain assemblages that occur in the areas targeted by small-scale fisheries, i.e. continental shelf and upper slope. They proved that the spatial distribution of demersal species is mainly influenced by depth, type of substratum and physical characteristics (such as temperature and salinity) of the water masses, e.g. Mahon & Smith, (1989), Bianchi (1992), Fujita et al. (1995), McClatchie, et al. (1997), Magnussen (2002), Gaertner, et al. (2005), Maravelias, et al. (2007). Some species appear to be widely distributed independently of the environmental gradients (Colloca et al., 2003) even though biotic interactions among assemblage members seem to be of less importance (Mahon & Smith, 1989; Sale et al., 1994).

The understanding of patterns of spatial distribution of fish populations is a critical consideration particularly in the eastern Mediterranean Sea, where the faunal composition has been drastically altered by the migration of numerous Indo-Pacific species from the Red Sea following the construction of the Suez Canal in 1869 (Por, 1978; Galil & Zenetos, 2002).

Regarding the spatio-temporal diversity and distribution of the species observed in this study, both showed seasonal variations and, in some cases, slight regional differences. Habitat selection by demersal species depends on several biotic and abiotic factors. Depth and temperatures account for much of the spatial variation in the species composition of demersal fish communities. Temperature is the key abiotic factor that controls the rate of metabolism and growth and prey abundance is the key biotic factor that influences habitat quality (Swain & Benoit, 2006). Seasonal changes in species composition and abundance also reflects spawning events and migrations (Livingston et al., 1976 ; Yoklavich et al., 1991 ; Potter et al., 1997). Water temperature and salinity have been considered the most influential physico-chemical factors determining the distribution and abundance of fish faunas (Haedrich et al., 1983 ; Kennish, 1990) and hence strong correlations between these factors and species is expected (Allen, 1982 ; Potter et al., 1986 ; De Ben et al., 1990). Other factors may drive pattern of abundance and distribution, including habitat structure, wave exposure, outflow of freshwater from the inland, turbidity, nutrient levels and heavy metal concentrations (Edgar & Shaw, 1995 ; Jenkins & Sutherland, 1997).

Strategic management planning

The valorisation of fisheries in Lebanon sectors should be pursued through management plans that would jump-start the operationalization of marine spatial planning. This could be done, to begin with, by assessing abundance and distribution of fishing resources, identifying spawning grounds, selecting zones allocated to aquaculture, establishing fishing restricted areas, discovering new fishing grounds.

Already in 2014, the General Fisheries Commission for the Mediterranean (GFCM) recognised the effort done by the CIHEAM-Pesca Libano project in putting the basis for standardised data collection in Lebanon (GFCM, 2014). The management of fisheries requires monitoring of the variation in resource abundance on the basis of international standardized procedure. Several Mediterranean countries are currently participating to the international fish abundance surveys program called MEDITS. GFCM was exploring the possibilities to set up similar surveys programs for non-European countries. In consideration of the obstacles in performing MEDITS-like surveys in Lebanese waters, GFCM proposed fishery independent abundance surveys to be performed by using sets of passive gears upgrading methodologies and gears already used for the data collection of the CIHEAM-Pesca Libano (described in Chapter 3) (GFCM, 2014).

In 2017, GFCM formally stated that MEDITS-like scientific surveys are expected to be conducted in Lebanon by 2019-2020 (GFCM, 2017). In anticipation and support of this activity, FAO-EastMed project planned (EastMed, 2016) and financed experimental surveys in offshore fishing grounds using CIHEAM-Pesca Libano methodologies.

Mediterranean fisheries policies have been developed in order to adjust the fishing effort in relation to the availability of fishery resources and to evaluate the fishing capacity of national fleets. Because of the wide variety of species characterizing Mediterranean fisheries, fishery management in the Mediterranean is not based on catch control via TACs and quotas. Furthermore, the results of this study can encourage to a longer term the implementation or the effective management of Marine Protected Areas (MPAs) along the Lebanese coast. The Ministry of Environment of Lebanon and IUCN-Med (International Union for Conservation of Nature in Mediterranean sea), with OAPN (Organismo Autónomo Parques Nacionales of Spain), AECID (Spanish Agency for International Cooperation and Development) and MAVA foundation, UNEP-MAP (Mediterranean Action Plan for the Barcelona Convention) and RAC/SPA (Regional Activity Center for Specially Protected Areas) launched in 2008 a project to support the development of a network of MPAs along the Lebanese coast ("*Supporting management of important marine Habitats and species in Lebanon*"; 2010-2012).

In 2012, 2013 and 2016, several Lebanese localities spread over the Lebanese shores were surveyed, aiming at the definition of coastal areas worth to be safeguarded for further and wider coastal protection and sustainable management.

In turn, this could stimulate experiences of co-managed that bring in fishermen and Local Authorities. Fishers would be trained and supported in diversifying sources of livelihoods. Activities around eco-tourism and sea-related attractions would be promoted. Fishermen would also be involved in marine ecosystem monitoring activities.

Life history aspects and overexploitation

Studies on life history parameters such as age and growth, along with basic information on distribution, abundance, movements, feeding, reproduction and genetics, are essential for scientists to understand and predict how populations will evolve and how they will respond to different stimuli.

Due to the broad definition of the term “demersal”, different life history traits are shown in this group. Generally, demersal species show relatively restricted adult movements. Their pelagic juvenile stages represent their most important dispersal mechanism (Cowen et al., 2006) although genetic evidences show that pelagic stages often fail to fully achieve their dispersal potential (Jin-Xian et al., 2007).

Early-life-histories vary greatly among demersal species. Some species may spawn benthic eggs from which pelagic larvae hatch while others may display life cycles where both the eggs and the larvae are pelagic. In other cases, peculiar forms of parental care evolved (Riginos & Victor, 2001). Pelagic larval duration as well as the spatial distribution of pelagic stages also shows great variability among marine species. In the Mediterranean, the Common two-banded bream (*Diplodus vulgaris*), the Striped red mullet (*Mullus surmuletus*), and the Comber (*Serranus cabrilla*) have an extended pelagic larval duration. An intermediate condition is shown by the Saddled bream (*Oblada melanura*), which spawns pelagic eggs and has offshore larvae but with a shorter pelagic duration. The Blackfaced blenny (*Tripterygion delaisi*) and the Cardinal fish (*Apogon imberbis*) are species with low potential for dispersal, producing benthic or mouth-brooded eggs, inshore larvae, and having shorter pelagic larval duration. The Peacock wrasse (*Symphodus tinca*) releases benthic eggs (Galarzaa, et al., 2009).

Understandably, direct withdrawal of fish individuals due to fishing activities may induce changes in the demographic characteristics of populations, including genetic variations (Rochet, 1998). Several Authors, such as (Pauly, 1979; Gulland & Garcia, 1984; Sharp & Csirke, 1984; Greenstreet & Hall, 1996; Sainsbury et al., 1997; Haedrich & Barnes, 1997; Bianchi, et al., 2000) documented changes in the structure of demersal fish communities. However, the understanding of how fishing activities affect demersal fish communities is still unclear. There is the evidence that the size structure of demersal fish communities is affected by fishing with an overall trend of reduction in large fish and relative increase in small fish (Bianchi et al., 2000). Data from more than 230 populations reveal a median reduction of 83 percent in breeding population size from known historic levels.

As a matter of fact, formal stock assessments (endorsed by GFCM) have not been carried out in Lebanon. However, private universities, the National Council for Scientific Research - Lebanon (CNRS-L) and FAO in coordination with the Ministry of Agriculture are putting the bases for a steady data collection to allow sound stock assessments. FAO-EastMed project is supporting Lebanese public institutions in building a new generation of scientists able to routinely run assessment of most common local and shared stocks. Similarly, catch and effort assessment system is still in calibration phase. In 2015, the Fish Landing Operational Utility for Catch Assessment – FLOUCA, developed for

storage and analysis of catch and effort data – was extended to cover the whole Lebanese coast. The system scope includes several key variables, such as catch, effort, CPUE, prices, values and average weight of individuals. The system launched in 2015 continued also in 2016 and in 2017 based on the new GFCM DCRF and is expected to provide soon clear results on landings and species abundances. Moreover, some Authors provided information on trends and abundances of Lebanese halieutic resources.

The outcomes of visual census observations carried out in 2012 and 2013 showed typical characteristics of overexploited fish populations (RAC/SPA - UNEP/MAP, 2014). Observed abundances and biomasses were lower in the South (Nakoura and Tyre) than those in the Central-North Lebanon (Raouché, Ras Chekaa and Enfeh). However, the high heterogeneity of habitats that occurs in the study area makes it possible to host a high diversity of fish species (RAC/SPA - UNEP/MAP, 2014). This is confirmed by the reconstruction of total catches for Lebanese coastal regions from 1950-2010. Also in this case, (Nader et al., 2014) estimated a reduction in fish stocks of this region over years. Lelli et al. (2007), Bariche et al. (2006), Sacchi & Dimech (2011), Colloca & Lelli (2012) noted that the effort of Lebanon's fishing fleet is concentrated mainly within the 6 nautical miles leading to a high fishing pressure on the coastal fisheries resources particularly within the 3 nautical miles zone.

On the other hand, it should be noted that the status of halieutic resources between 6 and 12 nautical miles is not known, but it can be considered as virgin stocks as nearly no fishing activities are conducted in the said area. A short offshore survey carried out by (Colloca & Lelli, 2012), set off a preliminary evaluation of the potentiality of offshore fishing grounds for local artisanal fishery in South Lebanon. This survey showed good yields (CPUEs higher than those of European Mediterranean countries) for the European hake (*Merluccius merluccius*) and the small shrimp *Plesionika edwardsii* (Colloca & Lelli, 2012).

In a general trend of declining of coastal resources, this thesis presented the case of *Sargocentron rubrum*, a well settled Lessepsian species whose life traits indicate on the one hand the healthy condition of the Lebanese population, and on the other the trend of the Mediterranean population to reach standard population's parameter typical of the Indo-Pacific populations. Three decades after the study of Golani & Ben-Tuvia (1985), the maximum length and thus the lifespan of the population increased and the spawning season expanded over a wider period.

BACKGROUND AND RECOMMENDATIONS

Lebanon’s fisheries sector is composed of a little artisanal fishing fleet, namely 2,005 licensed vessels (in 2015 according to the DFW) predominantly operated by rather aged fishers using old boats with dated equipment (Pinello & Dimech, 2013). Most of the boats are motorized and below 12 m in length using fishing techniques mostly based on passive gears such as gillnets, trammel nets, longlines, and purse seines. Fishing operations are mostly carried out at depths of up to 50 m (Sacchi & Dimech, 2011; Brême, 2004; Lelli et al., 2007). Few vessels are equipped with GPS, while the rest have very limited navigational or safety equipment (Majdalani, 2004; Sacchi & Dimech, 2011). Lebanese coastal waters contain a significant richness of marine organisms with more than 80 fish species being of commercial importance (Nader et al., 2012). Illegal fishing behaviors and harmful or unsustainable practices such as the use of small mesh nets and explosives thrive as a result of an outdated legislation and the lack of its enforcement (Sacchi & Dimech, 2011). Major anthropogenic threats are hindering the potential of coastal communities also resulting in ecosystem degradation further aggravating the on-going phenomena of coastal erosion, destruction of fish nurseries, destruction of bio-constructions. They include i) the artificialization of the coast line, including the excessive number of fishing ports, landing sites and infrastructural development along the coastal areas, ii) sea filling, iii) the privatization of coastal domain and iv) the inadequate waste management.

The revenue of the Lebanese fishing fleet generated an average annual salary of about USD 4,300 (on a full-time equivalent basis) which is below the Lebanon’s minimum wage for the manufacturing sector (FAO EastMed, 2016). In 2011 the annual salary was approximately USD 3,000/fisher to about 3,229 fishers and a gross income of USD 7,400/fisher-owner (Pinello & Dimech, 2013). According to the Department of Fisheries and Wildlife of the Ministry of Agriculture, in 2014, Lebanon started reporting to FAO, fisheries catch data (2,998 tons in 2014 and 3,483 tons in 2015) based on the system developed by FAO EastMed Project. Considering the local consumption of about 35.000 tons, more than 75% of the consumed fish is imported from abroad. Marine capture fisheries compromise about 0.06 % of the Lebanese GDP (Pinello & Dimech, 2013). Hence, it is not surprising that fishing communities are considered among the poorest in the Country and most marginalized (Figure 48).

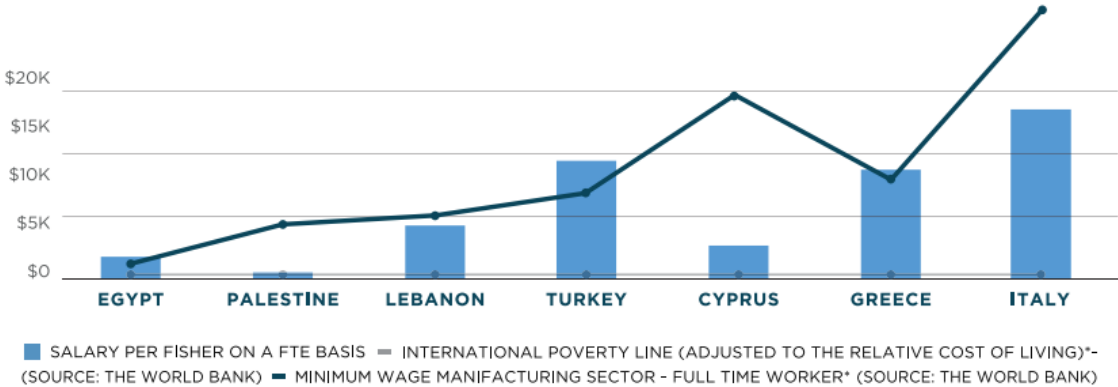


Figure 458. The average salaries against the national minimum wages and the poverty line at regional level. Source: (FAO EastMed, 2016)

There is neither a contract of employment in Lebanon nor any social security cover, which could protect fishers in case of disability, loss of employment and retirement (Pescamed, 2011). Thus, fishers remain heavily reliant on their earnings, possibly on private safety nets (such as remittances) or the credit system.

In the framework of the present study, a huge dataset was collected, creating hitches and strategic complications that had to be handled by a limited staff. Here is the breakdown of the of open issues and recommendations:

- The implementation of annual surveys for the fishery-independent assessment of the distribution and abundance of fisheries resources along the entire Lebanese coast has to turn into a constant exercise to ensure continuous and comparable sets of data for a correct management of the resources.
- When an adequate budget would be made available, the implementation of a second yearly-based survey to carry out in winter time (namely January and February) has to be considered a prerequisite to properly investigate species, biology and distribution according to the season.
- Protocols defined for sampling design, data collection and data treatment - in which the Project abides by international standards adopted in the Mediterranean - have to be followed in order to allow comparisons among different years defining trends and variations.
- The ecological role of a defined set of commercial species has to be thoroughly studied through the analysis of their stomach contents. Their age has to be identified by using bony structures of fish containing record of seasonal growth patterns (scales, otoliths, etc.). Knowledge of fish age characteristics is necessary for stock assessments, and to develop management or conservation plans.
- With regard to the sampling gears, it is strongly advised to widen the use of the trammel nets to the full depth range surveyed (0 - 150 m depth) disposing of the gillnets sunk in the first survey. As the Project did not follow international protocols or recommendations in the definition of the sampling gear, future improvements and/or fine-tuning can be applied.
- Staff of public Institutions involved (mainly MoA and CNRS-L) have to be steadily assigned to the aforementioned activities and properly trained to increase and update their knowledge on these domains. Capacity/institutional building has to be addressed to executive level to properly set priorities and autonomously assess strategies.
- In order to liaise with the world of operators towards the constant acquisition of scientific information, it is advisable to create a network of focal points (i.e. fishermen) distributed in major Lebanese ports and ready to report on abnormal or unexpected catches or sightings.
- To increase the ecological knowledge on the macro-system continental shelf / continental slope; following the interesting results obtained by previous local surveys especially concerning the presence of sexually mature female individuals belonging to the species *M. merluccius* in Lebanese waters; to collect detailed information on the stock of red giant shrimp identified by the surveys implemented by the Project; it is advised to set up a survey for the investigation of demersal and benthic resources in the continental slope also envisaging the support of international concerned organisations and of a well-equipped fishing trawler.

CONCLUSION AND PERSPECTIVES

In Lebanon for the future, cost, scale and complexity of marine research require clear vision and strategic goals, domestic commitment, international cooperation, and integrated plans. Different initiatives, projects and institutions have planted their seeds in the past few years and these are the key lessons learnt:

- A continuous enhancement of the cooperation with concerned institutions in Lebanon and throughout the Mediterranean.
- A strong commitment to establish long-term observation systems, databases and systematic evaluation, providing for long-term time-series datasets on the marine environment.
- The promotion of regional advancement and improvement of marine research.
- The continuous building of capacities of individuals, researchers, technicians while also initiating a positive multiplier effect with and ministries' officers and decision makers.
- The outstanding expansion of knowledge of the marine environment as a whole, its physical and biological parameters and processes, with emphasis upon its characteristic as a habitat for living resources, its geological and geophysical properties, including non-living resources in shallow and deep areas.
- Research and monitoring of marine pollution to measure and assess the effects of human activities, notably those resulting in degradation and contamination, especially in the coastal zones.
- The enforcement of channels of communication between the academia and the general public, raising awareness on the status of the marine environment and on the impact of people's common behaviour on it.

Quantitative understanding of responses to fishing activities is necessary to allow managers and decision makers to set sound strategies. In other words, the management of fisheries requires monitoring of the variation in resource abundance and distribution on the basis of international standardized procedure. Several Mediterranean countries are currently participating to the international fish abundance surveys program called MEDITS. The exploration phase to set up similar survey programs for Lebanon already started but fishery independent abundance surveys might be performed by using sets of passive gears: this can help researchers to get acquainted with these methodologies using a reduced amount of human and monetary resources. Upgrading and improving are suggested in the previous paragraph. Here, it is worth focusing on new tools already developed in other countries that can complement data collected through fishing surveys.

Sampling hard structures for the estimation of age data.

Knowledge of the age of individuals of fish populations greatly improves analyses of temporal variation in structure and abundance. The age structure of the population can be described and rates of key processes such as growth, recruitment, and mortality, can be quantified. This is crucial when considering dynamics of exploited populations and managing fisheries resources. In addition to the total increase in mortality rate caused by fishing, it is imperative to determine how the increased mortality is distributed among age groups in the population. Age-structured population analyses are therefore incorporated in the classical fish stock assessment models (Panfili et al., 2002). In many

cases a certain practice with otolith reading for each specific species is required. Otoliths of *Pagellus* may be tricky for the correct identification of winter rings, ageing schemes and ring overlapping in oldest specimens. In the case of *Sargocentron rubrum*, [Golani & Ben-Tuvia \(1985\)](#) and [Mouneimné \(1978\)](#) got to different conclusion for the first winter ring reading, leading to different ageing for the species.

Genetic analysis

In the last two decades, molecular techniques have been used to assess population sub-structuring (e.g. definition of stocks) or clarify the phylogenetic relationship among species in a wide range of animal populations, including many fish species ([Rocha-Olivares et al., 2000](#); [Takeyama et al., 2001](#)). Insights from genetic analyses can be useful for addressing population genetic issues, revealing whether two disjunctive populations share a common gene pool ([Heist et al., 1995](#)) or clarifying taxonomic relationships between species ([Gardner & Ward, 2002](#)). In this context, using DNA barcoding techniques, [Bariche, et al. \(2015\)](#) got to the conclusion that more than one species belonging to the genus *Sargocentron* has entered over time the Mediterranean from the Red Sea, remaining unreported and probably misidentified.

However, in spite of rapid advent of molecular methods, it is important to support and develop the traditional taxonomic knowledge for proper identification of new non-indigenous species. The participants of the last CIESM Congress Session 'Alien records' expressed their opinion that appropriately supervised 'citizen science' can also provide through social networks important data on exotic species status (established, not established, rare, common, etc.), their secondary spread and impacts ([Azzurro et al., 2013](#); [Bariche et al., 2013](#)). Provided that data are scientifically validated and standardized, such method is especially useful for relatively large conspicuous species, such as fish. Community involvement is also an important instrument to raise public awareness on the subject of migration of marine species in the Mediterranean.

Stable isotopes

In the eastern Mediterranean where NIS are altering previous equilibria, it is essential to properly answer to questions concerning the functional consequences of species replacements ([Woodward et al., 2010](#)). Stable isotopes analyses of nitrogen and carbon together with recently developed analytical tools to characterize the trophic structure of the perturbed rocky reef fish community was used in the eastern Mediterranean Sea by [Fanelli et al. \(2015\)](#). This is powerful way to depict the trophic characteristics of organisms, upon which niche research relies ([Newsome et al., 2007](#)), offers long-term estimates of the prey that have been incorporated into predator tissue, with promising applications in invasion biology (e.g. [Bodey et al. 2011](#)). Stable isotope composition provides an indication of the origin and transformations of organic matter to trace the use and fluxes of resources from the individual to the community level ([Newsome et al., 2012](#)).

Assess migratory species and Lessepsian species

Migratory species distribution is crucial to properly assess stocks. Bias can be generated when knowledge of migratory patterns of species are not known or underestimated. There are several ways to acquire knowledge about possible migrations of the species under study. An obvious and cheap way is to lap the knowledge of the fishermen. Common echo-sounders are very useful for the detection of vertical migrations, while more sophisticated acoustic equipment can be used to map the distribution and estimate the abundance, in relatively short time, in particular of small pelagic

fish. The classical way to study movements (and growth) of fish and invertebrates is a tagging programme. Identification tags are attached externally or placed in the body cavity, the fish is measured and released at a known spot, and a reward is given for any tag returned. Sophisticated acoustic and radio tags have been developed which allow the continuous observation of the movements of single fish as followed from a research vessel. The latest developments, usually applied in tuna research, include tags that are released at a pre-set moment, pop to the surface and transmit to a satellite (Sparre & Venema, 1992).

Due to its geographical location, Lebanon represents also an outpost for a comprehensive understanding of the dynamics driving the colonization of the Mediterranean by Indo-Pacific and Red Sea species. The Mediterranean Sea – and more in specific its easternmost shores - is one of the hottest hotspots of marine bio-invasions on earth (Rilov & Crooks, 2009).

Other issues

A certain number of action should be executed to allow a sustainable growth of the entire system that can drive the progress towards an autonomous, reliable and internationally acceptable assessment of the halieutic resources in Lebanon. Training on fishing gear technology, stock assessment methods, statistics are needed for researchers, ministry staff and managers. They should be backed by a continuous effort towards the development of the PhD programme in subjects related to the marine ecology. Multidisciplinary staff are to be built in order to respond to the rapid development of the sciences in this sector. They should include different expertise in biology, natural sciences, taxonomy, statistics, economy, social sciences, IT, etc. The behaviour of fishermen at sea have to be better understood and monitored to define ratio and content of by-catch and discards, fishing grounds, expenses and incomes, compliance with regulations. Fishing trials should be organised and conducted with professional fishers to increase the array of metiers available.

Small-Scale Fisheries (SSF) in Lebanon can develop in the context of food security and poverty alleviation (FAO, 2012). The SSF Guidelines should be grounded in a number of basic principles (FAO, 2012):

- Resource governance, access regimes and enforcement
- Safety at sea
- Social and economic development
- Disaster risks and climate change
- Post-harvest employment and value chains
- Social and gender equity
- Policy coherence, institutional coordination and collaboration
- Research and information needs, sources and exchange
- Capacity development
- Implementation support and monitoring

The social and cultural role of SSFs reflects the historic links to adjacent fishery resources, traditions and values, and supporting local cohesion. Around the world, about half of people involved in SSFs value chain are women, mainly engaged in post-harvest activities, handling the fish after it is caught and ensuring that this important source of nutrition reaches more than 1 billion consumers for whom fish is a key component of their diets (World Bank, 2010).

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ANNEXES

ANNEX 1. Communication to the 45th congress of the Italian Society of Marine Biology, May 9-23, 2014.



**45° Congresso della Società Italiana di Biologia Marina
Venezia, 19-23 maggio 2014**



VOLUME DEI PRE-PRINT



Référence : LA PORTA B., L. NICOLETTI, R. MOUAWAD, M. TARGUSI, P. LA VALLE, L. LATTANZI, S. LELLI, 2014. Benthic assemblages along the highly urbanized coast of Lebanon (Eastern Mediterranean Sea). 45ème congré de la Société Italienne de Biologie Marine, 9-23 mai 2014, 166-167.

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BENTHIC ASSEMBLAGES ALONG THE HIGHLY URBANISED COASTS OF LEBANON (EASTERN MEDITERRANEAN SEA)

POPOLAMENTI BENTONICI PRESENTI LUNGO LE ANTROPIZZATE COSTE LIBANESI (EST MEDITERRANEO)

Abstract - A preliminary analysis of the macrozoobenthos in the Lebanese continental shelf was carried out within the project "CIHEAM-PESCA LIBANO". 37 species belonging to Polychaeta, Crustacea and Mollusca were identified and two Invasive Alien Species (IAS) in the Mediterranean were found (*Rhinoclavis (Proclava) kochi* and *Conomurex persicus*). The macrofauna composition showed differences related to different environmental features and human pressures.

Key-words: benthic assemblages, soft-seabed, human pressures, Lebanon, Mediterranean Sea.

Introduction - In the last decades the Lebanese coasts have been undergone an overexploitation of coastal zone (e.g. urban encroachment, waste dumping) that heavily affected marine ecosystems. In the framework of the CIHEAM-PESCA LIBANO project and with the support of the CANA-CNRS project on "Establishing Monitoring and Sustainable Development of the Lebanese Sea" and in coordination with ISPRA (Italy), the preliminary analysis of soft seabed macrozoobenthos in the Lebanese continental shelf was carried out to complement the assessment of the distribution and abundance of fisheries resources along the Lebanese coast. This study also intends to provide preliminary information on macrobenthos in areas affected by different types of human pressures.

Materials and methods - Surveyed area was located along the Central Lebanese coast between Jounieh and Damour, respectively about 20 km north and south of Beirut. Sampling activities were performed from April to June 2013. In the same area where the sampling stations to study fisheries resources were located, benthic samples were taken in two replicates at 8 stations sited between 10 to 100 m depth by a Van Veen grab (25lt). Samples were sorted into Polychaeta, Mollusca and Crustacea and the collected individuals were classified to the lowest possible taxonomic level and counted. Abundance data were expressed as number of individuals per station and AMBI index was performed. Organisms collected in only one of the two replicates were analyzed to produce the preliminary results described in this work.

Results - The taxonomic analysis led to the identification of 213 individuals, 50 taxa and 37 species belonging to Polychaeta (12 species), Crustacea (14 species) and Mollusca (11 species). AMBI index classified almost all stations as slightly disturbed but the percentage of ecological groups (according to AMBI classification) showed differences among the stations. The northern station Jounieh2 (-70 m) had the richest assemblage dominated by polychaetes. Disturbance tolerant species (group III) as *Notomastus latericeus*, *Melinna palmata*, *Thyasira* cfr. *biplicata*, *Abra alba* and

Cyathura carinata coexisted both with disturbance indifferent species (group II) as *Aponuphis brementi*, *Paranaitis kosteriensis* and *Paralacydonia paradoxa*, second order opportunistic species (group IV) *Corbula gibba*, first order opportunistic species (group V) *Pseudoleiocardia fauveli* and with disturbance sensitive species (group I) *Nucula nitidosa*. Two stations were placed off Antelias, at 5 km to the north of Beirut. Antelias1 (-10 m) was characterized by a poor assemblage quite exclusively dominated by mollusks. Among them *Rhinoclavis (Proclava) kochi* and *Conomurex persicus*, were dominant and they have been recorded as IAS species in the Mediterranean (Streftaris and Zenetos, 2006). The station Antelias2 (-100 m) was dominated by mollusks too: *Nassarius turulosus* (II), typical of the eastern Mediterranean (Koukouras, 2010), *N. mutabilis* (II) and *Saccella commutata* (I). Dora is a suburb located north of Beirut, next to the commercial port. A relatively high diversity was recorded in the station Dora2 (-50 m) where polychaetes dominated; *M. palmata* (III) *Ancistrosyllis groenlandica* (III), *Sternaspis scutata* (III), *N. latericeus* (III), *P. fauveli* (V), *A. brementi* (II) and *Harmothoe antilopes* (II) coexisted with *C. gibba* (IV) and *T. cfr. biplicata* (III). The station Ramleh el Baida (-28 m) is off the southern suburbs of Beirut. Here the richest assemblage in terms of abundance was found. It was mainly composed by crustaceans and polychaetes. *Ampelisca brevicornis* (I) dominated, followed by *Scoloplos (Scoloplos) armiger* (III), *Phylo foetida* (I) and *Nephtys hystrix* (II). A very poor assemblage, exclusively composed by *Athanas nitescens* (I), *Notomastus* sp. (III), Syllidae (II) ind. and *Lumbrineris* sp. (II), was found in the second station of this area, Ouzaii2 (-88 m). In the station Airport1 (-100 m) no macrozoobenthic species were found. The last station investigated (-45 m) was in front of the small town of Damour located in a flat area to the north of the homonym river. This station had the poorest assemblage composed by *Gammarella fucicola* (III), *Cheirocratus sundevalli* (I) and *Anapagurus laevis* (III).

Conclusions - Our results represent a first contribute to the knowledge of soft seabed macrozoobenthos in the Lebanese continental shelf. Assemblages analyzed changed according to depth and to the percentage of ecological groups. Disturbance tolerant species and second and first order opportunistic species were mainly found in heavily urbanized Bay (Jounieh2) and in an area next to the commercial port of Beirut (Dora2). In particular, Dora, a suburb north of Beirut, lays in a heavily industrialized area where the local dumpsite currently discharges a dark percolate into the sea, resulting in a contamination of the sediments by high concentration of Hg. Assemblages founded at Ramleh el Baida station, off a sandy beach, was mainly characterized by an high percentage of disturbance sensitive species. Disturbance indifferent species characterized assemblages of the two deepest stations, Ouzaii2 and Antelias 2. The analysis of the remaining collected samples and further specific studies will contribute to assess if the variability observed among assemblages is significantly related to the human overexploitation of the Lebanese coastal zone.

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ANNEX 2. First page of a 2014's publication in the Journal of earth Science and Engineering.

Journal of Earth Science and Engineering 4 (2014) 236-244



Population Structure and Sexual Maturity of the Pufferfish *Lagocephalus sceleratus* (Osteichthyes, Tetraodontidae) in the Lebanese and Syrian Marine Waters (Eastern Mediterranean)

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Abstract: The pufferfish *Lagocephalus sceleratus* is an invasive Lessepsian species of Indo-Pacific origin that has established an increasing population over the past decade in the Levantine basin of the Mediterranean. Besides its toxicity due to the accumulation of tetrodotoxin in its body, it is causing damage to fishing gears and fishermen's catches. This study aims to provide data on the population structure and sexual maturity of this species in the eastern basin of the Mediterranean. A total of 214 individuals were collected in the coastal marine waters of Lebanon and Syria, between January 2012 and June 2013 by means of different types of nets and lines, on soft bottoms, at depths ranging from 10 m to 170 m. The TL (total length) of the samples varies between 10.8 cm and 71 cm. The most common size classes, represented by 125 individuals, are the ones between 30 cm and 50 cm TL, with a bulge at 40 cm, represented by 44 individuals. The average TL is 43.99 cm (standard deviation: $SD = 17.65$) for both males and females. The TW (total weight) of the specimens ranges between 14 g and 4,603 g with an average value of 1,458.52 g ($SD = 1,329.49$). The sex ratio (M/F) is 1:1.35 with a total number of 87 males, 118 females and nine unidentified individuals. The weight-length relationship ($TW = aTL^b$) shows a negative allometric growth with $b = 2.9481$ and $R^2 = 0.9806$. The condition factor (K) is close to one for all samples. The average value of the GSI (gonadosomatic index) shows a substantial increase from winter to spring. The spawning takes place between April and June.

Key words: *Lagocephalus sceleratus*, Lessepsian species, population structure, eastern Mediterranean.

1. Introduction

The Mediterranean Sea is home to numerous invasive marine species, some of which have already established prosperous populations. These invasive species might have entered through several routes: the Suez Canal, the Gibraltar Strait, ship ballast water, accidental release and other means. Nevertheless, the Suez Canal is considered the major route for migrating indo-pacific species, also referred to as Lessepsian

species, from the Red Sea into the Mediterranean. In total, the number of alien species has reached more than 790 in the Mediterranean Sea, with some of the invaders through the Suez Canal having been very successful colonizers of Mediterranean marine ecosystems [1-5]. The ichthyofaunal profiles of the eastern Mediterranean Sea, especially of the Levantine sub-basin, have been severely affected by Lessepsian migration [6-8].

The pufferfish *Lagocephalus sceleratus* commonly known as the silver-checked toadfish is a widely distributed species inhabiting the tropical Indian and Pacific Oceans, from which it originated. It made its

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ANNEX 3. Two communications to the 'Watch Letter' (CIHEAM), N°31, december 2014.



The Mediterranean Sea: Fisheries and Beyond



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International Centre for Advanced
Mediterranean Agronomic Studies

N° 31
December 2014

Research Vessel CANA-CNRS Five years of research activities in the Eastern Mediterranean Sea

Gaby Khalaf

National Council for Scientific Research, CNRS Lebanon



Milad Fakhri

National Council for Scientific Research, CNRS Lebanon



Alexandre Sursock

National Council for Scientific Research, CNRS Lebanon



Mouin Hamzé

National Council for Scientific Research, CNRS Lebanon



Stefano Lelli

National Council for Scientific Research, CNRS Lebanon



The Research Vessel (R/V) CANA-CNRS, a former fishing trawler, reveals the story of a success based on mutual support and collaboration resulting in placing science at the service of the Lebanese community. This story was jointly initiated by the Lebanese National Council for Scientific Research (CNRS-L) and the CIHEAM-Mediterranean Agronomic Institute of Bari that played a major role in the rehabilitation of the vessel.

Five years after the acquisition of the vessel, donated by the Italian Government (2009), marine research activities undertaken by the CNRS-L have experienced a remarkable growth. CNRS' Marine and Geophysical Centres in particular benefitted from the acquisition of up to date equipment (Multi-Beam Echo-Sounder, Rosette with 12 bottles, CTD, Box Corer, Sea Level Recorders) that allowed scientists to approach new horizons for marine research in Lebanon.

Research Vessel CANA-CNRS

This scientific research activities described in this paper were conducted as part of the four programs of scientific investigation tackled by the CANA project on "Establishing Monitoring and Sustainable Development of the Lebanese Sea", funded by the Italian Government and the CNRS-L. The four programmes are as follows: coastal bathymetry, fisheries and cetaceans, pollution. During its 5 years of implementation, CANA worked as a platform to attract international donors and partners (CIHEAM, WHO, RAC / SPA, FAO, the Italian Government, ACCOBAMS, Lebanese Public Sector) to underpin its field of intervention both at local and regional level (Khalaf et al., 2013a).

Scientific activities and Results

Sea Physical Environment

Mapping the topography of the seabed, and producing a morpho-bathymetric map represents a priority for Lebanon in order to valorise the biological and cultural resources of the sea. Task 1 of the CANA project aims at conducting a bathymetric study in the area of coastal waters to complete the study executed by a French-Lebanese team with the naval means of the IFREMER in 2003.

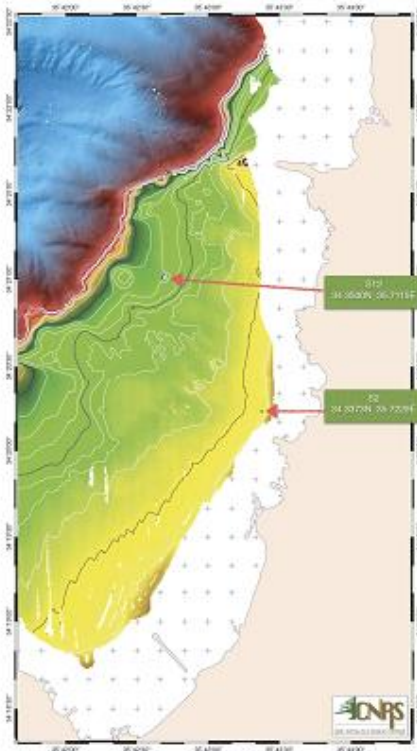
This cruise called Shalimar revealed important morpho-bathymetric features offshore Lebanon but left a strip of coastal waters unsurveyed. This strip represents the core of our research and for this purpose the high-resolution MultiBeam Echo-Sounder (MBES) system Kongsberg EM 710 was installed on R/V CANA-CNRS. The MBES has already revealed extraordinary information on the Lebanese seafloor such as steep dramatic canyons cutting the continental shelf of Beirut and Jounieh, objects of different nature hidden by the profundity of the sea, i.e. shipwrecks, etc. Down to 700 meters depth, the EM 710 performed to provide high quality and reliable data that can be used for hydrographic and nautical maps.

After 600 Km of navigation, almost at constant speed of about 6 knots, data were acquired over Central Lebanese coastal waters. Data were subsequently converted by the associated software into a universal text file where the measurements are represented in xyz file format, one depth measurement per line. The basic document is constituted by 20 million lines of genuine unprocessed depths.

Following the request of the Lebanese Prime Minister, CANA team performed a survey (August-September 2014) to establish the presence of marine fresh water resurgences and monitor water quality in northern Lebanese waters. The areas of Jounieh and Enfeh/Chekka were surveyed over more than 60 hours of navigation with the goal of determining those crater-like structures that are believed to produce resurgences.

Two major structures were mapped and thoroughly investigated and different water parameters (temperature, pH, dissolved oxygen, salinity and conductivity, nutrients and bacteria) were examined. These structures attracted the interest of geophysicists for their uncommon features and further studies are needed to provide a comprehensive understanding of the intricate submarine hydrologic system in Lebanese waters.

Figure 1
The result of the survey conducted between Chekka and Anfeh in September-October 2014



Hydrology, Hydrobiology and Biodiversity

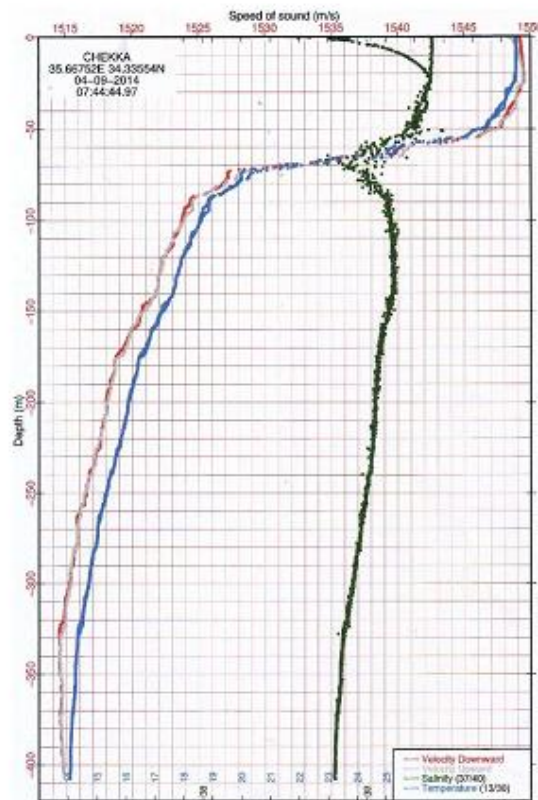
This research programme aims at determining and monitoring the quality of marine waters, studying vertical variations of the physico-chemical parameters and plankton populations and examining the sediments and the associated fauna. Mapping and analysis of the Lebanese marine biodiversity may support the identification of stakeholders' priorities and interests leading to a correct identification of conservation areas and, in general, to an efficient management of the coastal zone.

In the period between June 2010 and April 2014, 21 sites along the coastal area have been inspected to monthly determine surface inshore parameters such as temperature, salinity, nutrients, chlorophyll-a, pheopigments and microbiological features (i.e. faecal coliforms & faecal streptococci). Two sites (coastal and offshore stations) have been monthly surveyed in the area of Batroun to collect data on temperature, salinity, nutrients, phytoplankton, microzooplankton, zooplankton, chlorophyll-a, pheopigments, CO₂ acidification of the sea & partial CO₂.

In the same period, Toxic algae with particular focus on the dinoflagellate *Ostreopsis siamensis* were closely examined in 2 rocky sites (Abboud-Abi Saab et al., 2013).

Several water column profiles down to 750 m were collected with CTDs in order to study seasonal variations of seawater characteristics and to relate them to water contamination and global warming as well as to recalculate the variation of sound velocity, a crucial parameter for the calibration of the MBES transducer.

Figure 2
September 2014. Vertical evolution of water temperature, salinity and sound velocity over the water column in Chekka (North of Lebanon)



CANA has joined in the project ALTIFLOAT which was set up and implemented by multiple Mediterranean partners. The outputs gave information on surface currents generated mainly by winds and the use of verified algorithm and provided information on the dispersion of different types of contaminants along the Lebanese coastal and Eastern Levantine waters. Up till now, CANA deployed 12 Iridium drifters 2014 as well as one Argo float in the offshore water of Tyre between August 2013 and August 2014.

Under the coordination of international institutions, in the framework of the "Strategic Action Programme for the Conservation of Biological Diversity (SAP BIO) in the Mediterranean Region", aiming at establishing a well-managed, ecologically coherent network of Marine Protected Areas (MPAs) in Lebanese waters, CNRS-L carried out activities through the constant support of the CANA-CNRS vessel's staff and crew. In 2012 and 2013, two teams of international researchers had extensively surveyed the regions of Enfeh, Heri and Chekka (north) and Naqoura, Sarafand, Tyre and Saïda (south) to study the benthic and nektonic biodiversity, through various field trips supplemented by satellite images. 18 MPAs coastal and marine sites, from Naqoura to Aarida and including estuaries and deep waters sites, have been proposed.

Fisheries and Mammalian

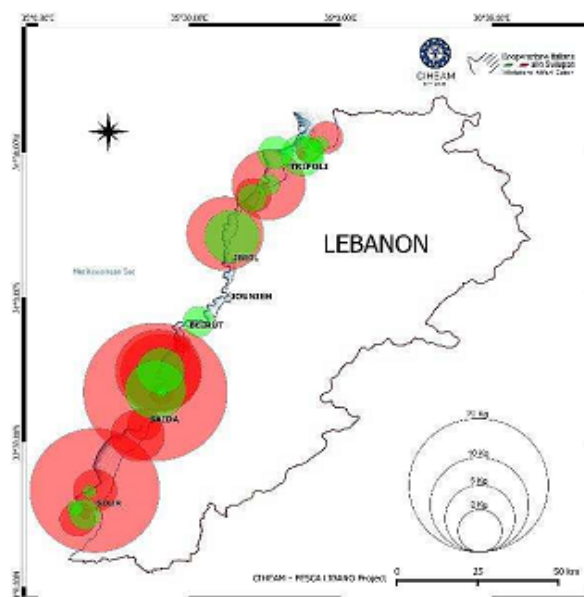
Capture fisheries and aquaculture are considered as a strategic component of the CANA project. A continuous collaboration with the Lebanese Ministry of Agriculture (MoA) has been developed in order to maximise the effectiveness of its efforts, creating synergies with the actors involved in the sector.

The project "Technical Assistance to the Ministry of Agriculture in the field of fishery development, CIHEAM-PESCA LIBANO" funded by the Italian Ministry of Foreign Affairs was run in partnership by CIHEAM-IAM Bari (leading partner), Istituto Agronomico per l'Oltremare, MoA and CNRS-L. With the support of CANA staff and its facilities; the NCMS-CNRS performed the action "Marine resources mapped, identified and better exploited" implementing two national fishing surveys aiming at collecting quantitative abundance and biological data on the main fish and shellfish stocks occurring along the Lebanese coasts. Data collected are a prime in Lebanon. They were acquired lowering experimental nets in semi-random points to reduce bias associated with the activities of the fishermen oriented to specific fishing grounds. 120 species of bony fishes, selaceans, cephalopods and crustaceans were collected, 16 of which are Lessepsian species particularly abundant in shallower waters. The most abundant species in all Lebanese waters is by far the redcoat, *Sargocentron rubrum*.

Nets filled with individuals of redcoat, *S. rubrum* (picture below).



Geographical distribution of *S. rubrum* in Lebanese waters (bubble plots of the observed abundances). Green bubbles: survey 2012; Red bubbles: survey 2013 (map on the right).



Autochthon species prevail in assemblages of deeper waters. Those assemblages are mainly characterised by commercially valuable species such as the red mullets, the European hake and the red giant shrimp, *Aristaeomorpha foliacea* (Lelli et al., 2014).

A research project on cartilaginous species along the Lebanese coast aiming at establishing the ecology, relative abundance and distribution of sharks, rays, and chimeras found off the Lebanese coast at different depths has been initiated. In the study 225 specimens of cartilaginous fish were sampled constituted of 25 cartilaginous fish species (11 sharks and 14 batoids). Batoid species such as guitar fishes, the bluntnose sixgill shark, and requiem sharks (family Carcharhinidae) showed high commercial significance in Tripoli and Sidon.

The presence of cetaceans in Lebanese marine waters was analysed for the first time between 2009 and 2013. The results highlight the regular presence of bottlenose dolphins in a central area of the Lebanese coast, adding a piece to the puzzle of the Mediterranean knowledge of this species' distribution. 91 individuals were detected in 32 sightings. The size of the groups ranged between a minimum of one individual and a maximum of 7 young and adult individuals. The individual's relative abundance and sighting rate are higher in Beirut area (0.11 ind·km⁻¹ and 0.032 sighting·km⁻¹, respectively) compared to values obtained for the entire Lebanese coast (Khalaf et al., 2013b). Noteworthy that this higher abundance in Beirut waters should conduct to identify this zone as an area of special interest for the conservation of this species in the Lebanese waters.

On the other hand, *Tursiops truncatus* occurs in higher numbers beyond the continental shelf, indicating that the bottlenose dolphins in the Lebanese waters belongs to the offshore ecotype. These results also constitute a solid base to other research that can study the impact of anthropogenic factors on these species and evaluate their heavy metal and organic contaminant levels.

Coastal Pollution

The "Coastal pollution" task is concerned with human activities causing pollution and performs measurements of chemical contamination levels along the Lebanese coast, in addition to bacteriological, organic (hydrocarbon) and heavy metal contaminants (HMCs). The main output is the pollution risk map and the proposal for coastal protection.

Research activities for the analysis of sediment characteristics of different coastal areas of the Lebanese sea were executed between 2011 and 2014 aiming to evaluate the state of environment of these zones subject to the impact of various anthropogenic stresses such as chemical industries, treated and untreated sewage water and urban development explosion. Some of these studies have been published in the last year and others are still on-going. The nature of chemical by-products discharged from the phosphate fertilizers plant at Selaata and the factory of cement at Chekka in combination with the hydrodynamic movements and the geographical distribution of the investigated marine zones greatly influenced the structure and composition of the sediment and led to the variability of the obtained results. These two chemical plants appear to increase the level of stress toward the marine environment of the Lebanese northern coast (Fakhri et al., 2014). Further studies on sediments characteristics are still on-going and covering hot spots of the Lebanese coast.

The CANA experts working on HMCs are carrying on with analyses of the levels of lead, cadmium and copper in marine sediments in different ports. This assessment is enabling researchers to evaluate for the first time the extent of trace metal contamination in these sediments. To evaluate the risk that these metals represent to living organisms, a study of their mobility in the presence of chemical reagents (ethylene diamine tetraacetic acid) is performed. On the other hand, analyses on the levels of some organic contaminants (Polycyclic Aromatic Hydrocarbons, PAHs) present in these sediments is carried out. In March 2013, a sediment sampling campaign was performed in the port of Tripoli. The port was characterized by many anthropogenic activities: urban and industrial wastewaters, small boats effluents, ancient boats and solid wastes, etc. The calculation of geochemical index showed that the sediment quality of the fishing port of Tripoli, varies between moderately and highly polluted, for the three trace elements (Pb, Cu, Cd). Studies on mobility show that extremely small percentage of copper is in ion exchange position thus representing the highest risk to the water column and to living organisms. In addition, in the presence of a complexing agent like EDTA, the mobility of the three elements increases tremendously, especially for Cd that represents the highest risk in the long term. Organic contaminant analysis conducted by GC-MS in the department of Chemical engineering in Balamand University were mostly concentrated on PAH levels. The sediments of the port of Tripoli were found to be mostly contaminated with high molecular weight 5- 6 ring aromatic hydrocarbons, which are highly toxic and carcinogenic. This is potentially due to diesel fuel consumption and incomplete combustion of fossil fuels. Same studies are now in the phase of implementation in the fishing port of Dora.

Map showing lead (Pb) distribution in the fishing port of Tripoli



Conclusions and Perspectives

CANA is a scientific tool designed to respond to the needs of communities and territories on a Mediterranean scale. Activities undertaken promoted research, improved awareness of civil society to the essential value of the environment and biodiversity, educated key-actors, gave sustainability to project actions. It is a matter of fact that marine research is increasingly becoming key to strengthening the capabilities of countries for socio-economic progress while contributing to the wellbeing and sustainable development of human communities.

Recent achievements in the field of mapping of the Lebanese seafloor led to the discovery of unprecedented and impressive features that need to be properly studied and evaluated. Unexpected results have been obtained in the field of fisheries sciences and several studies (i.e. pollution, toxic algae, etc.) may affect the whole marine environment on the one hand and directly the life of the Lebanese communities on the other.

For the future, cost, scale, and complexity of marine research require clear vision and strategic goals, domestic commitment, international cooperation, and integrated plans. The road is still long but the CANA project has planted its seeds:

- A continuous enhancement of the cooperation with concerned institutions in Lebanon and throughout the Mediterranean.
- A strong commitment to establish long-term observation systems, databases and systematic evaluation, providing for long-term time-series datasets on the marine environment.
- The promotion of regional advancement and improvement of marine research, through the acquired technical facilities of the project: such as vessel, seafloor mapping system, and water sampling system.
- The continuous building of capacities of individuals, researchers, technicians, and the crew of the vessel that will improve Lebanese CNRS' capacity and efficiency while also initiating a positive multiplier effect for human capacity development in marine research fields in Lebanon.

- The outstanding expansion of knowledge of the marine environment as a whole, its physical and biological parameters and processes, with emphasis upon its characteristic as a habitat for living resources, its geological and geophysical properties, including non-living resources in shallow and deep areas.
 - Research and monitoring of marine pollution to measure and assess the effects of human activities, notably those resulting in degradation and contamination, especially in the coastal zones.
 - The enforcement of channels of communication between the academia and the general public, raising awareness on the status of the marine environment and on the impact of people's common behaviour on it.
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During five years of activities, CNRS-L and the CANA project have been catalysing the attention and gaining the credibility of experts and institutions providing high-level scientific contribution. The Lebanese Administration (i.e. Ministries of Agriculture, Environment, Transport, Water & Energy), universities, NGOs as well as engineering enterprises are requesting CANA technical assistance and support to undertake their projects in the fields of fisheries, aquaculture, water quality monitoring, sea ports expansion, establishment of marine fresh water resurgences, topographic surveys of main ports entrances, and major coastal construction projects.

To provide proper responses, CANA developed an original and virtuous model of intervention where researchers and scientists can play a significant role in supporting projects aiming at the sustainable development of the Country.



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Fishery and aquaculture cooperation for the development of Mediterranean coastal communities

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The Mediterranean region shares common resources, and the coexistence of culturally, ethnically and economically heterogeneous countries means that the problems related to the sustainable management of marine and coastal resources cannot be solved by unilateral actions. Cooperation for the protection of the environment and of marine and coastal resources, the sustainable management of fisheries and the socioeconomic development of coastal communities are tools that can help different countries move towards the implementation of common strategies shared at the Euro-Mediterranean level. Ensuring the sustainable development of fisheries and fishing communities in the Mediterranean is a major goal for the future of the sector in coastal countries, and also to preserve this common heritage for future generations.

Focus on the Mediterranean: features and criticalities of fisheries and marine aquaculture

Fishing is a primary activity that still plays a very important socioeconomic role in the Mediterranean. Fish caught in the Mediterranean accounts for 1.6% of the world total, but corresponds to 4% of its worth, because the species caught have a high value. Total catches in 2012, including the Black Sea, accounted for about 1.3 million tons, of which one third, i.e. about 360.000, was caught by North African and Eastern Mediterranean Countries¹.

Over the last decades, the fishing industry has seen gradually depleting fish stocks set against growing consumption, which for Mediterranean countries was 9,631,000 tons² in 2011. The 2012 catch in the Mediterranean and Black Sea fell by 10.8% from the previous year, compared with a 3.5% decline worldwide³. The Mediterranean EU member countries, where fishing is more strictly regulated, have experienced the highest decline in catches at 12%, against the 2.3% growth seen in North Africa and Eastern Mediterranean countries; this growth is mostly due to a more permissive system, which risks repeating the mistakes made by developed countries in the uncontrolled exploitation of fishery resources⁴.

83% of Mediterranean fishing is done by boats less than 12 m long, using production strategies based on the seasonal use of different equipment (multi-specific fisheries) and targeting species with a high commercial value. Small-scale fisheries still play an important socioeconomic role, but are experiencing a steady decline of employment levels, mostly due to the falling stocks and the general decline of the sector's profitability.

At present, the data released by the European Commission confirm that over 96% of Mediterranean fish stocks are overexploited and that fishing should be reduced by an average of 45-51%⁵ in order to allow recovery of the sustainability level. These alarming data require appropriate actions aimed at integrating and diversifying the economic activities associated with the sector.

In this context, aquaculture would provide an opportunity for development of the fish supply chain to reduce pressure on fish stocks, while at the same time safeguarding employment in the sector. Fish-farming produces about 66.6 million tons worldwide, with a value of 137.7 billion dollars (the EU produces 4.3% of the world quantity and 8.9% of the value). At present, the main European fish-farming nations are Norway, Spain, France, United Kingdom and Italy, which together account for 3/4 of the quantity and value⁶ of fish caught.

In the Mediterranean area, aquaculture is booming in Egypt, Turkey and Tunisia. In Egypt alone, aquaculture output rose progressively from 139,000 tons in 1998 to 635,000 in 2007 and 986,820 in 2011, providing new employment and income opportunities with economically relevant initiatives. According to the General Authority for Fish Resources Development (GAFRD), total production amounts to 1,371,975 tons⁷. In the next decade this is expected to increase further, due to Egyptian governmental support in stimulating important private investments in aquaculture in the area between Alexandria and the Sinai Peninsula.

However, the development of aquaculture is currently linked to technologies requiring highly developed skills and professional and operational expertise, making it necessary to ensure appropriate training and a system of support to business start-ups.

Figure 1
FISHINMED: "A sea of dialogues" events
23rd August 2014, Polignano (Ba) – Italy



¹Morocco, Algeria, Tunisia, Egypt, Israel, Libya, Jordan, the Palestinian Authority, Lebanon and Syria

²Based on FAOSTAT, 2014 processed data

³FAO Fisheries and Aquaculture Department. 2014 - Global Capture Production Statistics 2012

⁴Based on FISHSTAT, 2014 processed data.

⁵Report of the scientific, technical and economic committee for fisheries (STECF), Assessment of Mediterranean Sea stocks, 2012

⁶Based on FISHSTAT, 2014 processed data.

⁷GAFRD, Fish Statistic Book, 2014

International cooperation for the integrated and sustainable development of coastal communities

Over the last few years, the activities developed by CIHEAM-Bari in the Mediterranean fishing sector have involved international and non-governmental organizations, national institutions, research institutes and professional associations in Mediterranean countries, and this has enabled us to identify the needs for a common growth of the sector aimed at:

- Studying social issues and fishery governance in various geographical locations;
- Developing networks for the exchange of good practices and information, pointing the way to a system of common rules for correct/rational exploitation of shared resources;
- Highlighting the ecological, technological and socioeconomic features of the Mediterranean fishing industry to help define a specific code for responsible fishing across the whole region;
- Setting up a system to detect alien fish species in the Mediterranean;
- Developing responsible marine aquaculture in order to reduce fishing and provide greater protection of marine resources;
- Improving the skills and professional expertise of the public and private operators involved in management and planning of marine and coastal resources;
- Supporting fisheries through diversification and the development of multifunctional activities.

CIHEAM-Bari has promoted several partnerships, capitalizing on the opportunities given by the 2007-2013 EU programmes and on the bilateral cooperation projects promoted by the Italian Government. These activities have enabled important results.

Strengthening Mediterranean institutional capacities for the enhancement of marine and coastal resources

The provision of technical assistance, training and transnational mobility has helped strengthen the institutional capacities of the public and private authorities in the Mediterranean region, by encouraging communication, awareness and the ability to understand and share the needs of Mediterranean coastal areas. CIHEAM-Bari has been a strong promoter of the dialogue between southern and eastern Mediterranean countries (institutions and society) on major themes including workers' rights in the fishing industry.

The *PESCAMED*⁶ project has focused on the International Work in Fishing Convention (ILO C188) and has also highlighted the different operational procedures of the professional associations and unions engaged in helping fishermen to develop a common philosophy to regulate and integrate the choices of all those involved in the supply chain. The associations and unions must attempt to overcome the limitations and weaknesses of the sector by providing training and information, along with services to businesses, and by promoting innovation and initiatives aimed at upgrading production, shortening the chain, ensuring legislative harmonization, internationalization of businesses, and diversification of income-producing activities.

CIHEAM-Bari has also promoted institutional strengthening targeted at the development of marine aquaculture, in particular in the Mediterranean coastal area of Sinai (Egypt). The *MADE*⁷ project has improved the skills and professional level of the competent public Egyptian authority (GAFRD) by providing international training, *in loco* technical assistance and the design of new marine hatcheries.

Figure 2
MADE project: Training in Italian marine hatchery (Sea bass sea bream reproduction)



⁶PESCAMED - "Development of cooperation in the Mediterranean fishery sector: world of labour, producers' organizations, consumers' associations and training" (funded by the Italian Ministry of Agriculture, Food and Forestry Policies Directorate-General for Fisheries. Project area: Italy, Albania, Algeria, Croatia, Egypt, Lebanon, Morocco, Montenegro, Syria, Tunisia, Turkey).

⁷MADE - "Marine Aquaculture Development in Egypt" (funded by General Authority for Fish Resources Development (GAFRD) through Italian Egyptian Swap Program. Project area: Egypt)

The programme involved the professional training of 9 Egyptian technicians in a marine fish breeding facility, selected for its technological reproducibility in Egypt. The technicians were trained in real production conditions and acquired the planned operational abilities, as proven by testing and their individual final written work. Technical Assistance involved 6 Italian experts working in Egypt to start up innovative production processes for Egyptian conditions and to prepare a sector-based "Road Map", with a view to contributing to the dialogue between the private and public sectors which has great strategic value in the country's present transitional phase.

Sustainable local development of small-scale fishing communities and coastal areas

Inter-sector and income-diversification initiatives (multi-functionality) provide an opportunity for the sustainable development of fishing communities by generating income, producing direct and indirect employment, facilitating and stimulating generational turnover. Important opportunities may be provided by upstream and downstream activities of the fishery chain that are often neglected; these may include the building and repair of boats and gears, port services, fish direct sale and processing, and catering.

An additional contribution to sustainable development of fishing communities may come from fishing-related tourism activities and attractions. However, inducing local communities to diversify their activities is a complex action involving a number of problems (legislative, social, financial, training issues), which are sometimes specific to different areas. The CIHEAM-Bari cooperation projects in this field have helped to strengthen an international and local network (of public bodies, scientific institutions, professional associations, coastal action groups) which can facilitate the exchange of knowledge and good practices, and can operate synergically in various areas to overcome criticalities and resistance to the process of modernizing the fishing industry. These actions are based on the following:

- *Networking: the Observatory on the diversification of fishing economic activities*, established in the *FISHINMED*¹⁰ project, has identified the main factors limiting the development of multi-functionality in the Mediterranean region, related to both the socioeconomic features of small fishing communities and to the limitations of a regulatory framework as yet unable to meet the fishermen's needs in terms of multifunctional development.

¹⁰FISHINMED- "Mediterranean Network of sustainable small-scale fishing communities" (funded by ENPI CBCMED 2007-2013 Programme. Project area: Puglia, Sardinia and Sicily (Italy), Greece, Lebanon, Tunisia and Egypt).

- *Support to employment: The READYMEDFISH*¹¹ project aims to identify and promote innovative professional profiles in the Mediterranean region, for targeted training activities to improve the professional skills of young fishermen. The objective is to stimulate private enterprise within a modern legal framework, concentrating on the need of multifunctional fishermen to innovate.
- *Improvement of local governance: with the participation of local operators, the NEMO*¹² project will strengthen the dialogue between coastal rural communities and local institutions by promoting a model of integrated and sustainable governance of coastal maritime resources (establishment of Coastal Action Groups) for the enhancement of natural resources, typical products and local crafts.

Figure 3
NEMO project: Typical variety of sponge of Zarzis



Protection, monitoring and management of marine and coastal resources

The cooperation activities of CIHEAM-Bari have enabled the development of tools for the monitoring, planning and proper management of marine and coastal resources. A priority of the *PESCA LIBANO*¹³ project has been to set up a territorial information system for the Lebanese coast, the *Marine Coastal Information System (MCIS)*; this has collected geo-referenced information already held by Lebanese institutions which is potentially useful for appropriate management of the coastal area and the fishery sector (infrastructures, services, economic activities, water quality, land use and protected areas).

¹¹READYMEDFISH- "Requalification of Employment and Diversification for Youth in the Mediterranean" (funded by the ENPI CBCMED 2007-2013 Programme. Project area: Puglia (Italia), Lebanon, Tunisia and Egypt).

¹²NEMO- "Cross-border rural coastal communities development in Libya and neighbouring countries" (funded by the Italian Ministry of Foreign Affairs- Directorate-General for Development Cooperation. Project area: Egypt, Libya and Tunisia).

¹³PESCA LIBANO- "Technical assistance to the Ministry of Agriculture in the field of fishery development" (funded by the Italian Ministry of Foreign Affairs- Directorate-General for Development Cooperation. Project area: Lebanon)

For the first time in Lebanon, efforts were made to collect as yet available and/or obsolete data on the distribution and abundance of the main coastal fishery resources. Together with other information gathered about fish marketing, the study of benthic species assemblages and fishing monitoring systems (VMS), this has supplemented the information possessed by the Marine Coastal Information System (MCIS). Because the MCIS is able to manage complex information involving different spatial and temporal scales, it can supply the Lebanese government with the information required in order to manage and regulate the fishery sector.

Figure 4
PESCALIBANO: Researchers collecting bio-morphological information on giant red shrimps harvested in the waters off Saïda, Lebanon



Within CIHEAM-Bari activities in support of the development of environmental (coastal and marine) themes and/or planning strictly related to the territory, it is worth mentioning the *BIG*¹⁴ project which involves the establishment of MARE – Mediterranean Outpost for monitoring coastal and marine ecosystems. This observatory will contribute to the work of the Regional Observatory for Biodiversity, which will play a fact-finding and proactive role in the conservation, use and enhancement of biodiversity and of the environmental heritage of Puglia Region. It will also try to sensitize and stimulate the participation of Puglia society on the themes of sustainable development and environmental protection.

The *CSMON*¹⁵ Project focuses on the participation and active collaboration of scientists, public administrations and citizens in monitoring and protecting biodiversity. The *citizen science* tools will be used to involve citizens in data collection and validation (using smartphones and tablets to gather geo-referenced primary data on biodiversity); this will contribute towards achieving the objectives of the 2020 European Strategy for biodiversity and help to train new professionals for a "green" economy.

Conclusions

The fishing industries of Mediterranean coastal countries face a major challenge, but also have an opportunity for dialogue and exchanges regarding joint and sustainable management of resources, environmental policy and research. The future of this sea, which has historically been such an important cultural and commercial crossroads, will largely depend on the will of these states to rationalize and regulate the fishing. This will involve a sustainable and integrated approach that combines environmental protection (sustainability of fish stocks) with the social cohesion of coastal communities (increase in employment, enhancement of coastal resources, economic diversification of fishery activities).

In this framework the fishery may still be considered as a strategic sector to enhance the quality of life of the local communities and create the professional and economic opportunities capitalizing on the specificities of the coastal area. On the other hand, the development process of the coastal areas needs to be supported by a strengthened network including the institutional and economic actors of marine and maritime sector, and focused on a correct data-based planning and management of marine and coastal resources.

CIHEAM-Bari cooperation initiatives have encountered some difficulties caused by the lack and heterogeneity of statistical data, especially in North African and eastern Mediterranean countries. This limits the development and elaboration of strategies to ensure a correct balance between the protection of fish stocks and the economic benefits resulting from their exploitation and the integrated development of coastal areas.

Via the Bari Institute, CIHEAM will pursue multilateral cooperation to develop transnational activities and to achieve shared international objectives for the extremely strategic fishing and aquaculture sectors, by promoting regional and inter-institutional dialogue and by supporting technical assistance, applied research and know-how transfer with the Mediterranean countries.



¹⁴*BIG*- "Improving governance and sustainability of coastal and marine protected areas and contributing to the implementation of the NATURA 2000 provisions in Italy and Greece"(funded by Interreg Greece-Italy 2007-2013Programme. Project area: Italy, Greece)

¹⁵*CSMON-LIFE PROJECT* - "Citizen Science Monitoring" (funded by LIFE+ Programme. Project area: Italy)

Citations: ZUCCARO M., TREVISI R., GALLI D., LELLI S., UGOLINI R., DI TERLIZZI B., MALORGIO G. (2014) - Fishery and aquaculture cooperation for the development of Mediterranean coastal communities. The Mediterranean Sea. Fisheries and Beyond Paris: CIHEAM, December 2014 - Watch Letter n°31.

ANNEX 4. First pages of the CANA book of 2014 and 2016.

The CANA Management Team

The Steering Committee (SC) is the body that provides the strategic guidance to the project. It is composed as follows:

<p>George Tohmé Mouin Hamzé Palma D'Ambrosio Guido Benevento Gianandrea Sandri Wafaa Sharafeddine Teodoro Massimo Milano</p>	<p>CNRS-L President of the Board of Administrators / SC Chairman CNRS-L Secretary General / PMU Chairman First Secretary of the Italian Embassy Former Director of the Italian Cooperation Office (UTL) Director of the Italian Cooperation Office (UTL) [Starting September, 2014] Representative of the Council for Development and Reconstruction (CDR) Italian Technical Expert</p>
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The Project Management Unit (PMU) is the implementing body and secretariat of the SC. The PMU meets regularly to deliberate and take decisions towards the active implementation of the project. Members attend SC meetings providing the necessary background, information and facilitating services. Its composition is as follows:

 Mouin Hamzé <small>CNRS-L Secretary General / PMU Chairman</small>	 Alexandre Sursock <small>CNRS-L Director of the National Centre for Geophysical Research / CANA Project Tasks Manager</small>	 Gaby Khalaf <small>CNRS-L Director of the National Centre for Marine Sciences / CANA Project Tasks Manager</small>
 Milad Fakhri <small>CNRS-L Researcher / CANA Vessel Management</small>	 Stefano Lelli <small>Scientific Expert</small>	 Dietmar Ueberbacher <small>Representative of the Italian Cooperation Office (UTL)</small>
 Rula Atweh <small>CNRS-L Programme Officer / CANA Project Officer</small>		

CANA Vessel Crew

 Michel Youssef <small>Captain</small>	 George Nachar <small>Mechanic / Engineer</small>	 George Touma <small>Assistant to the captain / Sailor</small>
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CANACNRS

A SCIENTIFIC VESSEL FOR LEBANON





CANA-CNRS

A SCIENTIFIC VESSEL FOR LEBANON

Main Scientific Achievements towards Strengthening the Sustainable Development of the Marine Environment

اتجازات مشروع قانا في البحوث البحرية

2013-2014


National Council for Scientific Research


Italian Development Cooperation
Ministry of Foreign Affairs
and International Cooperation


Embassy of Italy
Beirut

MARINE HYDROBIOLOGY

Hydrology
Coastal Pollution
Fishery
Cetacean (in French)

Gaby Khalaf, Milad Fakhri & Stefano Lelli
National Center for Marine Sciences

With the collaboration of
Marie Abboud Abi-Saab, Carine Abi Ghanem & Rita Mouawad
National Center for Marine Sciences

Mouin Hamzé
Secretary General of the CNRS-L

(...)

A scientific Vessel for Lebanon | 2009-2015 CANA-CNRS

With the keen understanding that marine ecosystems possess vast temporal and spatial scales and dynamics which interact with the land and the atmosphere, and increasingly, with socio-economic systems; on April 3, 2009 and under the patronage of the Presidency of the Council of Ministers and in collaboration with the Italian Embassy in Lebanon, and in the presence of notable Italian and Lebanese authorities, the CNRS inaugurated the CANA-CNRS Marine Research Vessel, the first of its kind in the Middle East.



National Council for Scientific Research

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Citation : KHALAF G., FAKHRI M., LELLI S. (2014) - Marine Hydrobiology: Hydrology, Coastal Pollution, Fishery and Cetacean. In: CANA-CNRS. A SCIENTIFIC VESSEL FOR LEBANON 2013-2014. 66-95.

An Unlikely Mediterranean Sea: Invasive Fish Species in Lebanese Waters

Stefano Lelli

If you walk down the road that leads you to the *mina*, one of the fishing ports spread across the Lebanese coast, you may be lucky enough to witness the collection of fish from the nets. Skilled fishers' hands free their preys deadly entangled, and deposit them in plastic bins. Shapes, colors, and variety can be overwhelming and surprising especially for those who are unfamiliar with this rite. Weird, one must say, for a sea that is considered by scientists as the poorest among the poorest. The Levantine Basin is the lowest marine primary production¹ region of a nutrients-deprived ocean like the Mediterranean.

This display table of a fishmonger in Tyre (South of Lebanon) houses numerous Lessepsian species. In the foreground, the "yellowstripe barracuda", *Sphyraena chrysotaenia*, and the recent invader "threadfin bream", *Nemipterus randalli* with its typical pinkish coloring and orange fins.



To understand the reason behind this blooming of colors and shapes, we have to take a step back to the nineteenth century, an epoch shaken by colliding drives and characterised by scientific discoveries and inventions with an extraordinary acceleration in the development of all fields of knowledge. Egypt, in the second half of this century, hosted two remarkable works of civil engineering, which were full of consequences for the Mediterranean in the coming decades:

- The construction of the Aswan Low Dam (initiated in 1899) to control the flooding of the Nile and provide water for irrigation. At that time, nothing of its scale had ever been attempted and, on completion, it was the largest masonry dam in the world. In 1970, Egypt completed the construction of the High Dam just a few kilometers downstream from the old one; and
- The construction of the Suez Canal started in 1859. This artificial canal connecting the Mediterranean and the Red Sea was opened ten years later and rapidly became an essential shortcut to navigate from Europe to Asia without circumnavigating the African continent.

The history of navigating through the Suez Isthmus starts roughly 2,500 years earlier, in the time of the Pharaoh Necho II who, according to the Greek historian Herodotus², tried to connect the Red Sea to the Nile River and from there to the Mediterranean Sea. The pharaoh reportedly never completed the project of the "Pharaoh Canal," whereas his successor Darius the Great, did. Later, ancient scribes

ANNEX 5. First page of a 2014's communication in the 20th International Scientific Conference New Frontiers in Sciences

20th International Scientific Conference New Frontiers in Sciences
Thursday, 27 March 2014 - Lebanese University-Rafic Hariri Campus - Hadath

First information on abundance, biology and distribution of the red giant shrimp *Aristaeomorpha foliacea* in Lebanese waters

Stefano Lelli¹, Myriam Lteif², Sherif Jemaa², and Gaby Khalaf²

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Abstract: The project CIHEAM-PESCA LIBANO funded by the Italian Government organised and implemented a survey aimed at estimating abundance, distribution and sex composition of demersal species inhabiting the lower part of the Lebanese continental shelf and the upper slope. 24 sampling stations between 100 and 300 meters depth were investigated. The survey - implemented in summer 2013 - covered the whole Lebanese coastal waters between El Aabde (north) and Rachidiyeh (south). This study provides the first information on distribution and population structure of the Lebanese stock of the giant red shrimp (*A. foliacea*). All specimens collected were measured, weighed and sex and maturity stage were determined. 263 specimens of *A. foliacea* were harvested up to 200 meters depth. The CPUE was 5.12 up to 150 m depth and 9.375 specimens/Km nets in deeper waters. The overall length–frequency distribution ranged between 20 and 57 mm CL, while the most abundant class was 47-52 mm CL. An evident predominance of female individuals was reported, the majority of which showing ovaries in a development stage. The geographical distribution of the red giant shrimp is clearly uneven as only 6% of the total catch was collected in sampling stations located north of Beirut.

Index Terms— *Aristaeomorpha foliacea*, Mediterranean, Lebanon, small-scale fisheries

I. INTRODUCTION

IN THE FRAMEWORK of the fishing surveys carried out by the project CIHEAM-PESCA LIBANO "Technical Assistance to the Ministry of Agriculture in the field of fishery development" funded by the Italian Government and managed by the CIHEAM Agronomic Institute of Bari; the CNRS-National Centre for Marine Sciences (NCMS) carried out a study aimed at estimating abundance, distribution and sex composition of demersal species inhabiting the lower part of the Lebanese continental shelf and the upper slope. A special focus in the study was given to the giant red shrimp, *Aristaeomorpha foliacea*, a crustacean belonging to the family Aristeidae which includes several important commercial species. It is a widespread species and one of the most important exploited crustaceans, having a long traditional and economical significance for deep fisheries also in the western and central Mediterranean. It occurs along the continental slope showing a preference for muddy bottoms, with aggregations mainly in submarine trenches and canyons. The species was rarely recorded in the eastern Mediterranean probably due to a lack of studies implemented.

II. MATERIAL AND METHODS

By applying a stratified random sampling design; 24 sampling stations between 100 and 300 m depth were selected and surveyed between the northern port of El Aabde and the southern village of Rachidiyeh. The survey was performed in summer 2013. Sampling gear was constituted by special multi-mesh (between 22 and 30 mm stretched) experimental trammel nets targeting a wide range of preys and rigged with a hanging ratio of approximately 0.5. Nets were manufactured in Lebanon to suite depths up to 250/300 meter. All specimens collected were measured by their cephalothoracic length (CL) at the lower millimetre and weighed. Sex and maturity stage were determined.

LELLI S. *et al.*

Citation : LELLI S., LTEIF M., JEMAA S. and KHALAF G. (2014) - First information on abundance, biology and distribution of the red giant shrimp (*Aristaeomorpha foliacea*) in Lebanese waters. 20th LAAS International Science Conference - Advanced Research for Better Tomorrow. March 27-29.

The comparative analysis of Mediterranean coastal communities: six case studies

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Jel classification, O18, Q57, O13

1. Introduction

Specific territorial conditions at social, economic and productive level, characterized by homogeneous organization patterns and strong relations among economic stakeholders, which are historically based on links of common tradition and culture, represent the roots of an integrated local development system. In this context, an industrial district, or industrial cluster may be defined as a socioeconomic institution, within a territory, characterized by a community of people and enterprises with traditional links (Becattini, 1989) and where, from a productive perspective, the mass of resources and competences has reached a critical threshold to provide a key position in a given economic branch of activity (Porter, 1998).

This paper provides an empirical application of the concepts introduced by Malorgio *et al.* (2017), which consider coastal communities as a specific case of industri-

Abstract

The aim of this study is to promote cooperation and actions for the benefit of coastal communities on the Southern and Eastern shores of the Mediterranean region by adopting an approach that integrates environmental, economic and social dimensions. These areas are traditionally based on Fisheries, especially small-scale fisheries (SSFs), which contribute to strengthen social cohesion, in that the seafood value chains still represent the backbone of the coastal economy. The six coastal communities analysed in this paper are located in Algiers port - Casbah (Algeria), Marsa Matrouh (Egypt), Tricase (Italy), Tyre (Lebanon), Nador Lagoon (Morocco), Zarzis (Tunisia). Conclusions emphasise the need to develop a comprehensive reference system for dialogue, cooperation and capacity building both at national and regional level. The cluster approach can help create a favourable cooperation and competition environment, generating income and employment opportunities for local communities.

Keywords: coastal communities, seafood value chains, industrial cluster, integrated development.

Résumé

Le but de cette étude est de promouvoir la coopération et des actions en faveur des communautés côtières sur les rives Sud et Est de la Méditerranée, en adoptant une approche qui intègre les dimensions environnementale, économique et sociale. Cette région est traditionnellement axée sur la pêche, et notamment la petite pêche, qui contribue à renforcer la cohésion sociale, car les chaînes de valeur des produits de la mer constituent encore la colonne vertébrale de l'économie côtière. Les six communautés côtières examinées dans ce travail sont situées à la Casbah-port d'Alger (Algérie), à Marsa Matrouh (Égypte), à Tricase (Italie), Tyre (Liban), dans la lagune de Nador (Maroc) et à Zarzis (Tunisie). Dans les conclusions, l'accent est mis sur l'importance de structurer un système de référence global pour encourager le dialogue, la coopération et le développement des capacités à l'échelle nationale et régionale. Le modèle du cluster pourrait contribuer à créer un environnement de coopération et de compétition favorable, générant des revenus et des emplois au niveau des communautés locales.

Mots-clés: communautés locales, chaînes de valeur des produits de la mer, cluster industriel, développement intégré.

al clusters, and propose a methodological approach to define their competitive characteristics, potentials and the current state of play. Furthermore, these areas are traditionally based on Fisheries, especially small-scale fisheries (SSFs), which contribute to strengthen social cohesion, in that the seafood value chains may still represent the backbone of the coastal economy.

The Mediterranean region (naturally and culturally inclined towards fishery) includes a multitude of fishery-related industrial clusters scattered along the whole Mediterranean coast (i.e. micro-clusters or coastal communities) characterized by:

- A defined spatial boundary, with specificities and interactions at biological and productive level.
- A homogeneity of enterprises (in particular SS-

Fs) from several perspectives: structure, technology, strategies, human capital, etc.

- Synergies consequent to well developed horizontal and vertical relations between the different local activities.
- An important role of institutions in fisheries management to provide support to enterprises.
- A traditional role of social relations with strong historic and cultural links.

Hence, SSFs certainly play an important role in the Mediterranean region (FAO, 2015; FAO and GFCM, 2016) even if statistical information is sparse and many small boats are not registered (Farrugio, 2015). A synthetic appraisal of the situation based on various sources (Sacchi,

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Weight-length relationships of 3 demersal fish species from Lebanese marine waters, eastern Mediterranean

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Funding information

Italian Ministry of Foreign Affairs and International Cooperation; Grant Research Programme of the CNRS-L

Summary

Weight-length relationships (WLRs) were estimated for 3 demersal species, from the Lebanese marine waters, eastern Mediterranean, namely *Coelorinchus caelorhincus* (Risso, 1810), *Scorpaena elongata* Cadenat, 1943 and *Stephanolepis diaspros* Fraser-Brunner, 1940. The specimens were collected using trammel and gill nets from June 2012 to October 2014. The values of parameter b of the WLRs $W = aL^b$ ranged from 2.922 to 3.708. Pronounced sexual dimorphism in WLR was observed for *S. diaspros* and none showed a WLR-based geographical pattern of distribution. WLRs reported in this study should be applied only within the observed length ranges.

1 | INTRODUCTION

Length and weight data are useful in fisheries management and standard results of fish sampling programs. Weight-length relationships (WLRs) are used for estimating the weight corresponding to a given length, and condition factors are used for comparing the condition, fatness, or well-being (Tesch, 1968) of fish, based on the assumption that heavier fish of a given length are in better condition. Both concepts have been used in fisheries research since the beginning of the 20th century (Froese, 2006). WLRs are only known for a restricted number of species, which hampers efforts to model aquatic ecosystems. On the one hand WLRs are used to predict the weight from the length of a fish, which is particularly useful for computing the biomass of a sample of fish from the length-frequency of that sample. On the other, WLR for a given population can be compared to average parameters taken from other regions, in different years in order to identify the relative condition or robustness of the population (Le Cren, 1951). Hence, WLR is considered an important tool in fisheries management (Froese, Tsikliras, & Stergiou, 2011).

Eastern Mediterranean halieutic species are poorly studied and very little biological information is available, notably for most of the commercially relevant species. There is an urgent need to manage and

regulate small-scale coastal fisheries in the region to ensure the long-term sustainability of fishery resources, and this requires basic population dynamics information for the target species (Santos, Hawkins, Monteiro, Alves, & Isidro, 1995).

In this paper, WLRs were estimated for 3 coastal species, i.e. *Coelorinchus caelorhincus* (Risso, 1810), *Scorpaena elongata*, Cadenat 1943, *Stephanolepis diaspros* Fraser-Brunner, 1940. We are providing wider size ranges than those found in science literature and to the best of our knowledge, this study presents the first estimation of WLRs for *S. elongata*. Specimens were captured in Lebanese waters in the framework of a multiannual fisheries-independent data collection for the assessment of demersal coastal species. Sex and geographic distribution effects on WLRs was also examined.

2 | MATERIALS AND METHODS

The specimens were collected from June 2012 to October 2014 in the Lebanese marine waters, Levantine Sea (eastern Mediterranean). Lebanese coastal line (220 km) was broken down into 4 regions (Figure 1) to allow geographical-based analysis. Specimens were sampled using trammel and gill nets with different mesh sizes lowered by

Résumé substantiel de la thèse en français

Préambule concernant la langue de rédaction de la thèse.

La langue des thèses et mémoires dans les établissements publics et privés d'enseignement est le français, sauf exceptions justifiées par les nécessités de l'enseignement des langues et cultures régionales ou étrangères ou lorsque les enseignants sont des professeurs associés ou invités étrangers. La maîtrise de la langue française fait partie des objectifs fondamentaux de l'enseignement. Pour les thèses en cotutelle, la langue dans laquelle est rédigée la thèse en cotutelle est définie par la convention conclue entre les établissements contractants. Lorsque cette langue n'est pas le français, la rédaction est complétée par un résumé substantiel en langue française.

Une synthèse d'une vingtaine de pages en français, intégrée au manuscrit, mettant en évidence les apports principaux du travail de thèse est requise par l'Ecole Doctorale 305.

Résumé substantiel de la thèse en langue française

Contribution à une meilleure connaissance de la biologie, la distribution et la diversité des espèces démersales le long de la côte libanaise, Méditerranée orientale : un focus sur les espèces de poissons lesseptiennes.

A l'heure actuelle, la biodiversité marine est menacée par l'accroissement des activités anthropiques. Malgré sa faible étendue à l'échelle mondiale, la mer Méditerranée est l'un des principaux réservoirs de biodiversité marine, comptant environ 17 000 espèces macroscopiques. Un grand nombre de ses ressources côtières notamment halieutiques sont menacées d'effondrement écologique en raison d'une mauvaise gestion, d'abus, et des crises sociales et politiques. L'introduction d'espèces non indigènes, la surpêche, la pollution, le changement climatique et la dégradation des habitats, comptent parmi les principales menaces des écosystèmes marins méditerranéens.

L'objectif de la présente thèse était d'améliorer la connaissance et la compréhension de la biologie et de l'écologie des ressources démersales libanaises afin de contribuer à l'amélioration de l'exploitation durable future des ressources halieutiques dans cette région. Une attention particulière a été portée sur les espèces lesseptiennes qui abondent dans cette région depuis l'ouverture du canal de Suez afin de mieux appréhender le rôle qu'elles tiennent dans le fonctionnement des écosystèmes de cette région. Cette étude est issue des activités mises en œuvre dans le cadre de projets financés par la Coopération italienne et pilotés par le Centre international des hautes études agronomiques méditerranéennes de Bari et le Conseil national libanais pour la recherche scientifique. Ces projets prévoyaient la collaboration d'organisations italiennes, libanaises et internationales et impliquaient des scientifiques et des étudiants d'Italie, du Liban et de France.

Chapitre I - Introduction générale. Contexte, problématique et objectifs.

La mer Méditerranée : Biodiversité, menaces et pêcheries

Aperçu géographique. La Méditerranée est une mer semi-fermée située au carrefour de l'Afrique, de l'Europe et de l'Asie. Elle est divisée au niveau du détroit de Sicile, en deux sous-régions occidentale et orientale. Elle a été connectée artificiellement à la mer Rouge et à la région de l'Indo-Pacifique lors de la construction du canal de Suez en 1869. En se déplaçant vers l'est, les eaux deviennent plus chaudes et plus salées pour couler au niveau de la mer du Levant. Les masses d'eau remontent ensuite vers l'ouest et sortent par le détroit de Gibraltar.

Elle est globalement considérée comme une mer oligotrophe et la baisse progressive de la teneur en éléments nutritifs, au fur et à mesure que l'eau se déplace d'ouest en est, entraîne une réduction globale de la productivité. Le climat méditerranéen se caractérise par des étés chauds et secs et des hivers frais et humides. Les températures de l'eau à la surface de la mer montrent une forte saisonnalité et des gradients importants le long des axes ouest-est et nord-sud.

Biodiversité. La mer Méditerranée est considérée comme un point chaud de la biodiversité mondiale malgré sa faible surface. Selon les auteurs, les estimations du pourcentage du nombre d'espèces marines macroscopiques méditerranéennes connues varient de 4 à 18% des espèces mondiales. Le biote marin actuel méditerranéen est principalement d'origine atlantique, mais la variété de climats et l'hydrologie particulière de cette mer a contribué à la co-occurrence et à la survie d'organismes issus de régions tempérées et sub-tropicales. Le niveau d'endémisme est relativement élevé (25 à 30% du niveau mondial) et il existe plusieurs habitats uniques, notamment les herbiers marins endémiques de *Posidonia oceanica* et les habitats des grands fonds marins et pélagiques qui abritent des espèces et des écosystèmes uniques dont certains sont en voie de disparition. La biodiversité de la Méditerranée a été, dans le passé, et sera, dans le futur, continuellement modifiée et modelée par des catastrophes naturelles et anthropiques. Néanmoins, au cours des deux derniers siècles, la biodiversité s'est modifiée à un rythme alarmant notamment en raison de l'arrivée de nouvelles espèces liées aux activités anthropiques avec une accélération apparente du taux d'invasions enregistrées au cours des dernières décennies.

Menaces. Le littoral est sous l'influence d'intérêts concurrents qui ont provoqué une détérioration marquée de la qualité des eaux côtières, des sites écologiques et des ressources naturelles. Les activités terrestres modifient les habitats naturels en raison du ruissellement des sédiments, des nutriments, des toxines et des polluants. Les changements dans les écosystèmes du large comprennent l'extraction des ressources minérales, la pollution due au trafic maritime et la construction d'infrastructures pour le développement pétrolier ou les parcs éoliens offshore. Les fermes piscicoles intensives peuvent libérer d'énormes quantités de déchets organiques et d'eau contaminée dans l'environnement naturel et propager les parasites et les maladies.

Les effets des activités humaines sont plus importants en Méditerranée en comparaison à toutes les autres mers du monde. De plus, la plupart du bassin méditerranéen est non géré et exposé à des menaces actuelles et futures dont les causes les plus importantes pour les espèces méditerranéennes sont la perte et la dégradation des habitats, la pollution, la surexploitation (aquaculture non durable et surpêche), l'eutrophisation, le trafic maritime, les espèces exotiques envahissantes, les perturbations humaines, les prises accessoires et le changement climatique.

Concernant ce dernier facteur, une augmentation globale du niveau de la mer d'environ 3 mm par an au cours des deux dernières décennies est également préoccupante, en particulier sur les rives sud de la Méditerranée.

La surexploitation, les prises accessoires, de même que les rejets non déclarés de ressources marines et les captures accidentelles d'espèces vulnérables peuvent entraîner la perte de ressources biologiques, entraînant d'importants impacts biologiques et écologiques. En Méditerranée, de nombreux stocks exploités commercialement ne sont toujours pas correctement évalués. Parmi ceux évalués, 91% des stocks étaient surexploités en 2014. En particulier, la surexploitation des top-prédateurs, engendrant un changement de biomasse et de composition spécifique, pourrait avoir un impact plus important que prévu sur la stabilité des écosystèmes, en particulier marins, que la suppression d'espèces de plus bas niveaux trophiques.

Pêcheries. La pêche et l'aquaculture doivent permettre de répondre aux besoins alimentaires et nutritionnels urgents d'une population mondiale en expansion tout en conciliant ces activités avec le caractère limité des ressources naturelles. Par ailleurs, ce secteur procure des moyens d'existence et des revenus, tant directement qu'indirectement, à une part importante de la population mondiale et contribue ainsi de façon déterminante à son bien-être et à sa prospérité. Si la part des captures issues des pêches

demeure stable, la production de l'aquaculture ne cesse d'augmenter et est responsable de la croissance impressionnante de l'offre de poisson pour la consommation humaine.

Des communautés de pêcheurs existent dans tout le bassin méditerranéen depuis des temps immémoriaux. De nos jours, des pêcheries industrielles (ciblant principalement les petits pélagiques tels que anchois et sardines), semi-industrielles et artisanales coexistent dans la région en utilisant une grande variété d'engins de pêche. Les pêcheries méditerranéennes exploitent généralement un large éventail de stocks de poissons benthiques, démersaux et pélagiques, ainsi que des mollusques et des crustacés. En raison de la configuration semi-fermée du bassin méditerranéen, de nombreux stocks sont communément partagés entre les flottes de différents pays. La flotte de pêche opérant en Méditerranée est estimée entre 80 000 et 100 000 navires pour environ 300 000 pêcheurs, mais il s'agirait d'une sous-estimation de la taille réelle de la flotte en raison du manque de données relatives à certains Etats riverains de la Méditerranée et de la mer Noire ou d'acteurs non étatiques. Les captures en Méditerranée ne représentent qu'une faible partie des captures totales dans le monde (un peu plus de 1%) mais leurs évaluations sont difficiles en raison des caractéristiques multi-spécifiques et multi-engins de la plupart de ses activités de pêche, de la dispersion des sites de débarquement et de la faible proportion des captures qui passe généralement par le biais des marchés de poissons organisés. La pêche en Méditerranée a tendance à être concentrée dans les zones côtières et environ 85 % de la production est attribuables à six pays (Italie, Turquie, Grèce, Espagne, Tunisie et Algérie).

Espèces démersales. Statut et traits d'histoires de vie.

Aperçu dans le monde entier. À l'échelle mondiale, les espèces pélagiques représentent la plus grande proportion des captures marines mondiales, suivies par les espèces démersales. Ces dernières sont définies comme les espèces vivant au fond de la colonne d'eau ou près de celles-ci, notamment pour satisfaire leurs besoins alimentaires. Ces espèces se trouvent habituellement sur le plateau continental ou à proximité, et sur ou près du talus continental ou le long du littoral.

Depuis le milieu des années 70, les captures d'espèces démersales au niveau mondial se sont stabilisées en dessous de 20 millions de tonnes. Dix espèces (colin de l'Alaska, morue franche, Poisson-sabre, merlan bleu, lançon, églefin, lieu noir, merlu du Cap, sébaste atlantique et poissons plats) ont produit 37% des débarquements démersaux totaux en 2009, avec une tendance décroissante comme celle des captures totales. La consommation annuelle d'espèces démersales par habitant s'est stabilisée à environ 2,9 kg. Pour capturer ces espèces, les navires utilisent une variété de techniques et d'engins de pêche, les plus importants étant les chaluts de fond et les sennes, ainsi que les chaluts à perche. Nombre de ces pêcheries capturent non seulement des spécimens d'une seule espèce ciblée, mais capturent simultanément plusieurs espèces présentes dans la zone de pêche, dans des proportions variables. Par conséquent, ces pêcheries sont appelées « pêcheries mixtes ».

Traits d'histoire de vie des espèces démersales. En raison de la large définition du terme « démersal », différents traits d'histoire de vie sont présentés dans ce groupe. Généralement, les espèces démersales montrent des mouvements d'adultes relativement restreints. Leurs stades juvéniles pélagiques représentent leur mécanisme de dispersion le plus important, bien que des preuves génétiques montrent que les stades pélagiques échouent souvent à atteindre leur potentiel de dispersion. Elles vivent près du fond mais ne dépendent pas de ce dernier. Elles circulent généralement dans la colonne d'eau pour se nourrir. Elles rassemblent des espèces à haute valeur marchande, souvent regroupées sous le terme de «

poisson blanc » en référence à la couleur de leur chair, comme la morue, le lieu (également connu sous le nom de colin) ou le merlu.

Les traits d'histoires de vie des stades relatifs à la reproduction varient considérablement parmi les espèces démersales. Certaines espèces peuvent pondre des œufs benthiques dont les larves pélagiques éclosent, tandis que d'autres peuvent afficher des cycles de vie où les œufs et les larves sont pélagiques. Dans d'autres cas, des formes particulières de soins parentaux ont évolué. La durée des larves pélagiques ainsi que la distribution spatiale des stades pélagiques montrent également une grande variabilité parmi ces espèces. Naturellement, le retrait direct des individus de poissons en raison des activités de pêche peut induire des changements dans les caractéristiques démographiques des populations, y compris les variations génétiques. Cependant, la compréhension de la façon dont les activités de pêche affectent les communautés de poissons démersaux n'est pas encore claire. Il existe des preuves que la taille de ces communautés est influencée par la pêche avec une tendance générale à la réduction des grands poissons et à l'augmentation relative des petits poissons.

Espèces démersales méditerranéennes (EDM). Statut, pêcheries et menaces

EDM - Statut. Les espèces démersales méditerranéennes les plus importantes comprennent des poissons tels que le merlu, le rouget, le merlan bleu, le merlan, les baudroies, la bogue, le picarel, des mollusques bivalves (*Chamelea gallina*), des céphalopodes tels que le poulpe et la seiche et des crustacés (crevettes). En Méditerranée, la profondeur joue le rôle principal dans la différenciation de ce groupe. Ces espèces représentent environ 30% des captures totales déclarées en Méditerranée et en mer Noire. Dans cette zone, les captures totales ont augmenté régulièrement, passant d'environ 0,7 million de tonnes en 1950 à environ 2 millions de tonnes pendant la période 1982-1988. Elles ont soudainement décliné à environ 1,3 million de tonnes suite à l'effondrement de la pêcherie de sprat et d'anchois de la mer Noire et ont depuis repris légèrement pour atteindre environ 1,5 million de tonnes. Entre-temps, les captures déclarées de la plupart des poissons et crustacés démersaux et semi-pélagiques ont augmenté régulièrement jusqu'à la période allant des années 80 à la fin des années 1990. Cela a été suivi par des déclinés de plusieurs espèces ces dernières années.

EDM - Pêcheries et menaces. Les pêcheries méditerranéennes sont dominées par de petits navires, dispersés sur un grand nombre de sites de débarquement dans la plupart des pays. Une caractéristique des pêcheries méditerranéennes est la capacité d'exploiter une variété d'espèces démersales tout en manquant généralement de grands stocks mono-spécifiques. En conséquence, les pêcheries méditerranéennes ont développé une multitude de métiers et d'échelles d'investissements. La production est essentiellement concentrée sur le plateau continental et le littoral. Les volumes annuels sont limités (1,5 à 1,7 million de tonnes / an), ce qui représente moins de 1% des captures mondiales. La situation des espèces économiquement et commercialement importantes (merlu, rouget, crevette grise, sole, sardine et thon), qui sont victimes d'une surexploitation non durable, est gravement préoccupante.

La durabilité des pêcheries méditerranéennes est également fortement affectée par les effets de l'augmentation de la pollution due aux activités humaines côtières, la dégradation de l'habitat, l'introduction d'espèces non indigènes et les impacts des changements climatiques. L'aquaculture a également connu une croissance importante (pisciculture d'eau de mer pour le bar, la dorade et le « grossissement » du thon) avec un double résultat : d'une part une augmentation de la production avec un impact réduit en termes d'effort de pêche, d'autre part, cela a entraîné une dégradation de la qualité de l'environnement marin et des habitats. Jusqu'à 85% des stocks pour lesquels une évaluation validée existe

sont pêchés en dehors des limites biologiquement viables. Les stocks de merlu européens présentent la plus forte pression de pêche, avec un taux de mortalité par pêche en moyenne 5 fois plus élevé que la cible, alors que seuls quelques stocks d'espèces démersales, comme le merlan, certaines espèces de crevettes, le picarel et le rouget être pêché au niveau ou en dessous du point de référence pour la mortalité par pêche.

Les introductions d'espèces non indigènes ont provoqué des changements majeurs, en particulier en Méditerranée orientale, où un nombre croissant d'espèces indo-pacifiques sont en train de s'établir dans des populations reproductrices entrant en Méditerranée orientale par le canal de Suez (migrants lessepsiens). Certaines de ces espèces ont un intérêt commercial, mais d'autres affectent négativement l'économie de la pêche ainsi que l'environnement marin. Le poisson-globe, *Lagocephalus sceleratus* se répand largement sur les eaux de la Méditerranée orientale sans concurrents naturels, créant des problèmes majeurs pour les pêcheries de la région. Il est considéré comme l'une des pires espèces invasives de la Méditerranée, avec un impact significatif sur l'écosystème environnant et sur le secteur de la pêche. Il est capable de déchirer et d'endommager les lignes de filets de pêche et les longues lignes. *L. sceleratus* est considéré comme un risque sérieux pour les consommateurs, car il contient une forte toxine paralytique appelée tétrodoxine, qui peut être mortelle pour l'homme.

Divers outils de gestion pour les écosystèmes côtiers

Actuellement, au niveau national et international, les politiciens, scientifiques et gestionnaires disposent d'un nombre important d'outils pour la gestion des zones côtières et des écosystèmes marins (réglementations, aire marines protégées, ...). Des politiques de pêche méditerranéennes ont été développées afin d'ajuster l'effort de pêche en fonction de la disponibilité des ressources halieutiques et d'évaluer la capacité de pêche des flottes nationales. En raison de la grande variété d'espèces caractérisant les pêcheries méditerranéennes, la gestion de la pêche en Méditerranée n'est pas basée sur le contrôle des captures via les Totaux Autorisés de Captures et les quotas. La réglementation de l'effort de pêche total à travers des permis limités et des mesures techniques telles que les fermetures de zones et de saisons, les limitations d'engins et les tailles limitées des débarquements sont les piliers de l'effort de pêche total à quelques exceptions près (comme le thon rouge qui est actuellement soumis à un système de quota dans toute la Méditerranée). La plupart des pays ont également introduit dans certains segments de la flotte une limitation du nombre de licences délivrées.

Les activités de pêche des États membres de l'UE sont réglementées par la politique commune de la pêche de l'Union européenne tandis que les pays tiers définissent leurs propres mesures de gestion de la pêche et veillent généralement à la cohérence avec les règlements de la Commission générale des pêches en Méditerranée (CGPM). La lutte contre la pêche illicite, non déclarée et non réglementée, la mise en œuvre de plans de gestion pour l'exploitation durable de tous les stocks de poissons et les mesures visant à réduire les prises accessoires, les rejets et les captures accidentelles d'espèces vulnérables.

Une approche écosystémique de la gestion des pêches semble particulièrement utile pour la Méditerranée et peut être rentable en prenant en compte les considérations environnementales et économiques et en s'attaquant aux problèmes intersectoriels. Le besoin de coopération et de coordination entre tous les pays riverains de la Méditerranée est reconnu depuis longtemps et a engendré l'établissement de diverses conventions et partenariats. Les principales priorités du secteur comprennent la nécessité d'un engagement politique fort, d'une coopération intergouvernementale et de la fourniture d'une assistance technique aux États riverains. Les conditions préalables essentielles sont une base de connaissances

consolidée, une collecte et une analyse améliorées des données et l'élaboration de mécanismes de gestion et de co-gestion intégrés aux objectifs environnementaux, y compris les aires marines protégées.

Espèces démersales de la Méditerranée orientale

En Méditerranée, la richesse des espèces présente un gradient d'ouest en est, la Méditerranée occidentale ayant les plus hautes valeurs de richesse spécifique, probablement en raison de l'afflux d'espèces atlantiques et de la large gamme de conditions physico-chimiques. Le bassin du Levant et le côté sud-est ont en général la plus faible richesse spécifique, due aux conditions défavorables de la zone, comme la salinité élevée et aussi probablement du fait d'un effort d'échantillonnage plus réduit. La Méditerranée orientale est considérée comme l'un des bassins les plus oligotrophes du monde. Le bassin du Levant a été affecté par deux grandes activités humaines qui ont influencé son écosystème : 1) la construction du barrage d'Assouan a entraîné la disparition de la sédimentation fluviale et des éléments nutritifs en Méditerranée, entraînant une forte diminution des populations de petits pélagiques et la chute subséquente de 90% de l'industrie égyptienne de la senne coulissante ; et 2) la construction du canal de Suez, achevée en 1869, qui reliait deux masses d'eaux avec des caractéristiques abiotiques différentes et des biotas particuliers distincts. Le nombre d'espèces de poissons migrant vers la Méditerranée, connu sous le nom de migrants lessepsiens, a augmenté de façon constante dans les décennies qui ont suivi les années 1920, mais s'est accéléré de façon spectaculaire après l'an 2000. Des centaines d'autres taxons sont entrés en Méditerranée en même temps, donnant lieu à l'une des plus grandes circonvolutions biogéographiques jamais observée dans le monde contemporain.

Au total, le nombre total d'espèces lessepsiennes marines (envahisseurs via le canal de Suez) s'élève à plus de 790 en mer Méditerranée, dont certaines ayant colonisé avec succès les écosystèmes marins méditerranéens. En outre, la Méditerranée est également influencée par des espèces introduites à partir de l'océan Atlantique par le détroit de Gibraltar et qui ont atteint la mer Adriatique et même, pour certaines, le bassin oriental. Leur nombre croissant a un impact sur les populations indigènes et peut amener à une réduction de l'abondance des espèces endémiques.

Actuellement, les espèces de poissons lessepsiens constituent une grande partie des captures commerciales, menaçant de remplacer de nombreux poissons indigènes par leurs homologues exotiques. C'est le cas de l'emblématique saupe, *Sarpa salpa*, poisson indigène méditerranéen, qui pourrait être remplacée par le migrant lesseptien *Siganus rivulatus* le long des eaux côtières libanaises. Cependant, selon certains auteurs aucune espèce méditerranéenne n'aurait disparu depuis l'ouverture du canal de Suez.

En résumé, les ressources démersales de la Méditerranée orientale sont un mélange d'espèces indigènes et non indigènes principalement d'origine lessepsienne. La composition des assemblages est principalement tirée par la profondeur et les secteurs les plus à l'est sont témoins de compétitions meurtrières où les espèces indigènes sont probablement remplacées par des NEI occupant des niches écologiques similaires. L'espace trophique global s'élargit sous la redondance croissante de la nouvelle communauté dans un écosystème pauvre en éléments nutritifs. Par conséquent, les communautés démersales de la Méditerranée orientale sont loin d'être dans un état stable.

Objectifs de l'étude

La poursuite des travaux de recherche sur les espèces démersales le long de la côte libanaise était une nécessité. En effet, ce groupe a été progressivement exploité dans cette région et très peu de connaissances n'existaient sur la présence et la répartition de ces espèces le long de ces côtes. Dans ce contexte, les objectifs de cette thèse étaient de contribuer à une meilleure connaissance :

1. des communautés démersales exploitées par les pêcheries artisanales libanaises via des pêches expérimentales, notamment les espèces lessepsiennes et du contexte socio-économique de ces pêcheries ;
2. de l'abondance relative et la répartition spatio-temporelle des espèces démersales libanaises et des informations biologiques, notamment les relations longueur-poids de ces espèces ; et d'établir un inventaire de la diversité de ces espèces dans cette région ;
3. de la biologie et l'écologie d'une espèce de poisson démersale lessepsienne abondamment trouvée dans les captures : l'holocentre rouge, *Sargocentrum rubrum*.

Certains chapitres de la thèse sont présentés sous forme d'articles. Après une introduction générale, constituant le chapitre I, la thèse est divisée comme suit :

Le chapitre II décrit le « matériel et les méthodes », généraux incluant une description de la zone étudiée, le protocole d'échantillonnage et la collecte de données ainsi que les analyses et tests statistiques utilisés tout au long de la présente thèse.

Le chapitre III est une revue bibliographique du secteur de la pêche au Liban décrivant les caractéristiques socioéconomiques, le contexte environnemental et les aspects liés à la gouvernance.

Le chapitre IV est consacré à l'étude de la répartition et de la diversité des espèces démersales exploitées par les pêcheries artisanales de la Méditerranée orientale et inclue une description et une analyse des assemblages biologiques des espèces démersales le long du plateau continental libanais.

Le chapitre V. Le chapitre V présente l'estimation des relations poids-longueur de plusieurs de ces espèces capturées dans les eaux libanaises.

Le chapitre VI présente la biologie et l'écologie d'une espèce de poisson lessepsienne, l'holocentre rouge, *Sargocentron rubrum*, dans les eaux libanaises.

Enfin, la discussion générale, la conclusion et les perspectives de ce travail sont présentées dans le dernier chapitre (chapitre VII). Des annexes sont incluses à la fin de la thèse pour compléter et améliorer son contenu.

Ci-après sont brièvement résumés le contenu et les principaux apports de chacun des chapitres et de la thèse.

Caractéristiques de la zone d'étude

La zone d'étude est située le long des côtes libanaises dans la partie centrale du bassin levantin (Méditerranée orientale). La côte du Liban s'étend sur environ 225 km avec un plateau continental étroit, en particulier dans le sud. La profondeur moyenne du plateau continental est de 20 à 40 m et la pente, parallèle à la côte et située à une distance de 25 à 30 km de cette dernière, s'étend de 1100 à 1400 m de profondeur, avant d'atteindre la plaine abyssale. Cette dernière est incisée à certains endroits par des canyons, la plupart liés à des rivières qui coulent des montagnes.

La direction dominante de la circulation générale le long de la côte du Liban est celle du nord durant la plupart de l'année en plus de la présence d'un courant tourbillonnaire de sens général antihoraire en Méditerranée orientale. Les mouvements d'eau le long de la côte sont également fortement liés aux courants de surface et aux facteurs météorologiques saisonniers. Les conditions océanographiques particulières des zones au large des côtes libanaises peuvent améliorer les accumulations de larves et de juvéniles et créer des habitats favorables à leur croissance et à leur survie. L'eau dans les 50 premiers mètres est bien mélangée en hiver et devient stratifiée pendant le reste de l'année. Les caractéristiques de la côte libanaise sans baies fermées ou golfe consentent aux eaux côtières à se mélanger en continu, empêchant ainsi les conditions d'eutrophisation et de disperser les nutriments et les polluants.

De manière générale, le Liban bénéficie d'un climat typiquement méditerranéen avec deux saisons très contrastées : un hiver froid et fortement humide ; et un été long, chaud et sec et deux saisons intermédiaires (printemps et automne).

Les eaux côtières libanaises sont caractérisées par des biotes thermophiles d'origine méditerranéenne et indo-pacifique. La biodiversité locale subit une altération rapide sous les pressions combinées du changement climatique et des impacts anthropiques. Cette côte est à l'heure actuelle, menacée par l'urbanisation (les principales villes côtières sont majoritairement jointives). La faune et la flore marines indigènes sont en compétition avec des espèces envahissantes provenant des océans Indo-Pacifique et Atlantique. Les fonds sont essentiellement rugueux avec de larges plaques rocheuses qui conviennent au déploiement d'engins de pêche démersaux. Les mesures de protection, pour les espèces ou les écosystèmes, sont encore rares.

Collecte des données.

La collecte des données a été réalisée à partir de 2012 à 2014, selon trois protocoles différents en vue d'évaluer la répartition et l'abondance d'un maximum de ressources halieutiques d'espèces démersales le long de la côte libanaise.

Le projet CIHEAM PESCA Libano. Financé par la Coopération Italienne au Liban, le projet CIHEAM-PESCA LIBANO « Assistance Technique au Ministère de l'Agriculture dans le domaine du développement de la pêche » visait à fournir au Ministère libanais de l'Agriculture des outils avancés pour une bonne gestion des ressources marines et halieutiques. Le Conseil National de la Recherche Scientifique du Liban (CNRS-L),

était chargé de la mise en œuvre de l'échantillonnage de pêche et a assuré le suivi de la collecte saisonnière des données en mer dans le Nord Liban.

L'échantillonnage a été effectué en 2012, 2013 et 2014, durant lequel divers types d'engins de pêches (filets maillant, trémail et palangre) ont été déployés sur 62 sites le long de la côte libanaise, à des profondeurs allant de 10 à 600 m. En raison du manque d'information sur la composition en taille des ressources démersales au Liban, différents maillages couvrant une large gamme ont été utilisés. Au Liban, les activités de chalutage sont interdites dans les eaux territoriales libanaises. Un plan d'échantillonnage stratifié a été employé, consistant en des pêches expérimentales indépendantes de la pêche commerciale. Les strates possédaient des caractéristiques communes concernant la composition des espèces et leurs densités et structures de longueur. Neuf pêcheurs artisanaux issus de huit ports différents ont été embauchés pour déployer les engins à des coordonnées spécifiées. La longueur des navires variait de 8,75 à 11 m et leur tonnage brut allait de 3,10 à 5,01 tonnes. En général, l'équipage incluait 2 à 4 personnes (avec au minimum un scientifique) et un maximum de 2 mises à l'eau d'engin a été effectué par jour, selon les conditions météorologiques et les conditions techniques du navire. Pour chaque trait, les espèces recueillies ont été identifiées et la date, la profondeur, le point GPS, le type d'engin déployé, et les mailles des filets utilisés étaient notés. Les espèces ont été identifiées selon divers guides d'identification des poissons de la Méditerranée orientale et les sexes étaient différenciés afin d'en déduire le sexe-ratio ainsi que le stade de maturité. Aucun appât n'était employé lors du déploiement des filets, mais des appâts ont systématiquement été accrochés aux hameçons des palangres (poissons hachés, tels que des harengs, des maquereaux ou des thons).

Tous les spécimens prélevés indépendamment de l'espèce ont été mesurés et pesés. Lorsque les prises d'une espèce donnée étaient trop abondantes pour être entièrement mesurées, des sous-échantillons représentatifs de la capture ont été prélevés. Les protocoles standardisés et les exigences minimales adoptées au cours des enquêtes étaient basés sur les protocoles du programme MEDITS.

Indices biologiques et maturité sexuelle

Diverses données biologiques ont été collectées, en plus de celles précédemment citées, pour l'étude approfondie des espèces collectées et en particulier de l'espèce de poisson *Sargocentron rubrum*. Des dissections des échantillons ont été effectuées et des mesures supplémentaires ont été prises, incluant le poids de l'estomac et sa teneur, la collecte des otolithes et le macro-examen des gonades. Certaines de ces mesures ont été utilisées pour calculer des indices biologiques importants, tels que le facteur de condition qui indique les périodes de stress ou de phénomènes physiologiques, tels que, le frai, l'accouplement, les modifications de la densité de la population, les conditions d'alimentation, ou les variations de température.

Les stades de maturité sexuelle de chaque individus capturés (poissons, crustacés et céphalopodes) ont été identifiés selon les protocoles du programme MEDITS déterminée par l'observation des gonades mâles et femelles et des états de maturation sexuelle.

Analyse des contenus stomacaux.

L'analyse des contenus stomacaux n'a été réalisée dans cette étude que pour l'espèce de poisson *Sargocentron rubrum*, pour laquelle plusieurs estomacs étaient pleins. Au cours de la dissection de cette

espèce cible, les estomacs ont été enlevés et leurs poids totaux ont été mesurés. Les estomacs contenant des aliments ont été conservés dans de l'alcool à 70% jusqu'à identification du contenu. Le nombre d'estomacs vides a également été noté. Chaque proie a été identifiée au plus proche taxon possible et comptabilisé. Le poids total de chaque groupe proie a été mesuré si possible au gramme le plus proche. Plusieurs indices ont ensuite été calculés pour analyser le régime alimentaire de l'espèce cible étudiée, reflétant sa composition alimentaire et sa stratégie d'alimentation.

Composition du régime alimentaire. Le coefficient de vacuité, reflétant la richesse ou le manque de nourriture dans l'environnement a été calculé et le pourcentage de remplissage de l'estomac a été évalué et classé par catégories. De plus, trois indices ont été calculés pour montrer l'importance des différentes proies dans le régime alimentaire des espèces cibles : la fréquence d'occurrence, le coefficient d'abondance numérique des proies et les pourcentages de poids. Ces trois indices ont servi au calcul d'un 4ème indice, l'indice d'importance relative, afin de mieux refléter l'importance de chaque proie dans les estomacs des espèces cibles.

Stratégie nutritives. Enfin, des pourcentages de l'indice d'importance relative ont été établis pour chaque type de proie afin de faciliter les comparaisons entre les types d'aliments. La stratégie d'alimentation de l'espèce cible a été analysée afin d'illustrer en particulier la dominance et la rareté de chaque groupe de proies durant les deux saisons et de la stratégie d'alimentation (spécialiste ou généraliste).

Estimation de l'âge des poissons et courbes de croissance

Les otolithes (concrétion minérale trouvée dans l'oreille interne des poissons téléostéens) ont été employées pour estimer l'âge du poissons *Sargocentron rubrum* (la zone opaque correspond à une croissance rapide et la zone translucide à une croissance lente du poisson). Une fois que les anneaux ont été considérés comme annuels, chaque spécimen a été assigné à une classe d'âge, en tenant compte des données de capture, des dénombrements d'annuli, de leur période de formation et de la biologie reproductive de l'espèce dans la région.

Les paramètres de croissance de la relation non linéaire de Von Bertalanffy ont été estimés à partir de l'analyse des données de longueur selon l'âge et a été réalisée dans le logiciel statistique R.

Analyses de données

Captures par unité d'effort. La capture par unité d'effort (CPUE) a été calculée seulement pour les espèces capturées au cours de l'échantillonnage scientifique CIHEAM-PESCA Libano, au cours duquel des palangres, trémails et filets maillants ont été déployés à des traits spécifiques avec des coordonnées et des profondeurs prédéterminées. La CPUE pour les espèces prises lors de l'échantillonnage a été calculée au moyen du logiciel statistique 'R' en kilogrammes et en nombre.

Indices de biodiversité. Le nombre total d'individus et le nombre total d'espèces recensées dans l'échantillon a été déterminé afin d'évaluer les variations saisonnière et spatiale de biodiversité. Pour ce faire, plusieurs indices de diversité ont été calculés : l'indice de Shannon, l'indice de Simpson et l'indice de diversité taxonomique

Enfin, la comparaison et l'interprétation des données a nécessité l'utilisation de plusieurs tests inférentiels (Wilcoxon, Kruskal –Wallis, Chi-deux de Pearson, ...) et analyses statistiques descriptives (Analyse en

composante principale, Analyse canonique des correspondances ...) ou outils de modélisation (régressions linéaires et non linéaires, ANCOVA, ...). Au préalable, des transformations de données (i. e. logarithmiques) se sont quelquefois avérées nécessaires, selon le cas d'étude considéré.

Le chapitre III a été dédié à une synthèse bibliographique et une analyse du contexte socio-économique, environnemental et du secteur de la pêche au Liban afin de mieux cerner l'influence que peut avoir le contexte local libanais sur les pêcheries des ressources démersales.

Contexte socio-économique

Le Liban est un petit pays (10 452 km²) à revenu intermédiaire, avec un PIB par habitant de 9 928 USD en 2013. Sa population est estimée à 6 237 738 en juillet 2016, dont 88% sont urbains. Plus d'un tiers de la population est concentrée dans sa capitale, Beyrouth. Il se classe 12^{ème} sur 21 en Méditerranée en termes de PIB et d'indice de développement humain. Le Liban se caractérise par une économie axée sur les services et un secteur agricole faible. Les principaux sous-secteurs sont le commerce, le tourisme et les services financiers. La zone côtière est considérée comme la zone la plus riche mais en même temps la plus menacée du Liban. Le Liban continue de faire face à d'énormes défis découlant de la guerre en Syrie, y compris l'accueil de la plus grande assemblée de réfugiés syriens, proportionnellement à la population. Le secteur de la production agricole et halieutique joue un rôle mineur dans l'économie. Il contribue à environ 5% du PIB et à 8% de la main-d'œuvre effective, ce qui correspond à environ 30% de la demande alimentaire nationale et a été constant au cours des dix dernières années.

Infrastructures : Transports. Le Liban comptait environ 22 000 km de routes en 2001, dont 30% sont classées et relèvent de l'autorité nationale, tandis que les 70% restants sont des routes non classées gérées par les municipalités. Actuellement, le Liban a l'un des ratios voiture / personnes les plus élevés au monde avec une voiture pour trois personnes. Beyrouth et Tripoli accueillent les deux plus grands ports commerciaux du Liban, et on observe une diminution du nombre total de navires de charge et de navires-citernes, passant de 3 887 navires en 1996 à 3 054 en 2000. Le transport terrestre, maritime et aérien entraîne des impacts importants et divers sur l'environnement en particulier le rejet des d'eaux de ballast.

Infrastructures : Énergie. Le Liban est actuellement confronté à un sérieux défi énergétique lié à la réalisation de ses objectifs de développement social et économique en raison du manque de ressources énergétiques nationales, de capacités de production réduites et de la demande croissante d'énergie. L'Électricité du Liban, établissement public produisant, transmettant et distribuant l'électricité à tous les territoires libanais, s'efforce continuellement d'assurer la livraison continue de son électricité mais le secteur de l'énergie souffre d'années de mauvaise gouvernance, d'une gestion insuffisante des agences du secteur et d'une grande inefficacité dans ses infrastructures, notamment les centrales électriques et les réseaux de transport et de distribution. Le taux d'électrification au Liban est d'environ 99,9%, mais ce taux élevé ne se reflète pas dans la continuité de l'alimentation électrique et des services fournis et de nombreux consommateurs ont considérablement investi dans des groupes électrogènes de secours du fait des pénuries d'approvisionnement, ce qui a fortement affecté l'efficacité énergétique du pays. Le Liban ne produit pas de pétrole ou de charbon et la plupart de ses besoins en énergie, c'est-à-dire principalement des produits pétroliers, sont importés. Les options d'énergie renouvelable sont disponibles mais ne sont pas largement utilisées (elles ne représentaient que 4% du bilan énergétique du pays en 2006).

Population. Le patrimoine culturel et linguistique du peuple libanais est un mélange d'éléments indigènes et de cultures étrangères qui sont venus gouverner cette région et son peuple au cours de milliers d'années. Environ 93% de la population du Liban comprend de nombreuses sectes musulmanes et dénominations chrétiennes. Parce que la question de l'équilibre religieux est une question politique sensible, aucun recensement national n'a été effectué depuis 1932, avant la fondation de l'Etat libanais moderne. Par conséquent, il n'y a pas de données précises sur les pourcentages relatifs de la population des principales religions et groupes. Il y a de 8,6 à 14 millions de Libanais et de descendants de Libanais dans le monde entier.

Emploi. Au Liban, les interventions en matière de protection sociale comprennent les assurances sociales et les interventions sur le marché du travail (y compris les régimes contributifs tels que les retraites), les services sociaux (accès à des services tels que la santé et l'éducation) et les programmes d'assistance sociale ciblés. Cependant, ces programmes n'atteignent qu'une petite partie de la population, ce qui n'inclut généralement pas les communautés de pêcheurs. Il n'y a ni contrat de travail au Liban ni couverture sociale qui pourrait protéger les pêcheurs en cas d'invalidité, de perte d'emploi et de retraite. Ainsi, les pêcheurs restent fortement tributaires de leurs revenus, éventuellement sur des filets de sécurité privés (tels que les envois de fonds) ou sur le système de crédit.

Ces dernières années, l'offre de main-d'œuvre peu qualifiée a rapidement augmenté en raison de la crise syrienne, réduisant les revenus des Libanais à faible revenu et pauvres. En 2012, le secteur de la pêche maritime employait 3 200 personnes (la majeure partie des opérateurs du secteur étant libanaise).

Système de crédit. Bien que le Liban se porte bien sur le plan régional en prêtant aux petites et moyennes entreprises, la culture de prêt conservatrice du pays limite l'accès au crédit, bien que partiellement atténué par les programmes incitatifs du gouvernement et de la Banque du Liban. Les entreprises libanaises dépendent fortement du secteur bancaire pour leur financement, puisque 53% de toutes les entreprises déclarent avoir bénéficié d'un prêt bancaire. Certaines facilités de crédit bancaire sont dans la pratique disponibles aussi pour les micro-entreprises et les pêcheurs. Peu de banques offrent un petit crédit et aucune ne le fait sans aucune garantie. Par conséquent, seuls les pêcheurs qui possèdent un bateau ou un autre bien de valeur peuvent demander un prêt. La facilité de crédit la plus courante desservant les communautés de pêcheurs est celle fournie par les vendeurs de poisson. Outre la subvention annuelle que certains donnent habituellement aux pêcheurs, ils sont souvent disponibles pour leur prêter de l'argent supplémentaire au cours de l'année. La seule obligation des pêcheurs est de vendre leur poisson à leurs prêteurs. Les autres facilités de crédit disponibles pour les communautés de pêche sont les micro-crédits qui comptent généralement sur des engagements forts et un taux de remboursement élevé.

Contexte environnemental

Environnement physique. Le Liban est l'un des plus petits pays du monde ayant une superficie de 10 452 km². Il est principalement montagneux et bordé par la Syrie au nord et à l'est et la Palestine occupée au sud. Le Liban dispose également d'un vaste réseau hydrologique de 2000 rivières dont une douzaine traversant la côte libanaise et qui jouent par conséquent un rôle important dans la qualité des eaux côtières marines. La côte libanaise est relativement courte - environ 225 km et affiche une forte densité de population. En général, le Liban bénéficie d'un climat méditerranéen typique avec deux saisons très contrastées : un hiver froid et fortement humide et un été long, chaud et sec et deux saisons intermédiaires (printemps et automne). La variation mensuelle moyenne de la température de la surface de la mer entre 2000 et 2012 a varié entre 17,82 ° C au minimum en mars et 29,71 ° C au maximum en août la variation mensuelle moyenne de la température de l'air a varié entre un minimum de 12,4 ° C en janvier et un maximum de 27,59 ° C en août.

Biodiversité. L'état de la biodiversité marine au Liban a été évalué en 1996 puis examiné à travers plusieurs articles publiés et non publiés. Selon certaines études, la mer côtière du pays comprendrait 1685 espèces, dont 367 espèces de poissons, avec 50 d'entre elles d'intérêt commercial. Le phytoplancton englobe 580 espèces, tandis que le zooplancton représente la plus grande part de la diversité faunique marine avec plus de 747 espèces recensées. Le micro-zoobenthos est représenté avec 12 espèces connues alors que le macro-zoobenthos est diversifié et englobe 662 espèces. Au moins 3 espèces de reptiles (tortues caouannes, tortues marines vertes et marines) et 5 espèces de mammifères (dauphins et marsouins), moins fréquentes dans les communautés locales eaux, baleines et phoques). Les informations sur l'état de conservation sont principalement disponibles pour certaines espèces (tortues et cétacés). L'étude sur la biodiversité de la biodiversité a identifié des habitats rocheux, sableux et herbeux submergés ainsi que des communautés de sciaphile, de photophile, d'endofaune et d'épifaune, dont 68 espèces menacées.

Secteur de la pêche

Aperçu des pêches libanaises. Le secteur de la pêche au Liban se compose d'une petite flotte de pêche artisanale, à savoir 2 005 navires sous licence (en 2015) exploités principalement par des pêcheurs âgés utilisant de vieux bateaux munis d'équipements anciens. La plupart des bateaux sont motorisés et mesurent moins de 12 m en utilisant des techniques de pêche essentiellement basées sur des engins passifs tels que les filets maillants, les trémails, les palangres et les sennes coulissantes. Les opérations de pêche sont principalement réalisées à des profondeurs allant jusqu'à 50 m. Peu de navires sont équipés de GPS, tandis que le reste a un équipement de navigation ou de sécurité très limité. Les eaux côtières libanaises contiennent une grande quantité d'organismes marins avec plus de 80 espèces de poissons d'importance commerciale. Les comportements de pêche illégale et les pratiques néfastes ou non durables telles que l'utilisation de filets à mailles courtes et d'explosifs se développent à la suite d'une législation obsolète et de son manque d'application. Le manque de gestion des déchets urbains et industriels ainsi que l'absence d'un réseau d'assainissement efficace contaminent les eaux marines et les eaux douces. Les zones côtières sont soumises à un étalement urbain incontrôlé et à des processus croissants d'artificialisation. Il est largement admis que les activités humaines affectent de manière inquiétante l'environnement étroit des zones côtières, ce qui entraîne une augmentation critique de son exposition aux risques géologiques. La pression humaine exercée sur la zone côtière et les faibles investissements publics dans le secteur au cours des dernières décennies ont réduit la valeur économique du secteur et, par conséquent, affecté la vie des pêcheurs.

Malgré sa gestion chaotique, le secteur de la pêche libanaise représente un cas unique en Méditerranée, étant le seul composé uniquement de petits bateaux artisanaux. En raison de sa situation géographique, le Liban représente également un avant-poste pour une compréhension globale de la dynamique de la colonisation de la Méditerranée par les espèces indo-pacifiques et de la mer Rouge. Les connaissances sur l'impact de la flotte libanaise sur les ressources côtières des pêcheries - invasives et endémiques - sont encore très limitées, étant donné que l'on ne dispose que d'informations éparpillées sur la répartition, l'abondance et les caractéristiques biologiques de quelques stocks de poissons et de crustacés.

Le Liban est en train de faire ses premiers pas dans la satisfaction des exigences internationales en matière de collecte de données sur ses ressources halieutiques à travers des évaluations des stocks, des prises et de l'effort. Les organisations internationales et les donateurs ont accordé des fonds et un renforcement des capacités pour développer des programmes de recherche adéquats afin de soutenir la capacité du

Gouvernement libanais à définir de nouvelles mesures pour une gestion appropriée et durable des ressources halieutiques.

Flotte, engins et terrains de pêche. La majeure partie de la flotte de pêche est constituée de navires artisanaux polyvalents, un petit bateau de pêche de 3 à 15 m, habituellement en bois, généralement non ponté ; et avec / sans moteurs in-bord ou hors-bord. En 2015, la longueur moyenne des navires de pêche autorisés est de 7,2 m avec 546 navires de moins de 6 m de longueur, 1 420 bateaux de 6 à 12 m et 39 bateaux de plus de 12 m de longueur. Les zones de pêche sont délimitées par la loi entre 500 m et 6 nm du rivage et les sorties sont limitées à 24 heures par sorties de pêche. Aussi, 78 % des pêcheurs pêchent à moins de 3 milles marins de la côte et moins de 10 navigent au-delà des 6 milles marins. Les techniques de pêche au Liban consistent principalement en des engins passifs tels que les filets maillants, les trémails, les palangres, les sennes coulissantes, les lamparos et les sennes de plage.

Ressources halieutiques. Les stocks de poissons au Liban n'ont pas été régulièrement évalués. Les universités privées, le Conseil national de la recherche scientifique du Liban (CNRS-L) et la FAO, en coordination avec le Ministère de l'agriculture, ont posé les bases d'une collecte régulière de données pour permettre des évaluations fiables des stocks. Une seule expérience systématique de collecte de données sur les ressources halieutiques libanaises avait été réalisée par George, et al., 1964. Leur étude reposait presque entièrement sur les pêcheurs commerciaux en tant que fournisseurs des spécimens. Ils ont décrit 177 espèces, dont 19 lessepsiens.

Des études récentes sur la pêche aux petits pélagiques ont montré qu'une fraction significative des spécimens débarqués étaient des juvéniles. Les petites pêcheries pélagiques constituent environ les deux tiers des débarquements libanais. Les pratiques de pêche ciblant les poissons juvéniles sont en partie influencées par le marché puisqu'elles favorisent les plus petits poissons, qui sont consommés entiers. De plus, tous les efforts de la flotte se concentrent principalement dans les 6 milles nautiques, ce qui entraîne une forte pression de pêche sur les ressources halieutiques côtières, notamment dans la zone des 3 milles. Le statut des ressources halieutiques entre 6 et 12 milles nautiques n'est pas connu, mais il peut être considéré comme des stocks vierges puisque pratiquement aucune activité de pêche n'est pratiquée dans cette zone. Une étude de courte durée a permis de procéder à une évaluation préliminaire de la potentialité des zones de pêche hauturière pour la pêche artisanale locale au Sud-Liban qui a montré de bons rendements (CPUE plus élevés que ceux des pays méditerranéens européens) pour le merlu européen et une espèce de crevette.

Profil des prises de poissons marins.

Au Liban, les débarquements sont composés d'un grand nombre d'espèces, dont beaucoup sont des migrants lessepsiens. Une vingtaine d'espèces représenteraient 80% des captures et les sardines et les anchois sont les espèces les plus importantes représentant plus de 25% de la production. Le pays importe 78% des produits de la mer consommés. L'exportation est négligeable par rapport à l'importation, ce qui signifie que la production nationale représente environ 22% des produits de la mer consommés, ce qui rend le pays fortement tributaire de l'importation. En 2011, la production annuelle des pêches de capture marines était évaluée à 4 632 tonnes dont 803 tonnes provenant de l'aquaculture et la consommation de produits de la mer par habitant était de 6,03 kg en 2005, soit environ le tiers de la moyenne en Méditerranée.

Gestion des pêcheries La gestion des secteurs libanais de la pêche et de l'aquaculture relève du Ministère de l'agriculture des pêches et de la faune. Au niveau local et professionnel, le secteur de la pêche au Liban est représenté par 34 coopératives de pêcheurs dans le cadre de l'Union générale des coopératives regroupant environ 43% des armateurs / exploitants. En général, ils ne fonctionnent pas comme un collectif selon un plan défini mais principalement basé sur les initiatives des individus. Cela rend ces coopératives incapables de prendre les bonnes décisions au profit des pêcheurs. En ce qui concerne les syndicats de pêcheurs, 5 sont actifs dans le pays. Le rôle des syndicats est de faire pression pour l'amélioration et le développement du secteur au sein du gouvernement. Il n'existe pas d'accord collectif national de travail en vigueur pour les opérateurs du secteur.

Les principaux ministères concernés par le secteur de la pêche sont les suivants : le Ministère de l'agriculture (MOA), le Ministère des Travaux Publics et des Transports (MOPWT), le Ministère de l'environnement et le Ministère du Travail (MOL).

La principale loi sur les pêches (Loi n ° 2775-Surveillance de la pêche côtière, 28/9/1929) est obsolète et remonte à 1929 pendant le mandat français pour le Liban. La FAO, la CGPM et le MOA ont rédigé une nouvelle loi qui a été finalisée en décembre 2014 et envoyée au Conseil des ministres pour approbation et transmise au Parlement pour discussion, amendements et ratification éventuelle.

En ce qui concerne les engins de pêche et leurs caractéristiques techniques, il existe actuellement un nombre très limité de réglementations et de restrictions sur les engins de pêche dans la législation libanaise en matière de pêche. La législation concerne la taille de l'engin et le maillage ainsi que les pratiques de chalutage de fond, de filets statiques et de surface et divers engins employés pour les petits poissons pélagiques (sennes et lamparos). En particulier, le chalutage est interdit dans les eaux territoriales libanaises et il n'existe actuellement aucun chalutier enregistré dans le registre de la flotte de pêche libanaise.

Le manque de ressources financières et d'une gestion claire et efficace des politiques ont conduit à négliger le potentiel des secteurs de la pêche et de l'aquaculture et entraîné un déclin progressif de leur productivité ainsi que du niveau de vie des pêcheurs et des travailleurs du secteur de la pêche impliqués dans des activités auxiliaires. En revanche, la connaissance limitée des modes de consommation et des potentialités du marché et du poisson dans les nouveaux produits récoltés ou cultivés, associée à l'absence d'une vision stratégique pour définir les priorités, entrave la création d'emplois. Au cours des dernières années, le projet FAO-EastMed, en collaboration avec le MoA, soutient le développement de plans de gestion des pêches cohérents au niveau régional entre les pays de la Méditerranée orientale.

Menaces

Plus de 60% de la population libanaise vit dans la zone côtière. L'impact de la densité de population et des activités économiques sur la biodiversité marine est donc immense et pose de formidables défis à la gestion des zones côtières, notamment la conservation des ressources marines et la protection des moyens de subsistance issus de la mer Méditerranée. La forte densité de population sur la zone côtière a conduit à une dégradation de l'écosystème côtier due aux effluents d'eaux usées, aux décharges publiques et à la gestion incontrôlée des zones côtières. Les installations industrielles (tannerie, acier, ciment, engrais, transformation des aliments, etc.), les établissements touristiques, les effluents agricoles et le transport maritime de pétrole sont d'autres sources de pollution d'origine terrestre.

L'environnement marin a été négligé pendant des décennies et a souvent été géré comme une ressource consommable. La concentration de l'effort de pêche dans une étroite bande côtière, associée à l'utilisation de pratiques néfastes, a probablement entraîné une surexploitation de nombreuses espèces commerciales côtières. Néanmoins, heureusement, les filets dérivants de fond et les chaluts de fond ne sont pas employés au Liban.

Le coût de la dégradation de l'environnement au Liban lié aux ressources terrestres et fauniques est estimé à 100 millions de dollars par an, soit 0,6% du PIB du Liban. D'autre part, la connaissance limitée des modes de consommation et des potentialités du marché et du poisson dans les nouveaux produits récoltés ou cultivés ainsi que l'absence de vision stratégique pour définir les priorités entravent la création d'opportunités d'emploi.

Chapitre IV – Partie 1. Pattern de répartition, diversité et abondance des assemblages démersaux le long de la côte libanaise en Méditerranée orientale et structure des assemblages

Partie 1. Pattern de répartition, diversité et abondance des assemblages démersaux le long de la côte libanaise en Méditerranée orientale

Dans une première partie du chapitre 4, l'accent a été mis sur les différents aspects de la distribution spatiale et saisonnière, la diversité, la biologie et l'écologie des ressources démersales le long de la côte libanaise, en Méditerranée orientale. Cette étude constitue la seule évaluation depuis 50 ans des ressources démersales dans cette région.

Dans le bassin méditerranéen, les espèces démersales représentent environ 30% des débarquements totaux de la région et représentent donc une ressource importante pour la pêche. Cependant, la durabilité à long terme des pêches démersales suscite de vives préoccupations. En effet, d'après les évaluations récentes, la plupart des stocks démersaux méditerranéens sont surexploités. Dans ce contexte, la pêche artisanale, et en particulier la pêche côtière à petite échelle, apparaissent comme des alternatives pertinentes pour une utilisation durable des ressources côtières. Le secteur de la pêche du Liban se compose d'une petite flotte de pêche artisanale, à savoir 2 005 navires de moins de 12 m de longueur, utilisant des techniques de pêche essentiellement basées sur des engins passifs. En raison de sa situation géographique, le Liban représente un avant-poste pour une compréhension globale de la dynamique de la colonisation de la Méditerranée par les espèces indo-pacifiques et de la mer Rouge.

Un programme de relevés expérimentaux de pêche de trois ans a été mené, issues du projet scientifique CIHEAM-PESCA Libano réalisé avec la participation du Ministère de l'Agriculture et le Centre national pour les sciences marines - Conseil national libanais pour la recherche scientifique (CNRSL). Les stations d'échantillonnage ont été étudiées au moyen de filets maillant expérimentaux abaissés jusqu'à 300 m de profondeur visant à évaluer la répartition et l'abondance des ressources halieutiques le long des Libanais. Nous avons estimé que le relevé indépendant de la pêche était l'outil le plus approprié pour fournir des mesures précieuses de l'abondance relative, des taux de variation de la population, de la taille et de la composition par sexe pour un large éventail d'espèces.

En trois ans de collecte de données, 121 traits ont été exécutés et 97 km de filets (0,351 km²) ont été abaissés. 3 579 spécimens appartenant à 129 espèces et 73 familles ont été recueillis avec un poids total de 601 kg. La capture était composée d'un mélange diversifié d'espèces incluant 18 crustacés, 8 céphalopodes,

91 téléostéens et 12 espèces d'éla smobran ches (n'incluant aucune chimère). *Sargocentron rubrum* était l'espèce la plus abondante, avec l'occurrence numérique la plus élevée, le poids total et la CPUE. *Dentex macropthalmus* était la deuxième espèce en termes d'abondance et d'occurrence numérique, alors que *Phycis phycis*, *M. merluccius* et *Lagocephalus sceleratus* étaient relativement élevés en poids. Parmi les 12 espèces d'éla smobran ches capturées dans cette étude, 6 sont considérées menacées d'extinction par la Liste rouge de l'UICN. Parmi ceux-ci, *Gymnura altavela* et *Squatina aculeata* sont considérés comme en danger critique, faisant face à un risque extrêmement élevé d'extinction dans la nature. Dans notre étude, 17 espèces non indigènes d'origine lessepsienne (13 poissons et 4 espèces de crustacés) ont été recensées dans les eaux côtières libanaises, dont 15 démersales, un pélagique (le hareng *Etrumeus teres*) et un autre benthique mixte comportement -pelagique (le crabe portunidé *Charybdis longicollis*).

Les données ont montré que la profondeur pour provoquer une diminution générale de l'abondance numérique et de la biomasse (au-delà de 150 m de profondeur) liée à une réduction générale de la disponibilité alimentaire qui affecte les assemblages épibenthiques et démersaux sur la pente. Ce schéma était dû à une diminution de l'abondance des téléostéens, qui diminuait avec la profondeur, alors que les crustacés décapodes et les éla smobran ches montraient une tendance opposée augmentant du plateau côtier à la pente moyenne.

Partie 2. Pattern de répartition et diversité et structure des assemblages démersaux le long de la côte libanaise en Méditerranée orientale.

Dans la seconde partie du chapitre 4, des assemblages de poissons démersaux ont été décrits à partir de 48 stations de pêche le long des côtes libanaises en Méditerranée orientale. Une méthode de classification hiérarchique ascendante a été utilisée pour identifier les stations où les captures étaient similaires, en termes de composition des espèces et de biomasse, et six assemblages ont été identifiés. La capture par unité d'effort a été utilisée comme un indice de l'abondance des poissons démersaux capturés et a montré des variations saisonnières et spatiales de distribution et selon la profondeur. L'analyse des données collectées a montré la présence de 6 groupes de stations avec une composition différente des espèces avec 4 assemblages majeurs dans les eaux libanaises : les groupes 1, 2 et 3 (16 stations d'échantillonnage) présentaient des captures médiocres dans le nord du Liban et plus fréquemment dans les eaux peu profondes. Un petit nombre d'individus de *Sargocentron rubrum*, *Portunus pelagicus*, caractérisait certaines des remontées appartenant à ces groupes. Le cluster 4 (6 stations d'échantillonnage) rapportait des stations situées entre la plate-forme d'Akkar et Tyr à des profondeurs comprises entre 40 et 100 m. Toutes les stations étaient caractérisées par *S. rubrum* comme espèce dominante des captures. C'est typiquement une espèce habitant les fonds rocheux, dans les récifs côtiers ou cachée dans des cavernes et des fissures de roches particulièrement pendant la journée. Cette espèce était habituellement associée à *Fistularia commersoni*, à *Pagellus acarne* et aux siganidés (espèces vivant dans des fonds de différentes natures) et à l'espèce benthopélagique *Trachurus picturatus*. Le cluster 5 (26 stations) était assez complexe à examiner car il comprenait des traits situés entre Chekka (Nord Liban) et Naqoura (Sud) à toutes les profondeurs étudiées. Le groupe 6 (3 stations) comprenait des traits situés dans le plateau continental sud plus profond. Le groupe d'espèces identifiées dans ce groupe est typique des fonds sablo-vaseux dans le plateau continental plus profond et la pente supérieure. La crevette géante rouge *A. foliacea* était particulièrement abondante étant associée à d'autres espèces typiques.

Cette étude peut servir de base pour évaluer les menaces des opérations de pêche et être une base de réflexion pour la mise en place de mesures de conservation possibles pour les espèces de poissons démersaux le long de la côte Libanaise en vue d'une gestion plus durable des ressources.

Chapitre V - Les relations longueur-poids d'une trentaine d'espèces démersales dans les eaux marines libanaises, Méditerranée orientale.

Dans le chapitre 5, des relations longueur-poids (RLP) ont été présentées pour une trentaine d'espèces démersales dans les eaux marines libanaises, en Méditerranée orientale.

L'information relative aux RLT des espèces démersales était presque absente le long de la côte libanaise. Cette étude a permis d'établir des RLT pour une trentaine d'espèces, parmi lesquelles certaines commercialement importantes et des migrateurs lessepsiens. Les RLT peuvent servir d'outil pour soutenir les mesures de gestion des pêches en fixant une limite minimale de capture lorsque les longueurs sont estimées en mer.

Les RLP de 3 espèces de poissons démersaux ont été publiées dans la revue « *journal of applied Ichthyology* ». Il s'agissait d'espèces pour lesquelles aucune RLP n'avait jusqu'alors été publiée en Méditerranée. Le résumé de cette étude est indiqué ci-après :

Les RLP ont été estimées pour 3 espèces démersales, des eaux marines libanaises, Méditerranée orientale, à savoir *Coelorinchus caelorhincus* (Risso, 1810), *Scorpaena elongata* (Cadenat, 1943) et *Stephanolepis diaspros* (Fraser Brunner, 1940). Les spécimens ont été prélevés au moyen de trémails et de filets maillants de juin 2012 à octobre 2014. Les valeurs du paramètre b des RLP $W = aL^b$ allaient de 2.922 à 3.708. Un dimorphisme sexuel prononcé dans la RLP a été observé pour *S. diaspros* et aucune espèce n'a montré un modèle de distribution géographique fondé sur la RLP. Ces relations signalées dans cette étude ne doivent être appliquées que dans les gammes de longueurs observées.

Il est envisagé de publier les RLP des autres espèces dans la revue « *Egyptian Journal of Aquatic Research* » et elles sont présentées à la suite du précédent article. Des comparaisons ont été effectuées avec les RLT établies dans d'autres régions géographiques proches. Les différences observées pourraient être dues à des procédures d'échantillonnage ou refléter l'influence des différences de facteurs environnementaux ou d'habitat.

Les RLT présentées dans cette étude sont uniquement utiles et efficaces pour les populations de poissons démersaux de la côte libanaise et pour les gammes de longueur et les sexes spécifiques étudiés.

Chapitre V - Biologie des populations du migrant Lessepsien *Sargocentron rubrum* (Forsskål, 1775) le long de la côte libanaise, Méditerranée orientale

Dans le dernier chapitre de la thèse, un focus a été porté sur la biologie et l'écologie d'une espèce lesseptienne la plus abondante dans les captures des eaux côtières libanaises.

Cette étude se concentre sur la biologie et l'écologie de la population d'Holocentre rouge *Sargocentron rubrum*, une espèce de poisson téléostéen et lessepsienne des eaux côtières libanaises. Entre juin 2012 et octobre 2014, 1109 individus ont été capturés par des trémails et des filets maillants de maillages différents, abaissés par les navires de pêche artisanale au-dessus des eaux marines libanaises côtières à des

profondeurs allant de 10 à 100 m. La longueur totale (LT) des spécimens échantillonnés variait de 12 à 22 cm avec une moyenne et un écart-type (sd) qui était respectivement de 17,38 et 1,69 cm. La classe de LT la plus courante était de 18 cm. Le poids total des spécimens variait de 33 à 248 g, et la moyenne \pm sd était de $97,56 \pm 29,74$ g. Un total de 432 mâles et 314 femelles ont été recueillis, et le rapport de masculinité était significativement différent de 1: 1. Le poids et la relation longueur-poids ont montré une croissance allométrique légèrement négative ($b = 2,993$ et $r^2 = 0,86$), et la moyenne \pm sd des LT où 50% des individus étaient sexuellement matures était de $17,62 \pm 2,28$ cm pour les femelles et de $17,45 \pm 3,87$ cm pour les mâles. Les principales proies trouvées dans les estomacs de poissons étaient des crabes (infra-ordre des Brachyura) et en particulier ceux appartenant au genre *Thalamita*. *S. rubrum* est un prédateur extrêmement actif entre mai et août alors qu'il se nourrit peu lors des saisons froides. Les estomacs ont montré la plus grande abondance en termes de nombre et de poids au mois d'août. La durée de vie de *S. rubrum* est supérieure à 6 ans avec une taille maximale réalisable, $L_{\infty} = 21.315$ cm. Les résultats de cette étude permettront de paramétrer les modèles de dynamique des populations de ce stock halieutique exploité afin de mieux comprendre son rôle dans le fonctionnement de l'écosystème et les interactions avec d'autres espèces indigènes exploitées commercialement.

Chapitre VII - Discussion générale, conclusion et perspectives

Les espèces démersales sont soumises à diverses menaces à travers le monde, en particulier en mer Méditerranée. La présence et le statut des populations démersales ont été décrits pour la plupart des régions méditerranéennes à l'exception du bassin oriental et notamment le long de la côte syro-libanaise où les informations sur l'abondance, la répartition et les assemblages de ce groupe d'espèces sont encore déficientes. Dans ce contexte, deux principaux aspects ont été abordés :

- La distribution et la diversité de ce groupe d'espèces le long de la côte libanaise et l'établissement de relations taille-poids pour les espèces trouvées dans les captures ;
- L'approfondissement des connaissances relatives à certains traits d'histoire de vie d'une espèce de poisson lesseptienne majoritairement exploitée dans la région, l'holocentre rouge.

Adopter des méthodologies appropriées. Les enquêtes sur l'abondance sont fréquemment utilisées pour obtenir des informations sur la taille et la répartition du stock. Les espèces de poissons démersaux marins sur fond meubles sont généralement arpentées par des chaluts de fond, tandis que les espèces pélagiques sont majoritairement étudiées par des méthodes acoustiques calibrées par les captures au chalut. Dans le cas du Liban, les espèces commerciales les plus importantes sont typiquement côtières et réparties sur des zones où le chalutage standard ne peut pas être effectué. Dans cette situation, d'autres engins de pêche (par exemple des palangres, des filets maillants et des pièges) devaient être utilisés pour explorer les zones. De plus, les activités de chalutage sont interdites dans les eaux territoriales libanaises. Pour cette raison, soutenus par des pêcheurs et des scientifiques, nous avons développé un filet expérimental capable de fonctionner sur le plateau continental et la pente supérieure, avec de mauvaises propriétés de sélectivité pour capturer une variété d'espèces et de tailles de poissons et d'autres organismes. Nous avons estimé que des relevés indépendants de la pêche était l'outil le plus approprié pour fournir des mesures précieuses de l'abondance relative, des taux de variation de la population, de la taille et de la composition par sexe pour un large éventail d'espèces démersales. En fait, ce type de relevés constitue la pierre angulaire de

nombreuses évaluations des stocks de poissons osseux et de mollusques, car ils sont moins sujets aux facteurs inconnus et souvent confondants qui compliquent l'interprétation des indices de l'état des stocks.

ESPÈCES DÉMERSALES

Présence et diversité. La surpêche, les prises accessoires, l'introduction d'espèces non indigènes, la pollution, la perte d'habitat et le changement climatique sont les principales sources de stress affectant les ressources démersales méditerranéennes. Le bassin du Levant est décrit comme ayant une faible diversité biologique en raison des conditions défavorables qui prévalent dans la zone mais aussi, le plus probablement, d'un effort d'échantillonnage réduit. Les pêches peuvent affecter les relations entre les espèces et la pêche intensive entraîne la disparition d'espèces plus grandes et à longue durée de vie, générant une pression de sélection importante pour la maturation précoce et des écosystèmes moins résilients.

Le gouvernement libanais est engagé dans la mise en œuvre de mesures de gestion sur les ressources halieutiques qui nécessitent un avis scientifique solide, sur la base d'une connaissance accrue sur la diversité et la répartition de ces espèces (et pélagiques) le long de la côte libanaise par rapport à la profondeur et à la présence d'espèces exotiques d'origine indo-pacifique et sur leurs traits de vie. C'est pourquoi cette étude s'est focalisée sur ces principaux aspects et à long terme, les résultats de l'étude sont censés contribuer à la mise en place d'une gestion des pêches plus efficace et durable en Méditerranée orientale.

Les espèces de poissons démersaux sont exigées dans le monde entier pour leurs parties de grande valeur et l'état des stocks varie selon le pays ou la région. En Méditerranée et la mer Noire, 50 % du stock de poissons est surpêché. Les pêcheries méditerranéennes sont dominées par de petits navires, dispersés sur un grand nombre de sites de débarquement dans la plupart des pays. Elles ont développé une multitude de métiers et d'échelles d'investissements. Dans le cadre de la présente étude, un total de 129 espèces ont été enregistrées à des profondeurs allant de 10 à 300 m. La plupart de ces espèces était démersales, et incluait les espèces les plus importantes sur le plan économique, à savoir le merlu européen, le rouget, la pandorée et les crevettes rouges. Les fluctuations et les pics des indices de diversité des espèces démersales selon les saisons et les régions le long de la côte libanaise ont été étudiés.

Espèces lesseptiennes. Dans notre étude, 129 espèces dont 17 espèces d'origine lesseptienne (environ 13% incluant 13 poissons et 4 espèces de crustacés) ont été recensés dans les eaux côtières libanaises, incluant 15 démersales, 1 pélagique (le hareng *Etrumeus teres*) et 1 à comportement mixte benthique-pélagique. Avant cette étude, un seul inventaire des ressources halieutiques libanaises sur l'ensemble des eaux côtières du pays datant de 1964 était disponible. Dans ce recensement, 177 espèces de poissons dont 19 d'origine indo-pacifique étaient signalées (soit presque 11 %).

Cela signifie qu'en 50 ans, le pourcentage du nombre d'espèces halieutiques autochtones est resté relativement stable. Bien qu'on peut supposer qu'en termes de biomasse, les valeurs étaient plus faibles il y a 50 ans qu'aujourd'hui. A la suite d'une étude dans les eaux syriennes, 224 espèces de poissons osseux ont été signalées, dont 37 étaient lesseptiennes (16,5%). Dans une autre étude, la proportion estimée est plus importante (25 espèces lesseptiennes sur plus de 110 espèces identifiées, soit 23%).

La mer Méditerranée - et plus particulièrement ses côtes orientales - est l'un des points chauds les plus chauds des bioinvasions marines sur Terre. Le succès des migrants de Lesseps dans la colonisation de la Méditerranée orientale a probablement été le résultat de l'occupation d'une niche insaturée et d'espèces

locales sur-compétitives sur des ressources telles que la nourriture et le logement. De nombreux auteurs attribuent le taux d'entrée accéléré à une augmentation de la température de l'eau de surface en Méditerranée. Cependant, le canal de Suez a été approfondi et élargi à plusieurs reprises au cours des dernières décennies et suite selon d'autres auteurs, l'augmentation du taux d'immigration des poissons de la mer Rouge pourrait également être davantage liée à la réduction des barrières de dispersion. Le succès de l'établissement des poissons de Lesseps était également significativement lié à la taille et au type de ponton. La récente extension du canal de Suez en 2015, pourrait exacerber la menace de la menace d'une augmentation spectaculaire du nombre d'espèces exotiques introduites.

Cependant, dans les assemblages d'eaux plus profondes, nous avons observé que les espèces autochtones prévalent confirmant la préférence des poissons lesseptiens pour les eaux peu profondes. Selon la présente étude, l'espèce la plus abondante de poissons de Lesseps dans les eaux libanaises est de loin, *Sargocentron rubrum*. Malgré sa colonisation réussie dans les eaux côtières de la Méditerranée orientale et sa capacité à se reproduire sur de longues distances, se reproduisant en eau libre ou dispersant des œufs sur le substrat, la répartition méditerranéenne de cette espèce reste limitée à l'ouest de la mer Egée bien qu'il ait été signalé dans les eaux côtières en Grèce il y a environ 70 ans.

La population libanaise de *S. rubrum* ne semble pas souffrir de surpêche ou d'autres menaces. Cependant, les mesures de gestion des ressources démersales, fortement affectées par les activités de pêche, devraient tenir compte du rôle écologique de cette espèce et de l'extension possible de ses congénères géographiques et de l'élargissement continu de la présence de la famille des Holocentridae en Méditerranée.

Indice d'abondance et variations spatio-temporelles. L'analyse de l'effort de capture par unité (CPUE) et de la variation totale de poids des poissons démersaux observée durant cette étude a permis d'obtenir des indications sur la variation spatio-temporelle de leur distribution et de leur abondance. Bien que les causes de la distribution spatiale d'une population de poissons soient encore mal comprises, les processus dépendants de la densité sont souvent suggérés comme une explication possible ainsi que le réchauffement récent du système climatique. Cependant, la nature des eaux libanaises, la disponibilité des proies, les mouvements journaliers et saisonniers de reproduction et d'alimentation ainsi que les techniques de pêche et les profondeurs de la pêche peuvent expliquer dans une certaine mesure la variation de la distribution et de l'abondance.

De nombreux auteurs ont analysé les changements fauniques et l'établissement de certains assemblages qui se produisent dans les zones ciblées par la pêche artisanale, c'est-à-dire le plateau continental et la pente supérieure. Ils ont prouvé que la distribution spatiale des espèces démersales est principalement influencée par la profondeur, le type de substrat et les caractéristiques physiques des masses d'eau.

En ce qui concerne la diversité spatio-temporelle et la répartition des espèces observées dans cette étude, les deux ont montré des variations saisonnières et, dans certains cas, de légères différences régionales. La sélection de l'habitat par les espèces démersales dépend de plusieurs facteurs biotiques et abiotiques tels que la profondeur, la température et la salinité. D'autres facteurs peuvent expliquer la structure de l'abondance et de la répartition, notamment la structure de l'habitat, l'exposition des vagues, les rivières, la turbidité, les niveaux de nutriments ou encore les concentrations en métaux lourds.

Planification de la gestion stratégique. La valorisation des pêcheries au Liban devrait être poursuivie à travers des plans de gestion qui relanceraient l'opérationnalisation de la planification spatiale marine. Cela pourrait être fait en évaluant l'abondance et la répartition des ressources halieutiques, en identifiant les frayères, en sélectionnant les zones affectées à l'aquaculture, en établissant des zones de pêche réglementées, ou encore en découvrant de nouvelles zones de pêche.

En 2017, la Commission générale des pêches pour la Méditerranée (CGPM) a formellement déclaré que des enquêtes scientifiques de type MEDITS (programme international d'échantillonnage de l'abondance des poissons démersaux) devraient être menées au Liban d'ici 2019-2020.

En outre, les résultats de cette étude peuvent encourager à plus long terme la mise en œuvre ou la gestion efficace des Aires Marines Protégées (AMP) le long de la côte libanaise, ce qui à terme serait bénéfique aux pêcheurs. Dans ce cadre des activités autour de l'écotourisme pourraient être encouragées.

Aspects du cycle de vie et surexploitation. Des études sur les paramètres du cycle de vie tels que l'âge et la croissance, ainsi que des informations de base sur la répartition, l'abondance, les mouvements, l'alimentation, la reproduction et la génétique sont essentielles pour comprendre et prédire comment les populations évolueront et réagiront aux différents stimuli. En raison de la définition large du terme « démersal », différents traits d'histoire de vie sont présentés dans ce groupe. Généralement, les espèces démersales montrent des mouvements d'adultes relativement restreints. Leurs stades juvéniles pélagiques représentent leur mécanisme de dispersion le plus important, bien que des preuves génétiques montrent que les stades pélagiques échouent souvent à atteindre leur potentiel de dispersion.

Les évaluations formelles des stocks n'ont pas été effectuées au Liban. Des outils opérationnels d'évaluation des captures sont en cours de développement et devraient fournir rapidement des résultats clairs sur les débarquements et l'abondance des espèces. L'effort de la flotte de pêche libanaise se concentre principalement dans les 6 milles nautiques entraînant une pression de pêche élevée les ressources halieutiques côtières, en particulier dans la zone des 3 milles marins. L'état des ressources halieutiques hauturières entre 6 et 12 milles marins n'est pas connu, mais il peut être considéré comme des stocks vierges car pratiquement aucune activité de pêche n'est pratiquée dans cette zone. Les abondances et des biomasses observées dans cette étude ont montré des signes de surexploitation et étaient plus faibles dans le Sud que dans le Nord et centre du Liban. Cependant, la grande hétérogénéité des habitats présents dans la zone d'étude permet d'accueillir une grande diversité d'espèces de poissons.

Contexte et recommandations.

Les revenus de la flotte de pêche libanaise ont généré un salaire annuel moyen d'environ 4 300 USD, ce qui est inférieur au salaire minimum du Liban pour le secteur manufacturier. Le Liban a commencé à faire rapport à la FAO sur les captures de pêche (2 998 tonnes en 2014 et 3 483 tonnes en 2015) sur la base du système FAO EastMed. Les communautés de pêcheurs soient considérées parmi les plus pauvres du pays et les plus marginalisées. Il n'y a ni contrat de travail au Liban, ni couverture sociale, qui pourrait protéger les pêcheurs en cas d'invalidité, de perte d'emploi et de retraite.

Les données collectées dans cette étude nous amènent à faire un certain nombre de recommandations : 1) des échantillonnages de la répartition et de l'abondance des ressources halieutiques sur l'ensemble de la côte libanaise indépendants de la pêche devraient à l'avenir être plus réguliers pour assurer des ensembles de données continus et comparables pour une gestion correcte des ressources ; 2) lorsque les ressources financières le permettraient, la mise en œuvre d'un second échantillonnage en période hivernale (janvier et

février) serait nécessaire pour améliorer les connaissances sur la biologie et la répartition des espèces selon la saison ; 3) le rôle écologique d'un ensemble défini d'espèces commerciales doit être étudié en profondeur à travers l'analyse de leur contenu stomacal ; 4) leur âge doit être identifié en utilisant les otolithes des poissons ; 5) en ce qui concerne les engins d'échantillonnage, il est fortement conseillé d'élargir l'utilisation des trémails à l'ensemble de la profondeur étudiée (0 à 150 m de profondeur) ; 6) afin d'assurer la liaison avec le secteur des opérateurs vers l'acquisition constante d'informations scientifiques, il est conseillé de créer un réseau de points focaux (pêcheurs) répartis dans les principaux ports libanais et prêts à signaler les captures ou observations anormales ou imprévues. Il conviendrait également d'accroître les connaissances écologiques sur le plateau continental et la pente continentale.

CONCLUSION ET PERSPECTIVES

La compréhension quantitative des réponses aux activités de pêche est nécessaire pour permettre aux gestionnaires et aux décideurs d'établir des stratégies rationnelles. En d'autres termes, la gestion des pêches nécessite un suivi de la variation de l'abondance et de la répartition des ressources sur la base d'une procédure normalisée internationale. Plusieurs pays méditerranéens participent actuellement au programme international d'enquêtes sur l'abondance des poissons appelé MEDITS. Ici, il vaut la peine de se concentrer sur de nouveaux outils déjà développés dans d'autres pays, qui peuvent compléter les données recueillies grâce aux enquêtes sur la pêche.

La structure d'âge de la population peut être décrite et les taux de processus clés tels que la croissance, le recrutement et la mortalité peuvent être quantifiés. Les otolithes de *Pagellus* peuvent être difficiles pour l'identification correcte des anneaux d'hiver, les schémas de vieillissement et le chevauchement des anneaux dans les spécimens les plus anciens. Dans le cas de *Sargocentron rubrum*, et ont abouti à une conclusion différente pour la première lecture du cycle d'hiver, entraînant un vieillissement différent pour l'espèce.

Analyse génétique et science citoyenne. La difficulté d'identifier les espèces a rendu la surveillance du commerce des produits dérivés de requins et empêché l'évaluation quantitative des stocks. Les résultats des analyses génétiques peuvent être utiles pour aborder les questions de génétique des populations, en révélant si deux populations disjonctives partagent un pool génétique commun ou en clarifiant les relations taxinomiques entre les espèces. Dans ce contexte, en utilisant les techniques de code-barres de l'ADN, on est arrivé à la conclusion que plus d'une espèce appartenant au genre *Sargocentron* est entrée dans le temps la Méditerranée de la mer Rouge, non signalée et probablement mal identifiée. La participation communautaire est également un instrument important pour sensibiliser le public au problème des espèces marines envahissantes.

Les isotopes stables. En particulier, en Méditerranée orientale, où les NEI modifient les équilibres précédents, il est essentiel de répondre correctement aux questions concernant les conséquences fonctionnelles des remplacements d'espèces. C'est une façon puissante de représenter les caractéristiques trophiques des organismes sur lesquels s'appuie la recherche de niche qui propose des estimations à long terme des proies incorporées dans les tissus prédateurs, avec des applications prometteuses en biologie de l'invasion. La composition isotopique stable fournit une indication de l'origine et des transformations de la matière organique pour retracer l'utilisation et les flux des ressources de l'individu au niveau de la communauté.

La répartition des espèces migratrices est cruciale pour bien évaluer les stocks. Le biais peut être généré lorsque la connaissance des schémas migratoires des espèces n'est pas connue ou sous-estimée. Une façon évidente et peu coûteuse est de consulter les connaissances des pêcheurs. Les échosondeurs communs sont très utiles pour la détection des migrations verticales, tandis que des équipements acoustiques plus sophistiqués peuvent être utilisés pour cartographier la distribution et estimer l'abondance, en relativement peu de temps, en particulier des petits poissons pélagiques.

La façon classique d'étudier les mouvements des poissons et des invertébrés est un programme de marquage. Des étiquettes d'identification sont attachées à l'extérieur ou placées dans la cavité corporelle, le poisson est mesuré et relâché à un endroit connu, et une récompense est donnée pour toute étiquette retournée. Des étiquettes acoustiques et radio sophistiquées ont été développées pour permettre l'observation continue des mouvements d'un seul poisson comme suite d'un navire de recherche. La mer Méditerranée - et plus particulièrement ses côtes orientales - est l'un des points chauds les plus chauds des invasions marines sur terre.

Autres issues. Un certain nombre d'actions devraient être mises en œuvre pour permettre une croissance durable de l'ensemble du système pouvant conduire à une évaluation autonome, fiable et internationalement acceptable des ressources halieutiques au Liban. Ils devraient être soutenus par un effort continu vers le développement du programme de doctorat dans des sujets liés à l'écologie marine. Un personnel pluridisciplinaire doit être mis en place afin de répondre au développement rapide des sciences dans ce secteur. Des essais de pêche devraient être organisés et menés avec des pêcheurs professionnels afin d'augmenter le nombre de métiers disponibles.

Le rôle social et culturel des pêcheries artisanales reflète les liens historiques avec les ressources halieutiques, les traditions et les valeurs adjacentes et le soutien de la cohésion locale. Partout dans le monde, environ la moitié des personnes impliquées dans le secteur de la pêche sont des femmes, principalement engagées dans des activités post-récolte, manipulant le poisson après sa capture et assurant que cette source importante de nutrition atteint plus d'un milliard de consommateurs pour lesquels composante clé de leur alimentation.

Abstract (1000 characters)

The aim of this study was to contribute to a better knowledge of demersal species in the Lebanese coastal waters, Eastern Mediterranean. Various aspect related to the distribution, diversity and biology of these species were studied. The data were collected from a three-year experimental survey in the framework of the 'CIHEAM-PESCA Libano project'. A highly diversified mix of fish species (teleosteans and selaceans), cephalopods and crustaceans were sampled. Spatio-temporal distribution and diversity was evaluated respectively using the 'Catch Per Unit Effort' which was considered as an approximation of an abundance index and the total number of species caught in the surveys.

Length-weight relationships have been established for several species with sufficient numbers of individuals. Finally, emphasis was placed on the biology and ecology of a Lessepsian species, the redcoat, *Sargocentron rubrum*. This study is a first step in fisheries management and conservation in this region.

Keywords

Lebanon, Conservation, Fisheries, Life history, Ecology, Suez Channel

Résumé

L'objectif de cette étude était de contribuer à une meilleure connaissance des espèces démersales dans les eaux côtières libanaises en Méditerranée orientale. Différents aspects relatifs à la distribution, la diversité, et la biologie de ces espèces ont été étudiés. Les données ont été collectées à partir de captures expérimentales dans le cadre du projet 'CIHEAM-PESCA Libano'. Un mélange hautement diversifié d'espèces de poissons (téléostéens et sélaciens), de céphalopodes et de crustacés, ainsi que de organismes macro-benthiques ont été échantillonnés. La distribution spatio-temporelle et la diversité ont été évaluées respectivement à l'aide de la 'capture par unité d'effort' qui a été assimilée à un indice d'abondance et du nombre total d'espèces capturées dans les relevés.

Des relations longueur-poids ont été établies pour plusieurs espèces présentant un nombre d'individus suffisant. Finalement, l'accent a été porté sur la biologie et l'écologie d'une espèce lesseptienne et exploitée, l'holocentre rouge, *Sargocentron rubrum*. Cette étude constitue une première étape dans la gestion des pêches et la conservation dans cette région.

Mots clés

Liban, Conservation, Pêcheries, Traits de vie, Ecology, Canal de Suez

Abstract (4000 characters)

Due to its geographical location, Lebanon represents an outpost for a comprehensive understanding of the dynamics driving the colonization of the Mediterranean by Indo-Pacific and Red Sea species. A 3-year experimental fishing surveys program was initiated in the framework of the 'CIHEAM-PESCA Libano project' and was continued by the National Council for Scientific Research, Lebanon (CNRS-L). Sampling stations were surveyed by means of experimental nets lowered up to 300 m depth aiming at assessing the distribution and abundance of fisheries resources along the Lebanese continental shelf and mid-upper slope. A fishery-independent survey was deemed as the most appropriate tool to provide valuable measures of relative abundance, rates of population change, size and sex composition for a wide range of species.

A highly diversified mix of fish species (bony fishes and selaceans), cephalopods and crustaceans. This gave us the chance to:

1. Investigate the biodiversity of Lebanese demersal species
2. Collect information on biological traits, relative abundance and distribution of demersal species
3. Widen the knowledge on demersal communities exploited by Lebanese artisanal fisheries
4. Investigate the ecological traits of the redcoat, a key demersal Lessepsian fish species

Spatio-temporal distribution and diversity was evaluated respectively using the 'Catch Per Unit Effort' which was considered as an estimation of an abundance index and the total number of species caught in the surveys. Data showed the depth to cause a general decrease in the numerical abundance and biomass (beyond 150 m depth) due to a reduction of the abundance of bony fishes, which decreased with depth, while decapod crustaceans and elasmobranchs showed an opposite trend increasing from the coastal shelf to the middle slope.

As the understanding of patterns of spatial distribution of fish populations is a critical consideration particularly in the eastern Mediterranean Sea, where the faunal composition has been drastically altered by the migration of numerous Indo-Pacific species from the Red Sea, species assemblages occurring along the Lebanese continental shelf and exploitable using gillnets and trammel nets were investigated.

In Lebanon - where management measures are limited or outdated and the fishing pressure is high on coastal fisheries resources while fishing practices targeting juvenile fishes are partially driven by the market - the use of basic but powerful descriptive tools of halieutic populations such as WLRs is highly recommended. In this study, WLRs were established for 30 species (24 bony fishes, 3 elasmobranchs and 3 crustaceans).

The population of the redcoat, *Sargocentron rubrum*, a Lessepsian species inhabiting the eastern Mediterranean has reached considerable size since more than three decades. According to the present study is the most abundant coastal demersal species in Lebanon. Despite its important ecological role, biological traits, abundance and behavior of this species have been scarcely investigated. Hence, the biology and ecology of this species were deeply investigated and parameters for population dynamics were assessed as a tool to better understand its role in the ecosystem functioning and the interactions with other commercially exploited native species.

The present thesis also includes a description of the Lebanon's fisheries sector that includes socioeconomic characteristics, environmental context and governance-related aspects, and a short essay on main traits, history, causes and effect of the so called Lessepsian migration based on original contents and bibliographic review.