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From consumption to production – development of fisheries and aquaculture in Portugal

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Abstract

Seafood is considered an important element of a healthy diet; therefore, worldwide consumption has been increasing. This growth has been partly based in the development of the aquaculture industry, which contrasts with the depleted status of an increasing number of fish stocks worldwide. Countries with high seafood consumption rates tend to develop high seafood deficits, as well as an external seafood dependency. In Portugal, roughly 2/3 of availability is met by imports. In addition, seafood consumption rates are the highest in Europe; the combination of these two factors puts considerable pressure on the seafood trade balance and the production sector.

Current consumption estimates only consider official availability data, by means of the apparent consumption method, which may induce errors in overall seafood consumption. Furthermore, the use of individual surveys has been shown to be a useful tool to obtain consumption data, regarding preferences and frequency of consumption. In order to estimate consumption, and the demand-based potential for an increase in production, a new methodology was developed. Official external trade volumes, as well as catch production and aquaculture yields, were combined with illegal fishing data, in order to estimate availability volumes. Therefore, through the integration of these estimates with the individual seafood consumption surveys, it was possible to estimate the growth potential of the aquaculture and fisheries sectors in Portugal.

Eight products (cod, sardine, hake, horse mackerel, tuna, salmon, gilthead seabream and European seabass), which encompass between 63% and 71% of total seafood consumption, were identified as the most consumed. The unmet seafood demand was estimated to be between 13 396 and 41 024 tonnes, which corresponds to a potential growth of the current Portuguese seafood market of between 2.5% and 7.6%. The most promising areas identified were in the farmed fish sector. Other axes of intervention, such as the mitigation of illegal fishing or the improvement of the ecological status of fish stocks, were also identified as promising areas in order to increase overall seafood production.

Keywords: seafood consumption, seafood availability, aquaculture and fisheries production, growth potential estimates

Resumo

O peixe e outros produtos marinhos fazem parte de uma dieta saudável e equilibrada, daí o gradual aumento do seu consumo um pouco por todo o globo. Este aumento é em parte explicado pelo aumento da produção aquícola, o que contrasta com o debilitado estado de conservação dos *stocks* pesqueiros um pouco por todo o mundo. Os países com consumos elevados de peixe e outros produtos marinhos, por vezes desenvolvem um elevado défice comercial, e uma dependência externa para suprir a procura interna de pescado. No caso Português, aproximadamente 2/3 da disponibilidade de pescado é composta por importações, o que, combinado com o elevado consumo de peixe, coloca pressão sob a balança comercial, bem como sob o sector das pescas e aquacultura.

Os métodos actualmente aplicados para estimar o consumo de pescado, utilizam os dados oficiais de disponibilidade dos países, o que pode gerar erros nestas estimativas. Além disso, o uso de inquéritos individuais já foi comprovado como sendo um método válido para obter informação no que concerne as preferências e frequência de consumo de pescado. De forma a calcular o consumo, bem como potencial de aumento de produção, baseado na procura, uma nova metodologia foi desenvolvida. As estatísticas oficiais de importações e exportações de pescado, capturas e produção aquícola, foram compiladas com informação acerca de pesca ilegal, de forma a estimar o volume total de pescado disponível. Desta forma, e através da integração destas estimativas com inquéritos individuais sobre preferências de consumo, foi possível estimar o potencial de crescimento dos sectores da pesca e aquacultura Portugueses.

O consumo de peixe em Portugal é concentrado em oito produtos principais (bacalhau, sardinha, pescada, carapau, atum, salmão, dourada e robalo), que concentram entre 63% e 71% do consumo total de pescado. A procura não satisfeita de pescado em Portugal foi estimada entre as 13 396 e as 41 024 toneladas, o que corresponde a um crescimento potencial do actual sector de produção de pescado entre 2.5% e 7.6%. As mais promissoras oportunidades identificadas foram no sector da aquacultura. Outras áreas de intervenção foram também detectadas na redução da pesca ilegal e na melhoria ecológica dos *stocks* pesqueiros explorados.

Palavras-chave: consumo de pescado e derivados, produção pesqueira e aquícola, estimativas de potencial de produção

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Acronyms list

CCMAR – Centro de Ciências do Mar

CEC – Council of the European Communities

CEU – Council of the European Union

DGRM – Direcção-Geral de Recursos Naturais, Segurança e Serviços Marítimos

EC – European Commission

ECDGMAF – European Commission Directorate General for Maritime Affairs and Fisheries

FAO – Food and Agriculture Organization of the United Nations

FAOSTAT – Statistics Division of the Food and Agriculture Organization of United Nations

ICCAT – International Commission for the Conservation of Atlantic Tunas

ICES – International Council for the Exploration of the Sea

IH – Instituto Hidrográfico

INE – Instituto Nacional de Estatística

IPMA – Instituto Português do Mar e da Atmosfera

MADRP – Ministério da Agricultura, do Desenvolvimento Rural e das Pescas

MAR – Ministério da Agricultura e do Mar

MSC – Marine Stewardship Council

NAFO – Northwest Atlantic Fisheries Organization

ONU – Organization of the United Nations

PCEU - Parliament and Council of the European Union

PCM – Presidência do Conselho de Ministros

English, Portuguese () and *Latin* names of the most common species referred in the text:

Cod (bacalhau) – *Gadus morhua*

Sardine (sardinha) – *Sardina pilchardus*

Horse mackerel (carapaus) – Includes: *Trachurus trachurus, Trachurus picturatus* and *Trachurus mediterraneus*

Tuna (atuns) – Includes: *Katsuwonus pelamis, Thunnus spp, Auxis spp, Sarda sarda*

Gilthead seabream (douradas) – Includes: *Sparus aurata, Diplodus spp,* other *Sparidae*

European seabass (robalos) – *Dicentrarchus labrax*

Hake (pescadas e abróteas) – Includes: *Merluccius merluccius, Urophycis tenius,* other *Merluccidae*

Salmon (salmão) – *Salmo salar*

Chub mackerel (cavala) – *Scomber colias*

1. Introduction

1.1. Problem definition

The Portuguese imported fish deficit has grown considerably in the last four decades, motivated by a large consumer demand and reductions in fishery volumes. These variations were not accompanied by an equivalent growth of alternative production sources, such as aquaculture, which led to an increased dependency on imported fish since the 1970s.

In many countries, the search for sustainable alternatives to fisheries has been motivated by food security reasons. Despite a number of outstanding issues regarding environmental impacts, marine spatial planning, and the particular biogeographic conditions of the Portuguese coast, aquaculture is a valid option in order to reduce the imported fish deficit and the consequent external dependency. This has motivated the creation of governmental plans and strategies, guided by the European framework. The support of scientific knowledge has also been crucial in breaking new ground regarding the variety of farmed species, as well as in the use of new marine areas.

Knowledge regarding seafood consumption is important in order to develop a sector which is both economically and ecologically sustainable. Despite the known difficulties in estimating potential growth volumes of either fisheries or aquaculture, the use of seafood consumption surveys can be helpful in obtaining approximations, based on seafood demand. In turn, these can be used to identify the species which present the best production increase opportunities.

1.2. Objectives and expected outcomes

In order to understand the Portuguese seafood sector from consumers to internal production, and identify the potential for an increase in fisheries and aquaculture yield, a step by step methodology was developed and followed, with a series of intermediate goals:

- Identify the key species and/or seafood products consumed in Portugal;
- Examine the total availability of key seafood products in Portugal, and categorize the origin of these species;
- Compare the availability and estimated consumption for each of the key species in order to obtain an optimized consumption volume, according to real availabilities;
- Quantify the potential for a production increase of the identified key species, based on consumption demand and available opportunities in Portugal.

1.3. Thesis layout

The study is divided into five chapters. The first section is an introduction to the work plan, definition of the problem, including a layout of the main objectives, as well as expected outcomes.

Chapter 2 contains the state-of-the-art. This is focused on important issues, such as the European Union framework, which are important in defining the evolution of the Portuguese seafood sector. This section also addresses the historical evolution and current status of the Portuguese seafood sector.

The methodology is described in Chapter 3. The methods applied are divided into two separate sections. The first part includes the seafood availability and consumption assessment, which results in the assessment of these two factors, with the identification of the key products in the national seafood sector. The second part addresses the growth potential of the fisheries and aquaculture sectors.

Results are presented in the Chapter 4, following the same arrangement. The first section shows the results regarding availability and consumption, including consumption estimates and identification of key species in the Portuguese seafood market. The second section presents the growth potential estimates, based on seafood consumption.

Chapter 5 contains the discussion. This includes the description of strategic areas of intervention, and how they best fit each key product. This chapter also includes some alternative considerations, as well as a sub-section describing issues identified regarding methodology and results.

The final chapter describes the main conclusions of this work, and makes recommendations for future studies.

2. State of the art

2.0.1. Consumption and production in the seafood sector

Seafood is widely accepted as part of a healthy and balanced diet, and the high demand for these products places considerable pressure on the environment. Traditionally the fishing sector has supplied the bulk of seafood demand, although roughly since the 1970's aquaculture has grown into a valid alternative. Both sectors have negative impacts on ecosystems at various levels. In addition, the large economic dimension of the seafood sector and the amount of people it employs are adequate motivation for understanding demand in a demand-driven sector, which is paramount to a more effective shaping of policies and marketing strategies (Carlucci et al., 2015).

Most data available regarding seafood consumption is based on a straightforward approach (apparent consumption method), which estimates values using a simple 'production + imports – exports = consumption' balance to identify consumed products. This approach is sometimes undermined by weak taxonomic resolution (Rodgers et al., 2008). Another important factor is the lack of subsistence, recreational, and illegal fishing volumes in most of these estimates, which can sometimes represent a considerable proportion of availability (Leitão et al., 2014). This is especially important considering the recently imposed landing obligation for certain fish species by the CFP reform, which will extend to all species by 2019 (PCEU, 2013). Assessment of seafood consumption using surveys has been acknowledged as a valid method to obtain data and extensively used (Cardoso et al., 2013; Carlucci et al., 2015). This information can be used to compare availability data and consumption patterns, in order to identify differences between the two and provide consumer-demand-based knowledge of seafood markets.

2.0.2. From wild to farmed fish

Worldwide aquaculture production has grown annually since the late 1970's, aided in part by a collapse of fish stocks, and taking total fish production worldwide to 167 million tonnes, 87% of which is destined to human consumption. World *per capita* levels of seafood consumption are at an all-time high of 20kg/person/year (FAO, 2016; Merino et al., 2012; Naylor et al., 2000). These production levels took farmed fish from slightly over 25% to approximately 50% of the seafood consumed worldwide in little over a decade, which creates the expectation of aquaculture becoming a solution to food security problems worldwide, as well as a vital complement to global capture fisheries. Asian countries have been leading this aquaculture "blue revolution", with over 90% of total production originating in their marine, brackish and freshwater environments – China alone accounts for 60% of global production levels (Campbell and Pauly, 2013; Ferreira et al., 2014; Naylor et al., 2000). Europe currently has a troubling seafood trade deficit, and with the expected increase in consumption, allied with a growing purchasing power on China and SE Asia countries, aquaculture products are likely to become scarcer and more expensive (Ferreira et al., 2014). With the collapse of fish stocks, the reliance on farmed fish is expected to increase, in order to support an increasingly larger world population and its demand for fish-based protein (Naylor et al., 2000).

Species diversity in aquaculture exploration spans from plankton-filtering mussels to carnivorous salmon, and can be practised in intensive, semi-intensive, or extensive forms, each of them with its advantages and disadvantages in terms of production output, environmental impacts, or profitability (Naylor et al., 2000). More recent developments, such as a growing interest in offshore aquaculture and the exploration of different trophic groups in Integrated Multi-Trophic Aquaculture (IMTA) farms in North America and Europe, motivated by environmental concerns and competition for coastal areas (Ferreira et al., 2012), can potentially open new and more sustainable prospects on world aquaculture practices. The concerns over a sustainable development of aquaculture in all its aspects (environmental, social, and economic) as well as market factors, have inhibited the expansion of this sector in European Union countries, limiting annual growth to 1% per year, or resulting in growth stagnation. In Europe, the licensing of aquaculture explorations has been characterized by a clear concern about the carrying capacity of ecosystems, and environmental legislation has implicitly promoted the Ecosystem Approach to Aquaculture (EAA) objectives (Nunes et al., 2011).

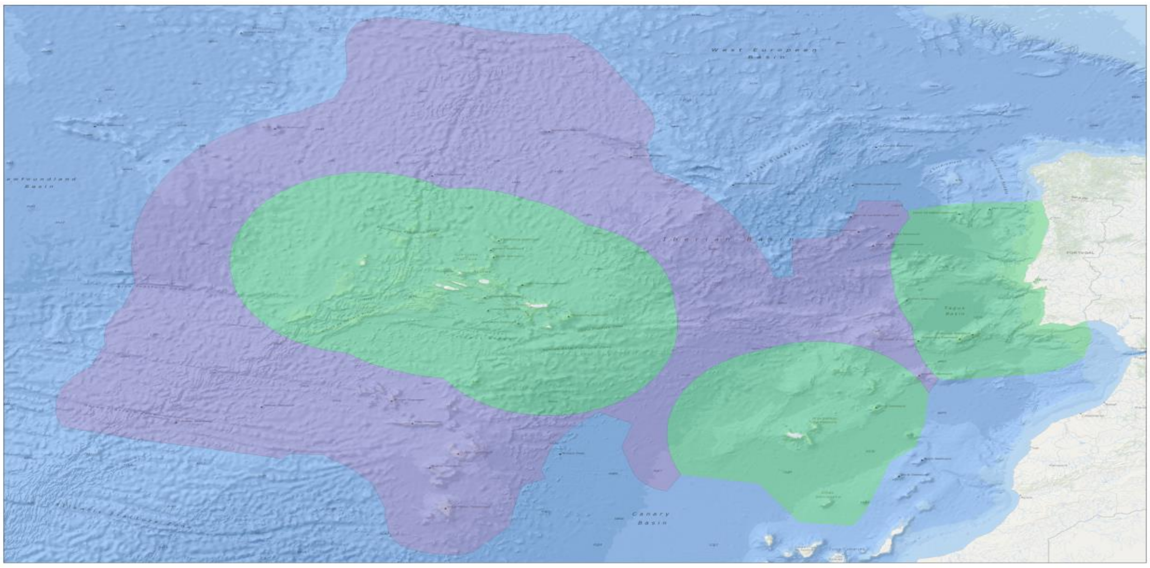
Aquaculture production increases remain a mixed blessing, since growth has been partly at the cost of wild caught fish (Naylor et al., 2000). Improvements in fisheries management can either benefit or stifle aquaculture growth, depending on the exploitation level of fish stocks, targeted species, and the emergence of new farmed products. There are some cases where successful fisheries management led to a restraint in aquaculture growth potential (Jensen et al., 2014). Despite difficulties in obtaining realistic estimates for potential aquaculture growth, the majority of studies have shown an increase in global aquaculture production, in contrast with the stagnation or decrease of wild fish landings. This has been a recurring tendency since 1980, which has helped in maintaining current seafood supply, and this tendency can prove a valuable ally for the future of seafood production (Campbell and Pauly, 2013; Gjedrem et al., 2012; Natale et al., 2013).

2.1. European Union framework

2.1.1. Portugal's maritime dimension within the EU

Portugal has one of the largest marine jurisdictions in Europe (Figure 1), and the considerable dimension of marine areas under Portuguese jurisdiction highlights its importance to the EU Atlantic strategy. Currently 1 727 408 km^2 compose the national Exclusive Economic Zone (EEZ) and, depending on the approval of the proposal for extension of the continental shelf submitted in the UN in 2009, the EEZ can increase to over 3.8 million km^2 (Santos et al., 2012; Vivero and Mateos, 2014). Among the uses for this vast area are fisheries and aquaculture claims, and the development and application of maritime spatial plans (MSP) is crucial, in order to avoid conflicts between different uses and achieve conservation objectives (Calado and Bentz, 2013).

Portugal is part of the Atlantic Arc peripheral maritime region and plays an important role in achieving the EU strategic objectives for the Atlantic Ocean, as well as the implementation of the ecosystem approach (EC, 2011, 2009a). The OSPAR convention for the protection and conservation of the Northeast Atlantic includes the Portuguese coastline and its waters. As for Regional Fisheries Management Organisations (RFMO’s), the Portuguese EEZ is located within the area of influence of the International Commission for the Conservation of Atlantic Tuna (ICCAT) and the North East Atlantic Fisheries Commission (NEAFC). The Northwest Atlantic Fisheries Organization (NAFO) also plays an important role in influencing some of Portugal’s catches (EC, 2009a). Portugal, as a part of the EU, must also implement the Marine Strategy Framework Directive (MSFD), which is considered to be the environmental pillar of the EU Integrated Marine Policy (IMP) (Santos et al., 2012).



Legend

Portuguese Exclusive Economic Zone

Extended Continental Shelf

Figure 1. Portuguese current EEZ and potential extension, pending the acceptance by the UN of the continental shelf extension submitted plan (IH, 2012).

2.1.2. Legal and political framework

The Integrated Maritime Policy for Europe has, for some time, been work in progress, and an objective regarding the required connection between all sectors which impact and operate on the sea (Fritz and Hanus, 2015; Santos et al., 2014a). This link among a series of cross-cutting policies is of critical importance for several maritime-related subjects. Marine knowledge and economic growth are issues that affect several EU policies, and the fishing and aquaculture sectors have vested interests in a series of these guidelines (ECDGMAF, 2014).

2.1.2.1. Common Fisheries Policy (CFP)

The Common Fisheries Policy dates back to the early 1970's. In those early days the main goal of political decision-makers was to avoid conflicts. Regulation was developed where Member States were allowed somewhat free access to each other's waters, thus maintaining traditional fishing grounds and practices, which in turn, caused its own set of issues (EC, 2009b; Hoefnagel et al., 2015). The initial set of regulations mainly referred market and structural measures. In 1983 the legislation adopted a more administrative concern over the community fisheries. This structural policy has been reviewed regularly every ten years since (Salomon et al., 2014). The annual Total Allowable Catch (TACs) and quotas system was created in 1976, as part of the CFP, in order to manage total catches, fishing area restrictions, and time, as well as gear limitations. It was legally established in 1983 (CEC, 1983) and was considered the CFP 'cornerstone of all conservation measures'. In the establishment of annual TACs the Scientific and Technical Committee for Fisheries plays an important role, estimating these based on the solid scientific data available—analytical TAC's—or based on a precautionary approach—precautionary TAC's—in order to assure a certain degree of conservation of relevant stocks (Karagiannakos, 1996; PCEU, 2013).

An important step towards a more sustainable European fisheries policy is the recent CFP reform. The integration of Maximum Sustainable Yield (MSY) concepts has the potential to shift the management approach on fish stocks from aiming to avoid stock collapse to increasing yields with clear benefits to environment, producers, and consumers. On the other hand the unambitious capacity ceilings and the entry/exit schemes are more a reflection of the current *status quo*, and therefore do not offer much promise in the much-needed reduction of the overall EU fleet capacity. The quota swapping is also a problematic issue, which has the potential to induce conflicts between states with an established scheme (or with the intention of creating one) and states that refuse to adhere to such practices. The mandatory and publicly available report from Member States on the balance between fishing opportunities and capacity is a positive tool which allows the Commission to identify and address structural overcapacity. The same can also be said about the required establishment by member states of multiannual strategic plans with objectives for aquaculture development (PCEU, 2013; Salomon et al., 2014).

The reduction of bycatch through the use of more selective fishing gear and elimination of non-commercial species is at the root of the discards ban implementation in the CFP reform. A discards ban requires considerable amounts of data on the fisheries in order to succeed, as well as incentives for compliance, and the prior implementation of methods that mitigate bycatch. Despite the positive intentions, some consider the discards ban an extreme measure, which could lead to more negative economic, social, and ecological impacts than benefits, especially in the small-scale fisheries segment. The low capitalization of this sub-sector, lack of incentives to ensure compliance, and shortage of enforcement authorities, all add to the increased vulnerability of this segment (Veiga et al., 2016).

Despite promising evolutions in the CFP, certain core reasons that drive the vicious circle of overfishing are yet to be addressed. The foundation principles of equal access and relative stability, developed to manage the fisheries of a few member states, currently have to manage the fishing activities in the waters of 22 member states. These basic principles may need to be reformed in order to solve certain issues and guide the EU fisheries in a more sustainable manner (Cressey, 2013a; Hoefnagel et al., 2015; Salomon et al., 2014).

2.1.2.2. European Maritime Fisheries Fund (EMFF)

If the TAC and quotas system has been in the past, and in part still is, considered as the essence of ecological concerns of the CFP, the EMFF and its predecessor the EFF (European Fisheries Fund), provide the financial backbone for fisheries, aquaculture and IMP measures and subsidies (CEU, 2006; PCEU, 2014). While overcapacity has been identified as one of the main causes for overfishing for some time, in the past the greatest portion of EU fisheries subsidies has been used for the enhancement and modernization of fishing fleets, which ultimately increases fishing capacity and fuels overfishing (Cressey, 2013b; Villasante, 2010).

In the EMFF reform, the EU Parliament voted against the proposal of subsiding new vessels. Despite this setback, capacity enhancing subsidies remained, and it will be possible to substitute old engines with new models, with improved fuel-efficiency, which contributes positively to climate change mitigation, in spite of the harmful effects to overfishing. The allocation of funds to research and data collection is a positive development (PCEU, 2014; Salomon et al., 2014).

2.1.2.3. Marine Spatial Planning (MSP) and the Marine Strategy Framework Directive (MSFD)

Organisation of the Portuguese marine environment and its uses is imperative, particularly when considering the vast area under national jurisdiction and its importance within the EU. Since 2005, two National Ocean Strategies have been developed in Portugal. The MSFD has been transposed into the legislative framework and an MSP process has been initiated by the government (Santos et al., 2014b). MSP and other similar policies provide a good starting point to ecosystem-based management of marine space, and a more sustainable use of marine resources (Katsanevakis et al., 2011). The MSFD creates the basis for maintaining a Good Environmental Status (GES) of marine ecosystems (Santos et al., 2012).

The interaction between these two directives is part of what allows the ecologically and economically sustainable development of all maritime endeavours in the EU marine space (Rätz et al., 2010). The key role of indicators for the assessment of environmental conditions, or management measures, is evident in the MSFD and is a significant part of the ecosystem approach to management (Reiss et al., 2010). These indicators serve as ’qualitative descriptors‘ to adapt management measures with the objective of achieving GES (PCEU, 2008).

Some authors distinguish between an ecosystem-based management of the marine space and a blue growth orientation. The first is based on ecological criteria, ecosystem goods and services oriented to human use and a precautionary approach, with the objective of ensuring sustainability. The second defines environmental sustainability as a pillar or sector of MSP, next to others such as fisheries, tourism or navigation. When considering these two distinct approaches to MSP in the EU framework, it becomes evident that both are priorities in several directives, as the CFP or MSFD. The adaptive management approach can be considered as a conciliation of these two attitudes towards MSP, and even perhaps the one which integrates the most EU goals. It is based on the systematic advance in knowledge about ecosystems via monitoring and assessment, adapting policies and management choices, which are reflected by acquired results. The precautionary approach is inherent in this method (Santos et al., 2014a).

Positive effects that can be achieved by the coexistence of several diplomas, regarding the preservation and sustainable use of marine resources, are sometimes undermined by a multitude of responsible entities for one same area or subject. This is particularly correct in Portugal, and has been recognized by the competent authorities. The Portuguese proposal is not yet finished and many strategy choices are still open to discussion, but initial views on the document suggest an overshadowing of ecological sustainability concerns by economic goals. Despite this, if the adaptive methodology is truly implemented, the diploma has the potential to provide an evolution to MSP, management measures and policies that can ensure the long-term sustainability of marine uses (Santos et al., 2014b, 2012).

2.1.2.4. Maximum Sustainable Yield (MSY)

The objective of MSY regarding fisheries is to keep fish stocks at a biological level that avoids a reduced recruitment of fish and therefore optimizes production levels, thus achieving a constant renewal of the stock. This concept is defined as “a scientific appraisal of the safe upper limits of harvest which can be taken consistently year after year without diminishing the stock” (Froese and Quaas, 2013; Mesnil, 2012; Steadman et al., 2014).

In December 2013 the EU CFP reform explicitly adopted in its objectives the aim of achieving a MSY level for all fish stocks by 2020 (PCEU, 2013). An MSY goal for the conservation of living resources had already been stipulated in the United Nations Convention on the Law of the Sea (UN, 1982), and the EU has committed itself to these objectives on several occasions, but it was never indicated as an objective in the most important fisheries-related legislation of the EU (Salomon et al., 2014). ICES is one of the advisory councils for several areas of the EU marine space, with working groups that produce reports concerning several species exploited commercially by the EU, and in turn assist the Commission by providing a scientific basis for setting fishing limits. MSY has been present for some time in ICES analysis and reports, coupled with the precautionary principle as a safeguard measure. Its concepts and guidelines have had some success in recovering fish stocks, and this is a compulsory component of ecosystem fisheries management (Mesnil, 2012).

2.2. Portuguese seafood sector

2.1.1 From history and tradition to politics and production

Traditional occupation and exploration of resources by Portuguese coastal communities created a profound knowledge of the natural cycles and riches provided by the sea, which shaped a multitude of fishing methods, boats and even dwellings (Abreu and Fernandes, 1987). As a result of this connection, certain coastal communities have subsisted and still subsist, some almost exclusively, from exploitation of marine resources, most notably fishing activities which have been historically achieved through small-scale fishing (Leitão et al., 2014).

Despite such a strong coupling between populations and nearby coastal and estuarine ecosystems, the most important seafood product to Portuguese consumers has been, and still is, cod (Dias et al., 2001). The root of such a predominance of this product, which is not an endemic species in Portuguese waters, especially in such a peculiar presentation – dried and salted – has been variously studied in literature. Initially, the abundance of this species in the North Atlantic, mainly in Newfoundland, shaped the history of certain coastal communities and seafood consumption patterns (Davies and Rangeley, 2010). Subsequently, politics helped form what would become part of tradition and culture, which left an indelible mark on Portuguese diet and traditions. Later, cod would help shape the Portuguese foreign fish deficit, with the end of free access to resources due the introduction of the two hundred nautical miles EEZ regime, and the stock collapse in the Newfoundland area, as the main drivers in the decline of cod landings (Almeida et al., 2015; Bjørndal et al., 2015; Coelho et al., 2011).

In 1967, the Atlantic cod catch reached 238 000 tonnes, representing 42.3% of the total 563 000 tonnes landed, making cod the most relevant species in national seafood production. The ’cod campaign‘ (*campanha do bacalhau*) promoted by the Portuguese government between 1934 and 1967 was the main reason for such high landing volumes. After the loss of free access to resources—the pillar on which the 'cod campaign' had been built—collapsed. From 1976 to 1978, landings dropped from 71 000 to 20 000 tonnes. With Portugal's entry into the EC in 1986 and the transposition of bilateral agreements—where certain historical fishing rights and its large consumption market were enforced—into the EC framework, quotas decreased, swiftly followed by total landings (Coelho et al., 2011). In 1992, a moratorium was declared on cod fishing in the Grand Banks, closing commercial exploration (Schrank, 2005). In the same year Portuguese landings dropped to current levels of under 10 000 tonnes per year (Figure 2) (Bjørndal et al., 2015; Dias et al., 2001; NAFO, 2014).

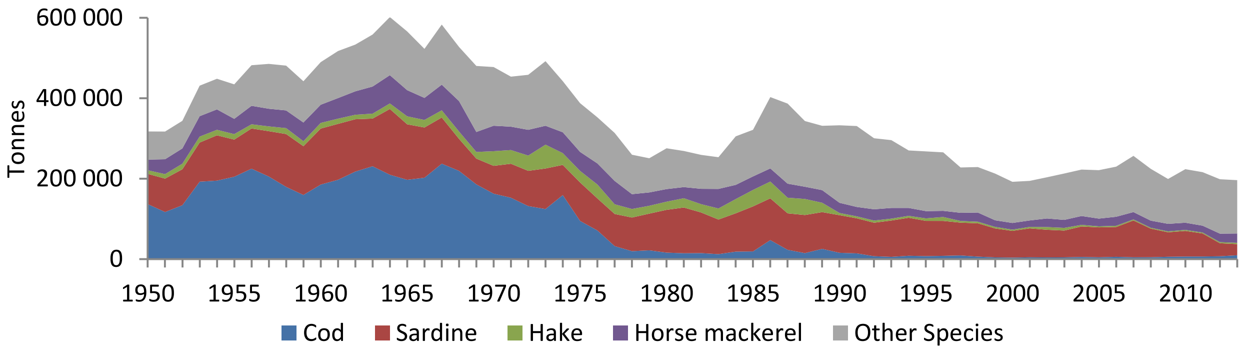


Figure 2. Evolution of the Portuguese fishing fleet landings from 1950 to 2013 (FAO, 2015).

Operations of the Portuguese long distance fleet were not confined to cod fishing in the North Atlantic. Hake catches suffered an abrupt decline in 1990. Other species have suffered considerable catch reductions over the decades, such as horse mackerel (Bjørndal et al., 2015). The 1974 (political) revolution, and the loss of control over certain important seafood resources of former Portuguese colonies, also contributed to landing reductions (Almeida et al., 2015; Mendes, 2005). Sardine production was mainly driven by the commercial interests of the canning industry. Sardine and other fish common in Portuguese waters, such as tuna or chub mackerel, were the drivers of the first canning industries near coastal villages and fishing ports. This led to the creation of strong bonds between populations and these marine activities, and the generated know-how became part of these communities' heritage and was passed down and improved through generations (Duarte, 2004).

Although the end of free access to resources in 1977 marked a tipping point in the Portuguese fleet catches, signs of the lack of sustainability of fishing practices in the Grand Banks area had been present since the late 1960's, when the first drops in cod landings were registered. From 1976, sardine became the most fished species, marking an evolution of the Portuguese fleet from predominantly targeting distant species to taking the majority of the catch in national or EU waters. The impact of joining the EC in 1986 represented an increase in total landings and a change in composition, with a wider range of landed species (Figure 2) (Almeida et al., 2015; Bjørndal et al., 2015; Schrank, 2005). In 2009, Portugal had the most heterogeneous landing composition of the EU, declaring a total of 349 species (OCEANA, 2012). This shift in exploited waters and targeted species was supported by an adjustment in terms of fleet composition. Currently the largest fleet section is the multi-gear fishery, responsible for the highest variety of species and the largest portion both in volume and value of landed fish (Gamito et al., 2015; INE, 2014a).

2.1.2 Shift in sourcing seafood and growth of the foreign fish deficit

Overall seafood availability in 2011 remains roughly at the same level as in 1961 (Esteban and Crilly, 2012). Despite the significant changes that have occurred in Portugal in the last half century, seafood consumption in 2011 was 56.80 kg *per capita*, standing at roughly the same levels as it did in 1961 when it was 55.62 kg *per capita* (Figure 15) (FAOSTAT, 2015). The regular availability which permitted such consumption levels suffered only a temporary decrease between 1977 and 1984. Availability and consumption recovered to previous levels in 1985 with a source shift from production to imports, with consequences for the foreign fish deficit (Figure 3 and Figure 4)(Almeida et al., 2015). Portugal's EEZ, despite its extensive dimension, does not possess an overabundance of fishing resources (Duarte, 2004). This is one of the reasons why the national fishing fleet traditionally exploited foreign fishing areas and why Portuguese fish landings fell with the end of free access to resources.

In 1974, national seafood production accounted for 69% of total availability, and during the fisheries crisis period (1972 to 1985) this ratio between imports and production remained somewhat constant at the expense of total availability. In 1986 Portugal joined the EC, production grew, and the ratio between internal and external seafood origin shifted in favour of production (56% and 52% of internally produced seafood in 1986 and 1987 respectively). From 1988 to 2011 Portugal gradually increased its dependence on external seafood, as production decreased and imports grew in order to sustain a similar *per capita* consumption level (Figure 4 and Figure 5)(Almeida et al., 2015; FAOSTAT, 2015).

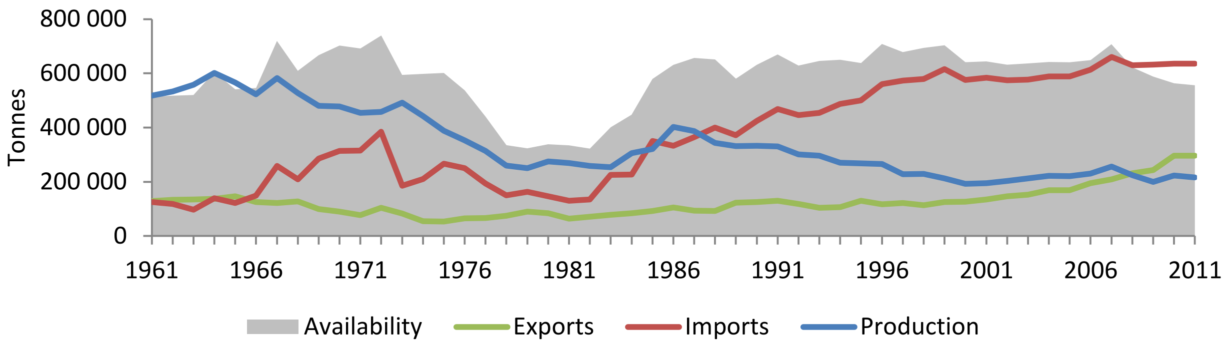


Figure 3. Historic profile of the seafood availability in Portugal from 1961 to 2011(FAOSTAT, 2015).

The evolution from internal to external seafood is clear in Figure 4, as is the impact on the foreign fish deficit. The growth tendency of the foreign fish deficit started during the fisheries crisis period (Almeida et al., 2015). In 1987 the seafood deficit grew substantially with Portugal's entry in the EC. Imports and overall catch production grew as well, however the import growth after entering the EC was a consistent tendency. Portugal's seafood self-sufficiency decreased from 52% in 1990 to 24% in 2009 (Esteban and Crilly, 2012). In 1961, imports played a lesser role in supplying the national market with 12% of availability from an external source, while national fleet landings accounted for the remaining 88% (FAO, 2015). The increase in imports combined with a landings reduction had an impact, not only in volume, but also in the value of the Portuguese seafood budget (Figure 5). The foreign fish deficit more than doubled in ten years (1988 to 1998), reaching a value of 838 738 X 10^3 € in 2011. The continued reduction of fish landings contributed to the increase in imports (Figure 4) (Bjørndal et al., 2015; Dias et al., 2001).

A noticeable factor for Portugal's shift from a distant water fishing state, capable of supporting the majority of its seafood demands, to a country with considerable foreign fish dependence, was the adhesion to the EC. The Gross Domestic Product *per capita* (GDP) growth and the monetary resource transference from the central EC economies to peripheral countries allowed an increase of imports. The increase of available income *per capita* also allowed for the maintenance of seafood consumption at pre-1974 levels, at the expense of higher imports (Baer and Nogueira Leite, 2003; Baer et al., 2013; Bjørndal et al., 2015).

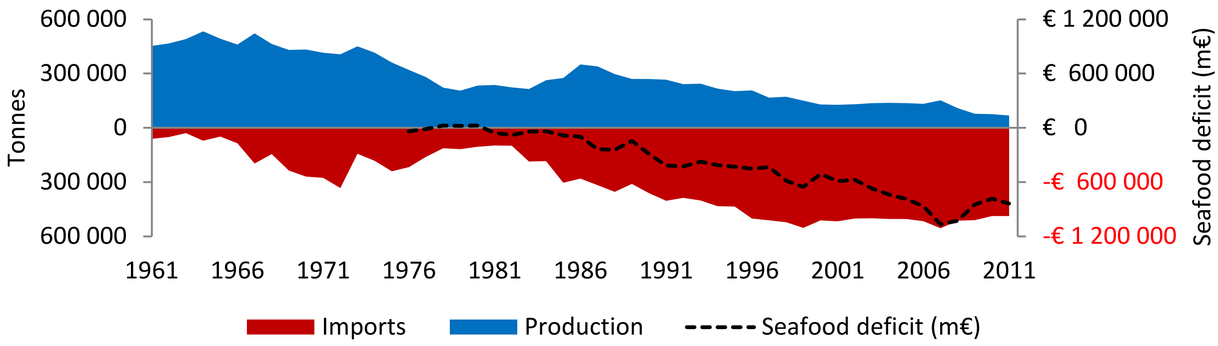


Figure 4. Evolution of the seafood products origin in Portugal (imports and production) from 1961 to 2011 (FAO, 2015), and impacts on seafood deficit in m€ between 1976 and 2011(FAOSTAT, 2015).

Despite the overall upward trend of Portugal's foreign fish dependency since 1976, the export value also increased, especially after 2002. The increase in value of both trade flows is partially caused by inflation, but the growth of exported and imported volumes (Figure 5) corroborates this upward tendency. Although reliant on external trade to meet consumer demand, the seafood sector in Portugal evolved. The processing industry, more notably the canning industry of tuna, sardine, and other small pelagic fishes, remained capable of adding value to wild caught and imported fish (FAO, 2015; FAOSTAT, 2015).

The Portuguese imports profile after 1976 (Figure 6 and Table 1) reflects the decrease in landings of certain fish species shown in Figure 2. The impact of the cod position on national diet is patent in its share of imports in either volume or value. Cod, despite not being an exploited species in Portuguese waters, has an important role in balancing the foreign fish deficit. In 2011 it is the most exported species in value, attesting the importance of the processing sector in the valorisation of these products (Dias et al., 2001). Other species have gained a more relevant role in the national seafood market during this period. Tuna imports and exports increased both in volume and value since 1976. Small pelagic fish such as sardine or mackerel, common in the Portuguese coast, constitute an important part of exports in volume—43% of the average tonnage—and value—28% of average worth (FAO, 2015). Sardine has experienced a reduction in production and exports since 2011, due to low stock biomass levels (ICES, 2015a). Since 2012, chub mackerel became the most produced and exported fish species in Portugal in volume (INE, 2015, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

Species diversity increase in the seafood market is also patent in import/export trade flows. The adaptive fisheries period referred by Almeida et al (2015) after 1986, was marked by a consumption increase of other species apart from fish, such as crustaceans, cephalopods and other molluscs. From 1976 to 2011 the weight of other fish species in relation to total seafood imports increased in volume and value. The taxonomy of exported species also became more diversified over the same time period in volume and value (Figure 6 and Table 1). This increase in the diversity of consumed seafood is patent not only through external trade but also production (Figure 2) (OCEANA, 2012).

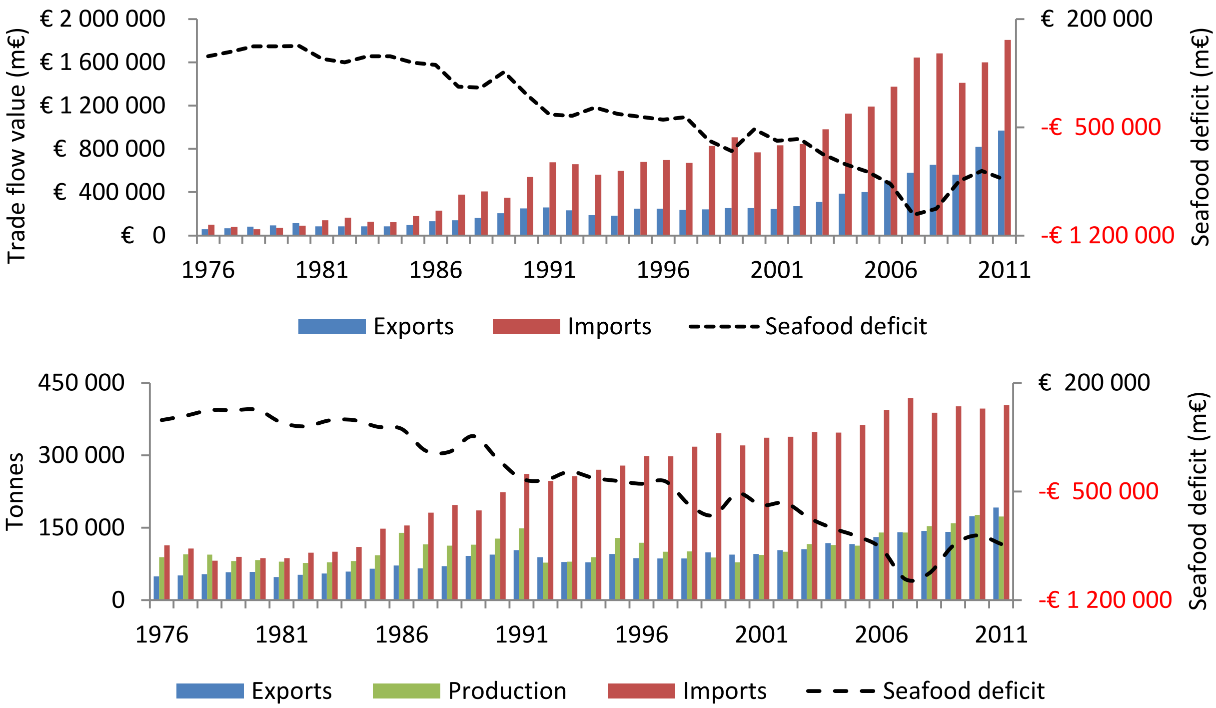


Figure 5. Evolution of the Portuguese seafood trade and foreign fish deficit (in m€) from 1976 to 2011 (top). Evolution of Portuguese imports, exports and seafood production in tonnes from 1976 to 2011. Evolution of the foreign fish deficit in m€ (bottom) (FAO, 2015; FAOSTAT, 2015).

Table 1. Most relevant imported and exported seafood products to Portugal in 1976 and 2011 (FAO, 2015).

Imports	1976				2011			
	Ton		m€		Ton		m€	
Cod	44.185	38.9%	65.138	66.4%	99.711	24.7%	525.948	29.1%
Sardine	3.737	3.3%	659	0.7%	13.331	3.3%	24.904	1.4%
Tunas	4.701	4.1%	2.715	2.8%	25.284	6.3%	93.203	5.2%
Hake	17.426	15.4%	9.041	9.2%	36.679	9.1%	138.493	7.7%
Jack and Horse mackerels	0	0.0%	-	0.0%	13.962	3.5%	25.140	1.4%
Other	43.460	38.3%	20.586	21.0%	214.899	53.2%	999.353	55.3%
Total	113.509	100.0%	98.139	100.0%	403.866	100.0%	1.807.042	100.0%

Exports	1976				2011			
	Ton		m€		Ton		m€	
Cod	1.453	3.0%	515	0.9%	17.904	9.4%	142.754	14.7%
Sardine	29.288	60.0%	33.740	58.3%	33.741	17.6%	104.765	10.8%
Tunas	1.685	3.5%	2.612	4.5%	11.531	6.0%	65.935	6.8%
Mackerel	3.054	6.3%	4.315	7.5%	28.336	14.8%	68.402	7.1%
Other	13.333	27.3%	16.677	28.8%	99.880	52.2%	586.448	60.6%
Total	48.813	100.0%	57.859	100.0%	191.392	100.0%	968.304	100.0%

Differences between each sector reflect the traded and, to some extent, the consumed species (Figure 7). Portugal's foreign fish dependency is clearer in certain sectors, with variable impact on the overall deficit depending on volume and value. Frozen fish has the highest contribution of all the sectors on both value and volume regarding the trade flow balance. Frozen fish is also the most imported and exported seafood in volume, however imports are more than double of the exported volume explaining the higher impact of this sector on the overall deficit (INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

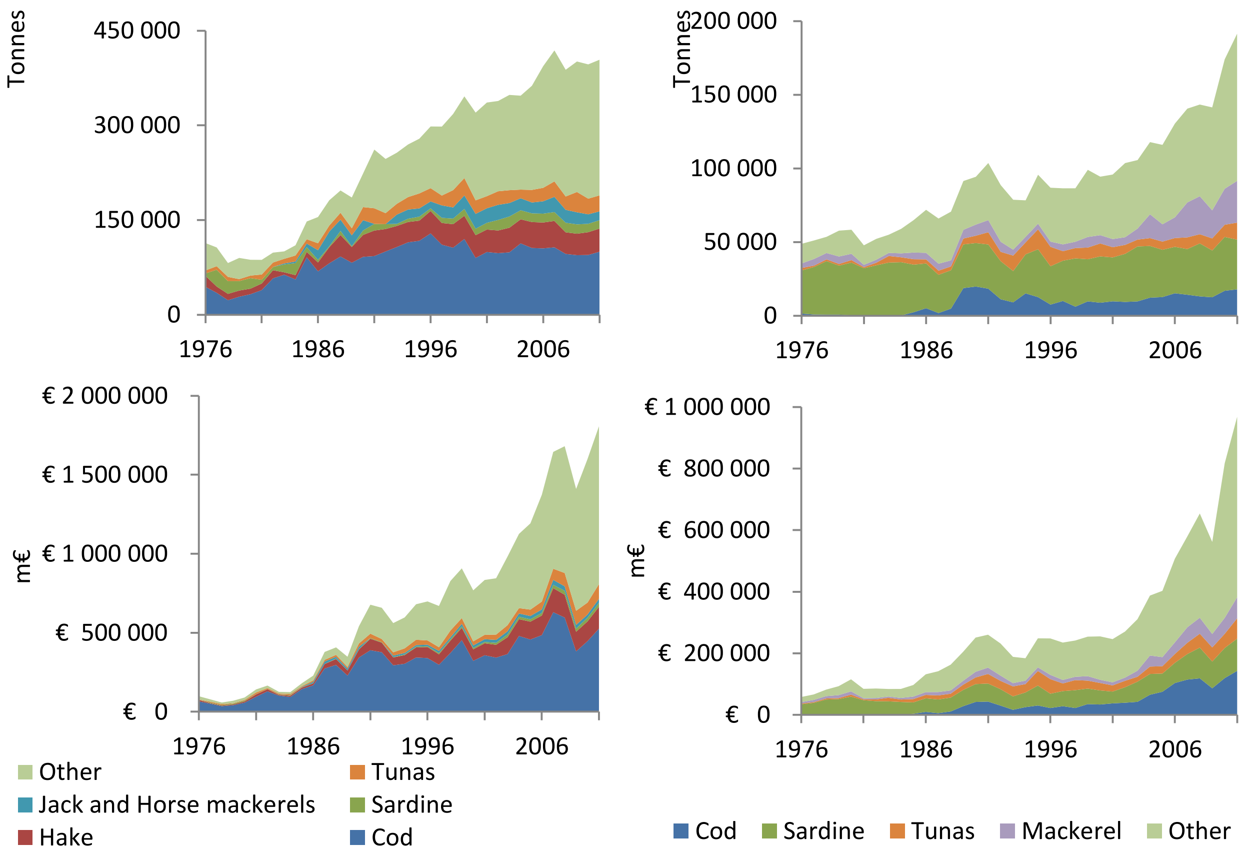


Figure 6. Portuguese seafood trade balances of the most important species between 1976 and 2011. Imports and exports in tonnage are represented in the top left and right panes respectively. Imports and exports in value (m€) are displayed in the left and right panes respectively (FAO, 2015).

The second most traded products are dry, smoked, and salted fish. In this sector the most important species is cod, explaining the high volumes and values involved due to its importance in Portuguese diet. Another factor that highlights this sector importance is the difference between the volumes shown in Figure 7 and the live weight, which is approximately three times the dry weight—1 kg of fresh cod corresponds to 0.233 kg of dried cod, and 0.333 kg of salted cod (INE, 2015). Canned fish—mainly of three species, sardine, tuna and chub mackerel—is the only sector with a positive balance in both volume and value. These positive values are more expressive in value than in volume, supporting the industry's historic know-how and capacity of adding value to seafood products (Duarte, 2004; INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

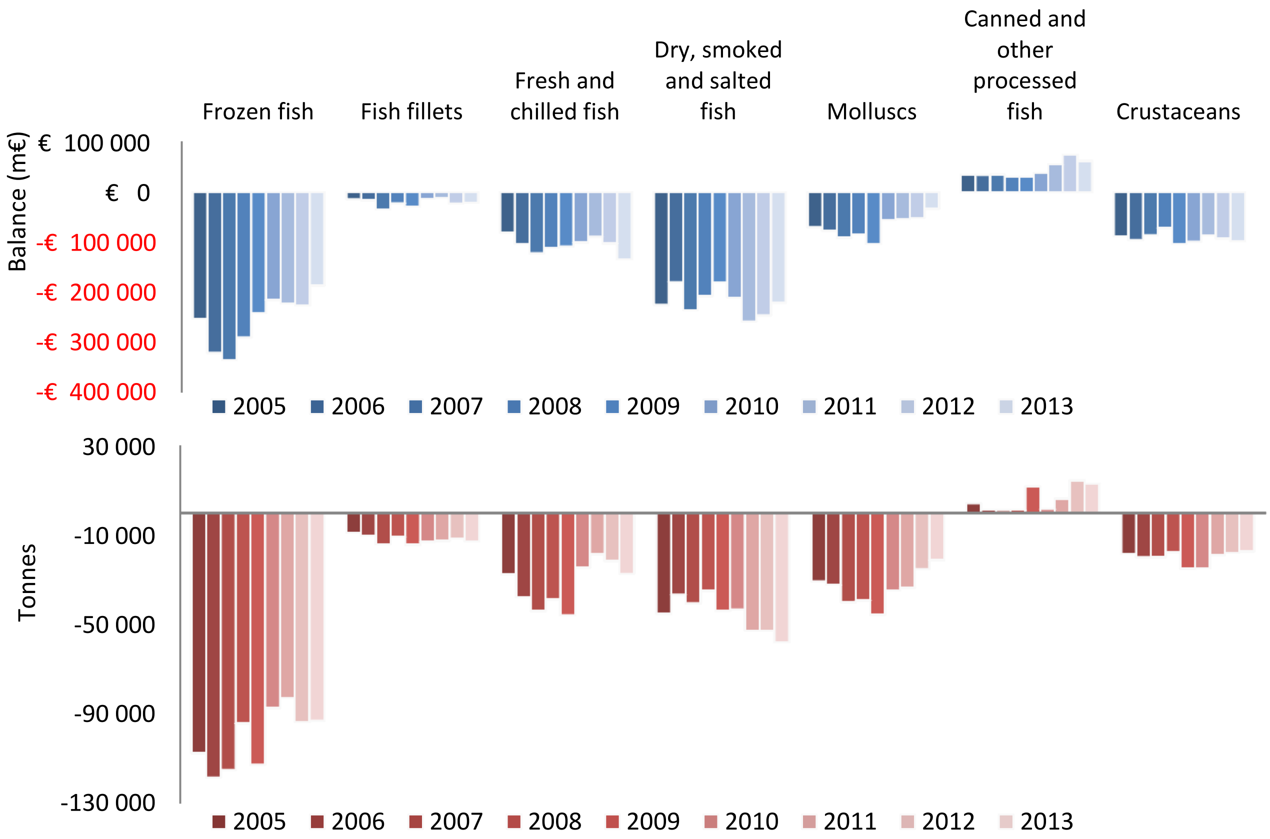


Figure 7. Balance of the external trade of seafood products in Portugal between 2005 and 2013. Negative values represent a deficit between imports and exports. Displayed data represent trade flows in value (top) and volume (bottom) (INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

2.1.2.1. Recent evolution of trade balance

Overall seafood deficit in both volume and value has decreased in recent years. From 2005 to 2013 the import/export ratio declined by 7.6%. Variation in traded values was slightly larger (9.4% reduction). These differences did not originate in the reduction of imports or increases in production, which increased and decreased respectively, but in the considerable growth of exports (INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

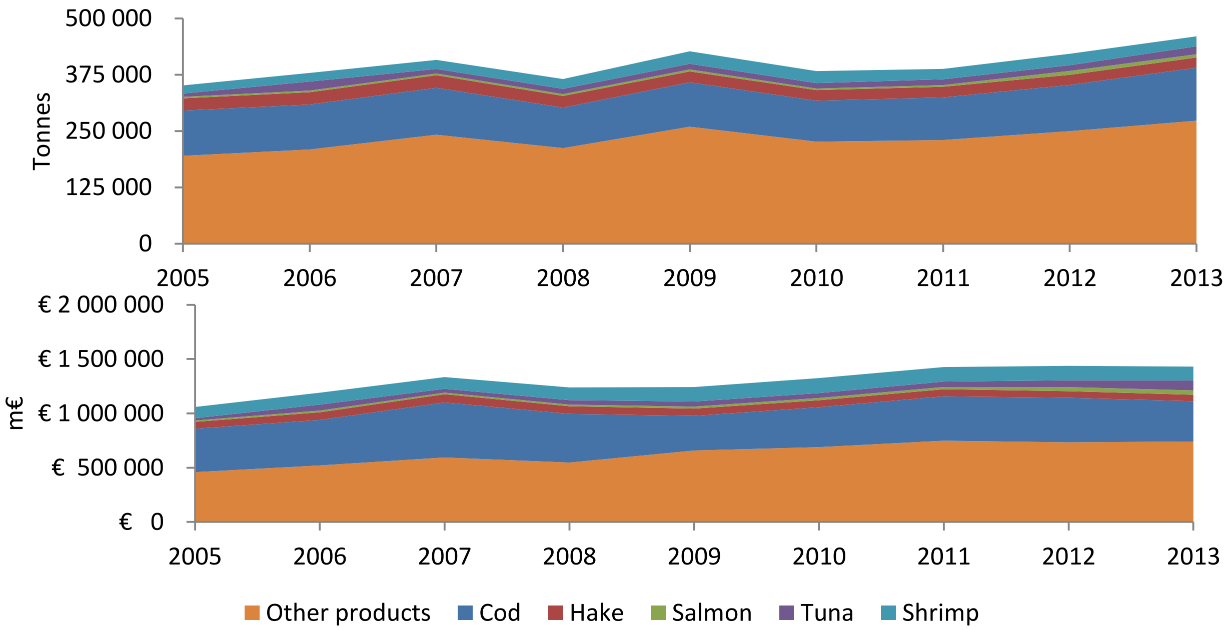


Figure 8. Most relevant seafood products imported between 2005 and 2013. Imports are displayed in volume per tonnes (top) and value per m€ (bottom) (INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

Total seafood imports to Portugal have increased recently. Between 2005 and 2013 an increase of 31.0% was registered from 351 344 tonnes to 460 261 tonnes. The variation in value was higher, and corresponded to a 35.1% increase (Figure 8). This increase was more expressive in salmon, tunas and other unidentified species.

Imports are topped by cod, accounting for 25.1% of imported volume and 31.2% of value on average, for the period between 2005 and 2013. The remaining species have considerably lesser volumes and values of imports. Hake (6.3%), shrimps (5.7%), tunas (3.3%) and salmon (1.2%) are the other relevant species in terms of volume. Despite the prominent role of cod, fish imports are varied, and other products represent 58.5% of imported tonnage and 53.7% of value on average (INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

Exports have increased considerably in both volume and value, more than doubling in recent years. Recorded growth of exports corresponds to an increase of 108.4% in tonnage, and 122.7% in value from 2005 to 2013 (Figure 9). Undifferentiated products are part of this development, with increases of 141.7% in volume and 151.5% in value. All products have grown in exported value, and in volume only sardine has decreased in this period, likely because of the reduced biomass levels and catch restrictions imposed (DGRM, 2012). Despite the reductions and considering the average exported volume from 2005 to 2013, sardine is still the most important species in exported volume (20.7%) and value (13.4%).

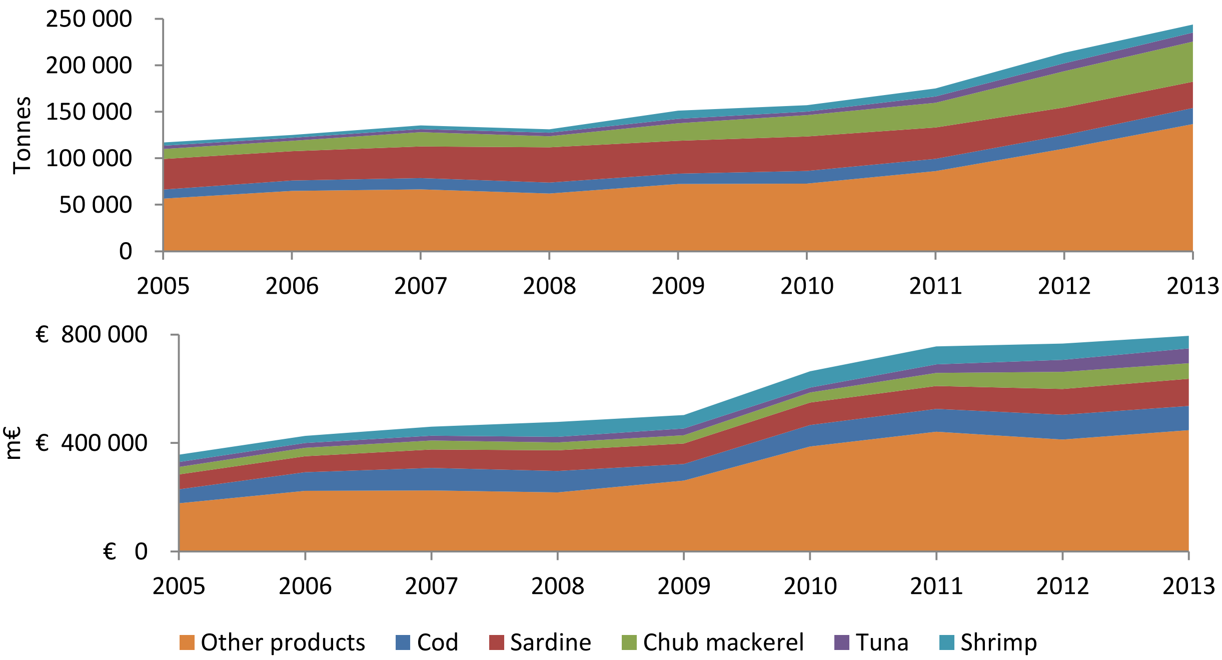


Figure 9. Most relevant seafood products exported between 2005 and 2013. Exports are displayed in volume per tonnes (top) and value per m€ (bottom) (INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

Chub mackerel is the product with the best growth rate in volume, growing by 302.4% for this period. Cod exports, which also increased, represent 13.2% in value and 7.9% in volume, making it the second most exported seafood product in tonnage (Figure 9).

2.1.3 Recent fisheries yields

Objectives and future plans for fisheries development in Portugal defend the long-term environmentally sustainable management of the sector, in order to contribute to food production while providing economic benefits (DGRM, 2014; MADRP, 2007; PCEU, 2013). The use of trawling and large-scale purse seining has not been permitted in the Azores region for some time (Gallagher et al., 2012), and the more recent regulation that limits the use of longlines and purse seine nets only for the capture of live fishing bait for use on board of licensed pole and line vessels in a vast area of the potential future Portuguese EEZ (Secretaria de Estado do Mar, 2014), both display a commitment for the reduction of the impacts of fishing on the marine environment. The fishing capacity of the national fleet is currently in balance with allocated opportunities and in compliance with the CFP objectives (EC, 2014a).

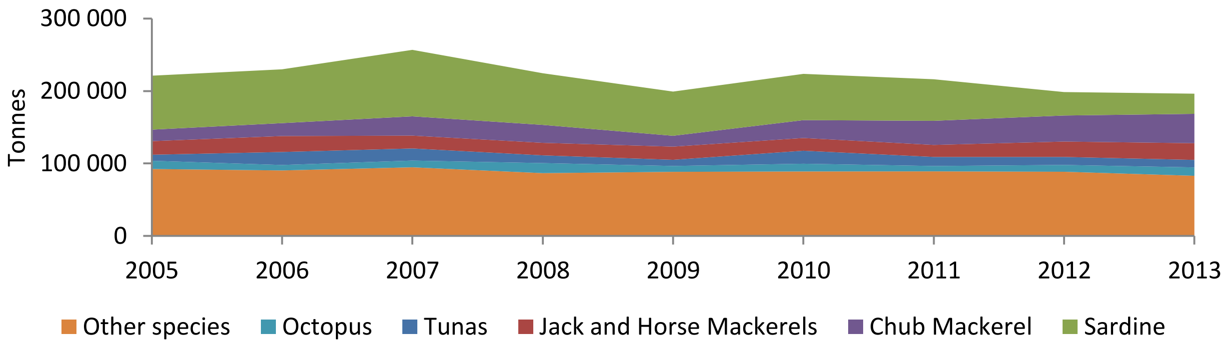


Figure 10. Catches of the most relevant seafood products by the Portuguese fleet between 2005 and 2013(FAO, 2015).

Fishing in Portugal between 2005 and 2013 has only decreased in volume, and remains somewhat constant regarding value. Yielded volume has decreased by 11%. Fisheries are highly diversified and composed by a vast number of species from different taxonomic groups (OCEANA, 2012). The most relevant species are small pelagic fish such as sardine or chub mackerel, common in Portuguese coastal waters. Octopus and other molluscs have also gained considerable importance in overall catches over the years (Almeida et al., 2015). Octopus represents 4.5% of total catches between 2005 and 2013. The high commercial value of this species and the valorisation and promotion campaigns developed for this product are likely to be significant factors for this increase (Figure 11 and Figure 10)(Docapesca, 2013; IPMA, 2013).

Sardine has historically been the cornerstone product of Portuguese coastal fisheries, however in 2012 and 2013 chub mackerel landings exceeded sardine. The sardine stock is subjected to a management plan from Portuguese and Spanish authorities (MADRP, 2010), and landings have declined more than 45 000 tonnes between 2005 and 2013 (Figure 10). The most recent ICES advice for 2016 recommends a catch limit of 1 587 tonnes (ICES, 2015b), which in real terms means the closure of this fishery. Both species are caught by purse seine fishing, and promotion campaigns for chub mackerel can also have an impact in the catch increase (DOCAPESCA, 2012). Jack and horse mackerels have also experienced a slight increase in catches, and the recent increase of the horse mackerel quota for 2015 is evidence of the good biomass levels for this species (EC, 2015; ICES, 2015a).

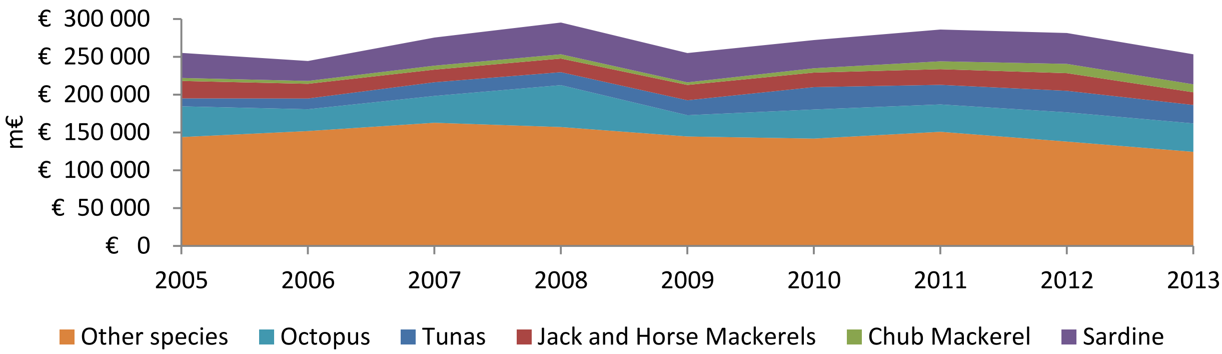


Figure 11. Value of landed fish in national ports between 2005 and 2013 (INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

The ICCAT is the competent organism in stock assessment and management of the vast majority of tuna fishing by Portuguese vessels. Portuguese catches are mostly composed of two species, skipjack (*Katsuwonus pelamis*) and bigeye tunas (*Thunnus obesus*) with 48% and 41% of total average catch (ICCAT, 2015, 2014). Tuna catches have remained somewhat constant, and correspond to 5.8% of total catch. The impact of the remaining species is considerable (41% on average) attesting to the multispecies profile of Portuguese fisheries (Figure 10)(Almeida et al., 2015).

Figure 11 and Figure 12 show the value and price variation for most important caught species over the period between 2005 and 2013. Octopus is the most important product, with 14.0% of overall average value. Chub mackerel catch is less relevant in value than volume, representing only 2.5%. The value of caught tuna has increased during this period, representing an average share of 7.8%.

Table 2. Average price and variation between 2005 and 2013, for most the important species landed by the Portuguese fleet (INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

Average price (€/kg) of landed species	**Price variation for the (2005—2013 period)**		**Overall average value for the 2005—2013 period (m€)**	
Octopus	3.91	-22.4%	37 716	14.0%
Tunas	1.82	37.2%	20 880	7.8%
Jack and Horse Mackerels	1.20	-38.6%	19 723	7.3%
Chub Mackerel	0.28	4.8%	6 765	2.5%
Sardine	0.81	119.0%	37 457	13.9%

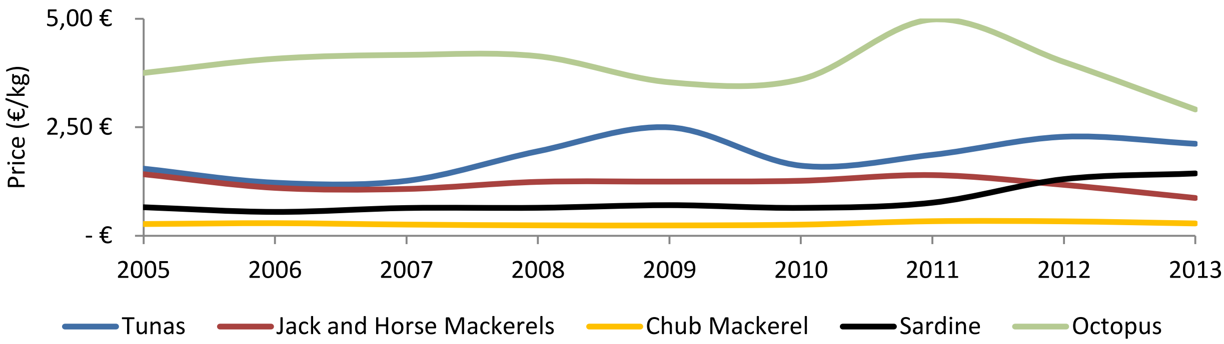


Figure 12. Price evolution of most important species of landed seafood by the Portuguese fleet (INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

Sardine total value has increased slightly, reflecting the scarcity of this species (ICES, 2015a), and motivating a rise in price. Sardine represents on average 13.9% of total value. The increase in jack and horse mackerel catches caused a decrease in value. The total percentual value of undifferentiated species for this period is 54.4%. The largest price increase registered was in sardine and tunas. Octopus, and jack and horse mackerel prices declined (Figure 11, Figure 12 and Table 2).

2.1.4 Fishing effort reduction and fleet evolution

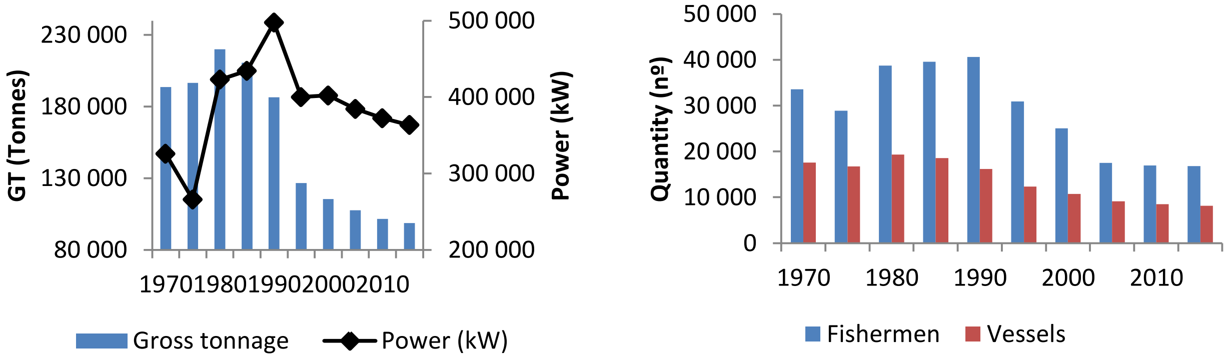


Figure 13. Evolution of the Portuguese fleet fishing capacity from 1970 to 2014. In the left—Gross tonnage and power (in kW) and in the right—number of fishermen and fishing vessels (INE, 2015).

The considerable drop in landings registered during the late 1970's and early 1980's was not accompanied immediately by a reduction in the number of vessels, which only declined after 1990. The number of fishermen registered a drop during the fishery crisis period (1972 to 1985), followed by a recovery to the previous pre-1970 values until 1990 (Leitão et al., 2014). In 1986 Portugal joined the EC and bound to the newly introduced Common Fisheries Policy (1983), the largest single management regime in the North Atlantic (Symes, 1997) to date. Since 1983 the EC developed a sequence of MAGP's (Multi-Annual Guidance Plans) with the objective of programming the evolution of the community's commercial fishing fleet. The goal of reducing fishing effort and capacity was achieved through a reduction in number of vessels, crew members, gross tonnage, and power of each country fishing fleet (Figure 13) (Perez-Labajos, 2012).

In the first period (1970—1990) only the gross tonnage and number of vessels had seen their quantity and numbers reduced, by 4% and 8% respectively. The number of licensed fishermen increased by 21% and the effort in fleet modernization was patent in the increase of 53% in power (kW), and a considerable reduction of the number of non-motorized vessels. After 1990, the overall reduction of the EU fishing fleet fishing capacity was carried out by all Member States. Portugal reduced the number of fishermen and vessels by 59% and 49% respectively, as well as the gross tonnage (47%) and power (27%) (INE, 2015; Villasante, 2010).

2.1.5 Impact of illegal, unreported and unregulated (IUU) catches

Fishing activities have direct and indirect impacts on both targeted and non-targeted marine species, and the lack of knowledge on the total fish removal from the oceans has been described as one of the main causes for the failure of marine management plans over the world. IUU fishing activities have a considerable impact on ecosystems and commercially exploited fish stocks, and undermine sustainability efforts to recover depleted stocks or to achieve a MSY status. Illegal fishing is very complex to assess, due to a total lack of reported data, such as fishing effort or catch volumes—consequently official fisheries statistics do not include such estimates. The lack of information about IUU catches and discards in fisheries statistics collected by countries leads to the under-reporting of total catch registered in global and regional fisheries organizations databases, such as FAO and ICES (Agnew et al., 2009; Coll et al., 2014; Diogo et al., 2016; Leitão et al., 2014). Unreported catches are often not considered in stock assessment however, and in order to develop sustainable and successful management plans based on an ecosystem approach, these should be taken into account. Knowledge of total fish removals can help understand the trophic effect of fisheries on the marine environment (Leitão et al., 2014).

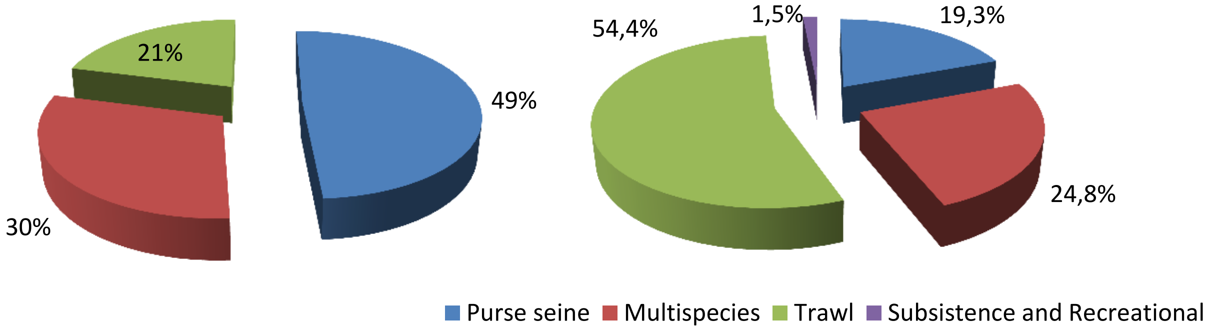


Figure 14. Official (left) and IUU (right) catches of the Portuguese coastal fishing fleet between 1938 and 2009, for each of the main fleet segments (Leitão et al., 2014).

Portugal meets some of the criteria that emphasize the importance of total catch underestimation, such as a highly differentiated fishing fleet, high seafood demand, or a reduced enforcement of fishery management (Coll et al., 2014). Average annual unreported catch for mainland fisheries is estimated at 123 000 tonnes which corresponds to approximately a third of the average reported catch. If all the commercial species from mainland catches had been used, nationally caught fish consumption *per capita* would rise from an average of 16 kg to 24 kg. Using the discarded commercial species would have covered seafood imports between 1969 and 1986, reducing the foreign fish deficit (Leitão et al., 2014).

Commercial fishing discards contribute the most to the total unreported catch in Portugal, and marketable species are among the more discarded or unreported. Sardine, chub mackerel, Atlantic horse mackerel, blue jack mackerel and hake are some of the most relevant species in the overall unreported catches according to Leitão et al (2014). These species are also some of the most relevant either in Portuguese consumption – case of the jack and horse mackerels, hake, and sardine (Cardoso et al., 2013) – or in foreign trade – for the chub mackerel (INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

2.1.6 Historic seafood consumption

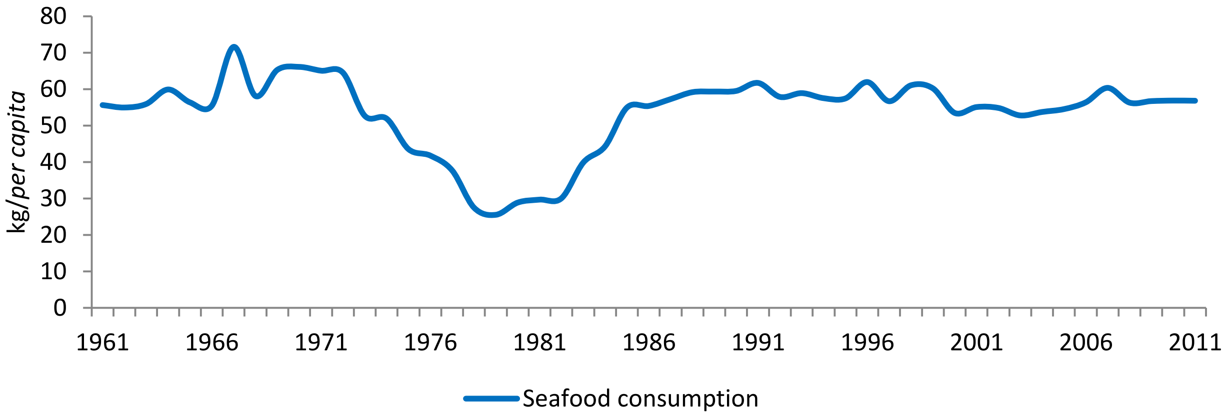


Figure 15. Evolution of the seafood consumption in Portugal between 1961 and 2011(FAOSTAT, 2015).

Portugal is the EU country with the highest seafood consumption *per capita*. With an average value of 53.5 kg between 1961 and 2011, seafood consumption has always been historically high (Figure 15). Only during ten years (1975 to 1984), after the 1974 revolution and throughout the fisheries crisis period, has the seafood consumption dropped below 50 kg/*per capita* (Almeida et al., 2015; FAOSTAT, 2015). Consumption values in Portugal are considerably higher when compared to the world average (20 kg *per capita*) and with the EU average (23.1 kg *per capita*) (EC, 2014b; FAO, 2016).

The causes for such elevated seafood consumption are several and the impacts of geography, resource availability, culture and politics have shaped the fish demand in Portugal (Almeida et al., 2015). In addition to these main drivers, other more personal factors also impact consumer opinions regarding their seafood choices, such as price, difficulty of preparation or health concerns (Carlucci et al., 2015). Gender and geography are as well aspects which determine consumption frequency and preferences (Cardoso et al., 2013).

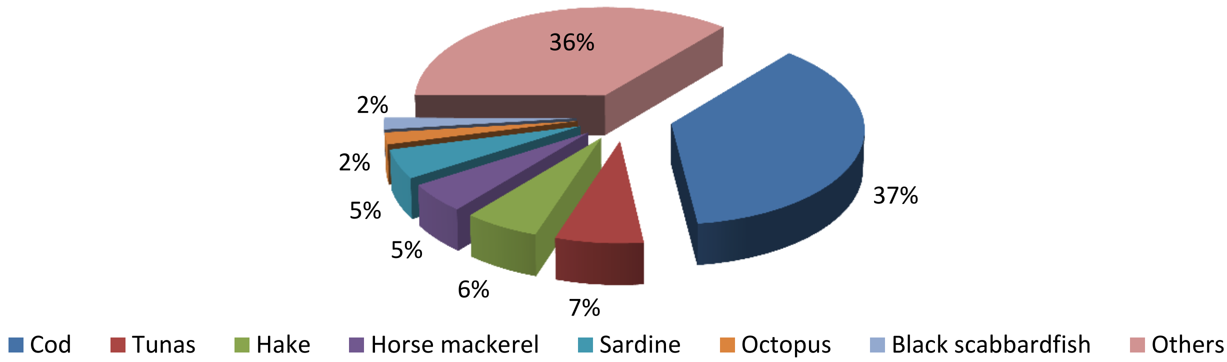


Figure 16. Portuguese household consumption of seafood in 2005, with the most important species (Almeida et al., 2015).

Cod and sardine are some of the products present in the Portuguese diet that illustrate these impacts. Despite the still considerable importance of these two species, the consumption of seafood in Portugal has diversified, especially since 1986. After entering the EC the Portuguese consumed less fish and more molluscs and crustaceans. This reflects the behaviour of catch and import tendencies (Figure 2 and Figure 6).

Seafood consumption is substantially concentrated in a small group of staple products, of which cod is the most relevant. “Soaked cod is an idiosyncratic Portuguese preference” (Cardoso et al., 2013). Reports of the exact volume consumed vary among studies, and it is difficult to estimate accurate values due to the different presentations in which this species is marketed. Despite these constraints it is widely assumed that cod is the most consumed seafood product in Portugal (Almeida et al., 2015; Dias et al., 2001; Willemsen, 2003).

Other staple products include tuna, sardine, hake, and horse mackerel which are predominantly found and consumed canned, fresh or chilled, and frozen. These species are mostly sourced via fishing or imports. The considerable penetration of farmed species, such as salmon and seabream, in the national diet highlights the diversification tendency that has been present since the mid-seventies. The increased importance of octopus or shrimps also shows this tendency to go beyond fish and to other *taxa* like molluscs or crustaceans. This is an opportunity that can be exploited by producers and distributors (Willemsen, 2003). Despite the impacts of culture, tradition and resource availability attested by the high consumption frequency of cod, sardine or horse mackerel (Figure 16), farmed fish products as salmon, seabass, or seabream have already penetrated the national diet. Other products such as crustaceans and molluscs have intermediate consumption frequencies and a relative importance, but also attest to the increasingly varied sea-based diet in Portugal (Almeida et al., 2015; Cardoso et al., 2013).

2.1.7 Aquaculture status in Portugal

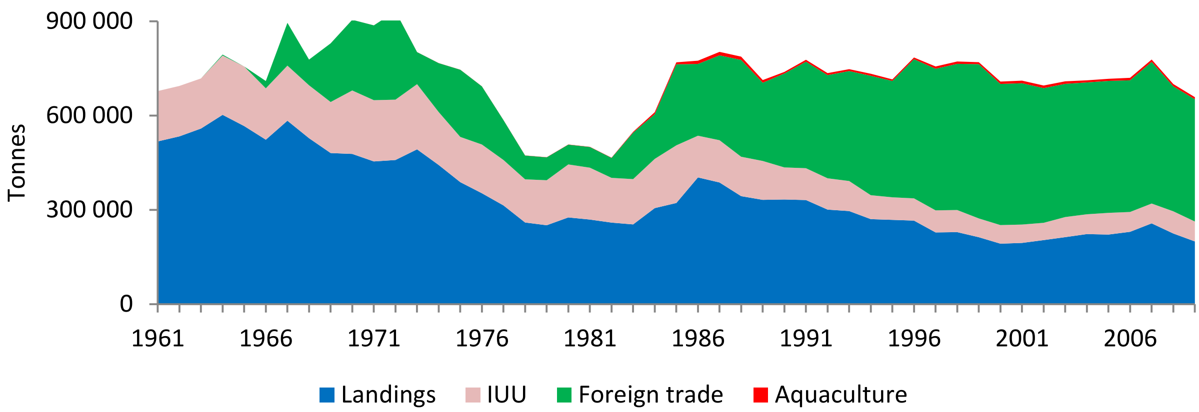


Figure 17. Source of seafood in Portugal from 1961 to 2009 (FAO, 2015; Leitão et al., 2014).

Geography, politics, market conditions, environmental constraints, and history pushed Portugal to search for alternative production solutions within its borders. According to official FAO data, aquaculture production in Portugal started in 1965 and rose above 10 000 tonnes in 1986. Despite this promising start, in 2009 Portuguese aquaculture only accounted for 1% of all available seafood and 3.3% of official production (Figure 17) (FAO, 2015). Notwithstanding favourable consumer-based market conditions, aquaculture development in Portugal has a number of constraints. These derive from its geographic location and natural conditions, corporate difficulties related to production associations, and access to hatcheries and nurseries for different species. Institutional and legal complications, mainly due to slow and complex licensing procedures and the large number of governmental institutions involved, have also been identified by responsible entities, and efforts are being made to simplify the licensing process (DGRM, 2014).

Realistic estimates for potential aquaculture growth are notoriously challenging to obtain. Nonetheless, projections show a clear increase in global aquaculture production (FAO, 2016, 2014), contrasting with the stagnation of wild fish catches (Campbell and Pauly, 2013; Gjedrem et al., 2012; Natale et al., 2013). This tendency is also patent in Portugal since the mid-1980's (Bjørndal et al., 2015). Even considering the many differences among countries, and based on a simplistic estimate of production per km of coastline, Portugal has a much smaller aquaculture sector when compared with other European countries (Table 3).

Table 3. Aquaculture average yield between 2005 and 2013 in European countries. Values in tonnes/km. Adapted from EC (2009a), Gjedrem et al (2012) and Maps of World (2015).

	Tonnes/km/year
Portugal	4.97
Spain	51.76
France	43.71
Ireland	28.88
Greece	8.45
United Kingdom	15.81
Italy	20.50
Norway	43.37

The potential for the development of innovative commercial endeavours remains. An example is the offshore IMTA park south of the Ria Formosa in the Algarve, one of the first for commercial use in Europe (Ferreira et al., 2014). Coastal and offshore solutions are also regarded as promising alternatives due to a growing demand for seafood (Ferreira et al., 2009). Despite that, the characteristics of the national coast are not very attractive for installation of offshore aquaculture (Kapetsky et al., 2013) which requires more advanced technological solutions in order to overcome the hydrological conditions (PCM, 2014). Such solutions are gradually emerging as an effect of cooperation between private and public sectors and aided by scientific research (Belton et al., 2004; CCMAR, 2015; Kaiser et al., 2010; Salmar, 2015).

2.1.6.1. Recent evolution of farmed species

Farmed species production has increased by 33% in Portugal. The farmed/wild ratio for total production has grown in value, from 11.9% to 17.5%, and in volume, from 2.9% to 4.3%, attesting to the valuable products provided by this industry. In Portugal, this seafood production sector is mostly concentrated in four products, which encompass over 70% of the average total of farmed species between 2005 and 2013 (Figure 18).

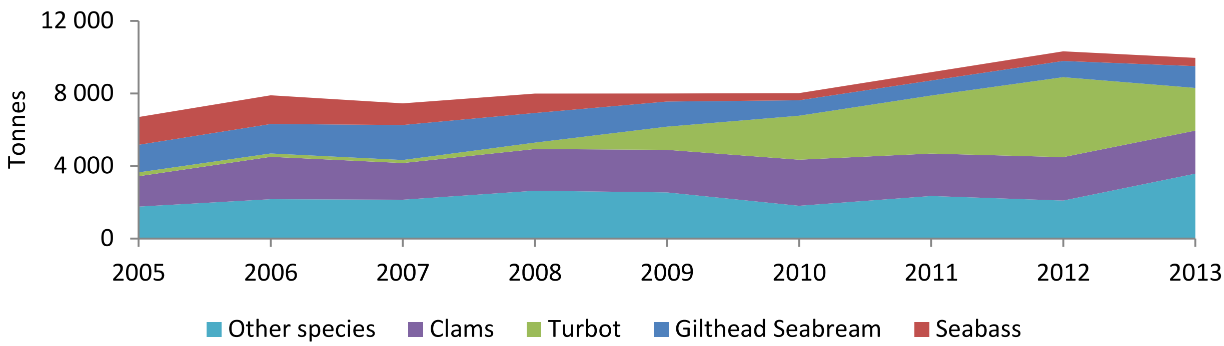


Figure 18. Production of the most important farmed species in Portugal (INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

Clam production, mainly of the *Venerupis decussata* species (grooved carpet shell) is the most important, with an average of 27% of the total between 2005 and 2013. Turbot production has recently increased, especially since 2009, from 4% to 16%. Two of the most important farmed products to consumers, gilthead seabream and seabass (Cardoso et al., 2013), have decreased their production in recent years. Seabream represented 23% (1 519 tonnes) in 2005 and in 2013 its quota of farmed products was 12% (1 201 tonnes). In seabass the reduction was more noticeable, from 1 530 tonnes (23%) to 455 tonnes, representing 5% of total aquaculture yield in 2013 (Figure 18) (INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

Total production value of farmed species has also grown by 56.0% in this period (Figure 19). Production is more concentrated in value than in volume, and the four most important species are responsible for 89.6% of value. Clam and turbot concentrate 64.5% of average value (DGRM, 2014). Similar to the growth in volume, farmed turbot is the product most responsible for this progression in value, which rose a substantial 705.7% from 2005 to 2013. The price of farmed turbot registered a decrease for this period. Clam yield in this period also grew by 83.7%, with a recorded average price of 9.13 €/kg. This species is responsible for 44.4% of total value, making it the most important product in value of all farmed species (Table 4 and Figure 20) (INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

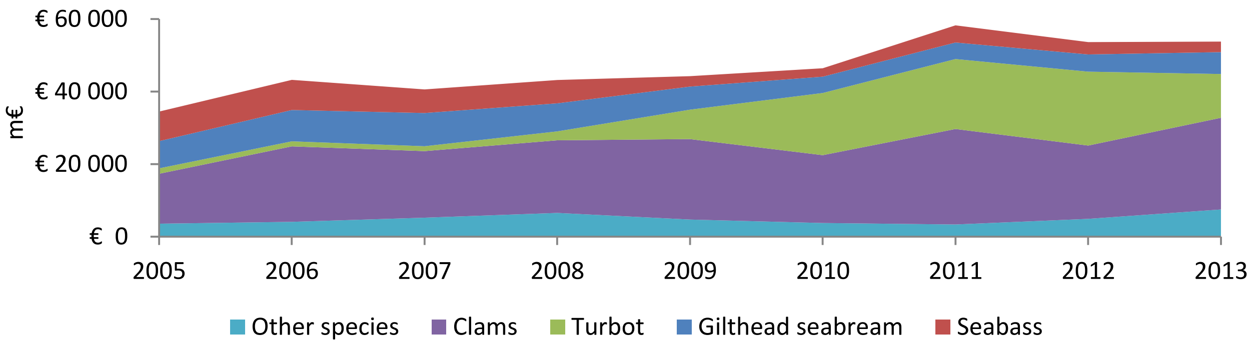


Figure 19. Value of aquaculture production in Portugal between 2005 and 2013, ordered by the most important farmed products (INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

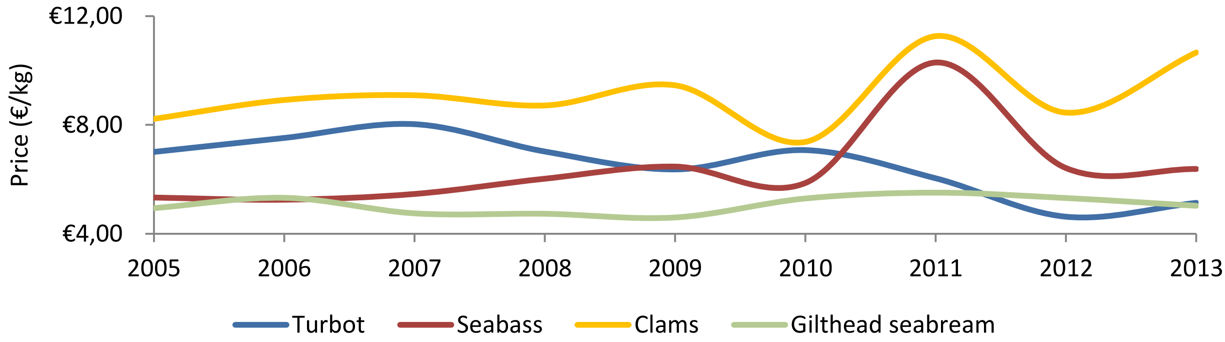


Figure 20. Price variation of the most important farmed species between 2005 and 2013 (INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

Conversely, gilthead seabream and seabass volume and value diminished. Seabass suffered the highest value reduction by 64.4%, while the production value of gilthead seabream decreased by 19.5%. Price variation of seabream was very small, with an average value of 5.05 €/kg. Seabass average value was 6.39 €/kg (Figure 20 and Table 4) (DGRM, 2014; INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

Table 4. Average price, price variation, and average overall value between 2005 and 2013, for the most important farmed species in Portugal (INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

Average price (€/kg) of farmed species		**Price variation for the (2005—2013 period)**	**Overall average value for the 2005 – 2013 period (m€)**	
Gilthead seabream	5.05	1.8%	6 584	14.2%
Turbot	6.53	-26.7%	9 300	20.0%
Seabass	6.39	19.7%	5 072	10.9%
Clams	9.13	29.7%	20 636	44.4%

3. Methodology

In order to understand the Portuguese seafood market, the identification of the most important products, consumed volumes, the ratios at which these are imported, exported, farmed and fished by means of regulated, subsistence or illegal fishing is essential. Although Portugal has a high seafood consumption value, information regarding consumed species is limited (Almeida et al., 2015), and the highly aggregated data makes it unmanageable to detach individual from aggregated chains in most cases (Rodgers et al., 2008). The currently available consumption data has limitations contingent to the methodology used to collect and process them. Food balance sheets tend to overestimate consumption, and questionnaires are dependent on the methodologies employed; however, a combination of the two can lead to more thorough and complete results (Almeida et al., 2015). Therefore, and given these constraints, this thesis proposes a new approach to the problem, using distinct data sources and literature from other authors in order to accomplish the required steps.

The methodology was divided into two parts. In the first part (Figure 21), key products are identified, as well as production sources—internal or foreign—defining the Portuguese seafood sector based on consumption volumes. In the second part, the products identified will be analysed, in order to determine which ones present a higher potential for production in Portugal.

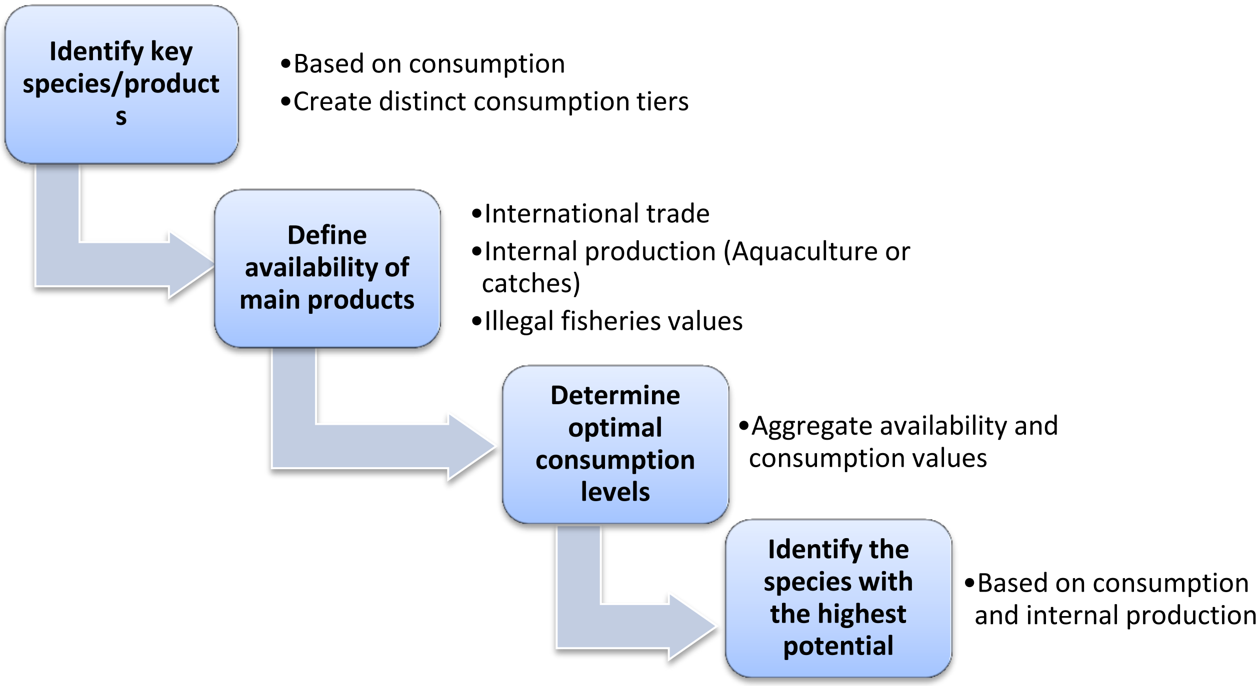


Figure 21. First section methodological scheme.

3.0.1. Data sources

No reliable single data source could be found combining all of the information required, while retaining the necessary level of detail, leading to the option of using different data sources for different sections of the work (Table 5).

Table 5. Data sources and main literature consulted for the achievement of the main objectives.

Consumption data	(Cardoso et al., 2013)	(INE, 2014b, 2013b, 2012b, 2011b, 2010b, 2009b, 2008b, 2007b, 2006b)	(FAO, 2015)
Availability data	(FAO, 2015)	(INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a)	
Illegal, unreported and unregulated fishing	(Leitão et al., 2014)	(Agnew et al., 2009)	

The use of different data sources for the same information has both advantages and disadvantages. In this case, the dissimilar time period of both data sets used for the availability values, as well as for a portion of the IUU values, narrowed the common time frame. Although this is not usually positive, in this work the negative impact is reduced due to the greater importance of average values for each product instead of the annual values.

3.1. Section 1 – From consumption to production

3.1.1. Consumption

No studies or data containing differentiated consumption per species could be found. In order to obtain annual consumption volumes and identify key seafood products to Portuguese consumers, surveys conducted by Cardoso et al (2013) were used to determine an approximate volume for the most important species consumed. The number of yearly/monthly/weekly meals of 23 different seafood products was obtained by means of surveys to 1083 valid respondents (Table 7). Considering the highly heterogeneous profile of available seafood in Portugal, in part due to the high number of wild caught species, the number of different seafood products in the questionnaires can be considered as low, therefore influencing the quality of the final results.

Table 6. Consumption *per capita*, and population for each year of the selected time period.

Year	Consumption (kg *per capita*)	Population
2005	53.5	10.570.000
2006	56.2	10.599.095
2007	61.4	10.617.575
2008	61.2	10.627.250
2009	61.1	10.637.713
2010	56.7	10.636.979
2011	56.8	10.541.840
2012	55.9	10.487.289
2013	55.0	10.427.301

Using these data, the daily consumption per inhabitant for each product was estimated regarding each year, based on yearly population (INE, 2014b, 2013b, 2012b, 2011b, 2010b, 2009b, 2008b, 2007b, 2006b) and yearly total consumption values of seafood in Portugal (Table 6) (FAO, 2015).

Table 7. Consumption frequency of the 23 selected products (Cardoso et al., 2013).

	Consumption frequency (%)				
	Annual	Monthly (number of meals)		Weekly (number of meals)	
Products/species	0	< 1	1 ≤ 4	2 ≤ 4	5 ≤ 7
Octopus	10.0%	55.9%	31.8%	1.8%	0.5%
Cod (soaked)	2.8%	13.8%	62.6%	18.8%	2.0%
Gilthead seabream	7.9%	37.1%	44.2%	10.2%	0.6%
Salmon	12.4%	30.3%	45.7%	10.2%	1.4%
Hake	9.9%	25.4%	45.0%	18.1%	1.6%
Sardine	16.7%	42.4%	32.0%	7.4%	1.5%
Horse mackerel	14.1%	42.6%	32.9%	9.0%	1.4%
Chub mackerel	58.5%	29.5%	9.3%	2.4%	0.3%
Canned tuna	5.5%	27.9%	45.8%	17.5%	3.3%
Canned sardine	43.9%	33.4%	17.1%	4.5%	1.1%
Black scabbard fish	32.9%	43.9%	19.6%	3.1%	0.5%
Squid	9.0%	53.5%	35.3%	1.8%	0.4%
Cuttlefish	20.8%	54.9%	22.7%	1.1%	0.5%
Shrimp	7.9%	57.7%	30.5%	3.6%	0.3%
Edible crab	34.6%	59.5%	4.9%	0.5%	0.5%
Common mussel	40.0%	52.1%	6.7%	0.9%	0.3%
Grooved carpet shell	21.7%	63.4%	13.4%	0.9%	0.6%
Seabass	13.9%	42.0%	36.8%	6.6%	0.7%
Panga	74.4%	16.3%	7.3%	1.4%	0.6%
Pink cusk-eel	37.0%	35.1%	22.8%	4.9%	0.2%
Redfish	44.0%	36.5%	15.7%	3.5%	0.3%
Perch	54.6%	30.5%	12.7%	1.6%	0.6%
Sole	35.2%	47.3%	14.5%	2.6%	0.4%

The *per capita* consumption value of seafood in Portugal, obtained on the FAO website(FAOSTAT, 2015), was used to calculate the amount consumed per day per year for each inhabitant. Assuming two daily meals, the amount of seafood consumed per meal was estimated (Equation 1). This approach was repeated for each year of the time period for the study (Table 8).

$$A = \frac{\left(\frac{B \times 1000}{365}\right)}{2} \qquad (1)$$

Where:

A - Seafood consumption per meal (grams)

B - Annual consumption of seafood (kg/*per capita*).

Table 8. Estimated daily and per meal consumption of seafood, based on yearly consumption volumes and population.

Year	Consumption (g)	
	Daily	*per* meal
2005	146.6	73.3
2006	154.0	77.0
2007	168.2	84.1
2008	167.7	83.8
2009	167.4	83.7
2010	155.3	77.7
2011	155.6	77.8
2012	153.2	76.6
2013	150.6	75.3

The consumption value per meal was then used to calculate the consumption for each product per person per year, based on the data available in the surveys for each time period – year, month and week, and according to the number of yearly meals – and for three different scenarios: minimum; medium and maximum consumption volumes. Given the quality of the surveys, and the intervals used in the original questionnaires to estimate the consumption frequency, average values were used in order to estimate the medium consumption level. For the minimum and maximum tiers, the lowest and highest number of meals respectively was used in order to obtain these values (Table 9). The values obtained for C_{min}, C_{med}, and C_{max} represent the *per capita* values of consumption for each product. These were then used to determine the total consumption for the 23 products, using population data (INE, 2014b, 2013b, 2012b, 2011b, 2010b, 2009b, 2008b, 2007b, 2006b) to match each year (Equation 2). This process was repeated for each consumption tier.

$$TC = \frac{C \times P}{1000} \tag{2}$$

Where:

C – Consumption level (C_{min}, C_{med} or C_{max}) (kg *per capita*)

P – Portuguese population for each year (number of inhabitants)

TC – Total yearly consumption of each product (TC_{min}, TC_{med} or TC_{max}) (tonnes/year).

Table 9. Equations used to calculate the consumption volumes for each product and ultimately identify the key products, using the work by Cardoso et al. (2013).

Consumption *per capita* for each product					
Minimum consumption level (C_{min})					
Number of yearly meals	0	0	12	104	260
$C_{min} = Y_{min} + M_{min1} + M_{min2} + W_{min1} + W_{min2}$	$Y_{min} = \frac{(0 \times A \times f)}{1000}$	$M_{min1} = \frac{(0 \times A \times f)}{1000}$	$M_{min2} = \frac{(12 \times A \times f)}{1000}$	$W_{min1} = \frac{(2 \times 52 \times A \times f)}{1000}$	$W_{min2} = \frac{(5 \times 52 \times A \times f)}{1000}$
Medium consumption level (C_{med})					
Number of yearly meals	0	6	30	156	312
$C_{med} = Y_{med} + M_{med1} + M_{med2} + W_{med1} + W_{med2}$	$Y_{med} = \frac{(0 \times A \times f)}{1000}$	$M_{med1} = \frac{\left(\frac{1}{2} \times 12 \times A \times f\right)}{1000}$	$M_{med2} = \frac{\left(\frac{5}{2} \times 12 \times A \times f\right)}{1000}$	$W_{med1} = \frac{(3 \times 52 \times A \times f)}{1000}$	$W_{med2} = \frac{(6 \times 52 \times A \times f)}{1000}$
Maximum consumption level (C_{max})					
Number of yearly meals	0	12	48	208	364
$C_{max} = Y_{max} + M_{max1} + M_{max2} + W_{max1} + W_{max2}$	$Y_{max} = \frac{(0 \times A \times f)}{1000}$	$M_{max1} = \frac{(12 \times A \times f)}{1000}$	$M_{max2} = \frac{(4 \times 12 \times A \times f)}{1000}$	$W_{max1} = \frac{(4 \times 52 \times A \times f)}{1000}$	$W_{max2} = \frac{(7 \times 52 \times A \times f)}{1000}$

Where:

A - Seafood consumption per meal (g/meal)

f – Frequency of consumption for each product (%).

Table 10. Average estimated consumption volumes for the 2005—2013 period for the three calculated tiers.

	Minimum consumption			Medium consumption			Maximum consumption		
Product	**Tonnes/year**	**Kg *per capita***	**%**	**Tonnes/year**	**Kg *per capita***	**%**	**Tonnes/year**	**Kg *per capita***	**%**
Total	218 139	20.67	100.0%	421 947	39.99	100.0%	625 755	59.30	100.0%
Cod (soaked)	26 886	2.55	12.3%	45 979	4.36	10.9%	65 072	6.17	10.4%
Canned tuna	26 896	2.55	12.3%	44 174	4.19	10.5%	61 452	5.82	9.8%
Hake	23 653	2.24	10.8%	40 209	3.81	9.5%	56 766	5.38	9.1%
Salmon	16 443	1.56	7.5%	29 839	2.83	7.1%	43 236	4.10	6.9%
Gilthead seabream	14 560	1.38	6.7%	27 725	2.63	6.6%	40 889	3.88	6.5%
Horse mackerel	14 123	1.34	6.5%	25 695	2.44	6.1%	37 266	3.53	6.0%
Sardine	12 863	1.22	5.9%	23 640	2.24	5.6%	34 416	3.26	5.5%
Seabass	10 916	1.03	5.0%	21 700	2.06	5.1%	32 483	3.08	5.2%
Shrimp	6 820	0.65	3.1%	15 970	1.51	3.8%	25 120	2.38	4.0%
Squid	5 957	0.56	2.7%	14 880	1.41	3.5%	23 803	2.26	3.8%
Octopus	5 823	0.55	2.7%	14 385	1.36	3.4%	22 946	2.17	3.7%
Pink cusk-eel	6 960	0.66	3.2%	14 345	1.36	3.4%	21 730	2.06	3.5%
Canned sardine	7 993	0.76	3.7%	14 655	1.39	3.5%	21 316	2.02	3.4%
Black scabbard fish	5 730	0.54	2.6%	12 425	1.18	2.9%	19 120	1.81	3.1%
Cuttlefish	4 307	0.41	2.0%	11 150	1.06	2.6%	17 993	1.71	2.9%
Redfish	5 253	0.50	2.4%	11 080	1.05	2.6%	16 906	1.60	2.7%
Sole	4 570	0.43	2.1%	10 410	0.99	2.5%	16 250	1.54	2.6%
Grooved carpet shell	3 420	0.32	1.6%	9 250	0.88	2.2%	15 080	1.43	2.4%
Perch	3 957	0.37	1.8%	8 340	0.79	2.0%	12 723	1.21	2.0%
Chub mackerel	3 660	0.35	1.7%	7 700	0.73	1.8%	11 740	1.11	1.9%
Common mussel	2 100	0.20	1.0%	6 230	0.59	1.5%	10 360	0.98	1.7%
Edible crab	2 007	0.19	0.9%	6 150	0.58	1.5%	10 293	0.98	1.6%
Panga (Vietnamese catfish)	3 243	0.31	1.5%	6 020	0.57	1.4%	8 797	0.83	1.4%

Average values of TC for the selected period (2005 – 2014) were calculated for each consumption level. Sardine and canned sardine products were grouped together, since they represent the same species. The resulting 22 products were then sorted by consumption volume in order to determine the key products. The items selected as key products corresponded to a consumption of at least 5% of the total calculated, in each of the three levels. The 5% limit was selected mainly because this percentage represented a consumption of at least 10 000 tonnes per year and a 1.03 kg *per capita* consumption for the lowest level. Below the 5% consumption level, calculated volumes decrease substantially (Table 10).

3.1.2. Availability

In order to compare calculated consumption volumes with the equivalent availability of the selected seafood products for the Portuguese consumer market, two different data sources were used for internal production and external trade origins: FAO (FAO, 2015) and the yearly fisheries statistics from the Portuguese Statistics Institute (INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a). For the IUU data, the work developed by Leitão et al (2014), and the data available in Agnew et al (2009), were used to estimate conventional values for non-regulated fishing activities.

3.1.2.1. Internal production

For the internally produced species, and for both the INE and FAO documents, the available data already had the detailed products and origin (aquaculture or capture fisheries) for the selected time period and for each of the key products. Data were arranged for the selected time interval according to data source, production origin (aquaculture or fisheries) and species.

3.1.2.2. IUU catches and discards

Official catch statistics do not contain estimates of illegal fishing or discards. In order to estimate a volume for each product, data from previous studies were used. Agnew et al (2009) suggested a volume between 1% and 10% of illegal fishing for tuna species worldwide. An average of this value (5.5%) was applied to tuna catches for both the INE and FAO data. Regarding the other internally fished key products, Leitão et al (2014) calculated discard volumes for several species, for different gear types and on a long time period (1938 to 2009), for the Portuguese continental coast. The discard volume for each species was correlated with the total estimates of discarded volumes. The total discard volumes for the period between 2009 and 2014 were estimated based on pre-2009 volumes, since these were not available in the work by Leitão et al (2014). For each species an associated discard volume was calculated for the 2005 – 2014 period.

Internal production for each key species was calculated using the IUU, catches and aquaculture data from both data sources.

3.1.2.3. Foreign trade

Seafood volumes of external origin for each key species were calculated using data from the INE documents and the FAO website (FAO, 2015; INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2007b).

3.1.3. Total availability

The availability of each key product was calculated using internal production and international trade volumes from both data sources. The total availability for each key species was calculated according to Eq. 3.

$$Availability = \Big[\big[[catches + IUU] + aquaculture\big] + Imports\Big] - Exports \qquad (3)$$

3.1.4. Aggregate availability and consumption data

In order to determine an **Optimal Consumption Level** (OCL), closer to reality, calculated consumption for the each of the 3 tiers was crossed with availability data. For each data source and for each key product, the OCL was determined by the lowest difference between the calculated consumption level (C_{min}, C_{med}, or C_{max}) and the availability (Table 11).

Table 11. Availability and OCL volumes (tonnes) estimated for each of the data sources. The determined OCL level is also included.

	INE		Selected	FAO		Selected
Product	Availability	OCL	**OCL tier**	Availability	OCL	**OCL tier**
Cod	95 989	65.072	**Maximum**	90 993	66.024	**Maximum**
Hake	33 404	36.471	**Medium**	42 546	40.797	**Medium**
Sardine	34 214	34.601		56 590	48.699	**Maximum**
Horse Mackerel	23 480	25.695		43 661	37.811	
European seabass	1 530	10.916	**Minimum**	4 701	11.076	**Minimum**
Gilthead seabream	1 643	14.560		7 923	14.773	
Salmon	3 805	16.443		5 898	16.683	
Tuna	20 522	26.896		31 905	32.093	

Based on the established consumption level, it was possible to determine the percentage of consumed seafood with partial or total national origin; the species 100% from a foreign source; the ratio between wild and farmed production of species with a national origin; and the impact of IUU values for each species. The ratio between availability and OCL was also calculated in order to identify the satisfaction level for each product.

This allowed the identification of the key species of national origin, as well as the most common production source. Adjusted consumption provided a starting point to define the growth potential for Portuguese aquaculture and fishing sectors, ultimately based on market and consumer demand.

3.2. Section 2 – Growth potential

The OCL volumes obtained in the first section provided a straightforward “supply and demand” basis for defining the fishing and aquaculture growth potential. The availability source identification of each key species provided an approach to sort these products.

In order to analyse each case according to its characteristics, two different classification systems were created. The first catalogues the availability according to its internal or external origin (Table 12). The second sorts the products according to the satisfied consumption level, based on the estimated OCL (Table 13).

Table 12. Species classified by its most important origin, import or internal production (Classification method developed by the author).

Type	Classification (description)	Conditions
A	Exclusively imported	100% external origin
B	Mainly imported	≥ 75% external origin
C	Mixed	25% > 75% of internal origin
D	Mainly internal production (aquaculture/fisheries)	≥ 75% internal origin
E	Exclusively internal production (aquaculture/fisheries)	100% internal origin

Table 13. Key product classification regarding the satisfaction of calculated consumption volumes (OCL) (Classification method developed by the author).

Type	Conditions/description	
V	≥ 100%	
IV	75% < 100%	
III	50 ≤ 75%	OCL satisfied
II	25% < 50%	
I	≤ 25%	

The classification of each key product regarding its origin (internal or external), and calculated consumption, allowed for a more bespoke approach to determine which species display the highest potential for a production increase, based on consumer demand and origin. These opportunities are divided into four main categories, which can be applied separately or jointly: product valorisation; IUU control and mitigation; biological stock status improvement and farmed fish production.

4. Results

4.1. From consumption to production

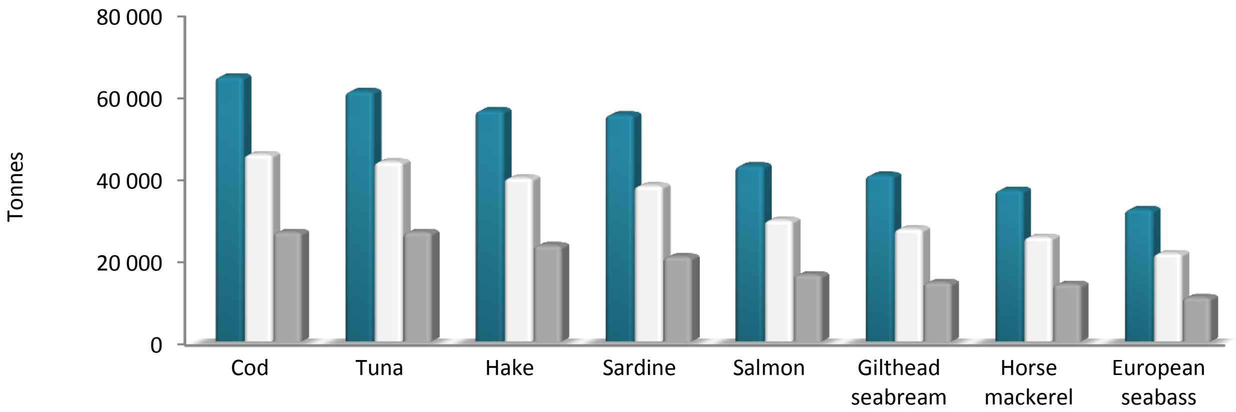
4.1.1. Consumption volumes and identification of key species

Total consumption and identified key species volumes are shown in Table 14. When considering total availability volumes, the calculated consumption tier with the highest correlation with official values is the maximum level.

Table 14. Volumes for each consumption tier defined for total seafood and key species identified. The official availability volumes (IUU estimates included) are also displayed.

Availability volumes (Tonnes)		Consumption tiers	Total	Key species	
			Tonnes		%
FAO	INE	Minimum	216 284	153 021	70.8%
543 216	556 358	Medium	418 359	271 288	64.8%
		Maximum	620 434	389 555	62.8%

The calculated consumption volumes for the most important seafood products in the Portuguese consumer market are presented in Figure 22. The cumulative consumption of the key eight species displays lower volumes in the maximum tier, which can be interpreted as a more varied diet for the biggest seafood consumers. Cod represents the most consumed seafood product in Portugal, comprising over 10% of the total average volume, and a *per capita* consumption between 2.53 kg and 6.11 kg. Despite the surveys used to calculate consumption only referring to soaked cod, the data obtained revealed the highest consumption volumes (Table 15).



	Cod	Tuna	Hake	Sardine	Salmon	Gilthead seabream	Horse mackerel	European seabass
Maximum	64519	60930	56283	55258	42868	40542	36949	32207
Medium	45588	43799	39867	37969	29586	27489	25476	21515
Minimum	26658	26667	23452	20679	16303	14436	14003	10824

Figure 22. Calculated levels of consumption and the eight key products identified for the Portuguese seafood

Average consumption of tuna is higher than cod in the lowest level, and *per capita* volumes also reveal similar consumptions. Similarly to cod, the surveys also only referred to canned tuna. The calculated consumption volumes of salmon, gilthead seabream and European seabass reveal the considerable dissemination of farmed fish products, of both internal and external origin (Figure 22 and Table 15).

Table 15. *Per capita* consumption volumes and impact of each key species to total calculated consumption.

Species	C_{min}		C_{med}		C_{max}	
	Kg *per capita*		Kg *per capita*		Kg *per capita*	
Cod	2.53	12.3%	4.32	10.9%	6.11	10.4%
Tuna	2.53	12.3%	4.15	10.5%	5.77	9.8%
Hake	2.22	10.8%	3.78	9.5%	5.33	9.1%
Sardine	1.96	9.6%	3.60	9.1%	5.24	8.9%
Salmon	1.55	7.5%	2.80	7.1%	4.06	6.9%
Gilthead seabream	1.37	6.7%	2.61	6.6%	3.84	6.5%
Horse mackerel	1.33	6.5%	2.41	6.1%	3.50	6.0%
European seabass	1.03	5.0%	2.04	5.1%	3.05	5.2%
Other species	4.79	29.2%	11.04	35.2%	17.28	37.2%
Total	20.50	100%	39.65	100%	58.80	100%

4.1.2. Consumption-availability aggregate and optimal consumption level

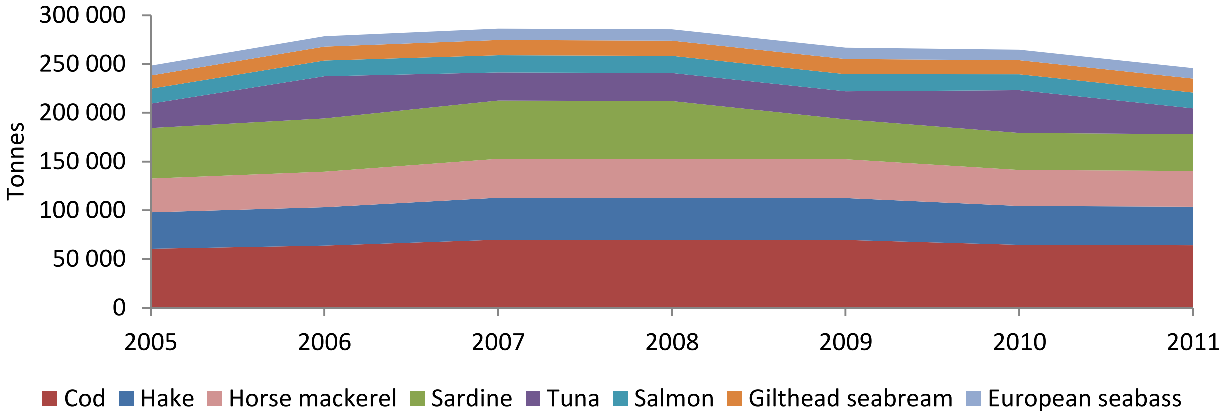


Figure 23. Calculated optimal levels of consumption using the FAO data.

The OCL, allowing for a more accurate quantification of demand, is presented in Figure 23, using the volumes from FAO as the availability data. The OCL volume for each of the key species corresponds to the calculated consumption tier closest to the availability. The average total key species OCL volume for this time period was of 267 956 tonnes, and an overall reduction on key species OCL values was mainly driven by the sardine decline.

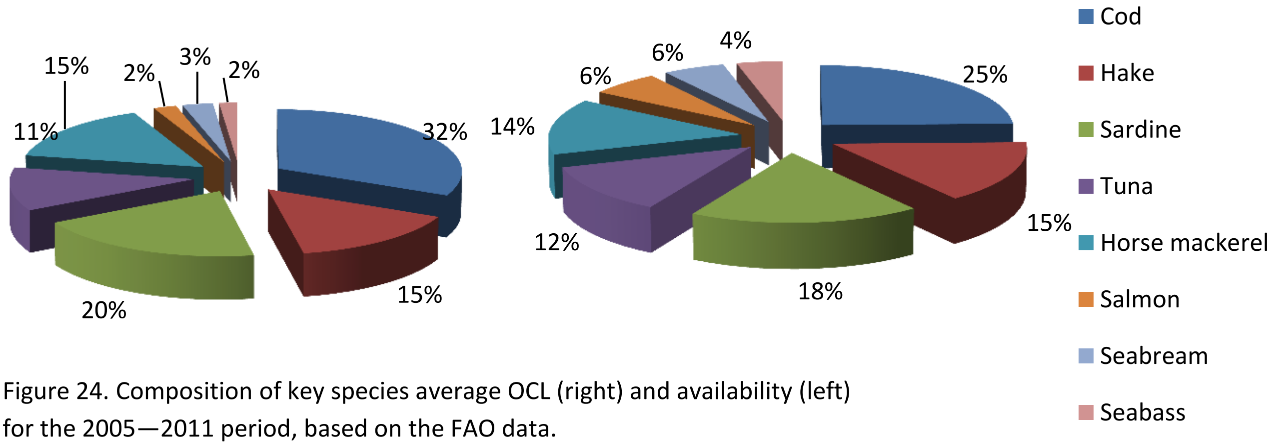


Figure 24. Composition of key species average OCL (right) and availability (left) for the 2005—2011 period, based on the FAO data.

Of all the key products (Figure 23), three display the highest consumption level: cod, sardine and horse mackerel (Figure 27, Figure 33, Figure 36 (a)). Cod availability greatly surpasses the highest consumption tier with an average of 90 993 tonnes to 65 944 tonnes of calculated consumption. Despite being an important part of Portuguese fisheries, sardine consumption shows signs of decline. In part, this is caused by an availability reduction, as a response to the limits imposed by the Iberian management plan for this species. Hake (Figure 34 (a)) is the only species situated at the intermediate level of consumption. The remaining four species have the lowest OCL level for the entire time period: salmon, gilthead seabream, European seabass and tuna (Figure 32, Figure 38 Figure 37 and Figure 35 (a)). Differences between the average availability volumes and calculated OCL are more significant in cod, salmon, seabream and seabass (Figure 24).

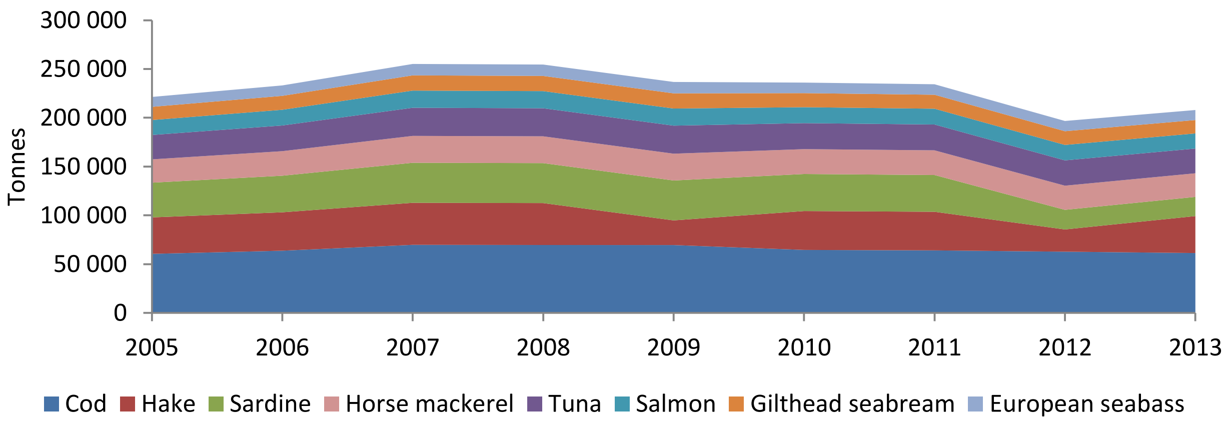


Figure 25. Calculated optimal levels of consumption using the INE data.

The OCL based on the INE data is presented in Figure 25. The average OCL volume is of 230 654 tonnes between 2005 and 2013. Cod (Figure 27 (b)) is the only species with the maximum consumption level registered for the entire time period. Hake, sardine and horse mackerel (Figure 34, Figure 36 and Figure 33 (b)) are all at the medium consumption tier and, similarly with the FAO data, the remaining four species (tuna, salmon, gilthead seabream and European seabass (Figure 32, Figure 38 Figure 37 and Figure 35 (b))) are all in the lowest OCL level.

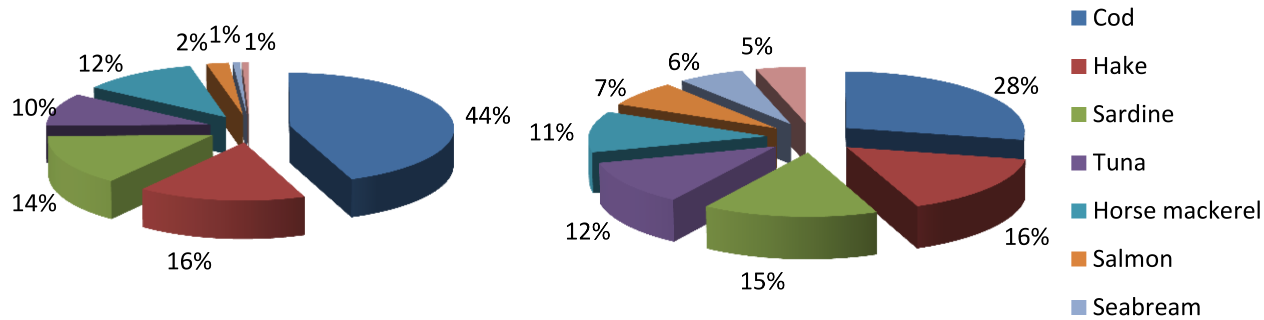


Figure 26. Composition of key species average OCL (right) and availability (left) for the 2005—2013 period, based on the INE data.

As in the FAO data, the largest differences between OCL and availability are more pronounced in cod, salmon, seabass and seabream (Figure 26).

4.1.3. Optimal Consumption Level per species

Table 16. OCL satisfied per species and source in volume (tonnes) and percentage. Data based on the FAO data set. Total volume displayed corresponds to the estimated OCL for each species.

	Optimal Consumption Level satisfied (% and tonnes)									
	External		**Internal**						**Total**	
	Foreign trade		**IUU**		**Production**					
					Aquaculture		**Fisheries**			
Cod	129.9%	85 765	0.0%	0	0.0%	0	8.1%	5 348	138.0%	66 024
Hake	84.5%	34 474	13.8%	5 630	0.0%	0	6.2%	2 529	104.5%	40 797
Tuna	53.5%	17 170	2.4%	770	0.0%	0	43.4%	13 928	99.3%	32 093
Sardine	0.0%	0	9.7%	4 724	0.0%	0	106.0%	51 621	115.7%	48 699
Horse mackerel	45.3%	17 128	21.9%	8 281	0.0%	0	48.4%	18 300	115.6%	37 811
Salmon	35.4%	5 906	0.0%	0	0.0%	0	0.0%	0	35.4%	16 683
Gilthead seabream	42.4%	6 264	0.3%	44	9.6%	1 418	1.4%	207	53.7%	14 773
European seabass	28.6%	3 168	0.5%	55	8.6%	953	4.8%	532	42.5%	11 076
Key species	56.4%	151 063	7.3%	19 508	0.9%	2 369	41.5%	111 277	106.1%	267 956

Table 16 displays the OCL of the eight key species identified, as well as the satisfaction level based on the availability data from the FAO source. Regarding overall volumes of key species, OCL is overly met (106.1%). Overall volumes also reflect the importance of externally sourced seafood in supplying consumer demand. Only one species (sardine) demand is completely met by nationally sourced seafood. By contrast, salmon is a 100% foreign product. Three species present OCL satisfaction levels below 75%: salmon, seabream and seabass. Seabream and seabass are nationally farmed products, and this source is the most important national origin for these two products. IUU volumes are more expressive in horse mackerel and hake, and in the first case IUU is responsible for over a fifth of OCL satisfaction.

Table 17. OCL satisfied per species and source in volume (tonnes) and percentage. Data based on the INE data set. Total volume displayed corresponds to the OCL estimated for each species.

	Optimal Consumption Level satisfied (% and tonnes)									
	External		Internal							
	Foreign trade		IUU		Production				Total	
					Aquaculture		Fisheries			
Cod	133.9%	87 132	0.0%	0	0.0%	0	6.2%	4 034	140.1%	65 072
Hake	68.4%	24 946	15.4%	5 616	0.0%	0	6.1%	2 225	89.9%	36 471
Tuna	28.7%	7 719	2.4%	646	0.0%	0	43.7%	11 754	74.8%	26 896
Sardine	0.0%	0	13.7%	4 740	0.0%	0	73.4%	25 397	87.1%	34 601
Horse mackerel	0.0%	0	32.2%	8 274	0.0%	0	62.5%	16 059	94.7%	25 695
Salmon	28.8%	4 736	0.0%	0	0.0%	0	0.0%	0	28.8%	16 443
Gilthead seabream	0.0%	0	0.4%	58	9.1%	1 325	1.4%	204	10.9%	14 560
European seabass	0.0%	0	0.5%	55	7.8%	851	4.7%	513	13.0%	10 916
Key species	43.3%	99 971	8.4%	19 375	0.9%	2 170	36.8%	84 800	89.4%	230 654

Optimal consumption based on the INE data (Table 17) is somewhat different from the FAO based values. In a number of species such as cod, hake, salmon and sardine, the tendencies are similar. National catches of tuna have a higher impact than in the FAO data.

Horse mackerel, gilthead seabream and European seabass foreign trade values are absent from official data. This is the main reason for these differences. Overall OCL values also present a high impact from externally sourced seafood. OCL is only totally met for one species (cod).

4.1.4. Impacts of presentation over consumption and availability - Cod

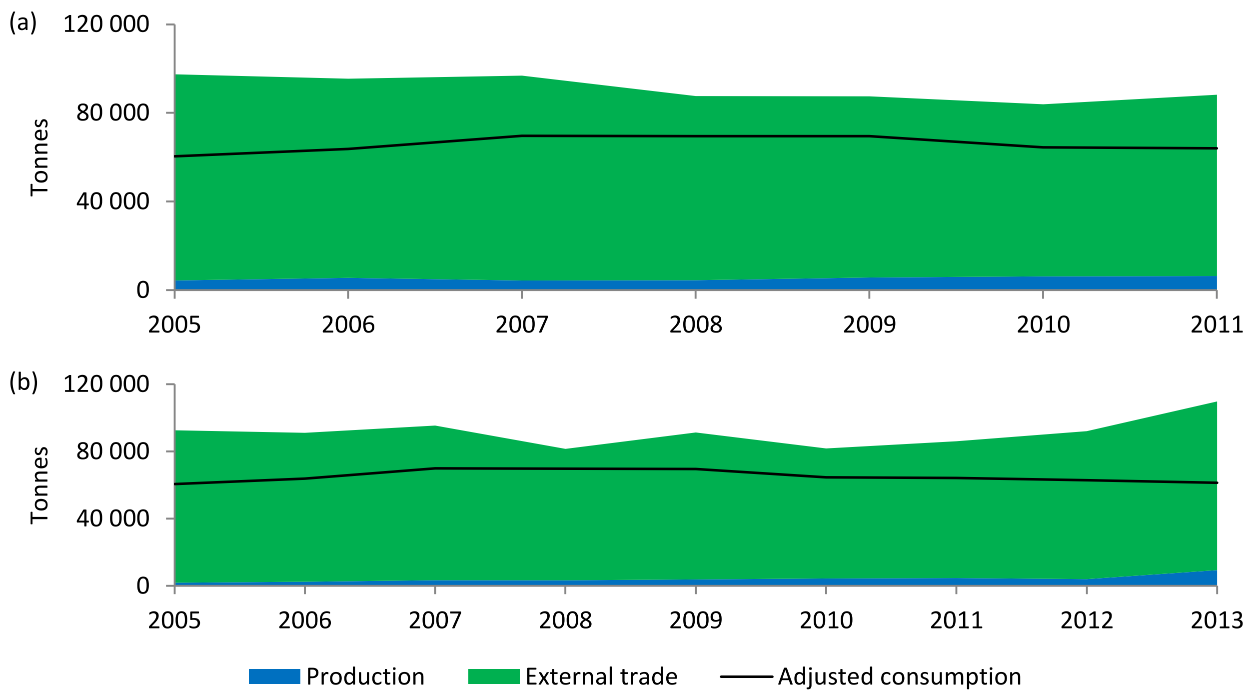


Figure 27. Cod total accumulated availability, origin and OCL according the FAO (a) and INE (b) data.

The product with the highest difference between estimated OCL and availability is cod (Figure 27). Despite being the most consumed seafood product, it is difficult to precisely estimate the *per capita* consumption of this species, in part due to the various presentations in which this product is imported, stored and distributed. In Figure 29 the difference between the uncorrected and corrected volumes is patent. When using the coefficients for live weight, and considering the different presentations—frozen (0.7), salted (0.4), dried (0.2) or other (1.0) (Johansen, personal communication; 2016)—the most common form is dried cod with 37%, instead of frozen cod, which in the previously untreated data represented more than half of total availability. The largest differences are in the dried and frozen forms.

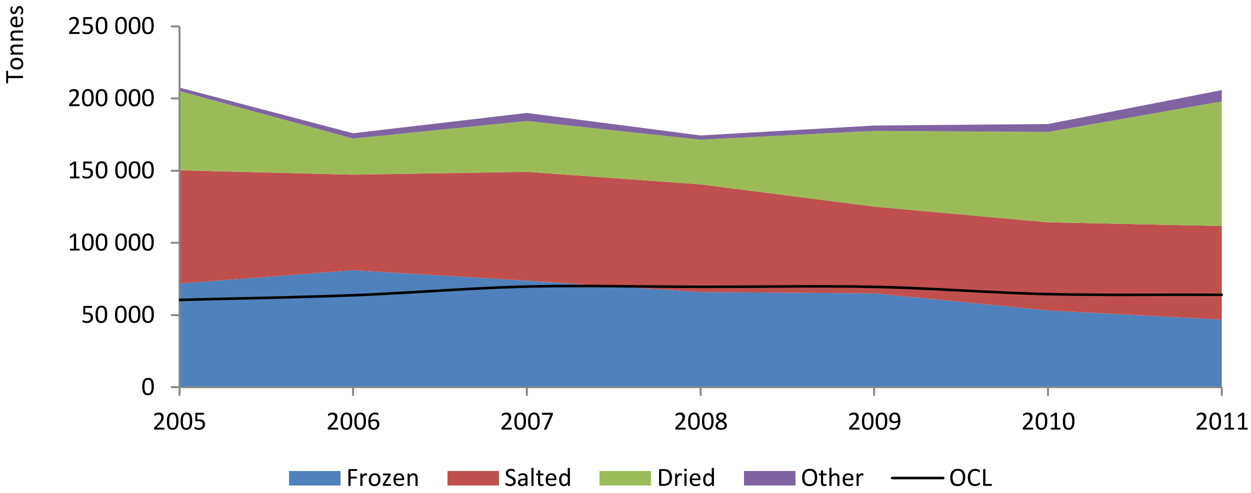


Figure 28. Corrected volumes for total cod availability and estimated consumption, using FAO data.

Total cod availability, using the corrected volumes, increased considerably from 90 993 tonnes to an average of 188 179 tonnes, for the 2005 – 2011 period (Figure 28), which corresponds to an even greater difference between the estimated OCL (66 024 tonnes) and total availability, corresponding to a satisfaction level of 285% for the FAO data. These differences have an impact over total *per capita* consumption of seafood, which increases from 58.1 kg to 72.8 kg between 2005 and 2011. The calculated cod consumption for this period is 17.75 kg *per capita*.

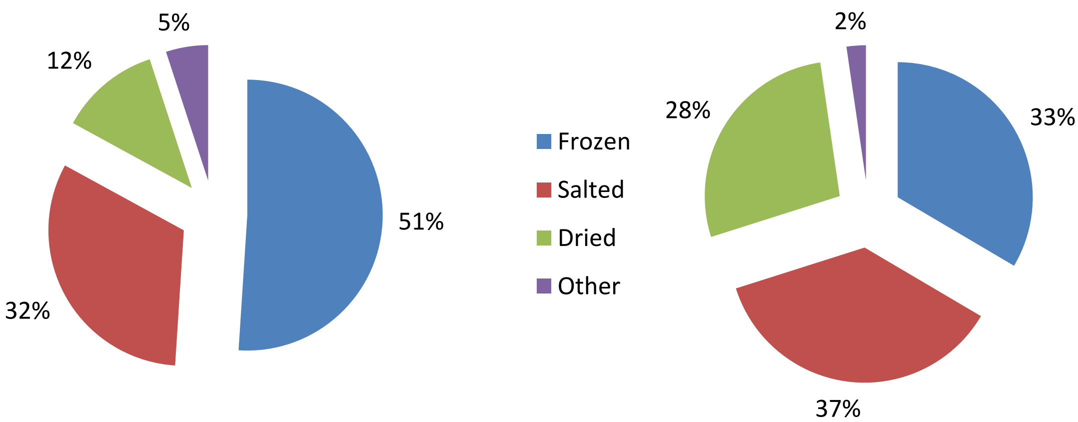


Figure 29. Uncorrected (left) and corrected to live weight (right) average cod availability between 2004 and 2011.

When applying the coefficients to the estimated cod OCL, and according to the availability of each product, OCL increases to 10.0 kg *per capita*, which emphasizes the importance of presentation, and reduces the difference between estimated OCL and the uncorrected availability. Frozen and salted cod are the most commonly consumed products with 3.3 and 3.7 kg *per capita* respectively (Table 18). The corrected OCL tonnage for cod stands at an average of 105 785 tonnes.

Table 18. *Per capita c*od consumption averages between 2005 and 2011. Recalculated using live weight coefficients: frozen (0.7); dried (0.2); salted (0.4) (Johansen, personal communication; 2016).

kg *per capita*	**OCL**		**Official consumption data (FAO)**	
	Uncorrected	Corrected	Uncorrected	Corrected
Frozen	2.3	3.3	8.1	11.5
Dried	0.6	2.8	1.9	9.5
Salted	1.5	3.7	5.1	12.6
Other	0.2	0.2	0.8	0.8
Total	6.2	**10.0**	21.5	**34.5**

When analysing the previously available cod consumption data (37% of total consumption), the consumed volumes are higher than the OCL volumes, corresponding to a *per capita* consumption of 21.5 kg. Using the corrected volumes, with the available coefficients, consumption increased by 38% to a total of 34.5 kg *per capita* (Table 18).

The impact of cod in the Portuguese diet, as well as its different presentations, is significant, and in order to analyse the seafood sector, it is important to understand the historical evolution of cod availability in Portugal. In the early of the 1900's, most of the available cod was imported. After the beginning of the 'cod campaign' during the *Estado Novo* (Salazar regime), domestic production surpassed 50% in 1945. Despite this, imported cod still played a major role in supplying the national market, and in 1970, imports once again represented the majority of the available cod in Portugal (56%). Since then imports maintained their role as the most important source of cod. The relevance of presentation in the total availability is noticeable, especially the importance of salted and dried cod after 1982. Frozen cod has also entered the market in 1990, and has been increasing in importance. Despite this, in 2011 frozen cod (20%) was the third most important presentation, after dried (42%) and salted cod (35%) (Figure 28, Figure 30).

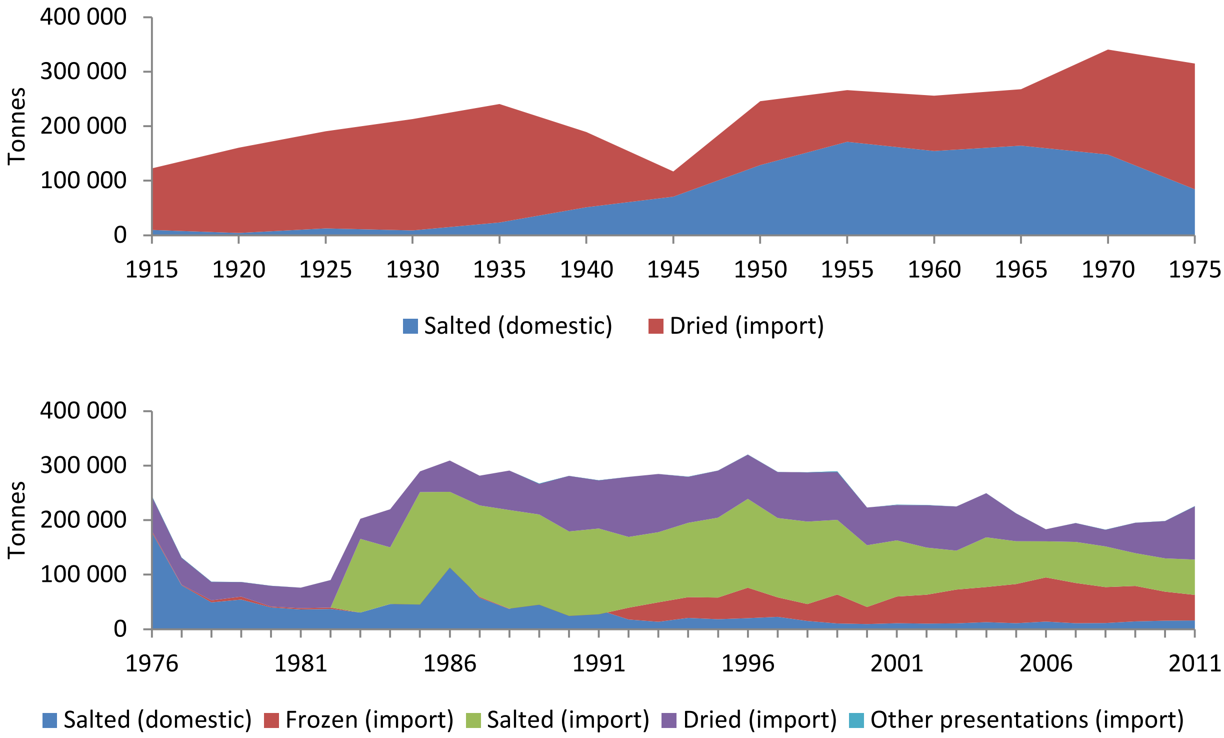


Figure 30. Historical cod availability in Portugal from 1915 to 2011 (corrected tonnage, using previous coefficients – frozen (0.7); salted (0.4); dried (0.2); other (1.0)) (Johansen, personal communication, 2016; adapted from: Cole, 1990; FAO, 2015).

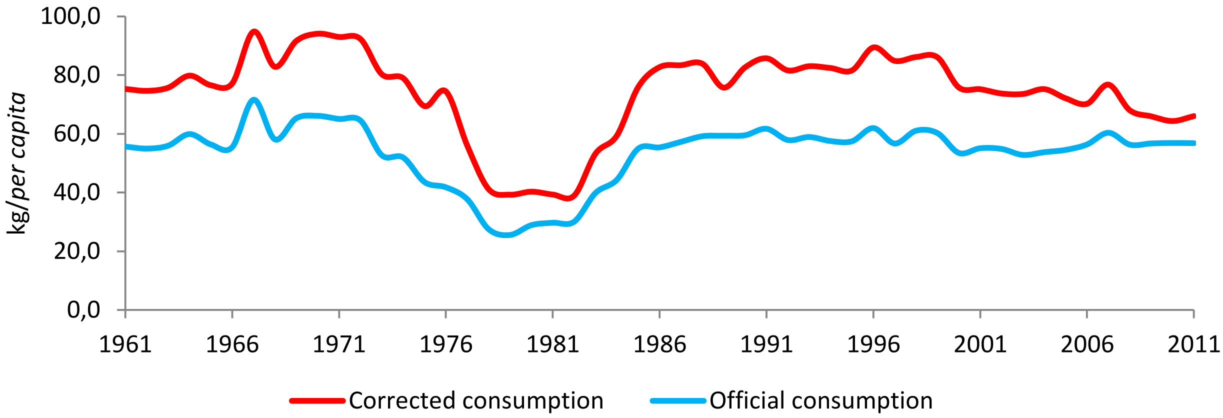


Figure 31. Historical aquatic products consumption in Portugal, from 1961 to 2011.

The influence of presentation over *per capita* consumption volumes is shown in Figure 31. Historical seafood consumption increased from an average of 53.5 to 74.1 kg *per capita* between 1961 and 2011. Using the corrected cod volumes, the maximum value of consumed seafood registered is of 94.8 kg *per capita* in 1967. The lowest consumption volumes registered were between 1977 and 1984, during the fisheries crisis period. Throughout this period *per capita* consumption dropped below 60 kg, and the lowest volume was of 39.8 kg in 1982.

4.1.5. Product-specific analysis

4.1.5.1. Tuna

Canned tuna consumption is at the lowest tier on both data sets. Average consumption is 31 121 tonnes from FAO data and 26 896 tonnes using INE data (Figure 32).

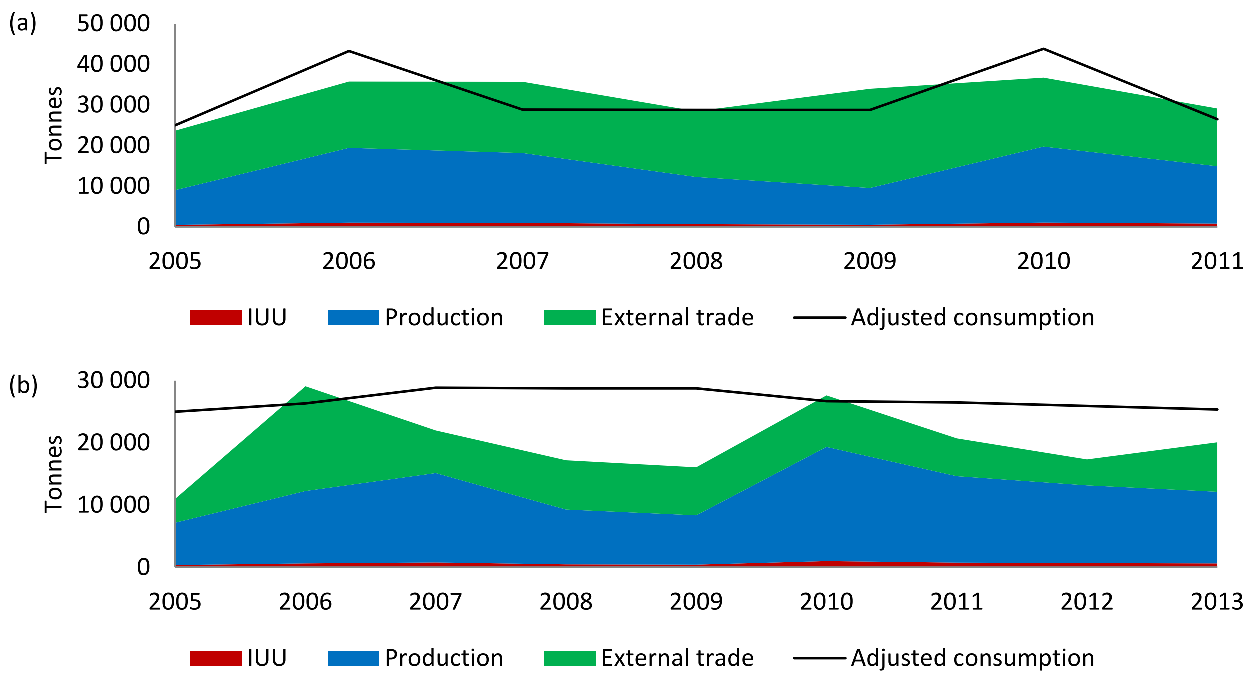


Figure 32. Total accumulated availability of tuna species, discriminated by origin. Values displayed represent FAO (a) and INE (b) data sources. OCL estimates are also included.

In both data sets the IUU impact is very small, especially when compared to other products, like horse mackerel or hake. 90% of production originates in the Azores and Madeira, and uses mostly hook-and-line fishing methods. It is dominated by two species, skipjack (*Katsuwonus pelamis*) and Bigeye tuna (*Thunnus obesus*) with 48.7% and 35.2% of catches respectively. Canned tuna is considered a staple seafood product—nevertheless most of the canned tuna found in large stores and supermarkets in Portugal do not refer the species.

4.1.5.2. Horse mackerel

Horse mackerel OCL (Figure 33) stands at the highest tier, for the FAO data set with an average of 37 765 tonnes, and at the intermediate level for the INE values, with an average of 25 695 tonnes.

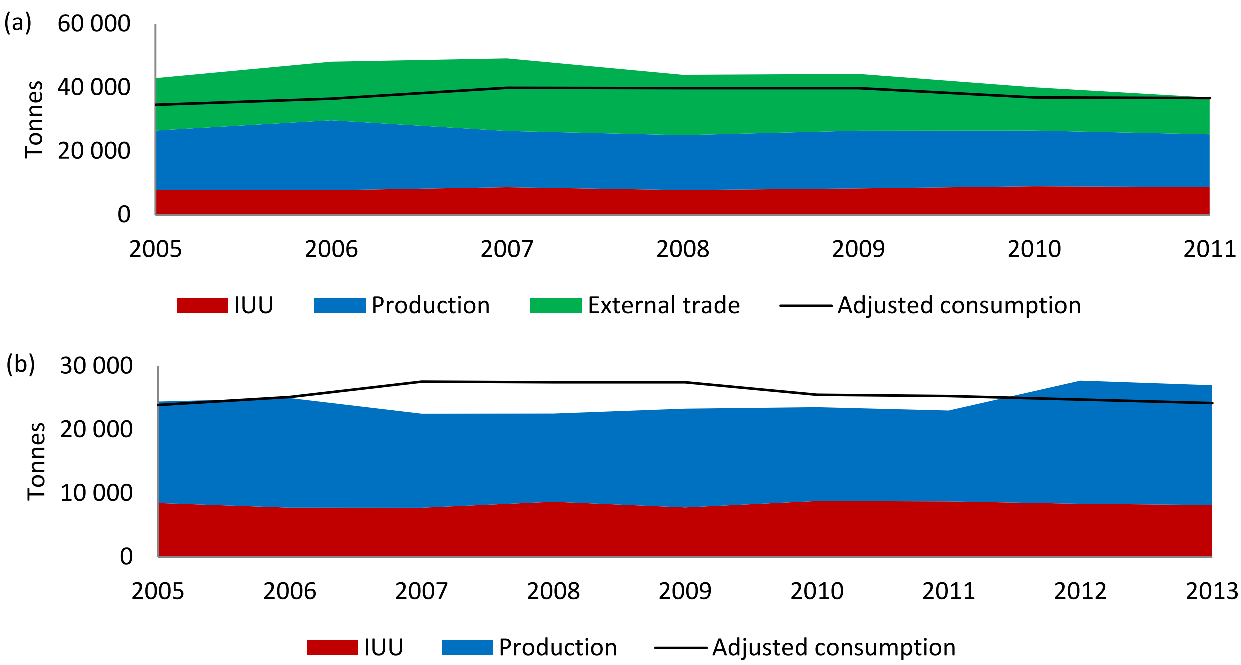


Figure 33. Horse mackerel total accumulated availability and OCL. Origin is discriminated regarding source for both data sets - FAO (a) and INE (b).

The origin of the largest portion available to Portuguese consumers is internal production via wild fish captures, mainly of two species: Atlantic horse mackerel (72% to 75%) and Blue jack mackerel (24% to 25%).

4.1.5.3. Hake

Hake OCL differs between FAO and INE data (Figure 34), with some evident partial declines in certain years in the INE data. Average consumption in INE values is 36 471 tonnes and in the FAO data set the average is slightly larger with 40 748 tonnes.

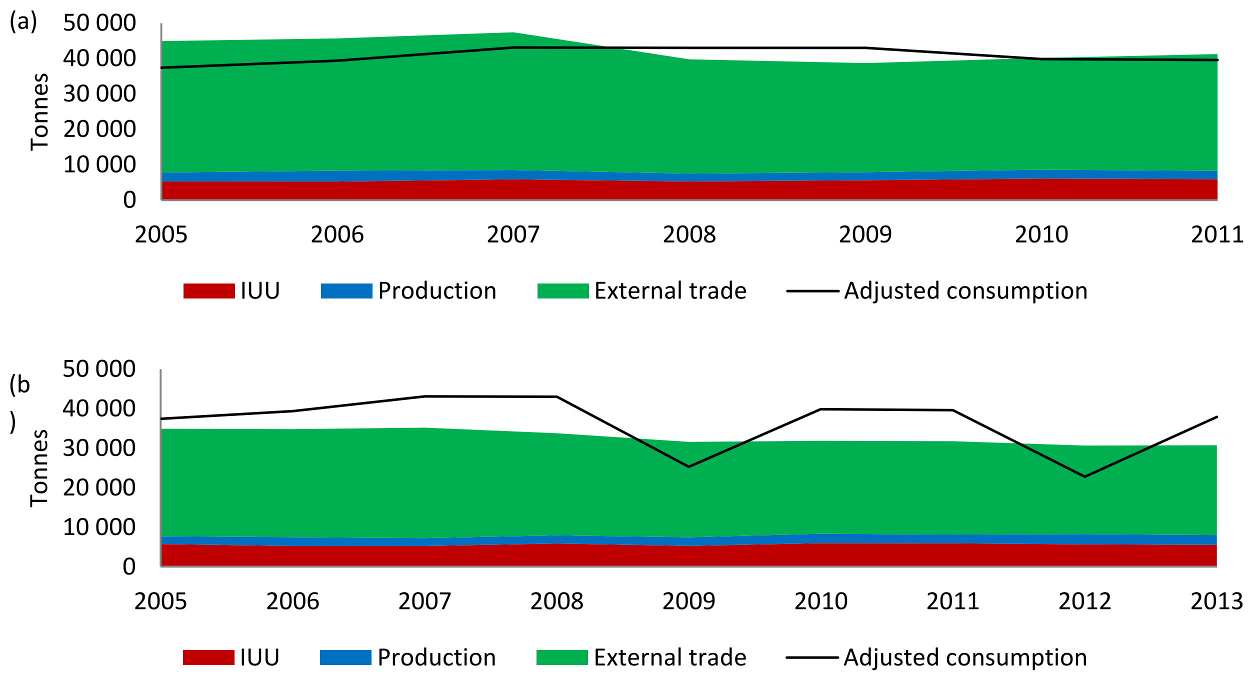


Figure 34. OCL, accumulated availability and origins for hake species from data sets, FAO (a) and INE (b)

Illegal fishing has a considerable impact, and estimated volumes place it between 14% and 15%, a number higher than the 6% of internal production. Catch production and illegal captures are, for the most part, of the same species, the native European hake. The majority of imported hake is frozen.

4.1.5.4. Gilthead seabream

Gilthead seabream OCL registers an average volume of 14 560 tonnes and 14 755 tonnes for INE and FAO data respectively (Figure 35).

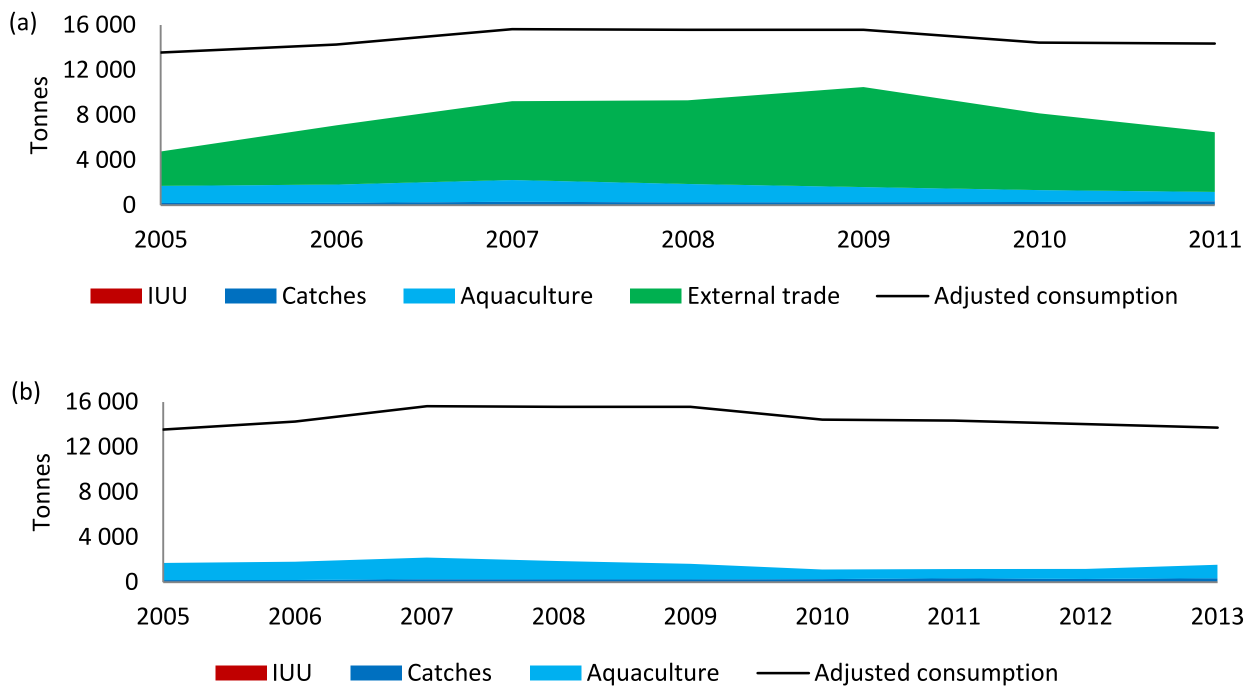


Figure 35. Gilthead seabream OCL and discriminated origin. Values are displayed for both FAO (a) and INE values (b).

Gilthead seabream is the most common species and according to FAO data, its key source is external trade, followed by aquaculture production. Catch (2.6%) and illegal fishing (0.6%) percentages are considerably smaller and on average do not exceed 300 tonnes per year.

4.1.5.5. Sardine

Despite a marked decline in availability in both data sets (Figure 36), which equally reflected on estimated OCL, sardine is still one of the most consumed seafood products in Portugal, with annual average consumptions between 34 601 tonnes (INE data) and 48 896 tonnes (FAO data).

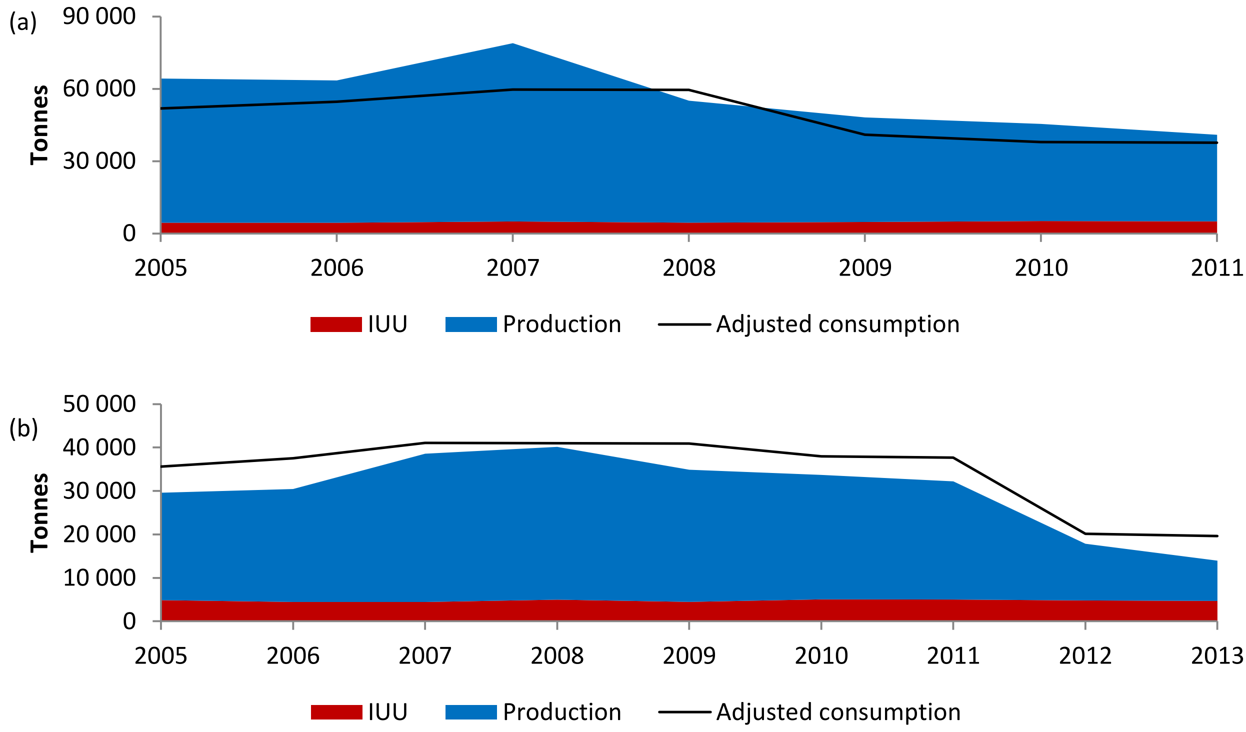


Figure 36. Sardine total availability, sources and OCL according to FAO (a) and INE (b) data.

IUU impact averages at annual tonnages of approximately 4 000 tonnes. Despite the differences between both data sets, the trends are similar.

4.1.5.6. European Seabass

European seabass OCL is at the lowest tier in both data sets, with average annual volumes of consumption of 11 063 tonnes and 10 916 tonnes for the FAO and INE data respectively. It is the eighth most consumed seafood product in Portugal and, along with gilthead seabream, constitutes another key internally farmed aquatic product (Figure 37).

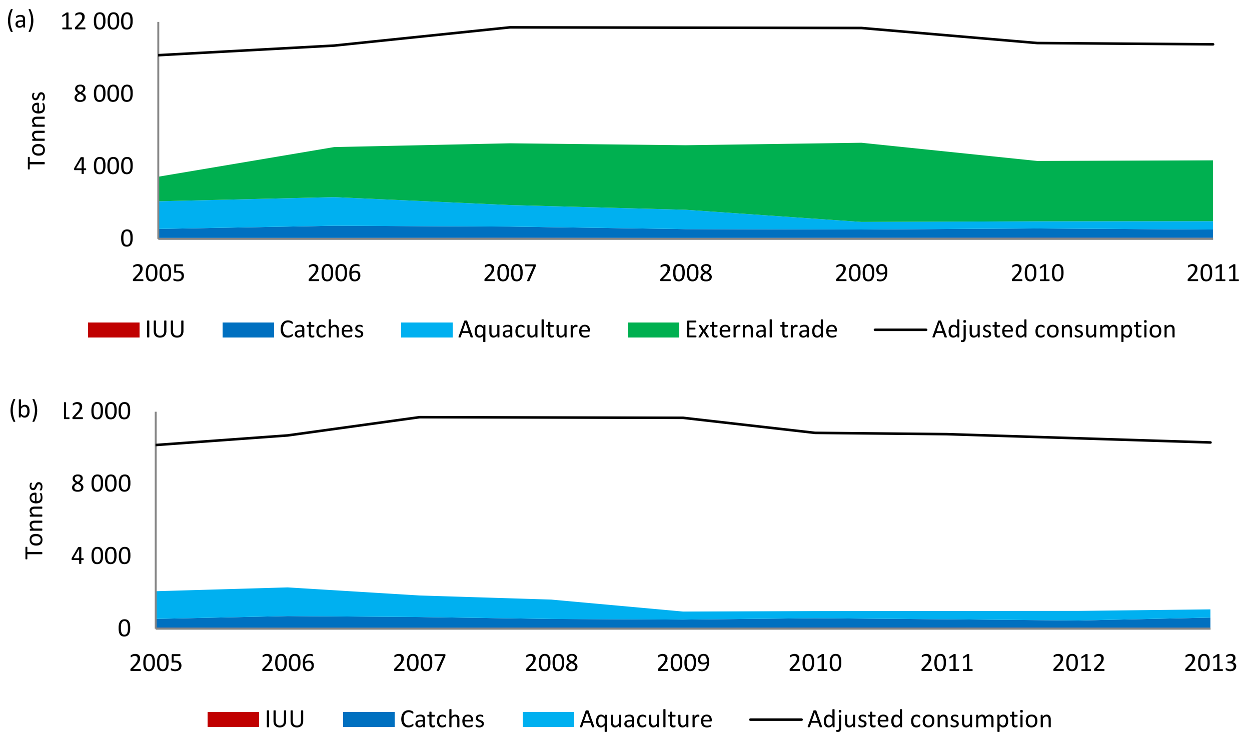


Figure 37. OCL for FAO (a) and INE (b) data sets discriminated source volumes for European seabass.

The differences between OCL and availability in both data sets illustrate that demand is not totally met.

4.1.5.7. Salmon

Salmon availability to Portuguese consumers averages 5 898 tonnes according to FAO data, and at 4 728 tonnes in the INE data set (Figure 38). Although INE average values are lower, an increasing tendency is evident, especially after 2012. Despite not being part of Portuguese culture or traditions, salmon is the sixth most consumed seafood product and yearly consumption is above 16 000 tonnes on both data sets.

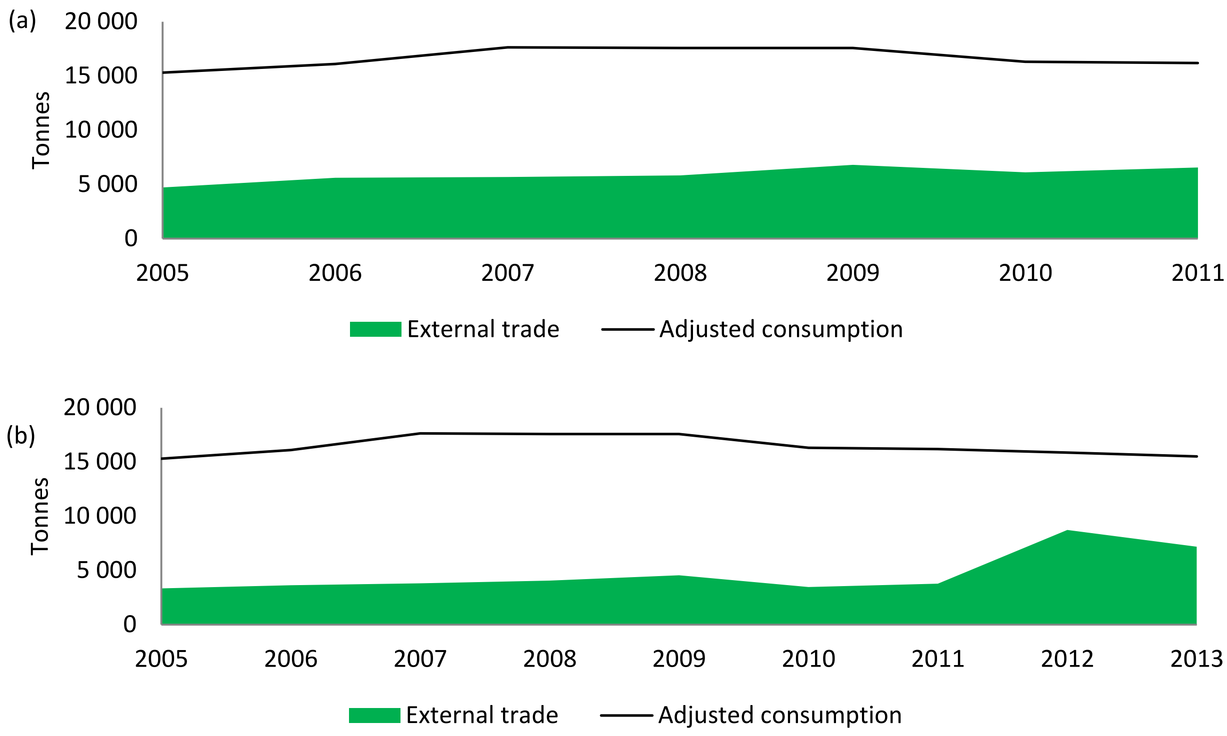


Figure 38. Salmon OCL and discriminated availability. Values for the FAO (a) and INE (b) data set are displayed.

4.1.6. Seafood sector overview

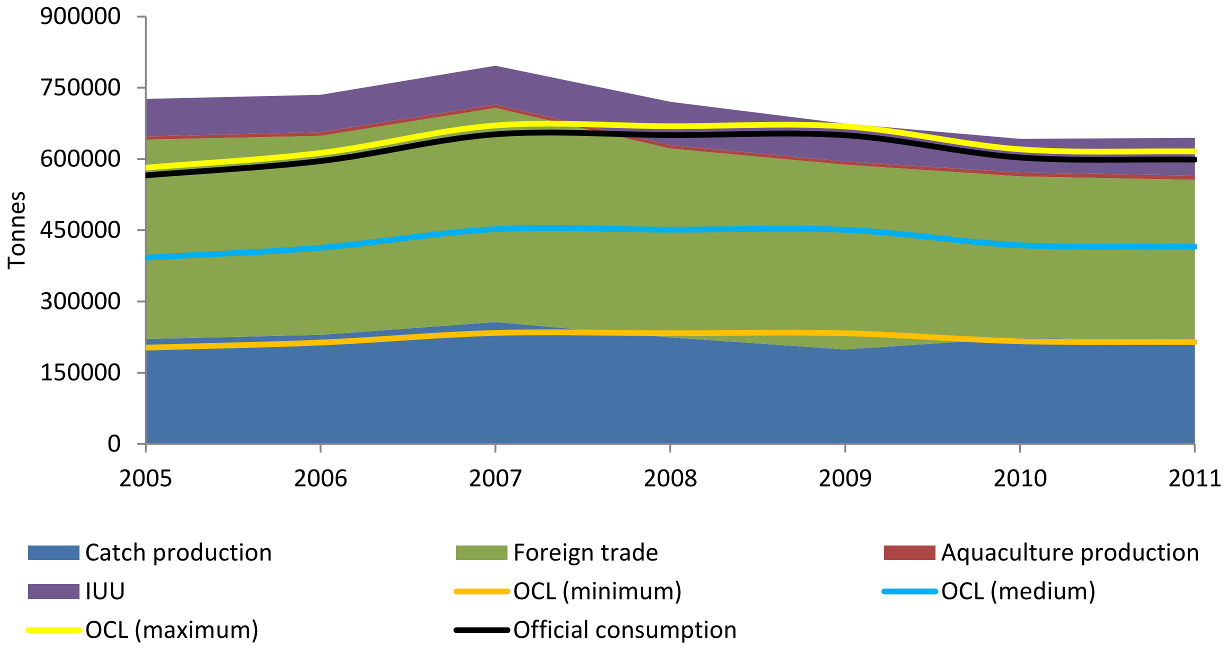


Figure 39. Portuguese seafood availability according to origin and including IUU fishing volumes. Estimated OCL for each of the three tiers is included, as well as the official consumption volumes according to FAO.

The Portuguese seafood sector is characterised by a dependence on external seafood, with 44% of all available seafood coming from outside the country. Also the reduced farmed fish production (1% of availability) is of note, especially when considering the high official consumption volumes of 58.1 kg *per capita*. The estimated three OCL tiers represent and average *per capita* seafood consumption of 20.8 kg (minimum), 40.3 kg (medium) and 59.8 kg (maximum). IUU fishing still represents a considerable portion of total availability with 11% (Figure 39).

Key species represent the majority of available seafood in Portugal (52%). Despite this, the large percentage of other species is a good indicator over the heterogeneous profile of consumption. Cod is the most important product to national consumers (17%), followed by sardine, hake and horse mackerel, with 8%, 8% and 10%, respectively (Figure 40).

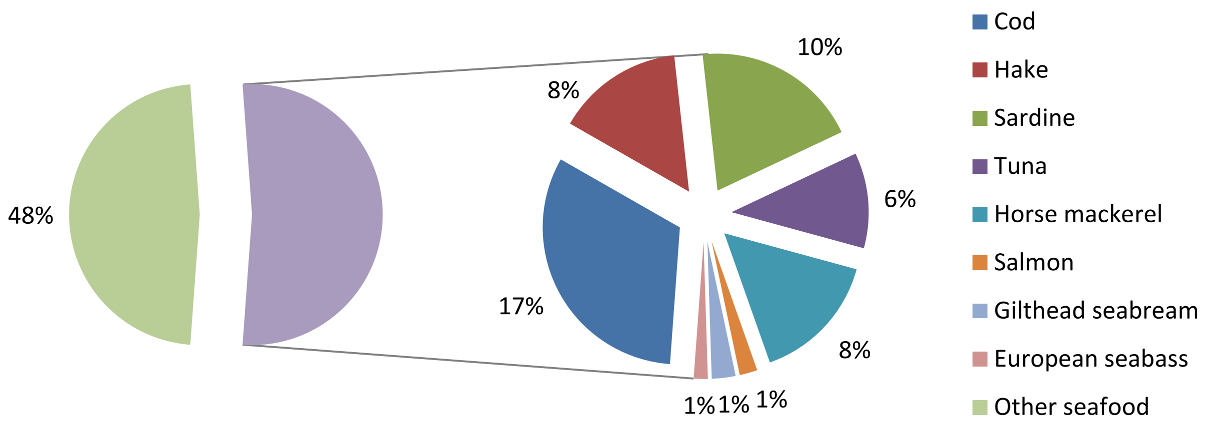


Figure 40. Composition of available seafood in Portugal, as a relation between key and other species (uncorrected tonnage).

The importance of presentation is of note, especially when considering the ways in which cod is conserved, transported and consumed in Portugal. As shown below (Figure 41), with the corrected tonnage of cod to live weight, according to the specific availability of each presentation, the importance of cod increases, representing 29% of total seafood available in the country, which emphasizes the role of this fish, as well as the specific historic and cultural settings which created such a relevance.

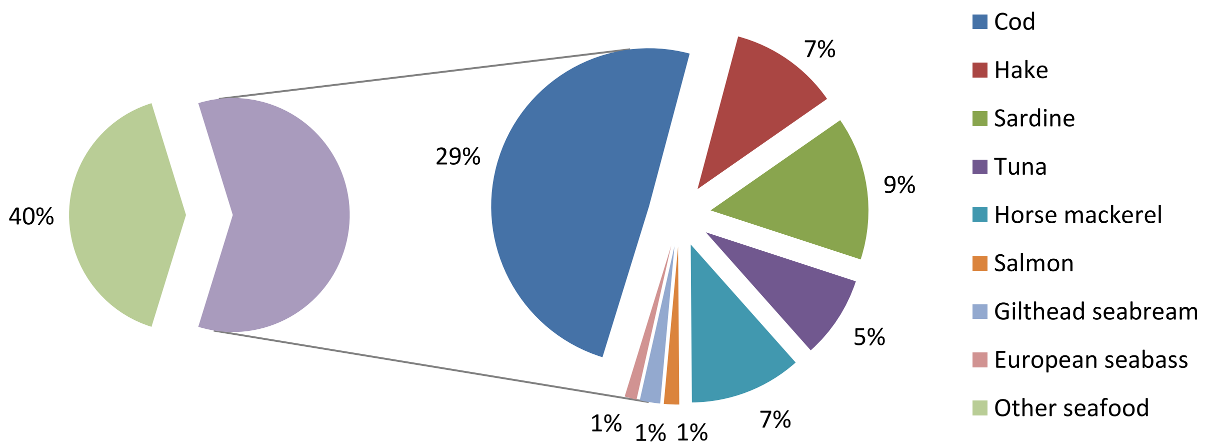


Figure 41. Composition of available seafood in Portugal, as a relation between key and other species (corrected cod tonnage).

4.2. Growth potential

To categorize the eight key products identified, using the two classification systems created (Table 12 and Table 13), un-aggregated availability volumes were necessary. The highly aggregated nature of certain key products in the foreign trade volumes of the INE data does not represent the reality. Therefore in this section only the FAO data set values were used to classify the products.

4.2.1. Product classification according to origin

Portuguese diet is composed of eight key products and more than half of availability is met by imports. Fisheries are the second supply origin with nearly 40% of key species availability, followed by IUU (6.9%) and aquaculture (0.8%). Of the four species classified as A (100% of external origin) or B type (over 75% of external origin), three (cod, hake and gilthead seabream) are produced internally (Table 19). Only one species is at the other end of the classification system (type E), the sardine.

Table 19. Key species availability with respect to origin. Arrangement is made from predominantly external (A) to predominantly internal (E), according to the classification system in the methodology (Table 12).

		Source (%)					
		External	Internal			External	Internal
		Foreign trade	IUU	Production			
				Aquaculture	Fisheries		
B	Cod	94.1%	0.0%	0.0%	5.9%	94.1%	5.9%
B	Hake	80.9%	13.9%	0.0%	5.2%	80.9%	19.1%
C	Tuna	53.9%	2.4%	0.0%	43.7%	53.9%	46.1%
E	Sardine	0.0%	8.4%	0.0%	91.6%	0.0%	100.0%
C	Horse mackerel	39.2%	19.0%	0.0%	41.8%	39.2%	60.8%
A	Salmon	100.0%	0.0%	0.0%	0.0%	100.0%	0.0%
B	Gilthead seabream	78.9%	0.6%	17.9%	2.6%	78.9%	21.1%
C	European seabass	67.4%	1.1%	20.2%	11.3%	67.4%	32.6%
	Key species	53.2%	6.9%	0.8%	39.2%	53.2%	46.8%

Only one product, Salmon, is classified as exclusively imported (A type). The second mostly imported product, with 94.1% of availability with an external origin, is cod. Of the remaining products with over 75% of external origin, hake and gilthead seabream, each has different sources responsible for the majority of the internally produced fish. Hake's second foremost source is IUU fishing (13.9%) and the smallest portion of availability is completed by regulated fisheries (5.2%).

Gilthead seabream is different from the other A or B type products, mainly because its second most important origin is aquaculture, which is responsible for 17.9% of availability. Of the three products – European seabass, tuna and horse mackerel – with a mixed origin, seabass presented the highest values of external trade (67.4%). As for gilthead seabream, seabass availability is composed by a significant percentage of internally farmed fish (20.2%).

Tuna represents the product most equally divided between external and internal origins, with 53.9% being imported from foreign countries and 43.7% fished by the national fleet. Horse mackerel is also classified as a type C product with external origins of 39.2%. This species case is peculiar, due to the high values of IUU fishing, which amounts to almost 20% of total availability. For horse mackerel, fisheries are the most important source with 41.9%.

Sardine is the only key product with more than 75% of internal origin. In fact, 100% of this species is supplied by the Portuguese fleet, which is dominated by regulated fishing (91.6%), with only a small percentage of illegally caught fish (8.4%).

4.2.2. Product classification according to consumption satisfied

The overall demand for key species in Portugal is totally met (Table 20). Five of the eight key species identified have over 99% of their demand satisfied, thus being classified as type IV and V. The remaining three species have less than 55% satisfied consumption. The overall OCL satisfaction values reflect the higher impact of certain species. Cod and sardine represent 42.8% of consumption; hake, tuna and horse mackerel are responsible for 41.3%. Together they represent 84.1% of key species consumption. The bulk of consumption is satisfied via imports (56.4%) and regulated fisheries (41.5%). Aquaculture has a smaller portion than unregulated fisheries, only 0.9% in contrast with the 7.3% of IUU.

Table 20. Key species OCL regarding source of consumed products and satisfaction. Sorting of species is according to classification system in methodology (Table 13), were OCL satisfaction is classified from ≤25% (I) to ≥100% (V).

		Optimal Consumption Level satisfied (%)				
		External	Internal			Total
				Production		
		Foreign trade	IUU	Aquaculture	Fisheries	
V	Cod	129.9%	0.0%	0.0%	8.1%	138.0%
V	Hake	84.5%	13.8%	0.0%	6.2%	104.5%
IV	Tuna	53.5%	2.4%	0.0%	43.4%	99.3%
V	Sardine	0.0%	9.7%	0.0%	106.0%	115.7%
V	Horse mackerel	45.3%	21.9%	0.0%	48.4%	115.6%
II	Salmon	35.4%	0.0%	0.0%	0.0%	35.4%
III	Gilthead seabream	42.4%	0.3%	9.6%	1.4%	53.7%
II	European seabass	28.6%	0.5%	8.6%	4.8%	42.5%
	Key species	56.4%	7.3%	0.9%	41.5%	106.1%

Cod has the highest supply level with 138%, mostly from external sources. Sardine and horse mackerel, both small pelagic species, are also products of type V with 115.7% and 115.6% of total OCL satisfied respectively. Despite the similarities in overall supply and the targeting of both species by the national fleet in Portuguese waters, the sources are considerably different. Sardine has a completely internal origin, and although the main source of horse mackerel is the same, this species has a more distributed supply with 45.3% originating from external sources.

Hake is the type V product with the lowest OCL satisfaction level (104.5%). The most important source is imports. It is the only product were illegal fishing supply surpasses legal fishing. Tuna is classified as the only type IV product, with 99.3% of OCL met. The main source in satisfying demand is foreign trade.

Opposite to the five species with over 99% of consumption satisfied are the three products which account for the remaining 15.9% of key species consumption: salmon, gilthead seabream and seabass. All three species are mainly farmed, either in or out of Portugal, and have OCL satisfaction levels below 55%. These species present the best opportunity, strictly on a simple supply and demand basis, for an increase in production. Salmon's OCL satisfaction is the lowest of all key products, with only 35.4% being met, exclusively by imports. European seabass has an OCL satisfaction level of 42.5% (type II species), which is primarily met via imports (28.6%). Aquaculture is responsible for 8.6% of demand, making it the most important internal source. Gilthead seabream, with a 53.7% of consumption satisfied, is the only type III product of the eight key species identified. Similarly with the other farmed species, imports are the main route for meeting demand (42.4%), followed by aquaculture production (9.6%).

4.2.3. Potential assessment

Table 21 displays the potential growth assessment for each product, according to source and OCL, and identifies the key fields of action in order to reduce foreign fish deficit via an increase in production.

Table 21. Each key product growth potential is considered, according to source and OCL satisfaction. The best areas of intervention are identified for each product. Products are classified according to its potential from lowest (- -) to highest (+ +).

Potential assessment			
Product	**Source**	**OCL satisfied**	**Priority areas of intervention**
Cod	+ -	- -	Product valorisation
Hake	+	- -	IUU control and mitigation; Biological stock status improvement
Tuna	+ -	-	Product valorisation
Sardine	+	- -	IUU control and mitigation; Biological stock status improvement
Horse mackerel	+	- -	IUU control and mitigation
Salmon	-	+	-
Gilthead seabream	+ +	+ -	Farmed fish production
European seabass	+ +	+	Farmed fish production

Salmon, gilthead seabream, and seabass present the best opportunities regarding the OCL evaluation, mainly due to unmet demand. The remaining five species, which have over 99% of consumption satisfied, are not classified the same way, mainly due to consumption being completely or overly met. Despite this, an increased production of these species could reduce imports and lower the foreign fish deficit.

5. Discussion

Four strategic areas of intervention were identified. In Table 21 each species was matched to its most adequate field of action. Nonetheless, certain areas are transversal to several species, such as biological status improvement or IUU control and mitigation, or even to all of them, regardless of their origin or placement in national consumption preferences, such as product valorisation. While difficulties in obtaining accurate growth potential estimates for both fisheries and aquaculture are notorious (Campbell and Pauly, 2013; Gjedrem et al., 2012; Natale et al., 2013), it was possible to obtain an approximation, based on seafood consumption demand and availability (Table 22).

Table 22. Growth potential estimates for aquaculture and fisheries of key species. Volumes in tonnes.

	Δ(Availability - OCL)	Δ(Availability - next consumption level)
Cod	25 048	25 048
Hake	1 798	-14 980
Sardine	7 695	111
Tuna	-216	-12 861
Horse mackerel	5 895	5 895
Gilthead seabream	-6 818	-6 818
European seabass	-6 364	-6 364
Aquaculture	-13 182	-13 182
Fisheries	-216	-27 841
Total	-13 398	-41 024

Estimates for the lower threshold are based on the difference between OCL and availability for the three products with OCL > availability, tuna, gilthead seabream and seabass. Regarding the higher threshold, estimates were based on the difference between availability and the next consumption level above for products with availability < next consumption level, hake, tunas, gilthead seabream and European seabass. OCL levels higher than availability volumes can suggest an unmet demand indicating an economic opportunity for suppliers. Despite this, in other species where OCL volumes are below availability volumes, there is still opportunity for improvement of biological stock status, reduction of discards and illegal fishing, which in turn could lead to improvements in production chains and higher added values and increased volumes.

5.1 Strategic areas of intervention

5.1.1 Product valorisation

The EMFF supports community-led initiatives and strategies that add value, create jobs and promote innovation, in any steps of the entire supply chain of fisheries and aquaculture products (PCEU, 2014). Certifications, such as the MSC ecolabel, provide additional value to products. Certain Portuguese seafood products, like the Algarve rope grown Mediterranean mussel, already display this endorsement (MSC, 2014). The use of these funds or other methods, which distinguish and promote a sustainable use of resources, can significantly improve national fisheries and aquaculture seafood products.

Cod is the most consumed product, and is almost exclusively imported. Due to its demand and value in several markets it is unlikely that national vessels will have an increase of fishing opportunities. Despite this, the importance of the cod processing industry, and the history linking this species to Portuguese traditions and populations, still places it as one of the most important exported products (Almeida et al., 2015; Cardoso et al., 2013), particularly in value of dried and salted fish (Dias et al., 2001). Tuna catches originate mostly from the Azores (INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a), and all captured species carry a ’Dolphin Safe‘ label, as well as other sustainability labels, depending on the species and the fishing arts (Gallagher et al., 2012). An important part of these labels is the predominance of small scale fishing vessels which provide more jobs, use less fuel and yield higher quality fish (Carvalho et al., 2011).

5.1.2 IUU control and mitigation

To prevent IUU fishing, the usual methods employed are more efficient monitoring and policing of fishing activities. Other approaches can also be used. The recent reform of the CFP, in which the gradual ban on discards, to be extended to all fisheries by 2019 (PCEU, 2013), was agreed upon, is one of the most notable innovations of the revised text (EC, 2009b; Salomon et al., 2014). The mandatory landing has the potential to greatly reduce IUU catches, which would be by itself a noteworthy advance. Another positive effect could be an increase on the use of more selective fishing methods, in order to avoid fishing less valuable and marketable species (Diogo et al., 2016; Veiga et al., 2016).

Some of the key species identified in Portugal have high values of IUU fishing. Horse mackerel presents the highest value (19.0% of total availability). This species is mostly caught by coastal trawling, which presents the highest IUU values. A shift to fishing gear with a reduced impact on ecosystems, such as purse seine or multispecies, could provide a decline of these volumes. Hake and sardine also present high volumes of illegal fishing and both have low biomass levels (ICES, 2015a, 2013), therefore a mitigation of the causes for IUU can also aid in fish stock recovery. Both species are mostly fished by multispecies and purse seine respectively (INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a). Promotion of multispecies fishing and small scale fisheries could provide positive results in avoiding unwanted catches, as well as aid in the reduction of IUU. In addition to the savings in fuel and higher quality fish yielded by the use of small vessels, negative impacts in marine ecosystems are lower and the harvesting of fish stocks is more efficient (Leitão et al., 2014).

5.1.3 Biological stock status improvement

In order to achieve a MSY level on fish stocks, temporary reductions are essential in the short to medium term, depending on scientific knowledge. The subsequent increase in yield from rebuilt stocks results in economic gains (Froese and Quaas, 2013), if fishing capacity is adequate and imposed limits are not exceeded (EC, 2014a).

Hake and sardine stocks are both under long term management plans. In the first case, hake stocks have been outside safe biological levels for years, with little success of implemented measures, such as changes in mesh sizes or the creation of marine protected areas (ICES, 2014, 2013). Conservation measures should be taken beyond scientific advice in order to restore stock levels, such as reduction of TACs. The discards ban could also help in improving the spawning stock biomass, despite a lack of concrete data on its effects in fisheries (Veiga et al., 2016).

ICES advice for 2016 indicates a catch limit of 1 587 tonnes for sardine (ICES, 2015b). This advice for catch limits is substantially lower than the volume of 16 000 tonnes for 2015, meaning an even greater pressure on fishermen for 2016. Despite the perceived negative social impact of this virtual closure of the sardine fishery, in previous cases acting in accordance with scientific advice has improved the spawning stock biomass of species and increased the future fixed quota, as is an example the recent horse mackerel quota (ICES, 2014).

5.1.4 Farmed fish production

Of the eight key seafood products consumed in Portugal, farmed species have the highest unmet demand, exceeding 40% in all three cases. Salmon, having the lowest OCL satisfied and meeting the consumption requirements, has the highest potential for production from a plain supply/demand perspective. Nonetheless this species does not occur naturally in Portugal, and average water temperatures are not appropriate to the successful commercial exploitation of the species.

Gilthead seabream and European seabass also have potential when considering unmet demand. In addition, both species are native to national waters and exploited by both fisheries and aquaculture. They are also popular in subsistence and recreational fisheries, being sold illegally or kept by fishermen (Leitão et al., 2014). Seabream and seabass, despite not reaching the high values of other farmed species as turbot and clams, are appreciated by consumers and sold at lower prices than wild caught fish of the same species (Cardoso et al., 2013; INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

Most coastal areas in Portugal are not ideal for aquaculture mainly due to strong hydrodynamics and high water depth; these disadvantages encourage the development of new and innovative ways to explored farmed species. Offshore aquaculture and IMTA are positive prospects, which can overcome competition for marine space (offshore) and reduce environmental impacts (Ferreira et al., 2012). Certain biogeographic constraints remain, such as high current speeds and inappropriate water column depth (Kapetsky et al., 2013). Nonetheless, technology continues to evolve, enabling the exploration of harsher environments (Kaiser et al., 2010; Salmar, 2015). The continued investment on scientific knowledge is also a positive factor, which can lead to improved technologies and enable more efficient farming of marine species (CCMAR, 2015).

5.2 Alternative considerations

Changes in targeted species, the dimension of fishing vessels or the adoption of multispecies gear could have positive outcomes in decreasing bycatch, illegal fishing or improve biological stock status (Carvalho et al., 2011; Veiga et al., 2016). Eco-certification is also perceived as a viable method to reach sustainability in fisheries which can be accomplished with cooperation between industry, scientific community and responsible authorities (Shelton, 2009). Despite this the highly depleted condition of so many fish stocks (CEC, 2009), presses for bolder and effective limits on fishing effort.

Legislative diplomas, such as the CFP or EMFF, provide framework and funding to the implementation of several measures, which support a sustainable development of fisheries and aquaculture, as well as data collection to support scientific advice. These vary from conservation measures, control and enforcement actions, research and development of new and less invasive fishing techniques, or the promotion of new products of increased value. Thorough scientific advice is paramount to the implementation of successful strategies. Correct assessment of the biological stock status of explored species; accurate volumes of discards, bycatch and illegal fishing; or synergies between industry and research institutions, are all necessary for achieving the CFP objectives regarding national fisheries (PCEU, 2014, 2013).

The national plan for aquaculture, and other strategies, have highlighted the importance, and established objectives, for the development of aquaculture in Portugal. Constraints, such as the excessive administrative burden, have been identified and simplified. Other obstacles as the competition for space with other marine uses are also to being solved (DGRM, 2014).

From a consumption perspective, the key products identified offer the best opportunities to reduce the foreign fish deficit. Despite this, other species also offer some potential in achieving this goal. Chub mackerel is a common species in the Portuguese coast, and in recent years its production and export volumes have increased, partly as an alternative target for the declining sardine fisheries (Gamito et al., 2015). Consumption estimates for this species are low, but recent promotion campaigns from government institutions, have stimulated an increase for this product demand (DOCAPESCA, 2012). Octopus, also promoted as a healthy seafood source, is another product that is common in the Portuguese coast, has a high commercial value and is accepted by consumers, presenting both a good alternative to consumption and exports (Docapesca, 2013; INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a; IPMA, 2013).

In addition Portuguese consumers display an acceptance for new seafood products, as well as for the diversification of seafood consumption (Almeida et al., 2015), which provides a positive starting point for supplying the national seafood market. Black scabbard fish, despite being less common than octopus or chub mackerel, is another valuable product with considerable potential from national fisheries, especially regarding exports. Aquaculture production also presents potential beyond the most consumed species. Both turbot and clams are valuable farmed species which, despite not presenting large consumption volumes, can provide alternatives to external products and therefore reduce foreign fish dependency (INE, 2014a, 2013a, 2012a, 2011a, 2010a, 2009a, 2008a, 2007a, 2006a).

5.3 Consumption and live weight – importance of salted and dried cod

Bacalhau is the most important seafood product in the Portuguese data, and it has been for more than 400 years in the national diet. The peculiar presentation of this fish, dried or salted, derives from an historic necessity of preservation over long voyages prior to freezing techniques. The techniques used to preserve the salted or dried cod have greatly varied, especially in the last century, in response to market factors or even product scarcity, which created a heritage directly related to the fishery and processing of cod (Silva, 2015). In addition to these factors, the different processing techniques for cod have an impact on the amount of water present in the final product. Dried cod retains 20% of the original live weight, whereas salted cod retains 40% (Johansen, personal communication; 2016).

The difference between live weight and the final product is considerable, and since the trade volumes do not convert these to live weight, the final consumption and import/export estimates may differ from the real volumes. These differences are significant, mainly due to two factors. First: most cod is imported, which makes it challenging to accurately estimate the ratio between live and dry/salted weight, due to the differences between the processing techniques. Second: the traditional culinary preparation method for these products involves a soaking of the salted/dried cod before freezing or cooking, which adds more water weight to the product prior to consumption.

5.4 Issues

The use of individual questionnaires and surveys to study seafood consumption preferences is a valid method to find tendencies and patterns, regarding the identification of consumed species and its frequency (Cardoso et al., 2013). Despite this, the use of such data to estimate overall consumption of much larger populations carries certain risks. Therefore these estimates should be taken into account with a moderate degree of uncertainty. Another important factor is the number of products present in the survey data, which in the Portuguese case can be considered as reduced, due to the high number of landed species (OCEANA, 2012) and when considering the official high seafood consumption volumes.

Another important consideration is the disparity observed between FAO and INE data, caused by the use of normalization factors in data sets. These induced differences in the availability volumes of certain products, which in turn propagated to the estimations of OCL values. In this particular study the differences between OCL and availability of certain products such as cod, gilthead seabream, European seabass and salmon are proof of these reservations. The highly aggregated nature of data sets, grouping several species in commercial clusters, reduces the taxonomic quality of data. This is an issue when estimating total availability. This was particularly valid in the INE data regarding foreign trade values.

Other products with OCL levels above 100% do not necessarily mean that the market and consumers will not absorb such products if provided at reasonable prices. OCL evolution on the considered periods regarding certain species, such as sardine, shows a reduction from the highest calculated consumption level to the medium in the FAO data, and from the medium to low level in the INE data. This is motivated by the reduction of availability, due to catch limits on the fishery caused by environmental reasons. Cod's OCL is below the availability volumes, which can be explained due to the significant importance of this species on Portuguese tradition and to the particular commercial presentation of such products (salted and dried). The characteristics of the sample group are also important in determining these volumes, which in this case could have led to an underestimation of OCL. In the three remaining cases the OCL is above availability, which can reflect more accurately an unmet demand or the specific preferences of the surveyed group, rather than the actual consumed volumes at national level.

Despite the higher employment numbers, higher quality yielded fish and reduced environmental impacts of small-scale fishing in the Azores (Carvalho et al., 2011), the influence of the discards ban in this sub-sector is still uncertain. Recent studies (Veiga et al., 2016) point to more negative than positive effects of this measure on economic, social and ecological aspects related to SSF. These factors must be taken into account when considering the adoption of SSF in detriment of the use of larger ships for conservation reasons.

6. Conclusions

6.1 Review

In this study, eight key species were identified as the most consumed and important in the Portuguese seafood market. Seafood consumption is considerably concentrated on a small number of products. The most common source in supplying the demand is foreign trade (56.4%). National fisheries are responsible for 41.5% and aquaculture accounts for 0.9% of OCL satisfied. IUU also plays an important role in contributing to the satisfaction of seafood demand, supplying 7.3%. In general, key species demand is overly met, with 106.1%. Three species are particularly significant to this scenario: cod, sardine and horse mackerel, with a satisfaction level above 115%. Four species have a predominantly foreign origin (salmon, cod, hake and gilthead seabream), and three have a mixed sourcing (tunas, European seabass and horse mackerel). Only sardine has a predominantly internal origin (Table 19 and Table 20).

Each product identified, due to its characteristics, presents different key areas of intervention (Table 21). Certain intervention areas are cross-sectional, as product valorisation or biological stock status improvement, and can be applied to most species. Certain species, despite having their calculated demand entirely or overly met, have some potential for a production increase. Valorisation of cod and tuna products can prove useful in increasing output values, which in turn can aid in the reduction of the foreign fish deficit. Other species have high illegal fishing volumes, which if shortened, can aid in the recovery of fish stocks and the improvement of management solutions. The highly exploited status of fish stocks is also a considerable problem for several species. In this particular case, hake and sardine have considerable potential for an increase in production, if biomass levels are returned to sustainable levels. On the aquaculture segment, seabass and seabream species present the highest potential for an increase in production.

These species were organized according to origin and OCL satisfied, and only one product was excluded (salmon), due to a total lack of internal production. Of the remaining products, seabass and seabream present the best opportunities, both in the aquaculture segment. Despite this, and considering the different consumption tiers, other species, as tuna or hake, also present some promise for an increase in production (Table 22).

Recent revisions in the European legal framework, such as the discard ban or the inclusion of the MSY concepts, can both support and stifle the development of certain species fisheries. Currently the impacts of such measures are mostly unknown, especially regarding the small scale fisheries sector. Despite this, the potential environmental benefits are preferable, as opposed to keeping the previous measures in effect.

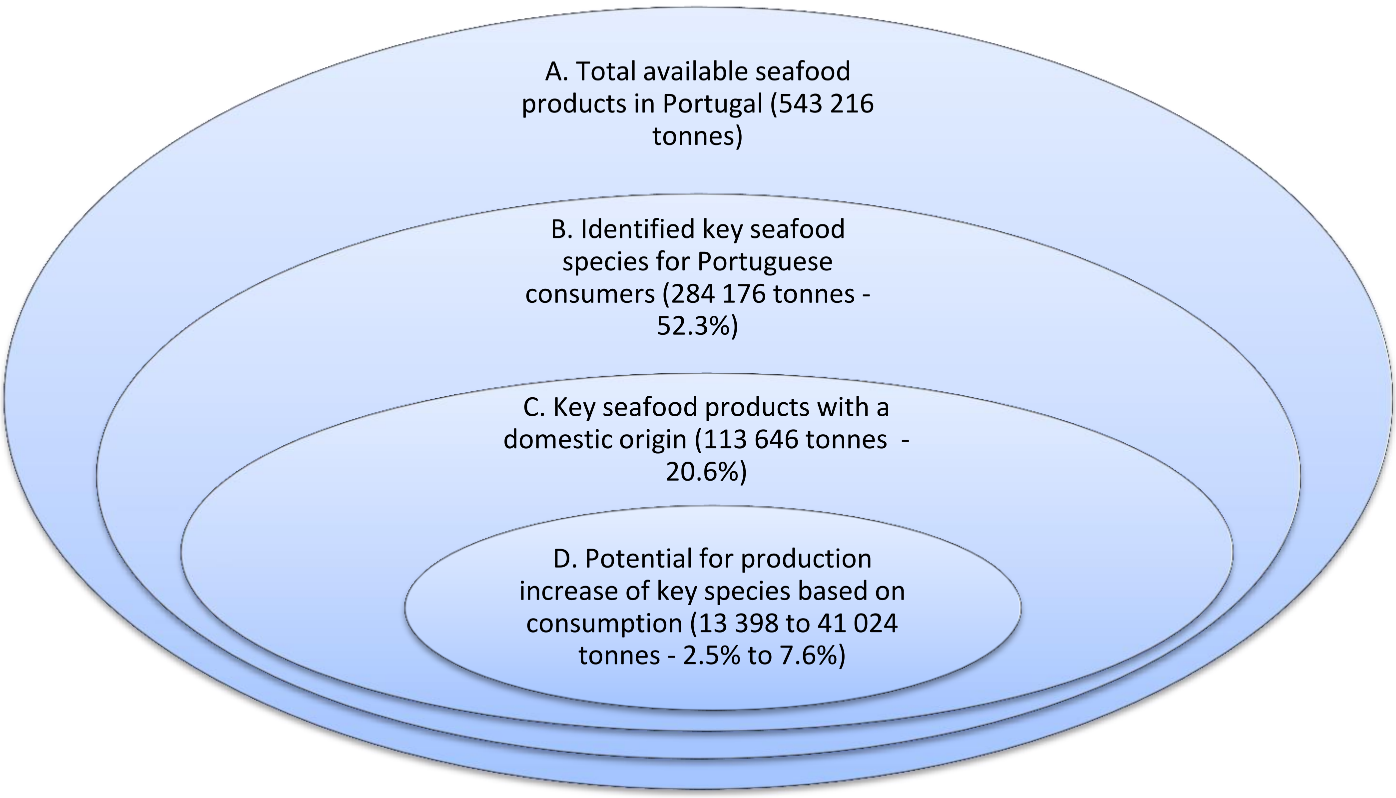


Figure 42. Venn diagram schematic of the Portuguese seafood market. The impact of each item in the overall sector and the growth potential, are displayed in tonnes and percentage.

The farmed fish sector in Portugal, despite its current reduced production, has the potential for a considerable growth, anchored on the two key species identified (seabass and seabream), as well as in other valuable products. The development of the recent national framework for aquaculture also allows for positive prospects for this sector development.

Variations between the live weight and the weight in the final processed products can influence both consumption and total availability of seafood products. In the Portuguese case, due to such a high consumption of cod, its processing (dried or salted) and preparation methods (soaked before cooking), in addition to the high level of imports for this fish, provides an additional importance to the correct estimation of seafood consumption. In this case, official annual *per capita* consumption increases to an average of 72.8 kg between 2005 and 2011. This contrasts markedly with the values of between 50-60 kg *per capita* per year, systematically reported for Portugal. The adjusted value of 69 kg *per capita* is the second highest in the world, after Iceland, and exceeds the value of 58.1 kg reported for 2011 by 18%.

Growth potential of the seafood production sector, based on consumption and unmet demand, is estimated between 13 398 tonnes and 41 024 tonnes, which amount to between 2.5% and 7.6% of the current Portuguese seafood market (Figure 42). Despite this, the estimates referred above only account for the key species identified, and are valid using the calculated OCL levels. Therefore other species, not identified as key in this thesis, could also present similar or greater potential.

6.2 Future studies and developments

6.2.1 Portuguese farmed seafood sector growth

The results obtained in this work support an increase in seafood volumes, based on an unmet demand of key species. The identification of strategic areas of intervention is also useful, in order to concentrate efforts on the most appropriate sectors, on both the wild and farmed fish industry. The next step is to consider the remaining factors, which impact the possibility of a production increase for each of the identified species. Despite the unmet demand of certain products, a gap exists between the potential growth of the seafood production sector, especially of the farmed fish sub-sector, and the actual achievable production increase.

These elements, displayed in Figure 43, can influence the successful establishment of infrastructures, or impact economically, the output value of the chosen species. Competition with foreign producers, capable of higher outputs at lower costs, (gilthead seabream in Greece and Turkey for example), can undermine the sustainable establishment of farmed fish businesses. In the Portuguese case, despite the vast availability of marine areas due to its extensive EEZ, most of these areas are not suited to the installation of cages for farmed fish production. Despite a promising evolution of national marine spatial planning, the real potential for fish farming, in both quality and quantity, is still mostly unknown.

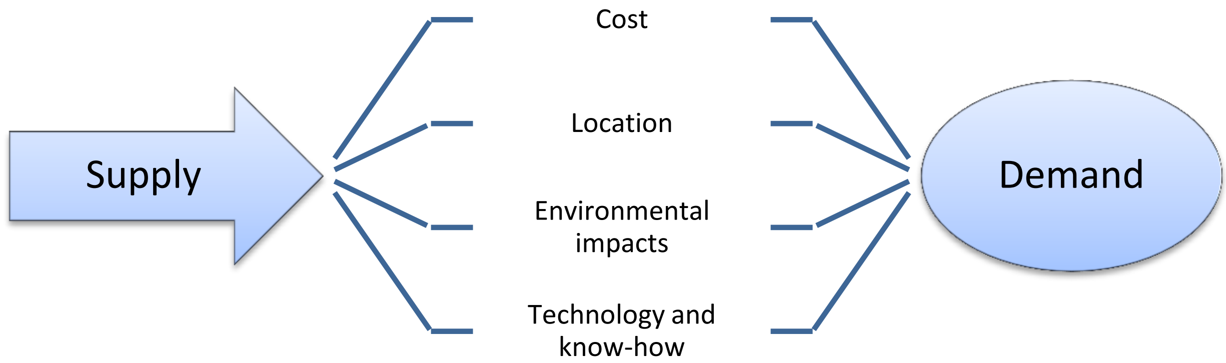


Figure 43. Key factors which influence the potential for a production increase of the farmed seafood sector.

European marine-related legislation is currently focused on EAA objectives. The ecological carrying capacity of ecosystems is an important part of a well-planed site selection. Although most farmed species production is concentrated on coastal and estuarine areas, recent developments have opened new areas to the ecological and economically sustainable exploitation of seafood production. IMTA and offshore solutions should be assessed, and the possibility of the use of new technologies, more resistant to harsher high sea conditions, is also a method to be considered, especially due to the biogeographic characteristics of the Portuguese coast.

6.2.2 Extended application of methodology

The method developed for assessment of the Portuguese seafood sector growth potential, barring certain identified issues, yielded acceptable results. Therefore, this approach could be applied in different countries, using official availability data and consumption surveys, which include the specific consumed seafood products. This would also aid in improving the methodology, in order to identify new issues and resolve current problems.

As an advanced objective, subsequent to the application of the methodology to several countries of the European Union, an ’EU map of seafood OCL‘ could be developed. This could aid in the identification of development opportunities for seafood production increases, in the broader scope of the European space. Such a tool could benefit the achievement of an EU-wide goal of reduction of dependence on imported fish, and increase seafood security in the European Union.

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