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Study of Atlantic chub mackerel's (*Scomber colias*, Gmelin, 1789) landings evolution in Portugal: importance for purse seine fleet.

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We cannot control the wind,

But we can direct the sail.

Popular saying

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Estudo da evolução dos desembarques de cavala (*Scomber colias*, Gmelin, 1782) em Portugal: sua importância para a pesca de cerco.

Resumo

A pesca de cerco em Portugal poderá ser sustentável se forem implementadas medidas para a sua diversificação. A cavala é uma das três espécies mais capturadas pelo cerco, tendo-se observado um aumento dos desembarques nos últimos anos, parte explicado pela campanha focada no seu consumo, promovida pela Docapesa.

Torna-se necessário compreender se a cavala poderá constituir uma alternativa sustentável.

Os resultados apontam para níveis de exploração acima do Rendimento Máximo Sustentável (RMS) estimado, atingido em 2011, quando os desembarques de cavala ultrapassaram as 30 mil toneladas, acima do RMS estimado de acordo com Schaefer (24 703 ton), Gulland (21 750 ton) e Cadima (23 250 ton), mantendo-se a tendência de sobre-exploração.

A cavala poderá ser uma alternativa para o cerco se: (i) estabelecido um limite de captura; (ii) criadas medidas de promoção de um mercado regulado pela lei da oferta e da procura (iii) aumentar o investimento em investigação.

Palavras-chave: pesca, cerco, cavala, sustentabilidade, recurso.

Study of Atlantic chub mackerel's (*Scomber colias*, Gmelin, 1789) landings evolution in Portugal: importance for purse seine fleet.

Abstract

The Portuguese purse seine fishery could be sustainable if measures to promote multi-specify catches are placed.

Chub mackerel is one of the top three species landed by purse seine and landings have been increasing, which could be partly explained by Docapesca's campaign promoting chub mackerel consumption.

Therefore, it is necessary to understand if chub mackerel could represent a sustainable alternative.

Results point to overexploitation levels, already exceeding estimated Maximum Sustainable Yield (MSY). The break point was registered in 2011, when chub mackerel landings surpassed 30 thousand tonnes landed, which is far beyond MSY estimates by Schaefer's (24 703 ton), Gulland's (21 750 ton) and Cadima's (23 250 ton) models.

Chub mackerel could represent an alternative to purse seine fisheries if: (i) a catch limit is established; (ii) measures to promote a regulated market on supply and demand laws are placed; (iii) research investment is augmented.

Key words: fisheries, chub mackerel, sustainability, resources.

Contents

List of Acronyms and Abbreviations

AINCP – Associação Nacional dos Industriais de Conservas de Peixe - National Association of Manufacturers of Canned Fish

CC – Council Commission

CECAF – Fishery Committee for the Eastern Central Atlantic

CIEM/ICES – Conseil International pour l'Exploration de la Mer - International Council for the Exploration of the Sea

DGRM – Direcção Regional dos Recursos Marinhos – Regional Direction For Marine Resources Affairs

EBM – Ecosystem Based Management

EC – European Commission

EP – European Parliament

EU – European Union

EEZ – Exclusive Economic Zone

GDP – Gross Domestic Value

GT – Gross Tonnage

IMP – Integrated Maritime Policy

INE – Instituto Nacional de Estatística – National Statistics Institute

IUCN – International Union for the Conservation of Nature

LOA – Length Overall

MSC – Marine Stewardship Council

MSY – Maximum Sustainable Yield

NAFO – Northwest Atlantic Fisheries Organization

NEAFC – North East Atlantic Fisheries Commission

NEF – New Economics Foundation

PP – Propulsion power in kW

POP – Programa Operacional das Pescas – Operational Fisheries Program

POs – Producer Organizations

RBM – Right-based management

RFO – Regional Fisheries Organizations

STECF – Scientific, Technical and Economic Committee for Fisheries

TFCs – Transferable Fishing Concessions

UNCLOS – United Nations Law of the Sea

WBCSD – World Business Sustainable Development

Glossary

AQUACULTURE –The science of farming marine or freshwater of both animals (crustaceans, fish and mollusks) and plants (seaweeds and freshwater macrophytes), under controlled conditions. Aquaculture occurs both inland (freshwater) and coastal (brackish water, seawater) areas.

BIOLOGICAL POTENTIAL – or Biotic potential, is the maximum reproductive capacity of an organism under optimum environmental conditions. Full expression of the biotic potential of an organism is restricted by environmental resistance, any factor that inhibits the increase in number of the population, such as competition, predation, harvesting and climate changes.

BIOMASS – The weight or total quantity of living organisms of one animal or plant species (species biomass) or of all the species in the community (community biomass), commonly referred to a unit. The weight or quantity of organisms in an area at a given moment is the standing crop.

BIONOMIC EQUILIBRIUM – Equilibrium condition of uncontrolled exploitation is such that the net yield (total value landings minus total cost) is zero (Gordon, 1952).

BYCATCH – Non target species (including fish, turtles, marine mammals, seabirds as well as undersized fish) that are caught incidentally.

CARRYING CAPACITY – The average population density or population size of species below which its numbers tend to increase and above which its numbers tend to decrease because of shortages of resources. The carrying capacity is different for each species in a habitat because of that species' particular food, shelter, and social requirements.

COMMON FISHERIES POLICY (CFP) – The Common Fisheries Policy is the European Union's way of organizing how EU fishing activities should take place – who can fish where, how, when.

COMMERCIAL FISHING – The taking of fish and other seafood and resources from marine or freshwater for the purpose of marketing them.

COSTAL FISHING – Fishing practiced at sea at a more or less significant distance from land (in areas defined under Article 64 (1) of Decree N. 7/2000, 30. May), usually at several hours or even of navigation days away from the port or anchorage site.

DEPLETION – Part of the harvest, logging, catch and so forth above the sustainable level of the resource stock.

DEMAND – The quantity of a good or a service that consumers wish to buy.

DISCARDS – Fish or other marine organisms thrown back into the sea after they are caught, usually dead.

DISTANT-WATER FLEET – Vessels that fish outside their national waters.

ECO-EFFICIENCY – Combined economic contribution and environmental burden by industry.

ECOSYSTEM – The complex of living organisms, their physical environment, and all their interrelationships in a particular unit of space.

ECOSYSTEM APPROACH – In fisheries management this involves a consideration of all the physical, chemical and biological variables within an ecosystem, taking account of their complex interactions. Also known as ecosystem approach to fisheries (EAF) and ecosystem based fisheries management (EBFM).

EUROPEAN MARITIME AND FISHERIES FUND (EMFF) – The proposed new fund for 2014-2020, allocating subsidies to fisheries and maritime activities.

EXTERNALITY – Actions that have effects upon people who are not parties to the contracts governing the actions.

FISHERY – A unit determined by an authority or other entity that is engaged in raising and/or harvesting fish. Typically, the unit is defined in terms of some or all of the following: people involved, species or type of fish, area of water or seabed, method of fishing, class of boats and purpose of the activities. Fisheries range from small family operations relying on traditional fishing methods to large corporations using large fleets and the most advanced technology. Small-scale fishery is ordinarily conducted in waters relatively close to a home port, but factory ships that are equipped to process the catch on board often go thousands of miles from home.

FISH LANDINGS – Fish landings are defined as the catches of marine fish landed in foreign or domestic's ports. Marine capture fisheries landings are subject to changes in market demand and prices as well as the need to rebuild stocks to maximum sustainable yield levels in order to achieve long-term sustainable use of marine resources. This

indicator concerns national landings in domestic ports, national landings in foreign ports and foreign landings in domestic ports. It is measured in tons and USD.

FISHING EFFORT – The amount of time or fishing power used to harvest fish. Fishing power can be expressed in terms of gear size and quantity, boat size, horsepower, fuel consumption, manpower, etc.

FISHING FLEET – The boats used in the fishing industry.

FOOD WEB – The sequence of transfers of matter and energy in the form of food from organism to organism, overlapping and interconnecting with the ecosystem.

GILL NETS – With this type of gear, the fish are gilled, entangled or enmeshed in the netting, which may be either single (gillnets) or triple (trammel nets). Several types of nets may be combined in one gear (for example, trammel net combined with gillnet). These nets can be used either alone or, as is more usual, in large numbers placed in line ('fleets' of nets). According to their design, ballasting and buoyancy, these nets may be used to fish on the surface, in mid-water or on the bottom.

GROSS TONNAGE (GT) – The Gross Tonnage is the measure of the total volume of a ship, determined in compliance to the provisions of the Decree-Law N. 245 / 94.

GROWTH – The increases in cell size and number, or in number of organisms that take place during the life history of an organism.

HABITAT (AND SPECIES) DIRECTIVE – (Council Directive 92/43/EEC on the conservation of natural habitats and of wild flora and fauna): requires EU member states to protect certain rare, threatened or typical habitats or species, as listed in Directive Annexes. The habitats include among others sandbanks, lagoons and reefs. The species include among others Atlantic salmon, bottlenose dolphins, harbor porpoise, common and grey seals, lampreys, otters and sturgeon.

HARVEST – Application of techniques to control the growth and harvesting of animal and vegetable products.

HOUSEHOLD INCOME – The combined gross income of all the members of a household who are 15 years old and older. Individuals do not have to be related in any way to be considered members of the same household. Alternatively, household income is the combined income of all members of a household who jointly apply for credit. Household income is an important risk measure used by lenders for underwriting loans.

INDIVIDUAL TRANSFERABLE QUOTA (ITQ) – Form of fishery management in which quotas are allocated to individual fishermen or vessels. The quotas can be sold to others.

INTEGRATED MARITIME POLICY (IMP) – EU policy launched in 2007, aiming to encompass all elements of marine activity and provide a management framework for a holistic and integrated approach to address economic and sustainable development of EU seas, including transport, competitiveness and research.

LIFE CYCLE – The series of changes that the members of a species undergo as they pass from the beginning of a given developmental stage to the inception of that same developmental stage in a subsequent generation.

LOCAL FISHERY – Fishing carried out by local fishing boats on rivers, estuary of rivers, lagoons, beaches and coast lines along the ground and always near where the ship brawls, anchors or docks.

LOGIST GROWTH – Characteristic of K-selected species, also called K-strategist, species whose populations fluctuate at or near the carrying capacity (*K*) of the environment in which they reside. Species whose populations are governed by their biotic potential (maximum reproductive capacity). Population growth in K-selected species behaves according to the logistic growth equation.

LONG LINE FISHERY – A fishing gear in which short lines carrying hooks are attached to a longer main line at regular intervals. Long lines are laid on the bottom or suspended horizontally at a predetermined depth with the help of surface floats. The main lines can be as long as 150 km and have several thousand hooks.

MARINE STRETAGY FRAMEWORK DIRECTIVE – (Directive 2008/56/EC establishing a framework for community action in the field of marine environmental policy): the aim of the Marine Strategy Framework Directive is to protect more effectively the marine environment across Europe. Member States must take measures to achieve good environmental status of the EU's marine waters by 2020.

MAXIMUM SUSTAINABLE YIELD (MSY) – Largest catch that can be taken from a fish stock year after year without harming its capacity to regenerate for the future.

ONTOGENY – All the developmental events that occur during the existence of a living organism. Ontogeny begins with the changes in the egg at the time of fertilization and includes developmental events to the time of birth or hatching and afterward—growth, remolding of body shape, and development of secondary sexual characteristics.

OVERCAPACITY – Capacity beyond what is normal, allowed, or desirable.

OVEREXPLOTATION – Over use of wildlife and plant species by people for food, clothing, pets, medicine, sport and many other purposes.

OVERFISHED – The state of a stock when it has reached a limit set by management, below which the population may fall to a level too low to ensure reproduction at a rate sufficient to maintain it.

OVIPAROUS – Species where female lays undeveloped eggs that are externally fertilized by a male. Typically large numbers of eggs are laid at one time and the eggs are then left to develop without parental care.

PELAGIC SPECIES – Fish that live in mid water or close to the surface. Pelagic fish include species such as sardine, chub mackerel, anchovy and alike species.

PELAGIC ZONE – Ecological realm that includes the entire ocean water column.

POLIVALENT FISHERY – Kind of fishery carried out by using a variety of fishing gears, such as hook devices, traps, and cages, amount others.

PRECAUCIONARY APPROACH – The principle of taking action based on the possibility of environmental damage, even before there is conclusive evidence damage will occur. In fisheries management due regard must be given to the uncertainties involved in fish stock assessment and management, and appropriate measures must be taken to avoid stocks falling below limit reference points.

PURSE SEINE FISHERY – Fishing performed using a wide fishing net wall, which is always long and wide. The net is dropped from a boat and operated in such a way as to involve the fish schooling and closes like a purse at the bottom, in order to reduce the leakage.

QUOTAS – Total allowable catch (TAC) divided according to different criteria, such as countries, regions, fleets or boats.

RECRUITMENT – The increase in a natural population as progeny grow and new members arrive.

REGIONAL FISHERIES ORGANIZATION (RFO) – The affiliation of different fishing nations which co-ordinate efforts to conserve and manage fish stocks in regions of the high seas.

RELATIVELY STABILITY PRINCIPLE – In the CFP, the principle by which the EU Member States are allocated a fixed share of the Total Allowable Catch (TAC) for a given fish stock, based on their fleet's past record of fishing activity.

SEXUAL DIMORPHISM - The differences in appearance between males and females of the same species, such as in color, shape, size, and structure, that are caused by the inheritance of one or the other sexual pattern in the genetic material.

SPAWING – To deposit eggs; produce spawn. To produce offspring in large numbers.

STOCK – Set of individuals of the same population that share biological and behavior characteristics and react in a relatively homogeneous manner to exploitation.

SUPPLY – Quantity of a commodity that producers wish to sell at various prices.

SUSTAINABLE FISHERIES – Fishing activities that do not cause undesirable changes in the biological and economic productivity, biological diversity, or ecosystem structure.

TOTAL ALLOWABLE CATCH (TAC) – The total amount of fish allowed to be caught from a particular stock over a specified period of time. The TAC´s are negotiated by the European Council once a year, or fixed for several years by long-term management plans that are agreed upon by Council. The EU parliament does not have co-decision on TAC´s.

TRAPS – Maze-like structures of netting or cage-like enclosures, made of metal or other strong materials. All traps have the same basic operating principle, allow the prey to enter but prevent them from escaping.

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1 Introduction

Fisheries have great importance in social-economy of coastal communities that rely in this sector for local development. Jobs and other economical related activities are strongly dependent on fisheries, although the demand for seafood has been increasing and production is not enough to meet human demand. It is also not environmentally affordable to continue exploring existing stocks, which started to display signs of overexploitation, in response to human consumption, more than two decades ago. According to NEF (2014), fish stocks from the European Union (EU) are heavily overfished, in other words, fish are being landed on fishing docks faster than stocks are allowed to recover, which depicts the current enormous global demand for seafood.

Small pelagic species are responsible for the maintenance of purse seine fleets. In Portugal, specifically, this type of fishing gear relies heavily on sardine (*Sardina pilchardus*, Walbaum, 1792) and landings have been decreasing dramatically over the last years. In fact, sardine quotas have been dwindling year after year, which raised an alarm in both fishermen and indirect stakeholders, such as the canned industry. On the other hand, Atlantic chub mackerel (*Scomber colias*, Gmelin, 1789) landings presented an almost constant and linear increase during the same period. This data raises some concern, since linear yields in landings is commonly perceived as an indicator of unsustainable harvesting, which is corroborated by Vasconcelos *et al.* (2012), in their study about this species in Madeira Island.

In Portugal, Atlantic chub mackerel, or chub mackerel, is typically caught by purse seine fishing vessels, and landings have been increasing gradually, which could be related to its abundance off the Portuguese coast, but also to a decreasing tendency in sardine catches, and both can also be related with climate changes, which are increasing mean sea surface water temperature (Gamito *et al*., 2015). Similarly to sardine, chub mackerel is one of the most abundant species in the Portuguese coastal area. It is an inexpensive fish, and it may be consumed in multiple ways. In the past, chub mackerel was considered a “fish of the poor” and thus associated to lower social strata. Nowadays, its consumption is more widespread but still far less accepted in comparison to sardine. Due to its abundance and nutritional value, Docapesca has been promoting a consumption campaign focusing on chub mackerel. Promoting this species fisheries is also a good means of deflecting catches from sardine and contributing to more variability in purse seine fisheries, as well as their sustainability.

Governance often offers subsidies to compensate fishermen for their losses, instead of investing in new alternative ways to ensure financial sustainability by searching and studying alternative stocks that may be harvested sustainably, especially during those times there is a lack in primary target species. This study therefore focuses on understanding if chub mackerel can be a valid alternative choice to purse seine fisheries management.

This study focused on the observation of sardine and chub mackerel landings between 1928 and 2015, and more specifically over the last fifteen years (2000-2015), which showed a seriously decreasing volume in sardine landings, accompanied by an increase in chub mackerel landings.

Sardine stocks are in need of an effective and rigorous management plan that offers fishermen sustainable exploitation alternatives. A management plan for sardine already exists – Sardine Management Plan (2012-2015), followed by the Commission for Sardine Accompaniment, representing all stakeholders involved (the government, fishermen, producer organizations, investigators, industry and civil society). However, discussion tends to center on fishing effort control and therefore not as much in finding alternative fishing options that might help reduce that effort.

As such, combining the Docapesca's campaign promoting chub mackerel consumption, and the increasing chub mackerel landing tendencies, this species may represent an alternative to reduce purse seine fisheries dependency and effort on sardine stocks.

2. Fisheries sector framework

According to the United Nations (2010), 64% of the stocks are overexploited, depleted or recovering; 23% are fully exploited, producing lower yields than their biological and ecological potential, and needing severe management plans to fully recover; 12% are moderately exploited; and only 2% are underexploited. Non-fully exploited stocks have decreased gradually in proportion since 1974 (FAO, 2012). On the other hand, overexploited stocks have been increasing, especially in the late 1970s and 1980s. After the 1990s, the number of overexploited stocks, while still increasing, has done so at a slower rate (UN, 2010). Increasing the production of these almost collapsed stocks, may be possible if effective rebuilding plans are enforced. Overcapacity is a major issue when stock recovery is intended. Many of TAC-regulated fisheries have experienced an increase in fishing capacity, with additional vessels taking temporarily positive rents. The misrepresentative economic models therefore predict regulated bionomic equilibrium at,

or close to, zero, which leads to a major impediment in achieving economically productive fisheries (Hilborn *et al.*, 2003). Regarding this issue, and in line with the new Common Fisheries Policy – CFP (implemented in 2015), governments should improve their fishing sector, venturing in new markets, and innovative ways to marketing sea products.

Portugal's natural characteristics provide for great abundance of small pelagic fish, such as sardines, which represent approximately 40% of the total catch in the country (STEFC, 2013). However, the fisheries sector represents a relatively small weight in the national economy. The Sea Sector Gross Domestic Product (GDP) accounts for 3% of the national GDP (EMFF, 2014), which is a low value, especially considering that Portugal has the 3rd largest EEZ in the EU, and the 11th in the world – covering 1 727 408 km² - and it is expected to expand to nearly 4 000 000 km² as a consequence of recent political negotiations. In a country where seafood is so traditionally rooted, production is not enough to meet demand per capita. According to the New Economics Foundation and an OCEAN2012 report (NEF, 2014), Portugal is the highest fish consumer in the EU and one of the most fish dependent countries. National consumption is higher than the national fleet landings, which renders the country dependent on fish import from non-community countries (NEF, 2015). According to the report "Macroeconomic context and sea economy" from the Bank of Portugal, in 2012 the sea sector had a 0.7% weight in the number of non-financial corporations and 1.5% in business volume, in which fisheries and aquaculture weight were 75% and 51%, respectively (Matos, 2014). For a country so traditionally dependent on fisheries, and with such high consumption levels, economics misrepresent the importance of this sector at regional level.

2.1 Portuguese fleet

Due to its geographical position, Portugal has always been a strategic place for transactions over the sea. From early days, fisheries have played a great importance and have been a major motive for population settlement. Fisheries became one of the most prominent sectors in Portugal during the beginning of the 20thcentury, with both economic and sociological importance (Ribeiro, 2010). In the 1960s and 1970s, Portuguese fisheries peaked its numbers with a fleet to explore local and long distance resources such as the Northeast Atlantic (Newfoundland) and in the South Atlantic (Mauritania). After the April 25th 1974 revolution, the sector began slowly decreasing, which led to a crisis that was difficult to overcome. Economical competition and the total lack of control led to overexploitation of the resources. This had economic and social impact in human populations who relied on the sea for their sustenance (Ribeiro, 2010).

According to STECF (2013), the national fleet register in 2011 was composed of 8 557 vessels with Gross Tonnage (GT) of 102.5 and Total Power (TP) 377.4 KW, with a mean age of 28 years. The Portuguese fleet has shown an overall trend to decrease fleet capacity, either in number of vessels, power and GT, and also in the number of active vessels, which is expected to continue for the next few years. This appears to be the result of the disappearance of older aged vessels from the fleet. Landings' price per kilogram features an increasing trend, related with the decrease in the total landings weight. The sardine action plan and its restrictions, resulted in a decrease of landings around 40% in 2012, from around 54 thousand tons (2011) to 32 thousand tons (STECF, 2013). However, this historical minimum in sardine biomass, may not only be related with fisheries, but also with other factors, such as environmental changes (Gamito *et al.*, 2015). Portuguese vessels operate mainly in IX and X CIEM areas and CECAF, and they are mostly registered as multigear, which means they are licensed for bottom longlines, gillnets, shelter and cages traps. The main species landed are sardines (*Sardina pilchardus*) Atlantic chub mackerel (*Scomber colias*), horse mackerel (*Trachurus trachurus*, Linnaeus, 1758), black scabbard (*Aphanopus carbo*, Lowe, 1839) and tunas (FAO, 2012). Regardless of its aged vessels, and mainly focussing on coastal area, the Portuguese fleet occupies the 4th place in the EU with the highest number of vessels behind Greece, Italy and Spain. Nevertheless, the Portuguese fleet is mainly artisanal; according to Eurostat 91% of the vessels are less than 12 meters in length (STEFC, 2013).

2.2 Risks and opportunities

Fisheries play a key role in human food consumption, as the benefits for human health and well-being are significant. Fish and seafood are a vital supply for the global demand for food, and provide around one-fifth of animal protein consumption worldwide (FAO, 2012).According to the same report, seafood represents a highly valuable source of protein and essential micro-nutrients needed for health and good nutrition. In 2009, the amount of fish for the world population's intake of animal protein was 16.6%; that is 6.5% of all protein intake worldwide. Seafood and aquaculture products, provide for about 3 billion people.

Portugal occupies the 3rd position in global fish consumption, with 57 kg per year per capita, right behind Iceland (first) and Japan (second) (NEF, 2014), which means that part of the national consumption needs to come from external markets. Seafood consumption per capita in the EU appears to achieve a peak after a decade of dynamic growth, the costs of seafood in the EU increasing only 1% between 2011 and 2012

(STECF, 2013). However, the installation of a global crisis must be taken into account while taking conclusions. In more recent years, an increase in concern about making more environmentally-friendly choices, on health benefits and well-being, and on the advantages of consuming seafood products, has been noticed on the consumers' part. Even so, the lack of information is remarkable, and consumers are facing confusing settings of environmental and origin label claims on fish products, defaulting their choices (Client Earth, 2011). Seafood labels claim to guarantee, to consumers and retailers, who want to support non-exploited stocks, which species came from sustainable fisheries.

The Marine Stewardship Council (MSC) is a certifying organization which certifies sustainable fisheries and seafood products (Froese, 2012). Portuguese sardines already received this certification, which was suspended in 2014, due to its decreasing biomass (MSC, 2014). Overexploitation and ecosystem damage, associated with the high levels of demand for fish, have produced a global crisis in seafood production (NEF, 2014). The risks are clear, if global seafood production doesn't manage to supply, in a sustainable way, global demand for fish, overexploitation risks will become even higher. On the other hand, the opportunity to rethink how to process and respond to global demand for fish, may lead the sector to innovate and extend to new business opportunities.

2.3 Stock assessment and management tools

Since early days, the European Union (EU) has faced signs of overfishing amongst its members. There are some historical, well-known, recovery management plans to avoid the collapse of some stocks such as Atlantic cod (*Gadus morhua*, Linnaeus, 1758), European hake (*Merluccius merluccius*, Linnaeus, 1758), and blue-fin tuna (*Thunnus thynnus*, Linnaeus, 1758). The licensing of maritime fisheries activity in international waters has, as a purpose, the use of fishing opportunities of each country's features, according to the Relatively Stability Principle established by the Common Fisheries Policy – CFP, in offshore waters ruled by Regional Fisheries Organizations (RFO) (DGRM, 2012). However, former CFPs were confronted with great challenges and didn't achieve the desirable sustainable exploitation of fisheries as well as conservation, economic and political goals. In 2006, the Council Commission (CC) and the European Parliament (EP), released a statement with the aim of achieving sustainable fisheries in the EU through MSY (Maximum Sustainable Yield) (EU, 2006). In 2007 the European Commission adopted an Integrated Maritime Policy (IMP) that provides a holistic overview of the ecosystem integrated with human activities, which requires understanding the ecosystem as the basis for decision making, a strategy known as

Ecosystem Based Management (EBM). This strategy ensures all elements of maritime activity are simultaneously considered. Economically important fish species have been isolated and distinguished from other species and habitats, as it is extremely important to preserve their entire habitat while assessing the impacts of fisheries. Therefore, it will be possible to manage a sustainable and economic system, not just because of fisheries, but also because climatic changes can affect the size of fish population (WOR, 2013). Facing overexploitation, overcapacity of the fishing fleets, and the reduction in biomass size of fish stocks, in 2009 the European Commission released the Green Paper on the reform of the Common Fisheries Policy (EU, 2009). Its main goal was restoring the productivity of fish stocks in order to guarantee economic and social viability of the fisheries sector. After a period of public consultation, the new CFP was agreed by Council and Parliament and has been in effect since January 1st 2014 (EU, 2015). The new CFP is applied through the EU's waters and fleets, and it lays the foundation for sustainable fisheries management in the EU. If properly implemented, it could lead to stock recovery. A discard ban was also included, intended to be implemented gradually until 2019, which will bring more accurate data on real catches, leading to a better knowledge of resources and consequently better planning (EU, 2015). New CFP calls for more regional responsibility of the member states, especially concerning transparency, social and environmental criteria while allocating fishing opportunities. Rules and policies must be more monitored and governments should ensure their good practices. Also, fisheries management plans must be developed and implemented, leading to the restoration of the EU's fish stock, MSY based, at least until 2020. New CFP will be supported by the European Maritime and Fisheries Fund 2014-2020, which contains some positive measures, as well as more funding to enhance data collection, and improve knowledge of the sea and its resources (EU, 2015). It also leaves it up to member states to choose how to implement the reformed CFP, and how quickly they are to achieve stocks restoration based on MSY.

2.3.1 Maximum Sustainable Yield: its principles and challenges at fisheries management

Maximum Sustainable Yield (MSY) has been very important in biological renewable resources management with commercial value. It is the number or weight of a species that can be removed from the stock of animals, without impacting the long-term stability of the population (NOAA, 2014). MSY provides an indication of the average catch which may be harvested sustainably from a stock under external environmental conditions. The fundamental assumption, behind all sustainable harvest models that seek to MSY, is that populations of organisms grow and replace themselves, i.e., that they are renewable

resources (Holt, 2011). It is also further assumed that growth, survival and reproduction rates increase when harvest reduces population density. Thus it is assumed that there is an excess of biomass that can be removed by harvesting, otherwise it would not be possible (Beverton and Holt, 1957). This harvest rate is based on "surplus production model" theory, that fisheries produce and grow an excess that can be extracted. This theory focuses entire regulatory attention on the outputs and consequences of the regulatory process and the desired biomass of the exploitation (Holt, 2011). The main key to sustainable harvesting is assessing the population abundance trend, and catch only the institutional capability to regulate harvest. Knowing this trend, theoretically, catches can be reduced until stocks stops declining, ensuring the integrity of the stock, although this does not guarantee maximization of the fish stock. The relationship between population size and sustainable harvest needs to be understood if maximum yields are required, as it will prevent stocks from collapsing. Also, it will be possible to identify the ideal population size more prone to maximum harvest (Hilborn *et al.*, 2003). Since the 1950's, fishery policies managed populations applying MSY (Holt, 2011), to the point, presently, it is still the reference in setting sustainable stock levels. According to a statement by Pauly (2014) to OCEANA, fishing "just right" cannot involve a fixed and unchanging MSY, and instead must use a Total Allowable Catch (TAC) set annually, since it seems to allow fish, facing natural environmental fluctuations, inducing natural fluctuations in the size of fish populations. However, this status can be undefined by lobbying, when profits by exploitation of a species with low abundance are allowed to continue operating, when it shouldn't, due to stock recovery. As Pauly (2014) states, MSY's concept is also an important component of the United Nations Law of the Sea (UNCLOS), which requisites countries with Exclusive Economic Zones, or EEZs. Only these countries are allowed to assess their fish stocks relatively to their MSY, and to allow distant-waters fleets access to their EEZ if there was a surplus, which means that they didn't exploit their resources at MSY level. Nevertheless, as fish populations continue to decrease, it is noticeable that MSY, in itself, is not sustainable. It has been criticized by many authors, including Holt (2011), for ignoring several key factors of a proper management at fisheries, and it is lacking biological aspects, namely: (1) errors in calculation, (2) predation, (3) illegal, unregulated and unreported fisheries and (4) atmospheric variables. It is therefore often assumed as a tool of the government instead of scientific knowledge, as reported by Finley (2011), and should be considered a "limit" and not so much a "target".

2.3.2 Individual Transferable Quotas

An alternative way to establish more equality in fisheries, in line with the Relative Stability principle from the CFP, is to utilize Individual Transferable Quotas - ITQs. According to Coelho *et al.* (2011), the idea of creating markets for fishing rights is based on the need to internalise the externalities derived from the common property of fisheries. This system allows the creation of a market for quotas, in which the goal is that, after a period of time, the property rights be driven to the most efficient agents. Since they are the "real owners", they will, most likely, internalize the effects of externalities, as it was intended with this system, allocating the resource with the perspective of optimal sustainable use along the time (Coelho *et al.*, 2011). ITQs are rights over fishery stocks, and they are established by a form of rights-based management (RBM) by the TFCs system – Transferable Fishing Concessions (Buck, 1995; Runolfsson, 1999). The European Commission (EC) claims that, by introducing TFCs, overcapacity will be reduced, and it will probably improve the economic performance for fishermen and ship owners. The European Commission also alerts for the fact that TFCs are doomed to be recognized as an economic tool, thus they will be unsuccessful in achieving, directly and by themselves, environmental and conservation goals. Generally, the ITQ system requires the determination of a TAC, which ensures the sustainable use of the fish stock. The total amount obtained is divided in several units – quotas – that are distributed among fishing companies or enterprises (Coelho *et al.*, 2011). Several fishing nations now have regularly use this organized rights system, including Australia, New Zealand, Iceland, Canada and Namibia (Hauge *et al.*, 2009). An effective rights system amends the economic fisheries incentive, and prevents competition between fishermen for the stock. With their fishing opportunities safeguarded, fishermen can make more rational economic choices concerning when and where catches will occur (Hilborn *et al.*, 2003; Hauge *et al.*, 2009). Another advantage of an ITQ system is allowing the industry to settle on a fleet capacity, adept to optimize individual economic yield to vessels. Moreover, fishermen may often be expected to support management actions that protect and improve fish populations, not only because the values of quota share increased as stocks became more abundant (Hilborn *et al.*, 2003; Coelho *et al.*, 2011). Adopting an ITQ system requires both enforcement and scientific monitoring and some key factors must be considered: incentive structure, institutional capacity, and stakeholder's contribution (Buck, 1995). To be successful, the management must contain a competent management authority, capable to set and implement regulations while monitoring the stock status, along with some terms of rights-based allocation to fishing operations to avoid overcapacity (Runolfsson, 1999; Hauge *et al.*, 2009). If a holistic overview is made

of these management areas, the evidence for the pros of ITQs in supporting resource sustainability is mixed, yet showing more positive incomes (Hauge *et al.*, 2009). Other management systems non-ITQ based, not always fail in maintaining sustainable fish stocks and, on the other hand, ITQ systems are not always successful. The main additional key requirement appears to be the adoption of a management strategy settled on predefined rules of what to do in different circumstances. According to Hilborn *et al.* (2003), the most successful management approaches are expected to combine rights-based systems while creating incentives to fishermen to operate efficiently and with a long-term sustainability basis. Also, an adequate control of fishing activities is required. The ITQ system should be considered along with other tools, integrating the highest possible variability of factors. Nevertheless, there is a problem of property concentration, and a consequent unemployment issue. After a period of quotas changing in the market, it could lead to monopolization of the sector, the number of owners decreasing due to less efficiency of some vessels, thus the importance of the use of integrated strategies to innovate, and the creation of more opportunities to improve the sector while creating more jobs. The use of the Rights Based Management schemes is considerably recent in Portugal. As reported by Coelho *et al.* (2011), there are three types of RBM systems that manage Portuguese fisheries: (1) considering demersal fishery in NAFO, Svalbard, NEAFC, and Norway waters, regarding trawlers, especially those targeting cod stocks; (2) long-liners to the north of the 5th N parallel, concerning swordfish fishery, in the jurisdiction of ICCAT areas; (3) a Community quota approach applied to Producer Organizations – POs – regarding coastal boats targeting sardine. In this case, POs receive an upper limit of catches by the national authorities, although they have the autonomy to input restrictions concerning the number of vessels, fishing days and hours per day, and catches. In the sardine's case, it's not exactly ITQs, but rather "rights to manage", and they are given to POs, not directly to ship owners. As described by Coelho (2010), this participating approach involved all purse seiners, and has allowed national authorities and POs to guarantee control and surveillance on sardine fishery, and it makes part of an Action Plan aiming to protect sardine's juveniles and regulate harvesting and marketing. However, in light of the latest issues regarding sardine fishery, it seems that this "rights to manage" system should be reconsidered.

2.4 Atlantic chub mackerel: Aspects, characteristics and social-economic importance in fisheries

Recently, *Scomber japonicus*, Linnaeus, 1758, usually seen as a cosmopolitan species, was split in two, according to its geographical distribution. The species living in Indo-Pacific waters kept the name *S. japonicus*, while the Atlantic Ocean waters' species were assigned as *Scomber colias*. In light of recent genetics studies, particularly based on mitochondrial and nuclear DNA analysis, *S. colias* is now considered a separate species from the Indo-Pacific congener (Scoles *et al*., 1998; Catanese *et al.*, 2010). *Scomber colias* can often mistake and misidentified as *Scomber scombrus* in fishery landings (Fig.1). Chub mackerel presents phenotypic variations and individuals with a spotted belly and bigger eyes (Matsui, 1967; Scoles *et al*., 1998), which is a distinguishing feature to mark the mackerels. Chub mackerel may be considered the southern congener of Atlantic mackerel. The two species overlap in the Iberian Peninsula, Atlantic mackerel being predominant in the north and chub mackerel south of Lisbon (Martins *et al.*, 2013).

Atlantic chub mackerel, Spanish chub mackerel or chub mackerel, *Scomber colias*, is a

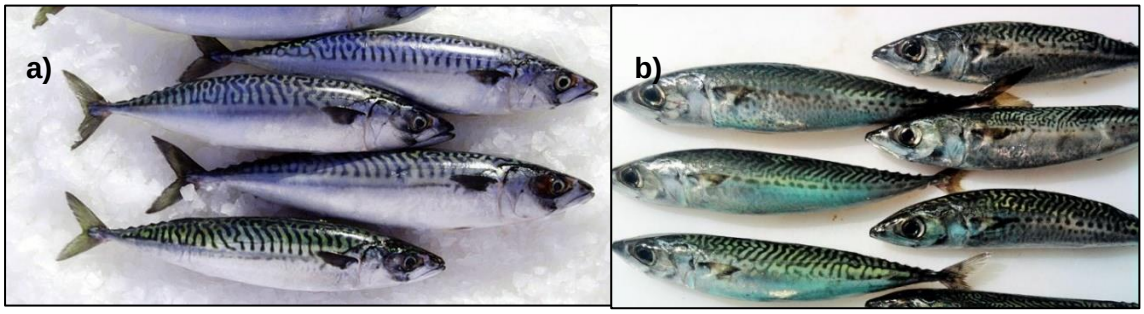

Figure 1 – a) Atlantic mackerel (*S. scombrus*); b) Chub mackerel (*S. colias*)

coastal pelagic schooling fish species, occurring at depths of 250 - 300 meters (Collette, 1986). Widely distributed across the Atlantic Ocean, preferably in warmer waters, eastern and western coasts, where the Mediterranean and southern Black Sea are included (Fig.2). This species shows migratory behaviour (Collette and Nauen, 1983). As many as other commercial species of fish, presents an iteroparous reproductive strategy, which means that they spawn several times along their life cycle. It is an oviparous species, laying eggs in the water column (Vasconcelos *et al.*, 2012). Typically, pelagic fishes spawn in areas with high biological production to ensure the feeding of older larval states, with temperature playing a crucial role during spawning (Vasconcelos *et al.*, 2012). This species presents a migratory pattern between April and September, heading towards the coastline and channel areas for spawning where after, both adults and offspring, migrate deeper into cold offshore areas (Cikes and Zorica, 2012). Chub

mackerel features temporal differences in sexual maturity throughout the Atlantic Ocean (Vasconcelos *et al.*, 2012). Spawning occurs in Portuguese mainland water, between February/March and May/June, under temperatures around 15°C to 20°C (Hernández and Ortega, 2000). Like other small pelagic fish, *S. colias* is a fast growing early maturing species, and may reach 50 cm of total length and 13 years of age, as described by Hernández and Ortega (2000). Total length, in Portuguese waters, reaches up to 20 cm in the first year of life and sexual maturity at 1 - 2 years of age (Martins *et al.*, 2013). Both juveniles and adults feed mainly on zooplankton (Martins, 2004), although adults' diet is varied. Since it is an opportunist species, it may range from copepods, invertebrates, small pelagic fishes and fish eggs (Abreu, 2011; Castro, 2012). Off Morocco and the Western Sahara, adults also feed on sardines (*Sardina pilchardus*), as reported by Hernández and Ortega (2000). The ontogenetic change in diet is associated with a tendency for older individuals to be distributed more offshore (Baird, 1978 in Martins *et al*., 2013). This species also presents a migratory pattern across latitudes and between costal and offshore areas, not only concerning spawning but also feeding behaviour (Sinclair 1985; Hernández and Ortega, 2000). Although within European Atlantic waters, spawning grounds and migrations patterns are not well known (Martins *et al.*, 2013). This species is an essential element in the diet of larger fishes and mammals and therefore plays an essential key role in the food web due to its intermediate level biomass (Cikes and Zorica, 2012).

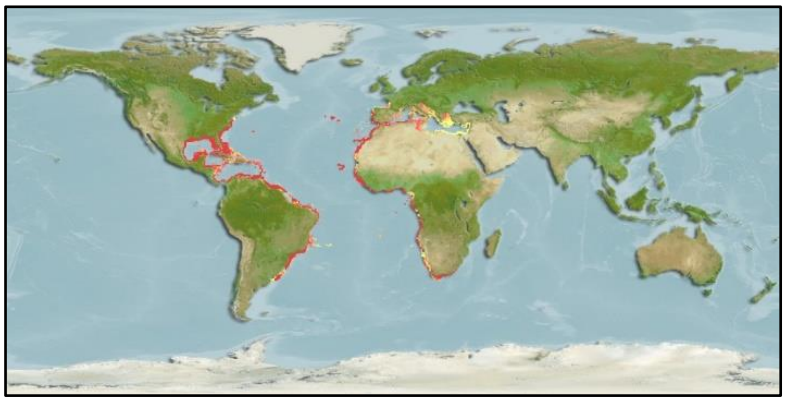

Figure 2 – Atlantic chub mackerel (*Scomber colias*) distribution range.

According to the IUCN (2011) chub mackerel is considered a "Least Concern" (LC) species, there is no TAC implemented and it has commercial importance. The greatest landings reported are from the eastern central Atlantic, where landings have fluctuated, although an assessment by STECF (2009) determined that the stock is fully-exploited. However, there is no evidence of long term declines. Despite the fact this species is listed as Least Concern, there are some indications of regional declines and cases of local depletions should be monitored closely (IUCN, 2011).

2.4.1 Role in fisheries

Despite its importance in the food web, chub mackerel also has commercial importance for fisheries and it is traditionally exploited in several areas as well as the Adriatic Sea (Cikes and Zorica, 2012). This kind of fish is usually caught by purse seine fishing gear targeting sardines and similar species and catches pelagic species together, often causing misidentification. In Morocco fishery landings, for example, mackerels are identified as *Scomber* sp., neglecting species level identification, as reported by Cissé and Belghyti (2005). In the European Union the correct identification to species level is important for fisheries management and setting fish quotas among the members (Vasconcelos *et al.*, 2012). These species are typically a bycatch and may provide a viable and potential alternative to the economic and social value of fisheries, particularly in Portugal, where it may be used as an alternative income if there is low availability of targeted species, such as sardines. Also a report on evaluation of Good Environmental State (GES) of Portuguese fishing stocks, from IPMA (2012) featured a good GES for chub mackerel, although they advised for the insufficient data, and the lack of consistent data collection focused on this species (Azevedo *et al.*, 2012).

Regarding consumption, it is a diversifying fish and may be consumed in a wide variety of ways, as well as fresh, frozen, canned, smoked and salted. According to the FAO (2012), annual landings, in the eastern Atlantic, are around 200 000 tons, and 80% of the catches occur in northwest Africa. In Portugal, chub mackerel is mainly caught through purse seiners targeting sardines. Nevertheless, and regardless of its low commercial values, chub mackerel is the second highest in total annual landings biomass, right after sardines (INE, 2011). According to Martins *et al.* (2013) and Gamito *et al.* (2015) since the 1980s, national chub mackerel landings seem to vary inversely with sardine landings and represent around 10% of total purse seine landings. Commercial landings mostly catch 1 - 2 year old individuals, and a scarcity of larger individuals could be a consequence of aspects such as a deeper distribution and avoidance of fishing gear, migration of the elders, or both (Martins *et al.*, 2013), although southern Spain landings present individuals 6 years old (Velasco, 2011). Martins *et al*. (2013) report claims that in years with high abundance, the fishery expands to the north-western areas of the Iberian Peninsula, and this appears to be motivated by improved recruitment. Nevertheless, other factors may be involved, as well as targeting to compensate sardines losses and the opening of new markets (Martins *et al.*, 2013). Chub mackerel also plays an important role in canned manufacturers, in fact the majority of this species' landings is absorbed by this industry. Along with sardine and tunas, chub mackerel ranked in the top three of most used species for canning. According to the

ANICP (2010) 16 000 tons of canned chub mackerel are produced in Portugal, which represents 27.3% of total production in a 250 million € turnover business, representing a positive input to the national trade balance. About 60% of this production is focused on external markets and it is also the industry, in Portugal, with the largest capacity for using national feedstock (Castro, 2010).

2.4.2 Interactions between chub mackerel and sardine

According to Hernández and Ortega (2000), chub mackerel booms and busts were part of global changes, often associated with environmental shifts affecting pelagic ecosystems in some regions in a decadal scale. Martins *et al*.'s (2013) study with landings and recruitment indexes, suggests that, due to the complementary spatial distribution of chub mackerel and sardine, and the inverse correlation between their occurrence's frequencies, there seems to be a possible association with climatic variation, also suggested by Gamito *et al* (2015). A demonstrative example was reported by Takahashi (2009), concerning pelagic ecosystem off Japanese waters; Pacific sardine (*Sardinops sagax*, Jenyns, 1842) and anchovy (*Engraulis ringens*, Jenyns, 1842) displayed intense out-of-phase fluctuations in abundance since the 1940s, leading to an anchovy period up to the late 1960s followed by a sardine period in the 1980s, shifting over in the 1990s. Nonetheless, Martins *et al's* (2013) study did not show any significant effect in the number of sardines in the presence of chub mackerel, either with a common area effect or with separate modelled area effects, and landings of both species generally reflect their spatial distributions: chub mackerel in south and southwestern areas while sardine is fished mostly in the northwest area. More recently, in Portugal, chub mackerel has grown in interest in line with the perception, shared by fishermen and scientists, of a synchronized increase of its availability and decrease in sardine's abundance.

2.4.3 Consumption as an alternative choice

While the productivity of EU fish stocks has decreased, fish consumption remains at a level beyond that of which EU waters are able to support. Governments and industries also have a role to play in promoting responsible consumption (NEF, 2014).

Led by its mission of providing a quality service, particularly during the fish's first sale level and included in the "Comprovativo de Compra em Lota - CCL project" (proof of purchase in auction), the Docapesca has been promoting a campaign to promote chub mackerel consumption since 2012. This campaign results from a partnership between Docapesca, Portuguese Municipalities, Tourism and Hotel Business schools and ANICP

(National Association of Manufacturers of Canned Fish) (Docapesca, 2014). Since then, the promotion of multiple marketing actions has been conducted in different regions of Portugal, in order to raise interest for chub mackerel consumption. During a first phase, these actions were carried at municipal markets and supermarkets, showing this species to the public and promoting different ways of consuming it. The second phase of the chub mackerel's campaign project was focused on professional stakeholders and in promoting it internationally. The purpose was to enforce the positive perception of this species and its health benefits, gastronomic versatility as well as its low price and environmental sustainability. More recently, and in line with its strategic goal of valuing transacted sea products at fish auctions, Docapesca released a culinary contest, under the title "Fish gourmet", in order to find innovative and ready-to-eat ways to consume chub mackerel, opening doors to new, both national and international, markets (Docapesca, 2014). This campaign increased fishermen revenues in 2 million euros in 2013 and also the amount of chub mackerel sailed in auction to 22.8% (Fileira do Pescado, 2014).

3 Study objectives

In order to assess if chub mackerel can be an alternative and a sustainable choice within purse seine fisheries it was necessary to analyse four different perspectives:

1 – Landings evolution over time. How chub mackerel landings have evolved and how it correlates with sardine landings. This was accomplished through the analysis of landings trends in official statistics fisheries data.

2 – Monetary value for the fishery. Did the increase in chub mackerel landings influence auction first price? What is chub mackerel's importance to the ship-owner? Which was analysed through comparisons using data from a specific purse seiner vessel.

3 – The resource status. How is the chub mackerel stock and where are current exploitation level? This was analysed by assessing MSY numbers using different approaches to assure that resources stay in healthy levels.

4 – The consumer. How much is chub mackerel consumed in Portugal? How willing are consumers to include new species in their eating habits and what are their motivations in including it? This aspect was analysed through a survey conducted to obtain indicators of consumption and results on a Docapesca campaign.

The study and analysis of these four aspects will allow to draw conclusions concerning the main question, which is if chub mackerel can be environmentally and economically sustainable as an alternative within purse seine fisheries. Also, this overview will allow understanding of the strengths and weaknesses of chub mackerel exploitation and promotion while offering a view of associated opportunities and risks. Finally, this study pretends to contribute towards sustainable Portuguese fisheries and target fish, ensuring that stocks do not decline to worrying levels, as well as the preservation of the ecosystem where they are integrated.

4 Methodology

4.1 Landings data analysis

Data were collected from two different data bases: 1928 – 1969 – Statistics of Fisheries from the Portuguese Marine Ministry provided by IPMA[1]; 1970 – 2015 – INE – National Institute of Statistics. Only data from Portugal's mainland landings were considered since, in the Madeira and in the Azores Regions, purse seine does not have the same social and economic importance as it has in the mainland. Data collection focused on the total landings of purse seine, chub mackerel and sardine.

A graph for landings' evolution, between 1928 and 2015, was drafted for the three variables in study: purse seine, chub mackerel, and sardine. The aim was to get a perception of what the evolution of these species has been and how they have interacted with one another historically. This is important to analyse and understand the data in view of the social, economic and political environments in Portugal throughout these years and how that has reflected in landings.

A graph for the proportion of each species in the purse seine landings' total was also drafted for the same time period (1928 - 2015). The aim was to understand how each species' proportion varied throughout that period, and to pinpoint the moment when chub mackerel started getting more attention from the sector. This leads to the moment when chub mackerel's commercial interest began, facing the decrease of sardine landings. This is important when overviewing the social, economic and political scenario in Portugal, since then (2000 - 2015). Before this, chub mackerel was regarded as a discard

[1] Instituto Português do Mar e da Atmosfera; Rua C do Aeroporto; 1749-077 Lisboa, Portugal Telefone (+351) 218 447 000 Fax (+351) 218 402 370 http:\\www.ipma.pt

species of purse seine, and its landings were mainly used by the canned industry, thus, the species didn't have commercial importance.

A correlation test (Pearson's correlation test) was applied for chub mackerel and sardine landings to assess how dependent mackerel landings were from sardine landings, in the last fifteen years. This is important to understand how both species landings have influenced with each other, and how dependent they were from each other. All results were considered statistically significant at the 5% level (i.e., when p-value < 0.05). All data were treated with the statistical software IBM SPSS Statistics 22.

4.2 Landings value

Statistics data were collected from the National Institute of Statistics (INE) and from the annual balance sheet of a purse seiner. Mestre Comboio is a purse seine fishing vessel operating in Peniche, with the following characteristics: 23m LOA; 84.97GT and 317Kw. This vessel was considered to be representative due to its characteristics being within the average of the national fleet (20m LOA; 44.39GT and 224.19Kw) (Feijó, 2013) and knowing that the expenses for this type of vessel are similar (*Com pess*. Anabela Leitão, ship owner). This allows an analysis on chub mackerel's economical potential to purse seine fleet.

A graph of individual contribution for both chub mackerel and sardine landings on purse seine total landings was drafted and its variations during the time period considered (2000 - 2015) were analysed. This is done to assess how the total purse seine's value has evolved during the last fifteen years and how each species studied contributed for it. This is important facing the recent economic and social situation in the fisheries sector.

In order to assess how individual value has evolved and to understand how the increasing (chub mackerel) and decreasing (sardine) landings influenced the transaction price and the first price in auction, a graph for total value evolution tendency was drafted and data were analysed. An analysis allows understanding of the potential that chub mackerel has to generate revenue, and if those revenues exist due to the increasing landings, or due to an increase of transaction value per unit (kg/€).

The results of the profit generated by different increases in first price in auction were computed and displayed on a table. This is relevant to discuss the importance of establishing a fair trade price in auction.

Chub mackerel's contribution to cover operational expenses was estimated using the information gathered from "Mestre Comboio", a fishing vessel and company that exists since 2007. Considering that the first 3 years were investment periods, consisting mostly of expenses, only revenues from 2010 - 2015, were used for this study analyses. When executing a quick economic overview company, the last five years are often used as representative.

Vessel weight in the total landings' value of purse seine fleet was assessed by the following expression (1):

Equation 1

$$Vessel\ Proportion = \frac{Vessel\ revenue}{Total\ fleet\ revenue} * 100$$

This allows results to be closer to the reality of the ship owner.

To assess evolution of the chub mackerel and sardine values for this vessel, the incomes from both species were estimated considering its total value landed by purse seine fleet. A graph was drafted displaying chub mackerel and sardine estimate income for this vessel between 2000 and 2015. Data from annual expenses for each considered year (2010 - 2015) was also added to the graphic. This information was used to understand the evolution of chub mackerel's importance to fishermen and to discover the moment when it began to fulfil total expenses and generate profit. Values from inflation were not considered, since its variation during this short period of time was not significant for this microeconomic scenario, it being between -0.3% and 3.7% (INE, 2010:2015).

4.3 Estimation of MSY for Chub mackerel

Surplus production models have been broadly used in fisheries since early, due to their simplicity and user-friendly procedures. The theory behind these models is that, because cohorts are not used, parameters such age and growth are not taken into account, which is a reason why these models are so often used in fisheries' management. Despite the importance of such parameters, they are not easily accessed and, most of the time, data are not available.

There are certain aspects needed to be kept in mind when dealing with surplus production models: they are holistic models, dealing with the stock as a unit of biomass and taking into account fishing effort and total catches. These models were theorized to be applied to data for catches and fishing effort, when available for a period of time.

Regarding the fact that chub mackerel's commercial interest has recently increased, and that data were available concerning landings and fishing effort, as well as biological data (such as natural and fishing mortality, and estimated biomass) available in literature (Azevedo, *et al.,* 2012), MSY was estimated using different approaches as suggested by FAO (1998). The number of purse seiners was used as fishing effort unit.

Knowing the fragility and the risks of estimating value for catches, especially concerning recently exploited stocks, which are expected to poorly correlates, different MSYs were estimated using the following Production Models as described:

4.3.1 Schaefer Model

According to King (1995), Schaefer's Model (1954) assumed that the increase in stock biomass corresponds to S-shaped curve, in which r is the rate of increase, or stock growth rate, and B_{max} - maximum biomass - that occurs at half of the environment carrying capacity. Thus, the logistic equation describing the rate of change in stock biomass can be described as:

Equation 2

$$\frac{dB}{dt} = r * B\left(1 - \frac{B}{Bmax}\right)$$

If the stock is exploited, the catch rate or yield (Y) per year can be deducted as:

Equation 3

$$Y = r * 1 - \frac{B}{Bmax}$$

This equation suggest that maximum yield occurs when biomass is one-half its unexploited level. According to catchability coefficient definition – q – catch or yield from a stock can be described as Y = q * f * b, and considering Y/f is equivalent to catch per unit effort: CPUE = q * B, and therefore:

Equation 4

$$B = \frac{CPUE}{q}$$

Substituting eq.4 in eq.3 gives:

$$Y = f(CPUE) = r\left(\frac{CPUE}{q}\right)[1 - \frac{\frac{CPUE}{q}}{\frac{CPUEmax}{q}}]$$

Where $CPUE_{max}$ correspond to the catch per unit effort at maximum biomass (B_{max}) of the stock, which can be divided by CPUE given:

$$f = r/q(1 - \frac{CPUE}{CPUEmax})$$

Thus:

$$CPUE = CPUEmax - \left(CPUEmax * \frac{q}{r}\right)f$$

Which is a straight line with a slope b = (-$CPUE_{max}$ q/f)*f and an intercept a = $CPUE_{max}$ that is a line of the form:

Equation 5

$$CPUE = a + bf$$

Where *a* and *b* are constants. Multiplying by fishing effort, f, and recalling that yield (Y) is equal to f * CPUE gives:

Equation 6

$$Y = af + bf^2$$

Which represents the equation for Schaefer's model relating yield and fishing effort. As suggest by King (1995), this models approach intends to use long series of annual catch and effort data.

Schaeffer Production Model biological assumptions, formulated by Ricker (1975) as cited by FAO:

"Near maximum stock density, efficiency of reproduction is reduced, and often the actual number of recruits is less than at smaller densities. In the latter event, reducing the stock will increase recruitment;

When food supply is limited, food is less efficiently converted into fish flesh by a large stock than by a smaller one. Each fish of the larger stocks gets less food individually; hence a larger fraction is used merely to maintain life, and smaller fraction for growth;

An unfished stock tends to contain extra older individuals, relatively, than a fished stock. This makes for decreased production, in at least two ways: (a) larger fish tend to eat larger foods, so an extra step may be inserted in the food pyramid, with consequent loss of efficiency of utilization of the basic food production. (b) Older fish convert a smaller fraction of the food they eat into new flesh – partly, at least because mature fish annually divert much substance to maturing eggs and milt."

This surplus production model assumed that population were in an equilibrium state, meaning that catches biomass were in equilibrium with "real" biomass. All results were considered statistically significant at the 5% level (i.e., when *p*-value < 0.05).

4.3.2 Gulland's Formula

Used for understudied stocks where there were no data available regarding historical data of catches and effort, despite virgin biomass (Bv) and natural mortality (M) being known. This empirical formula could give a primary, yet rough, estimation on MSY based on the few data available. In this study, this formula was considered due to the recently commercial interest in chub mackerel, even acknowledging historical landings.

Gulland suggests estimating MSY according to the following equation (7):

Equation 7

$$MSY = 0.5 * M * Bv$$

Where: *M* – Natural mortality; *Bv* – Virgin biomass.

This formula is supposed to be used in understudied and slightly exploited stocks. Gulland advised the necessity of using virgin biomass so it should only be applied for non-exploited stocks.

Gulland's formula assumptions according to Tiurin (1962) and Alverson and Pereyra (1969), cited by FAO (1998):

a) MSY must be dependent of the virgin biomass, Bv;

b) Higher natural mortality (M) corresponds to a higher production;

c) If biomass = 0.5 * Bv and F = M, under an optimum exploitation level, MSY can be estimated;

Population stocks features equilibrium between births and deaths.

4.3.3 Cadima's Formula

A more comprehensive formula was proposed by Cadima (Troade, 1977 in FAO, 1998) to estimate MSY of exploited stocks with few data available.

According to Cadima, MSY could be estimated using the following equation (8):

Equation 8

$$MSY = 0.5 * Z * \bar{B}$$

Where: Z - Total deaths (M + F) and $\bar{B}$ – average biomass (annual).

This equation was often used in developing and some developed fisheries, where time series for catch and effort data weren't available, but occasionally estimated biomass values were present.

This equation was regarded since there were important parameters available considered important to be used such as, average biomass between 2007 and 2009, natural mortality (M), fisheries mortality (F) and the consequent total deaths (Z).

According to Garcia *et al.* (1989) Cadima's formula only gives unbiased estimates when:

a) The stock is virgin, therefore correspondent to Gulland's Formula;

b) The stock examined is being fished at MSY levels at the time of the survey for biomass estimates.

c) It is assumed that stock population was in constant equilibrium.

4.3.4 Garcia, Sparre and Csirke Model

Regarding Gulland and Cadima's assumptions, Garcia *et al.* (1989) proposed an alternative way to estimate MSY based on Schaefer's Model. It was assumed that average biomass and current yield were known for one year. It also assumes that natural mortality (M) is available and there was a relationship between M and f_{MSY} represented by: $f_{MSY} = k * M$; where k was a constant. Assuming that k = 0; $f_{MSY} = M$ (for stocks where f_{MSY} is unknown, which corresponds to the most cases) Schaefer's production model may be applied and MSY could be estimated according to the following equation (9):

Equation 9

$$MSY = \frac{M^2 * B^2}{2 * M * B - Y}$$

Where *M* – natural mortality; *B* – estimated biomass; *Y* – year catch

As the authors stated, this model was developed to feature a rough first overview of MSY.

Model assumptions considered a pair of observations on catches and biomass, and the relationship between M and f_{MSY} (f_{MSY} = k * M) as enough to assess a first value of MSY. The model also assumed that the stock population was in an equilibrium state and the average estimated biomass and catches have the same age/lengths structure. As so, biomass values should not include juveniles, and seasonal oscillations such as growth, mortality or recruitment should be considered and levelled off, as far as possible, to obtain an appropriate annual average of the total biomass.

In order to assess chub mackerel landings evolution (2000 - 2015) and correspondent exploitation level, a graph was drafted featuring chub mackerel landings and MSY estimations from the four considered production models.

4.4 Chub mackerel consumption in Portugal

Survey

A survey was carried out in 4 different geographical areas from Portugal's coastal area were Docapesca campaigns, promoting chub mackerel, were in effect: Aveiro; Peniche; Lisbon and Olhão (Fig.3). Therefore, in each location, consumers from supermarkets and traditional markets were targeted for the survey. This selection ensures heterogeneity in behaviour as far as species consumption level, habits and tradition. That is, these choices were made having in mind the eventual differences in habits and traditions between regions and the eventual differences between supermarket and traditional market consumers. Data were collected between June 2014 and June 2015, during different times of the year at the selected regions. Sampling from traditional markets was done on Saturday mornings, since these markets are usually less visited by consumers during the week, compared to the weekend. On the other hand, the supermarket surveys were conducted along multiple times of the different days of the week and in different supermarkets per region.

These regions were primarily chosen for sharing the general assumption that the Docapesca chub mackerel promoting campaign was carried in each. Therefore, regions were chosen regarding intrinsic characteristics thought to be relevant, as described next.

Aveiro was chosen due to it was considered as the northern limit concerning chub mackerel catches, since to the north of Aveiro chub mackerel landings were not as noteworthy, so less consumption was expected. Also, Aveiro is a capital district city, meaning that, due to its size, it is not entirely dependent on fisheries, despite the importance of its fishing port. It was therefore expected less traditionalism in consumers regarding their food habits.

Peniche is one of the most important fish ports in the country, and the majority amount of the fishing fleet relies on purse seiners, which harvest small pelagic fish stocks, such as sardine and chub mackerel. The local economy is strongly dependent on the fisheries sector, and so traditionally rooted. Also, the Municipality and canned producers, in line with the Docapesca campaign, joined efforts to create a chub mackerel can printed with images of Peniche, promoting both the fish and the region.

The choice of Lisbon related to the fact that it is a metropolis. Traditionalisms concerning consumption were not expected, due the variability of consumers, life-style, and the fact that it is a large and cosmopolitan city. This was assumed to bring some heterogeneity to the sample.

Olhão was chosen regarding its traditional nature, being a fishery community, and for its dependence on fisheries. Also, Olhão is a fishing port with very relevant landings and one of the less touristic regions of south, which is important in trying to understand traditional patterns regarding consumer choices.

The survey was composed of 7 closed questions and conducted following a traditional interviewing method. All answers were anonymous, thus ensuring a higher level of participation and honesty. Also, age and gender were registered to outline the profile of chub mackerel consumers. Participants were chosen randomly.

Two assumptions were taken into account while conducting the interviews: (1) only fish consumers were considered and (2) only local residents were considered. These assumptions, along with the chosen selling points and regions, guarantee the homogeneity in terms of consumption levels of fish, habits and traditions, which will therefore including only local fish consumers. The goal in filtering these two assumptions

is to ensure homogeneity at this level, meaning that only the residents who usually consume fish were considered. This is important to targeting campaigns.

Figure 3 – Portugal districts map highlighting the cities where survey was conducted.

Objectives and research questions

The first aim of this study is to assess chub mackerel consumption according to the consumers' willingness to consume this species. It is important to know whether fish consumers have - or haven't - included chub mackerel in their food habits, considering preferences of fish eating habits as an independent variable. Another objective was to assess how Docapesca campaigns have - or haven't - influenced consumers' choice for chub mackerel.

The second aim is to segment consumers by region (Aveiro, Peniche, Lisbon and Olhão) according to their habits and preferences, considered as independent variables a set of socio-demographic attributes, as well as motivational and behavioural characteristics.

In particular, it is important to identify the residents segments that are more prone to consume chub mackerel as well as the key variables that characterize them. Hence, the core research hypotheses are:

H1 – Age does not influence chub mackerel consumption.

H2 – The point of sale (traditional market / supermarket) does not influence chub mackerel consumption.

H3 – Residence area does not influence how chub mackerel is consumed (fresh / canned).

H4 – Docapesca campaigns to promote chub mackerel consumption haven't influenced its consumption.

Determination of sample size (n)

According to Vicente (2012) sample size was estimated considering simple random sampling in line with Larossi's (2011) definition that every individual has the same probability of α. This kind of sample size determination approach relies on 3 factors: 1) Sample size; 2) variability of the parameter intended to calculate; 3) Intended level of precision and confidence.

Sample size was therefore determined for one of each of four regions. Data from the last official Portuguese census (INE, 2011) was collected to assess the different numbers of residents, which was considered as population size (N) (Tab. 1).

Sample size was thus calculated according to the following formula:

Equation 10

$$n = \frac{Z^2_{\propto/2} P(1-P)}{e_0^2 + Z^2_{\propto/2} \frac{P(1-P)}{N}}$$

N – Population size

n – Sample size

P – Population proportion

e_0- Intended precision level

α – Intended confidence level

$Z_{\alpha/2}$- Z distribution corresponding to α level of confidence

A total sample of 783 residents (segmented by location; see table 1) was therefore determined using the most conservative estimate for a single proportion (0.5), a confidence level of 95% and a margin of error of 7%.

Table 1 – Number of residents in each sampled city

Region	N (residents)	Sample size (n)
Aveiro	48450	196
Peniche	27753	195
Lisbon	547733	196
Olhão	45396	196

Source: National Institute of Statistics (Censos, 2011)

Pilot test

The research instrument was the object of a preliminary test, a pilot test, before its final implementation. The first survey version was therefore taken with few fish consumers at the traditional Peniche market and 3 experts in statistics, social sciences, economics and natural resources assessment, with vast experience in survey and questionnaire analysis. The goal was to validate the text, structure, content and extension.

The pilot test was conducted during May 2014. As a result, some changes were implemented, which led to the final survey (appendix questionnaire). After survey validation, data collection took place personally in traditional markets and supermarkets at the 4 regions Aveiro, Peniche, Lisbon and Olhão (Fig. 3).

The main advantage of applying the questionnaire personally was to ensure additional accuracy in obtaining a proper profile of the subject, which is important to know consumption habits of chub mackerel from global and regional point of view. Also to ensure the correct effort in fulfilling the assumptions made.

Data analysis methods

Data analysis in this study began with the descriptive assessment of consumers' behaviour and attitudes regarding preferences. This was followed by data analysis using parametric (namely, t-student and analysis of variance tests, (Zar, 2010)) and non-parametric tests (namely, Chi-squared test for association in contingency tables (Siegel, 1988)).

For t-student test and analysis of variance, all assumptions related with them (namely, normal data and homogeneity of variances) were validated. When those requisites failed, the non-parametric test of Kruskal-Wallis was applied. When adequate, multiple comparisons were made by the Bonferroni test.

On the other hand, a Chi-square test was applied since it is a statistical test commonly used to determine whether there is a significant association between two variables according to a specific hypothesis. Therefore, it is thus possible to detect and describe patterns of association (or dissociation) between the various issues addressed throughout the questionnaire.

Due to the research hypotheses 1 (H1), a t-student test was used to evaluate differences in the age of the individuals when compared their habit in consuming chub mackerel (that is, question 2 of the questionnaire; see appendix questionnaire). Additionally, one factor analysis of variance (ANOVA-one way) was applied to evaluate differences in age when compared consumer preferences and practices (namely, preference between fresh or canned and habit in terms of consumption time, that is, questions 3 and 4 of the questionnaire, respectively; see appendix questionnaire).

A Chi-square test for association in contingency tables was used to determine whether there is a significant association between sampling regions (Aveiro, Peniche, Lisbon and Olhão) versus consumption of chub mackerel and selling point (traditional market or supermarket) (questions 2 and 5 of the questionnaire, respectively; see appendix questionnaire) according to the specific hypothesis 2 (H2). The same procedure was applied to address the objective under research hypothesis 3 (H3) (that is, the relation between sampling regions versus the preference of consuming chub mackerel fresh or canned, i.e., questions 2 and 3 of the questionnaire, respectively; see appendix questionnaire).

Finally, a Chi-square test was identically applied to answer the last hypothesis (H4). This consisted of evaluating if chub mackerel consumption was independent of the knowledge of the Docapesca campaign, and if that campaign influenced the inclusion of chub mackerel in daily diet food habits (questions 2, 6 and 7 of the questionnaire; see appendix questionnaire)

When appropriate, all results were presented as mean $\pm$ standard deviation (SD). All results were considered statistically significant at the 5% level (i.e., when p-value < 0.05). All data were treated with the statistical software IBM SPSS Statistics 22.

5 Results

5.1 Landings data analysis

From the late 1920s until the late 1940s, sardine landings displayed multiple increases and decreases, although always representing most part of total purse seine landings. However, this confirmed the previous assumption that, from early, sardine had always great importance in landings, either by its traditionalism or by its abundance. During the same period of time, chub mackerel landings were very low, rarely reaching more than hundreds of tonnes landed (Fig.4). Additionally there were no data available for purse seine's total landings, making it impossible to compare with partial landings (lack of data: 1928 - 1938; 1946; 1948 - 1959; 1987 - 1997).

During the 1950s, as it was also shown in figure 4, landings started to increase until the mid-1960s. These results could be explained by improvements in technology used in fisheries, especially concerning engine power and Gross Tonnage (GT), a consequence of the 2nd World War, allowing fishermen to catch more, more often, and further way from port of origin. Fisheries were also free-access by that time. During this time period, chub mackerel landings also increased, but remained far from being comparable with sardines'.

Graphic analysis reveals a period of great volume of total landings in the 1960s, heavily supported by the high volume of sardine landings. The decade after, landings started to decrease and that tendency remains to this day (Fig.4). Two main factors might be responsible: the first one associated with signs of over exploitation and the fact that stocks were not recovering; a second one related with the political environment after the fall of the regime and the economic instability felt, as supported by Ribeiro (2010), followed by Portugal's admission to the European Union in 1986, which brought new rules and goals to the country. Historically, sardine landings always suffered periods of low abundance followed by periods of great abundance which is in accordance with this species behavioural pattern concerning biomass variations. After the last largest low abundance period, in 1969 (Fig.4), sardine stocks started to show some fragilities in its recovery and never reached historical landings. Nevertheless, it remained constant in the 1980s, progressively decreasing during the 1990s. By the end of the millennium, sardine had reached a historical minimum from which it never fully recovered. Sardine landings kept decreasing progressively until the second half of the first decade of 2000 where it reached very low volume of landings, comparing with the historical register. This decrease was followed by an increase of mackerel landings which had remained very low and relatively constant until then, despite one or two peaks, for example in 1970,

right after a low abundance year of sardine (1969). Nevertheless the relationship between these landings was very difficult to correlate. Two peaks were also registered (1999 and 2000) after a sardine minimum in 1998, also very difficult to relate. It was after 2004 that mackerel landings featured a tendency of almost linear improvement accompanying the regular decrease of sardine landings. Mackerel landings have been increasing and have since 2012 passed sardine landings, remaining higher (Fig.4).

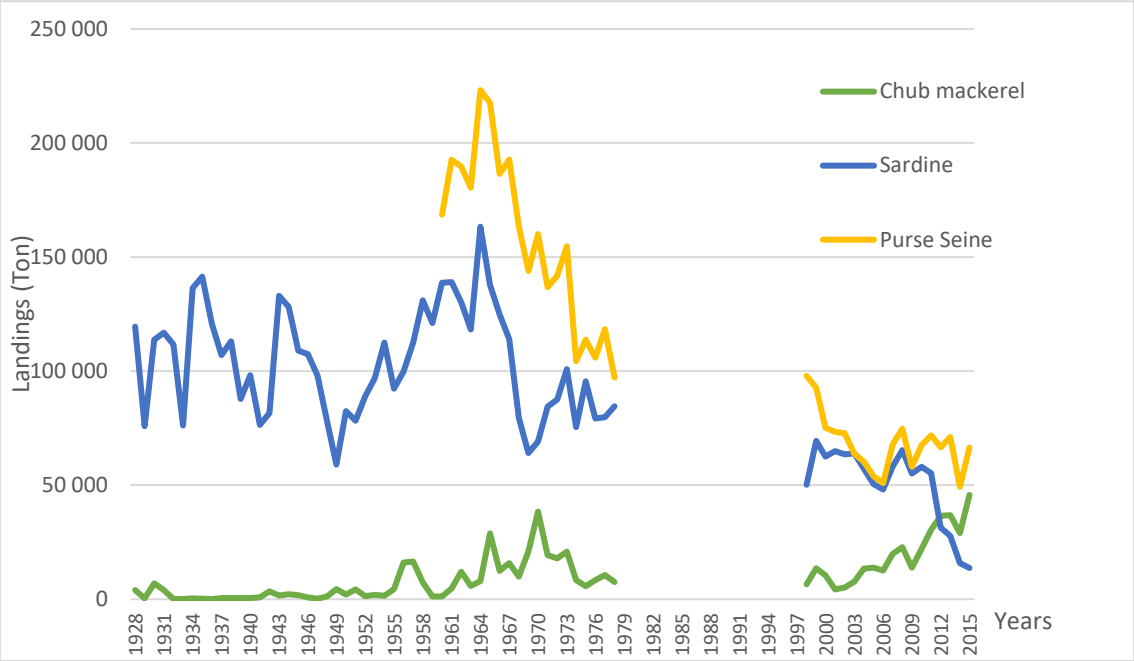

Figure 4 - Evolution of the purse seine, chub mackerel and sardine landings in Portugal between 1928 and 2015

Results show that variations in the purse seine's total landings are accompanied by variations of sardine landings revealing the great importance of this species in this fishery. This species' landings always ensured approximately 50% of the total volume landed by purse seine fleet (Fig.5). On the other hand, chub mackerel barely achieved 10% of purse seine landings during the time series until 2004. Since then, this species has being increasing in volume reaching over 30% in the last two years. Chub mackerel have been growing more in weight in total landings since 2000. This marks the moment when the sector featured some changes in its behaviour looking for alternatives to sardine. Faced with this and with the recent events in the sector's social and economic activity, it is important to set a time series that better translates the current exploitation level for chub mackerel since, until very recently, it was considered a bycatch species with low importance, whose landings were mainly used by the canned industry. Thus, the last fifteen years (2000 - 2015) were considered to be noteworthy for this study.

Landings from both species revealed a strong inverse relationship between them. Pearson's product-moment correlation coefficient displayed a negative correlation between the two variables ($r = -0.804$, $r^2 = 0.646$, $p < 0.05$). This confirms the decrease of sardine landings strongly influences the increase of the chub mackerel landings. Approximately 65% of the increase in chub mackerel landings were related to the decrease in the volume of the sardine landed in the last fifteen years. A linear regression was applied to assess the increase rate of chub mackerel landings due to the decrease of sardine landings (Fig.6). The linear regression equation displayed a slope equal to -0.57 which, besides displaying the negative correlation, also shows chub mackerel landings improved 0.57 ton for each ton of sardine not landed.

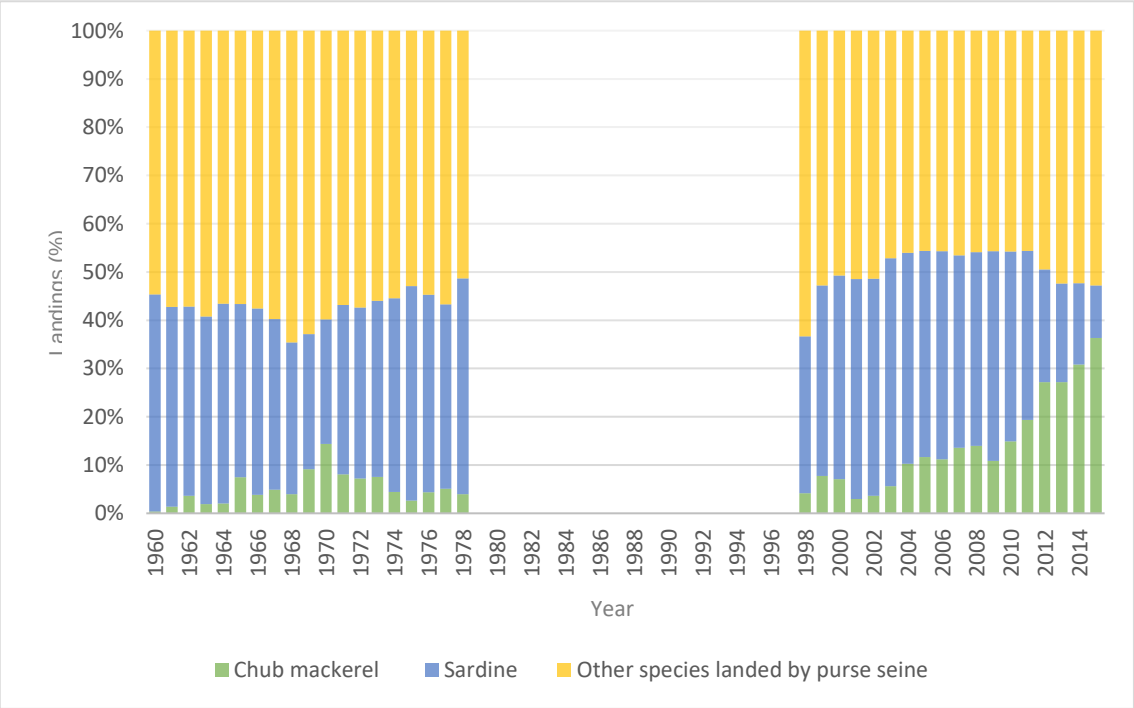

Figure 5 – Proportional weight of chub mackerel and sardine landings in total purse seine landings in Portugal, from 1928 - 2015.

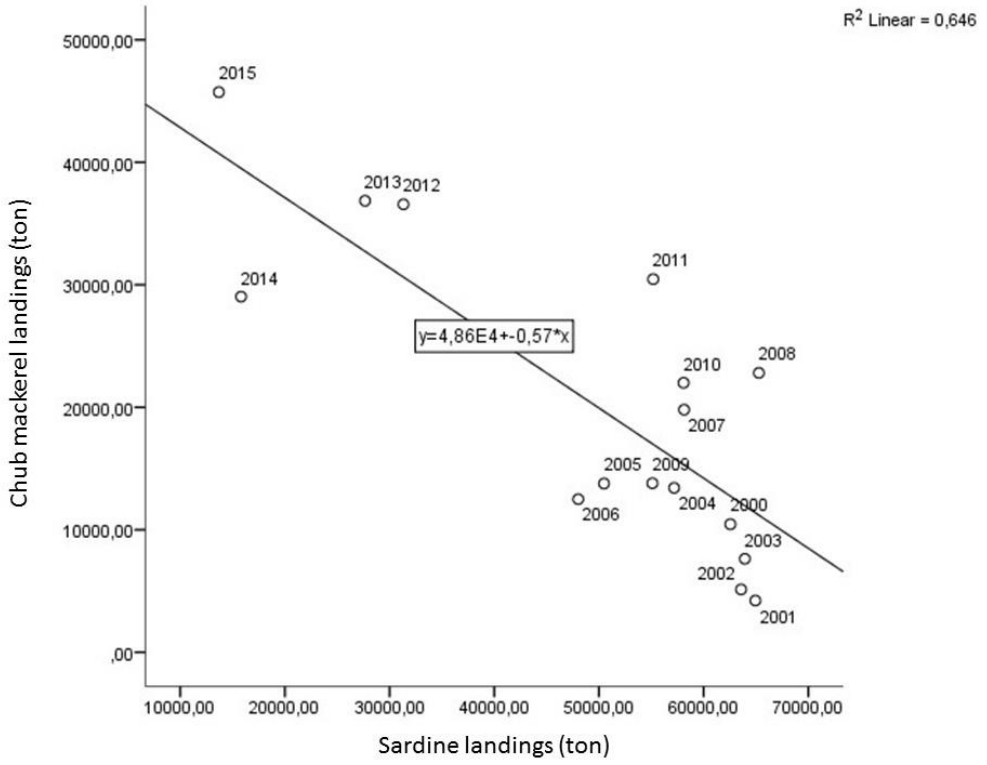

Figure 6 – Linear regression of the dependency relationship of chub mackerel landings on sardine landings.

Because the test was statistically significant ($p < 0.05$) and the correlation was so strong, it is possible to estimate chub mackerel landings from sardine landings. Using the linear equation obtained it was possible to estimate the maximum landing tonnes for chub mackerel (Y_{max}), which is the value that corresponds to the moment when sardine landings are zero (Y_{max}; X = 0).

$$Y_{chub\ mackerel\ landings} = -0.572 * 0 + 48561.07$$

$$Y_{chub\ mackerel\ landings} = 48561.07\ ton$$

According to results, and maintaining the present exploitation level, sardine landings will reach zero when chub mackerel landings ranges 48 561 ton, which is not very far from where we are now, with 45 728 ton of chub mackerel landed in 2015. It is, very unlikely that sardine landings collapse to zero due to the management plan in place to prevent that from happening. However chub mackerel exploitation level seems to be increasing quickly. In 2015 chub mackerel landings were nearly 40% more than in the previous year (47 728 ton and 29 033.8 ton, respectively), which considered it a large increased.

5.2 Landings value

The results show that, despite sardine landings decreasing in tonnes, their value remains constant, allowing sardines to maintain their high weight on the value of purse seine total landings (Fig.7). This demonstrates the importance of the species in total purse seine sales, representing more than 50% in purse seine revenues. Despite the increasing tendency of chub mackerel landings, its value per kilo has remained constant and considerably low (Fig.8), meaning the increase in value of total landings was exclusively due to the increase in tonnes landed.

In turn, sardines price per kilo has been increasing as the landings decrease, contributing fairly to purse seine's total landings income, unlike chub mackerel, whose input barely achieved 10% (Fig.7).

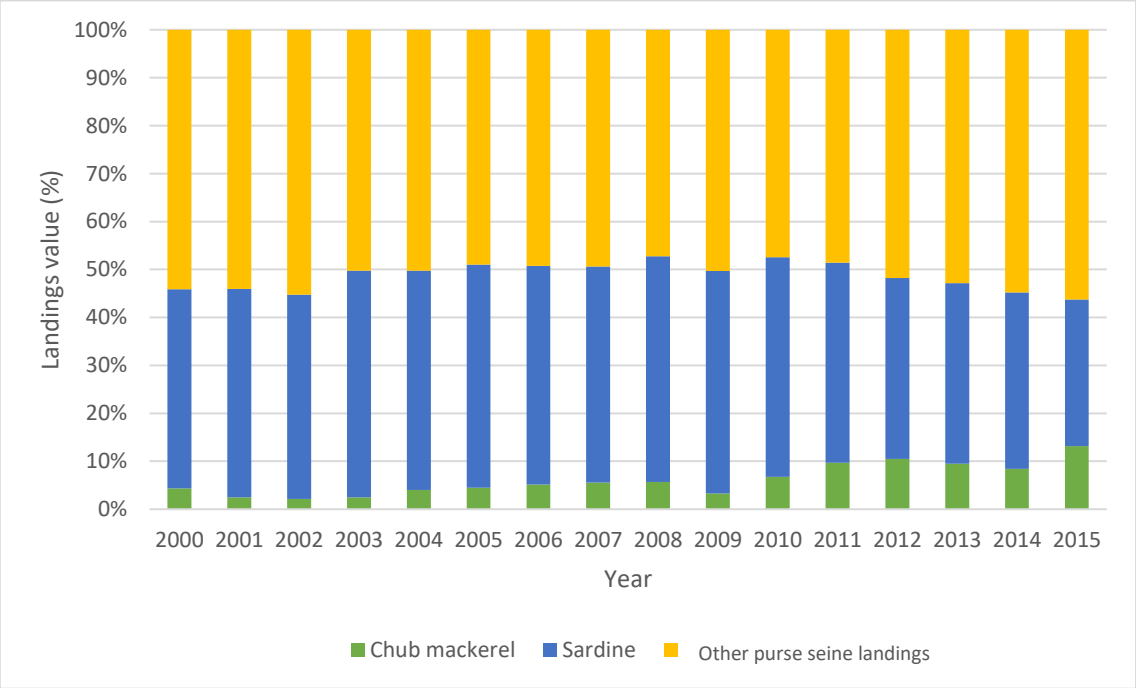

Figure 7 – Individual value contribution of chub mackerel and sardine in the total value transacted by purse seine.

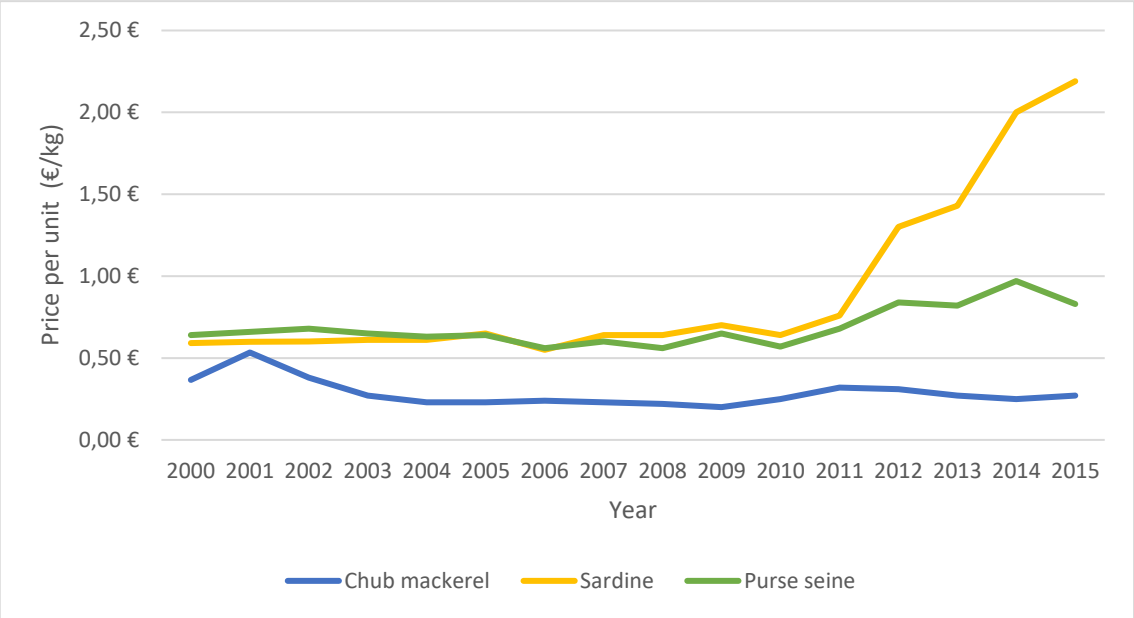

Figure 8 – Evolution of the price per kilo purse seine, chub mackerel and sardine.

Computing the mean value of chub mackerel landings, analysing different improvements in the first sale price in auction became possible, as displayed in table 2. Between 2000 and 2015, the mean value of chub mackerel landings was 5 523 173.23€ in sales, which corresponds to 0.29€ per kilo.

Table 2 – Improvements in first sale price in auction

1st Sale Price Improvement (%)	€/kg	Extra €
10%	0.31	1 735 626.78€
20%	0.34	1 893 411.03€
30%	0.37	2 051 195.28€
40%	0.40	2 208 979.53€
50%	0.43	2 366 763.79€

The results show that small improvements in first price sale in auction could represent significant improvement in the total sales value. For example, a 10% improvement represents 0.02€ more in the average price per kilo (0.31€ minus 0.29€) which translates into more than 1.5 million euros in profit that could potentially be made. In order to double total landings' sales, price per kilo should improve 0.12€ (0.43€ minus 0.29€), which represents almost 2.4 million euros in profit.

Chub mackerel contribution to cover operation expenses[2]

To assess vessel proportion in the fleet, data from the last year (2015) were considered and used to compute the equation 1:

$$Vessel\ Proportion = \frac{Vessel\ revenue}{Total\ fleet\ revenue} * 100$$

Vessel revenue$_{2015}$ = € 869 921, 54

Total purse seine fleet revenue$_{2015}$ = € 54 257 000, 00

Currently, Mestre Comboio has 1.6% of weight in the total revenue from the purse seine fleet; it is then assumed that similar vessels should present similar weights. Thus, it was possible to estimate vessel income by species and compare it with annual expenses (Fig.9).

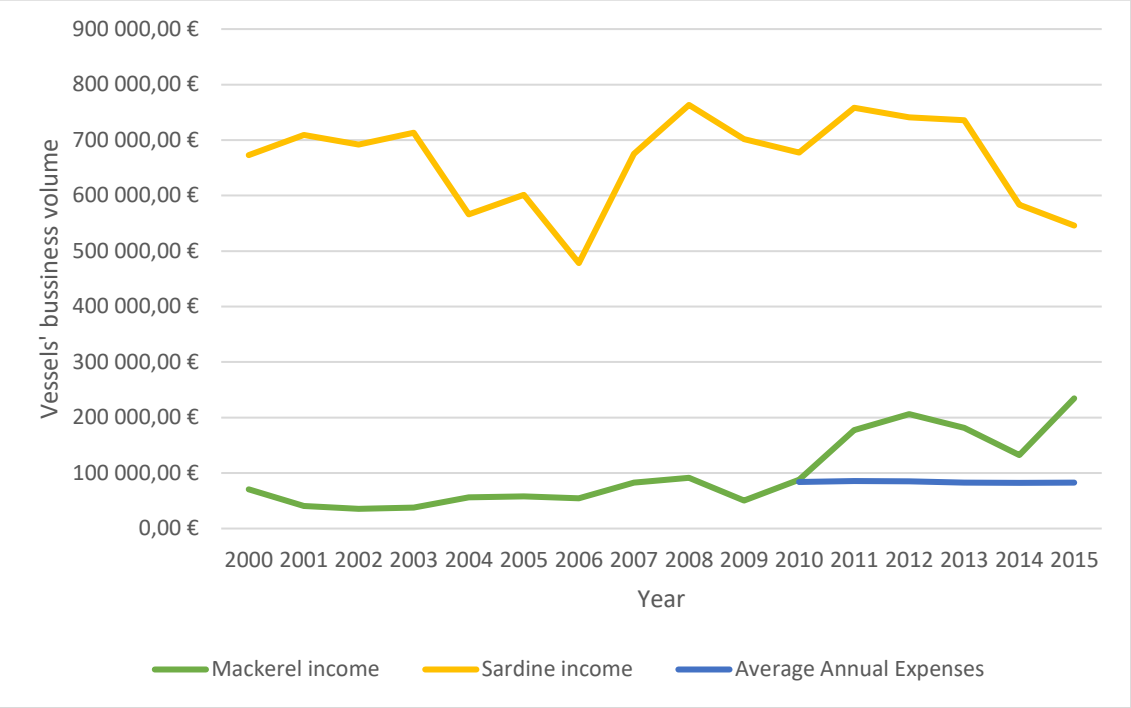

Figure 9 - Vessel incomes from both mackerel and sardine revenues compared with annual vessel expenses.

Results show that chub mackerel already represents profit to the vessel, which from the ship owner's perspective is a good indicator, having the turnover happened in 2010 when chub mackerel estimated revenue achieved € 88 169.00, and vessel expenses € 83 677.51. However, as it is evidenced in the results above, this increase in profit was

[2] Data assessment from the fishing vessel was kindly provided by the owner of Mestre Comboio.

related to the increase in tonnes landed, meaning profit was made by adding effort into resource, which is not a positive indicator from a resource sustainability point of view.

Sardine revenues represent a large amount of profit to fishermen; however, it seems to follow a decreasing trend. Furthermore, a fishing interdiction plan put in action between September 2014 and May 2015, after sardine landings reached alarming low numbers, contributed to the low value in total purse seine landings in 2014. Because this plan affected all purse seine landings, this decrease was also seen in chub mackerel revenue.

Both species seem to be able to generate profit to fishermen, which corroborates the theory that multi-specific fisheries are more likely to sustain than specifics ones.

5.3 Estimation of MSY for chub mackerel

Results were displayed in a table (tab.3) showing the four models and MSY results for each. Assumptions for each model were presented in Chapter 4 – Methodology.

Table 3 – Results for estimated MSY according to four production models

Production Model	**Equation**	**MSY (ton)**
Schaefer's (eq.6)	$\frac{dB}{dt} = fMSY * B - \frac{fMSY.B^2}{fmax}$ f_{msy} = 100,9 f_{max} = 201,8 B = -2.43	24 703
Gulland's Formula (eq.7)	*MSY = 0.5 * M * Bv* M = 0.29 Bv = 150 000	21 750
Cadima's Formula (eq.8)	$MSY = 0.5 * Z * \bar{B}$ Z = 0.31 (0.29+0.13) B = 150 000	23 250
Garcia *et al.* Schaefer's model approach (eq.9)	$MSY = \frac{M^2 * B^2}{2 * M * B - Y}$ M = 0.29 $B_{(2007-2009)}$ = 150 000 $Y_{(2009)}$ = 13 798	MSY $_{(2009)}$ = 33 898

Despite their specific assumptions, all of these four models presented very similar results, which suggest the general assumption that the population stock is in equilibrium. All of them assume the catches biomass is in equilibrium with the "real" biomass, which was considered very difficult to assess. This does not mean that exploitation has been sustainable and in line with the previous results on landings, it seems that the current fishing effort is above the MSY level.

MSY from Schaefer's production model was estimated according to CPUE data and fishing effort during the 2000 - 2014 time interval. Landings from 2015 were not considered since they represented a 40% increase in comparison to the previous year, which was thus marked as an outlier. This very substantial increase was most likely due to the fact that restrictions were in effect in 2014, which unable some fishing from occurring. Nevertheless, this rapid increase should be closely monitored and compared with the upcoming annual landings. Results from CPUE and fishing effort displayed significant relationship (p = 0.03).

MSY was estimated with a computing regression equation (intercept equals to f_{max} = 201.8 vessels, when Y equals zero; and slope (B) = -2.43 (Fig.10). MSY was estimated to be 24 703 tonnes with an associated fishing effort of approximately 101 vessels (Fig.11), which is considered a very low value regarding the data from last years' landings and the number of operating vessels. In 2014 for example, and considering the interdiction fishing plan placed, the number of purse seiners operating was 176, landed 29 033.08 tonnes of chub mackerel. Regarding 2015, operating vessels registered was 181, raising some alarms due its proximity to f_{max}, and consequent overexploitation situation, which is not desirable to any of the parts involved, such as resource, fishermen, and policy due CFP goals in achieving sustainable fisheries and resources.

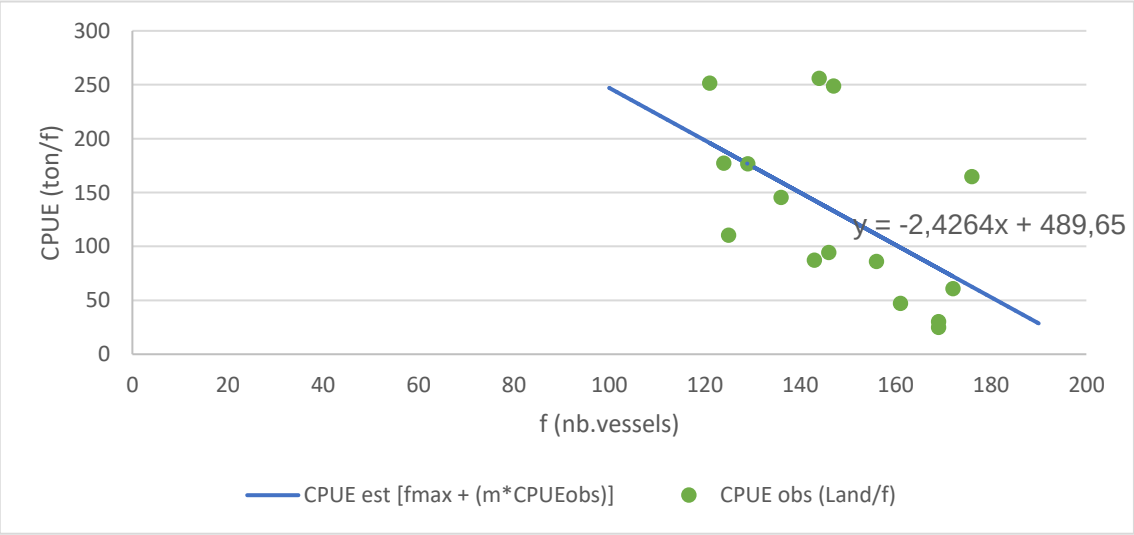

Figure 10 –Catches in tonnes per unit of fishing effort (number of vessels).

Results from the Schaefer's model shows that current fishing effort has been beyond optimum fishing effort, f_{MSY} = 100.9 (Fig.11). Which raised concerns regarding stocks' health, as state above.

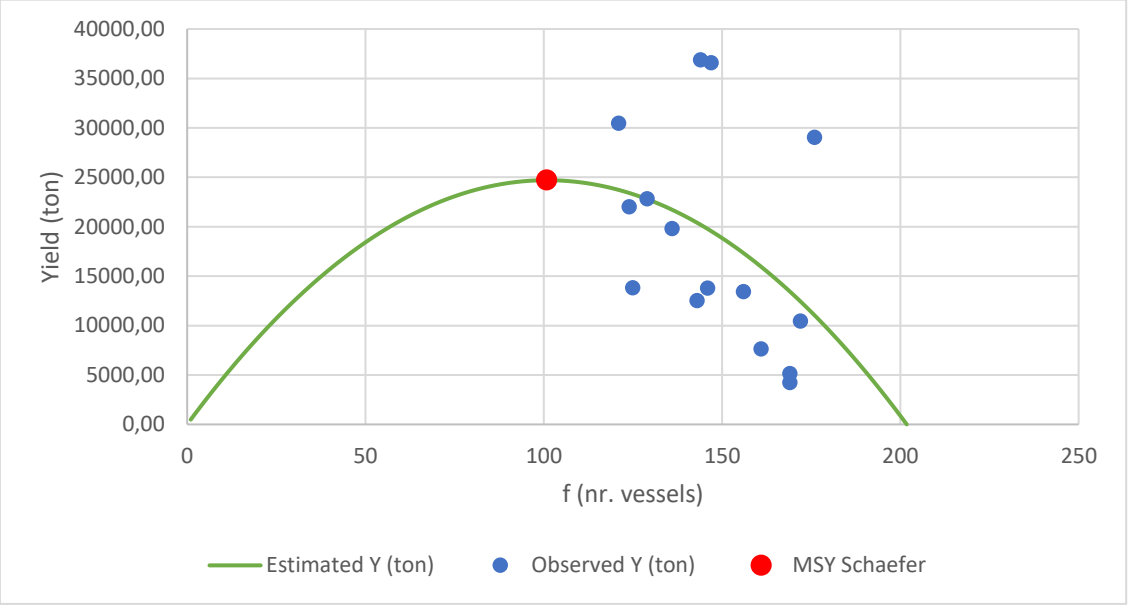

Figure 11 – Maximum sustainable yield and current fishing effort of chub mackerel.

Parameters used in Cadima's, Gulland and Garcia *et al.*, were accessed from literature (Azevedo *et al.*, 2012).

Gulland's formula, using natural mortality (M) and estimated biomass as virgin biomass (Bv), as displayed in equation 7, featured more conservative MSY - 21 750 ton – predicting less 3 000 tonnes than Schaefer's (Tab.3). Nevertheless the results could be considered close to the first model approach, despite not using the appropriate biomass value.

Cadima's, in turn, revealed a MSY closer to Schaefer's, i.e. 23 250 tonnes, which can be explained by means of total mortality (Z = M (natural mortality) + F (fishing mortality) – Tab.3).

Results for Schaefer, Gulland and Cadima's models displayed similar MSY values, varying in approximately 4 000 tonnes, which states the importance of using different approaches to estimate biomass available for harvesting, and more importantly the necessity of good stock assessment data to validate this models.

Garcia *et al.* MSY was estimated considering landings from 2009 and using estimated biomass (2007 - 2009) from literature (Azevedo *et al.*, 2012). Results from Garcia *et al.* model featured more promising values which are explained by the increment of annual

landing to the equation, which varies according to the tonnes landed in each year, as showed in table 3.

These MSY values appeared to be very low when compared to chub mackerel landings (Fig.12).

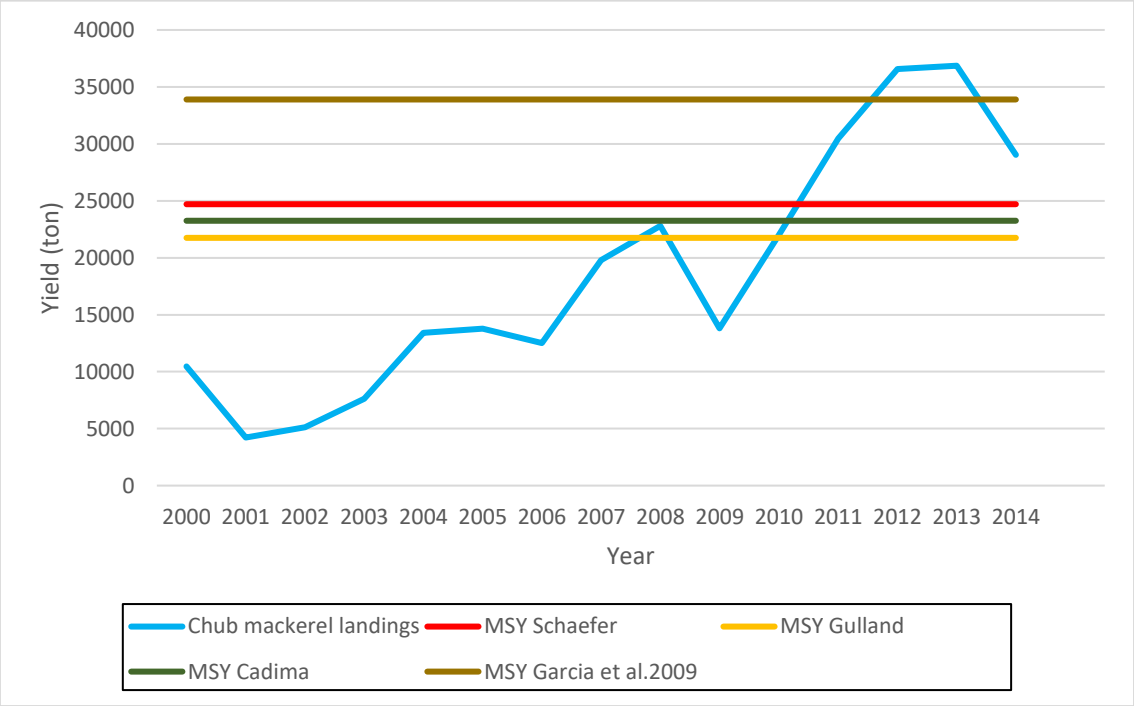

Figure 12 – Chub mackerel landings evolution in Portugal, from 2000 - 2014, and estimated MSY according to Schaefer, Gulland, Cadima and Garcia *et al.* models.

Results show that chub mackerel MSY had already been exceeded in 2011 and landings kept increasing since then. In 2015, landings reached 47 728 tonnes which appears to be approximately the double of what is suggested by results of Schaefer's, Gulland's and Cadima's models (24 703 tonnes, 21 750 tonnes and 23 250 tonnes, respectively). The MSY based in Garcia *et al.* appears to be very risky since MSY varies with year catches (Tab.3), and data from biomass were not very robust.

These results raise some concerns since resource sustainability indicators appear to point to a scenario of overexploitation. More importantly, these results show the importance of using different models and approaches when trying to achieve MSY, especially if there were data available regarding estimated biomass and mortalities (M and F). Those data will most likely closer the MSY to a more ecosystem based approach while stock assessment is conducted.

All of these models could be used in a first management approach for establishing a total catch value, while scientific research and stock assessment collects and improves data from effective biomass and tries to assess a more ecosystem based MSY.

5.4 Chub mackerel consumer's outline. Analysis and characterization.

In order to assess, and analyse, chub mackerel consumer's profile, results were displayed in two main parts: (1) sample description and characterization – to access species consumer's profile; (2) study and analysis of the settled research hypothesis – to access associations regarding habits and traditions.

Surveys were applied to 789 fish consumers, 398 from traditional markets (50.4%) and 391 from supermarkets (49.6%). All the results were presented first at global approaching and second at local perspective.

Additionally, it is important to remember that question 1 ("Do you usually consume fresh fish?") was used as a filter to obtain only fish consumer respondents. Those who answered "No" were immediately rejected, as well as non-residents.

The survey presented an average age of 50.79 ± 13.83 years and the majority of the respondents were female, 509 out of 789 (64.5%).

Profile characterization of chub mackerel consumer's. Descriptive analysis. Global overview

When questioned about the use of chub mackerel in their food habits, the majority of the respondents, 452 out of 789 (57.3%), replied affirmatively. Also, individuals who had included these species in their diet were three years older (52.06 ± 13.34 years old) than the non-consumers (49.10 ± 14.28 years old).

Therefore, and independently from age, the majority of chub mackerel consumers were more willing to consume it fresh (Tab.4).

Table 4 – Frequencies distribution of chub mackerel consumer's age and preferences in consuming

Product type	Number of consumers	%	Age means
Fresh	267	58.94	52.23±13.62
Canned	79	17.44	50.52±14.99
Both	107	23.62	52.76±11.21
Total	453	100.00	52.06±13.34

From the 57.3% of chub mackerel consumers, 77% have been so for a long time, over 10 years. Moreover, long-time consumers were older (16, 15, 12 years) when compared with the other time consumption groups (less 1 year, over 1 year, over 5 years, respectively – Tab.5).

Table 5 – Frequencies distribution of Atlantic chub mackerel consumer's age and time in consuming

Time in consuming	Number of consumers	%	Age means
Less 1yr	5	1.10	39.20±9.55
Over 1yr	51	11.23	40.02±13.18
Over 5yr	48	10.57	43.56±9.04
Over 10yr	350	77.04	55.18±13.33
Total	454	100	52.06±13.34

When inquired about the point of sales used to purchase their fish, 52.3% of the sampled population usually acquired it at traditional market. Remainder respondents were distributed between supermarkets and those who acquired fish at both (Tab.6). Results showed that both consumers and non-consumers will rather purchase their fish at traditional markets. Nevertheless the percentage of chub mackerel consumers that usually go to traditional markets is higher than the percentage of non-consumers, 32.8% against 19.5% respectively (Tab.6).

Table 6 – Frequencies distribution of chub mackerel consumer's and selling point

	Traditional market		**Supermarket**		**Both**		**Total**	
	Nº	%	Nº	%	Nº	%	Nº	%
Consumers	259	32.8	91	11.5	102	12.9	452	57.3
Non-consumers	154	19.5	100	12.7	83	10.5	337	42.7
Total	413	52.3	191	24.2	185	23.4	789	100

Regarding the knowledge of Docapesca's campaign, data showed that only a small amount of respondents, 20.5%, were aware of it. Despite not knowing about the campaign, 37.0% of the respondents had included these species in their food routines. Chub mackerel consumers who were campaign awareness represent 14.8%, (Tab. 7).

Table 7 – Frequency distribution of respondent's and campaign knowledge influence in chub mackerel consumption

		Campaign awareness	**Non-campaign awareness**	**Total**
Consumers	Nº	117	292	337
	%	14.8	37.0	42.7
Non-consumers	Nº	45	335	452
	%	5.7	42.5	57.3
Total	Nº	162	627	789
	%	20.5	79.5	100

Respondents who answered "No" (they weren't aware of the campaign) were labelled as "Not Applicable (NA)", and data was interpreted, despite the sample size was misrepresentative. From the 162 individuals who had that knowledge, 37.0% claimed it led them to include or continue to consume chub mackerel while 63% didn't feel motivated to change their food habits, that is, to include this species in their daily diet or they were already consumers and it didn't make a difference.

Profile characterization of chub mackerel consumer's. Descriptive analysis. Regional overview.

Regional analysis was pursued in order to compare the differences between the settled cities. It is important to observe habits and patterns of chub mackerel consumption, as well as the knowledge and influence of Docapesca's campaigns when comparing the four different areas of action (Aveiro, Peniche, Lisbon and Olhão).

The number of respondents from both selling points (supermarkets and traditional markets) for each settled city is displayed in table 8.

Table 8 – Number of individuals who answered to the survey for each city at each selling point

	Aveiro	**Peniche**	**Lisbon**	**Olhão**
Supermarkets	98	97	98	98
Traditional Markets	98	98	98	104
Total	196	195	196	202

Consumer's age and preferences profiles

When questioned about the preference in consuming the species, independently from age, Aveiro stands out due to the fresh chub mackerel consumer's preference 89.6%. (Tab.9).

In Peniche, independently from age, the majority of chub mackerel consumers also showed preferences in consuming it fresh (46.08%) – Tab.9.

In Lisbon, and also independently from age, 53.95% of the consumers declared preferences for fresh chub mackerel. Nevertheless, Lisbon was the only region where consumers showed a preference mostly for canned chub mackerel were higher than those who have preferences in consuming both ways (Tab.9).

Chub mackerel consumers from Olhão showed more willingness to consume it both fresh and canned, i.e. 47.5%. Consumers who show a preference in both fresh and canned chub mackerel, were on average 11 years older than those who prefer it canned (Tab.9).

Table 9 – Distribution of chub mackerel consumer's age and preferences in consuming

	Aveiro		**Peniche**	
Preferences	**Consumer's percentage (%)**	**Age Means**	**Consumer's percentage (%)**	**Age Means**
Fresh	89.57	43,22±10,37	46.08	50.49±13.08
Canned	2.61	49±13,08	22.55	52.35±18.57
Both	7.86	52.76±11,21	31.37	51.63±9.47
TOTAL	100	52.78±13,51	100	52.78±13.51
	Lisbon		**Olhão**	
Preferences	**Consumer's percentage (%)**	**Age Means**	**Consumer's percentage (%)**	**Age Means**
Fresh	53.95	51.88±17,29	47.5	51.47±11.83
Canned	32.89	56.04±15,04	17.5	43.93±8.61
Both	13.16	55±16,28	35	54.54±10.63
TOTAL	100	53.78±16,37	100	51.23±11.44

Consumer's age and longevity

The gap between mid-time and long-time consumers, from Aveiro, were 17 years of age, being the middle time consumers younger. Comparing with "over one year" group, "over five years" consumers were 7 years younger. Regarding long-time consumers they were 16 years older than less than one year consumers, and 9 years older than those who had decided to include chub mackerel in their habits for more than one year, and they represent the majority of the consumers (79.1% - Tab.10).

In Peniche, the majority of respondents claimed to consume chub mackerel for over 10 years. This region registered the highest percentage of long-time consumers with 91.26%. Less than 1 year group and over 5 years, only registered one person each. Therefore, consumers who declared to add chub mackerel to their habits for over one year were younger than the consumers from the other time intervals, with an average age of 33.14±7.04 years. Long-time consumers (more than 10 years) had on average 52.97±13.05 years of age, which represent twenty years of difference between long-time consumers and the new ones (Tab.10).

Regarding longevity of consumption, Lisbon didn't have any less than one year consumer, and long-time consumers were 18 years older than those who consume it for

over one year, and 12 years older than those who have decided to include chub mackerel in their food preferences for over five years. Mid-time consumers (more than 5 years) are 7 years older than those who just added it for over than 1 year (Tab.10).

Olhão displayed the highest difference between consumers with different consumption longevity especially when compared with recent chub mackerel consumers. Long-time consumers are 22 years older than the ones who decided to add this species to their habits less than one year, and 15 than the more than one year consumers, while comparing with the consumers that added it more than five years the difference is 6years, being long-time consumers (over 10 years) older (Tab.10).

Table 10 – Distribution of chub mackerel consumer's age and time in consuming

	Aveiro		**Peniche**	
Time	**Consumer's percentage (%)**	**Age Means**	**Consumer's percentage (%)**	**Age Means**
Less 1yr	1.74	40.0±9.90	0.97	50
Over 1yr	5.22	47.0±13.67	6.8	33.14±7.04
Over 5yrs	13.92	39.06±9.46	0.97	56
Over10yrs	79.13	55.68±12.48	91.26	52.97±13.05
TOTAL	100	52.78±13.51	100	51.35±13.42
	Lisbon		**Olhão**	
Time	**Consumer's percentage (%)**	**Age Means**	**Consumer's percentage (%)**	**Age Means**
Less 1yr	0			
Over 1yr	26.36	40.85±17.41	11,25	39.44±3.83
Over 5yrs	3.95	47.33±4.62	17,5	45.29±8.28
Over 10yrs	69.79	59.02±13.43	70	54.93±10.35
TOTAL	100	53.78±16.37	100	51.23±11.44

Independently of consuming or not chub mackerel, respondents from Aveiro showed their preferences in purchase their fresh fish at traditional markets, 25.5% of the consumers and 21.9% of the non-consumers (Tab.11).

Respondents from Peniche usually purchase their fish at traditional markets instead of supermarkets, regardless their preferences in consuming or not chub mackerel, 34.9%

consumers and 26.2% non-consumers. Only a few respondents prefer purchasing at supermarkets, while 1.5% of the consumers have this habit and also 3.1% of the non-consumers (Tab.11).

Chub mackerel consumers from Lisbon that usually purchase at traditional markets were 17.9%, while 29.1% of the non-consumers prefer purchase at supermarket (Tab.11).

The majority of the respondents from Olhão prefer purchasing their fish at traditional market, 58.4%; 52.5% were chub mackerel consumers and 5.9% were non-consumers. The remainder were both consumers and non-consumers, which usually purchase their fish at supermarkets, while 1% of the non-consumers typically go to both places (Tab.11).

Table 11 – Distribution of chub mackerel consumer's and selling point

	Aveiro		**Peniche**	
	Consumers (%)	**Non-cons. (%)**	**Consumers**	**Non-cons. (%)**
Traditional Market	25.5	21.9	34.9	26.2
Supermarket	11.2	4.6	1.5	3.1
Both	21.9	11.7	15.9	18.5
TOTAL	58.7	41.3	52.3	47.7
	Lisbon		**Olhão**	
	Consumers (%)	**Non-cons. (%)**	**Consumers**	**Non-cons. (%)**
Traditional Market	17.9	24.5	52.5	5.9
Supermarket	16.8	29.1	16.3	13.9
Both	3.16	8.2	10.4	1
TOTAL	38.3	61.7	79.2	20.8

Neither of the non-consumers from Aveiro showed any knowledge of the Docapesca campaign, which represents 41.3% of total respondents. 53.1% of the consumers also declared not knowing about this promoting campaign and only 5.6% of the respondents, who were also consumers, were aware of the Atlantic chub mackerel promoting campaign (Tab.12).

At Peniche, 35.4% of the respondents were chub mackerel consumers and they weren't aware of Docapesca campaign. For those who had noticed the campaign, 16.9% of them are chub mackerel consumers (Tab.12).

The majority of Lisbon respondents (58.2%) were non-consumers and didn't know about chub mackerel promoting campaign. Only a few percentage of the respondents did notice the Docapesca campaign, 3.1% were consumers and 3.6% non-consumers (Tab.12).

Respondents from Olhão seem to be more aware of the Docapesca campaign, 33.2% of them are consumers and 4.5% are non-consumers, nevertheless the percentage of consumers who didn't know about the campaign was higher 46% (Tab.12).

Table 12 – Distribution of respondent's and Docapesca's campaign knowledge

	Aveiro		**Peniche**	
	Consumers (%)	**Non-cons. (%)**	**Consumers (%)**	**Non-cons (%)**
Knew	5.6	0	16.9	14.9
Didn't knew	53.1	41.3	34.5	32.8
TOTAL	58.7	41.3	52.3	47.7
	Lisbon		**Olhão**	
	Consumers (%)	**Non-cons (%)**	**Consumers (%)**	**Non-cons (%)**
Knew	3.1	3.1	33.2	4.5
Didn't knew	35.2	58.2	46	16.3
TOTAL	38.3	61.7	79.2	20.8

Respondents who answered "No", actually knew about the campaign, and were labelled as "Not Applicable" (NA) and they weren't taken into account since the aim was to obtain indicators of Docapesca's campaigns' influence. Respondents who had knowledge of the campaigns were questioned if such campaigns influenced their choice to include chub mackerel in their food habits.

Aveiro stands out with 36.4% of the respondents answering "yes" to the question of did the campaign have an influence in either to maintain chub mackerel in their habits, or including it (Tab.13).

In Peniche, only a few respondents said that the campaign had influenced them, 6.35% (Tab.13).

In Lisbon, only one person answered that the Docapesca campaign influenced his choice (Tab.13).

Olhão was the region where consumers who were aware of the campaigns showed to have been more influenced in adding to their food habits or continuing to consume chub mackerel with 67.11% positive answers (Tab.13).

Table 13 – Distribution of the Docapesca campaign influence

	Aveiro	**Peniche**	**Lisbon**	**Olhão**
Did influence	36.36	6.35	7.29	67.11
Didn't influence	63.64	93.65	92.3	32.89
Total	100	100	100	100

Consumer's age and the relation with chub mackerel consumption habits, preferences and longevity

As far as the global approach, there were statistical significant differences in age, when comparing chub mackerel consumers and non-consumers ($t_{(787)}$ = -2.976; *p*-value = 0.003; Fig.13). Thus, individuals who had include this species in their diet are older than those who don't have the routine in consuming this particular species.

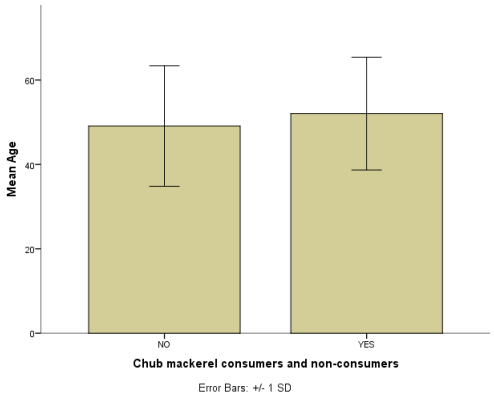

Figure 13 – Global view of average age of chub mackerel consumers and non-consumers. Results are presented as mean ± SD.

Focusing on the regional view of Peniche and Olhão showed statistical significant differences in the age when comparing the chub mackerel consumers and non-consumers (Peniche: $t_{(193)}$ = -2.652; *p*-value = 0.009; Olhão: $t_{(200)}$ = -4.916; *p*-value = 0.000). Chub mackerel consumers are older than the non-consumers.

On the other hand, Aveiro and Lisbon indicated no statistical differences in age when both groups of fish consumers were compared (Aveiro: $t_{(194)}$= -1.483; *p*-value = 0.140; Lisbon: $t_{(194)}$ = -0.077; *p*-value = 0.939) (Fig.14).

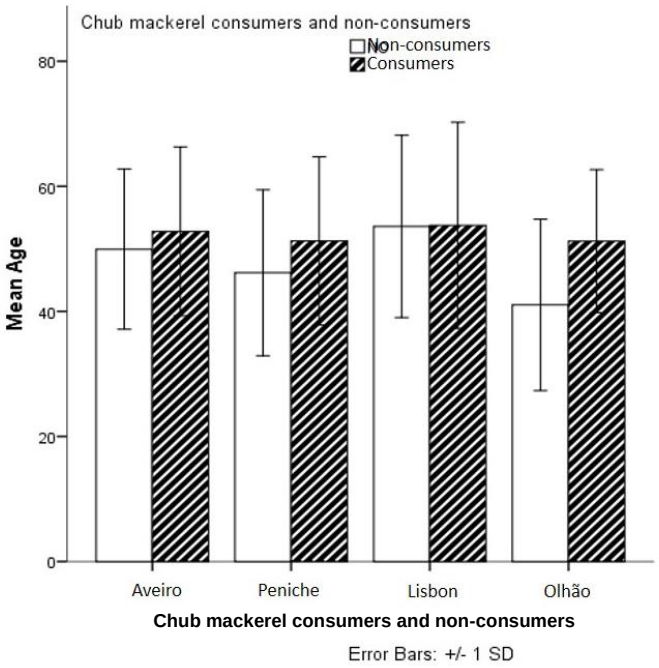

Figure 14 – Regional view of average age of chub mackerel consumers and non-consumers. Results are presented as mean ± SD.

Regarding consumption preferences (fresh, canned, both) versus consumer's age, the results revealed no statistically significant differences (Kruskal-Wallis, *p*-value = 0.178), from a global approach. Results on regional differences revealed that only Olhão presented statistically significant differences in age when consumption preference was compared (fresh, canned, both) – Tab.14.

Table 14 – Independent samples test between age's means and consumption preferences. Regional view

Region	**df**	**F**	***p*-value**
Aveiro	2;112	2.703	0.071
Lisbon	2;73	0.618	0.542
Olhão	2;157	8.851	0.000
Peniche	*Kruskal-Wallis test*		0.848

Additionally, Olhão showed differences in age when canned and both were compared (Bonferroni, *p*-value = 0.000). Therefore, consumers that prefer the two types of consume were 11 years older. Also, differences were observed between fresh and canned (Bonferroni, *p*-value = 0.006). The consumers of fresh chub mackerel were 8 years older (Fig. 15).

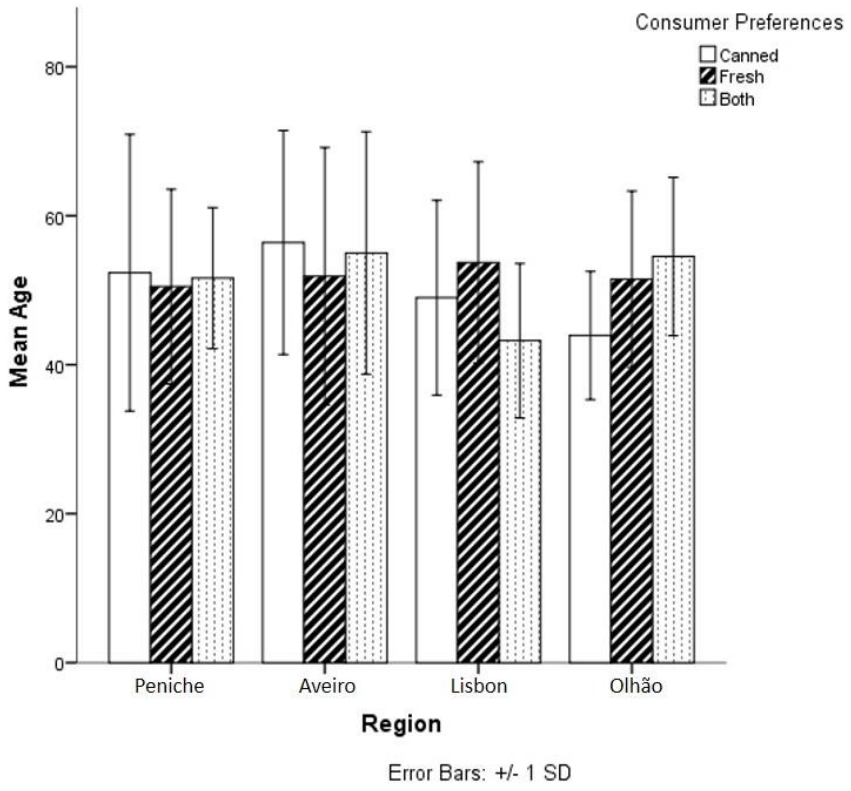

Figure 15 – Regional view of average age of chub mackerel consumers and their consumption preferences. Results are presented as mean ± SD.

Global results from consumption time versus age showed statistical differences (ANOVA: $F_{(3;450)}$ = 34.613, *p*-value = 0.000). Over ten years consumers presented statistical significant differences, when compared with the consumers from other longevities in consuming chub mackerel (Fig.16)

Also, the average between more than 10 year's consumers, and the other time groups, presented statistical significant differences (Bonferroni test: $p\text{-value}_{(<1yr)}$ = 0.021; $p\text{-value}_{(>1yr)}$ = 0.000; $p\text{-value}_{(>5yr)}$ = 0.000).

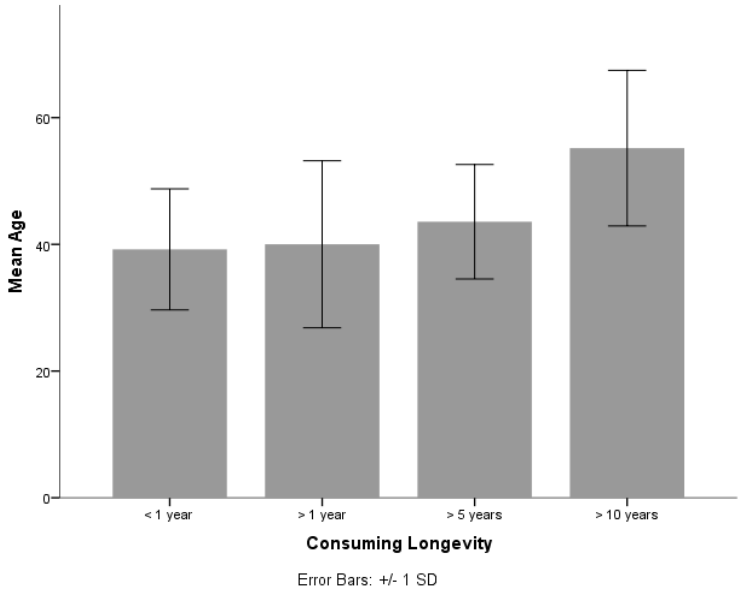

Figure 16 – Global view of average age of chub mackerel consumers and consumption time. Results are presented as mean ± SD.

Similar analysis was performed for the studied regions. The results showed that all presented statistical significance differences in the consumer's age when compared with longevity in consuming (Tab.15).

Table 15 – Independent samples test between age's means and consumption preferences. Regional view.

Region	**df**	**F**	**p-value**
Aveiro	3;111	9.927	0.000
Lisbon	2;73	11.837	0.000
Olhão	3;156	19.544	0.000
Peniche	*Kruskal-Wallis test*		0.002

At Aveiro, differences were disclosed between long-time consumers (over 10 years) – and middle-time consumers (over 5 years - Bonferroni, *p*-value = 0.000). Being the long-time consumers older (Fig.17).

Differences in Lisbon were registered between long time consumers and over one year consumers (Bonferroni, *p*-values = 0.000). Long-time consumer are older than those who only started to consume more than one year (Fig.17).

At Olhão, long-time consumers displayed differences with all other consumption time groups (Bonferroni test: $p\text{-value}_{(<1yr)} = 0.013$; $p\text{-value}_{(>1yr)} = 0.000$; $p\text{-value}_{(>5yr)} = 0.000$) thus, the individuals from over 10years group were older (Fig.16).

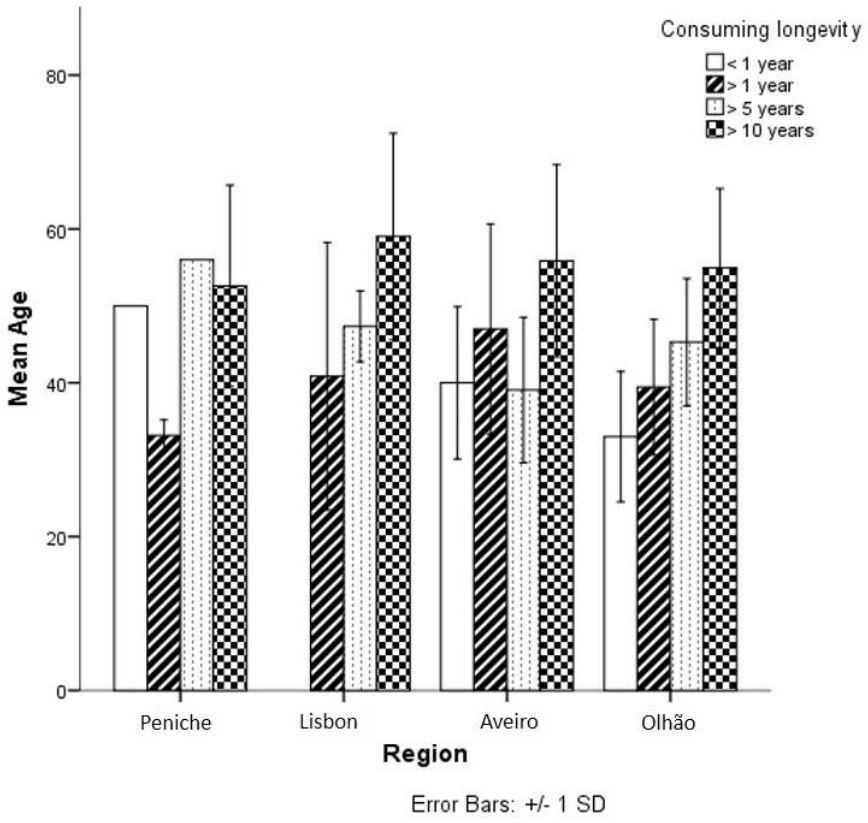

Figure 17 - Regional view of average age of chub mackerel consumers and consumption time. Results are presented as mean ± SD.

5.4.3. Consumer's attitude and selling points

From a global approach, the results presented a statistically significant association ($\chi^2_{(2)}$ = 12.576; *p*-value = 0.002), which means that chub mackerel consumption and selling point (traditional market/supermarket) were mutually dependent. Individuals who have a habit of consuming this species usually acquire their fresh fish at traditional markets (Fig.18), however the correlation intensity is weak (Phi coefficient=0.126) meaning that even though these variables are dependent, the relationship within them is very fragile.

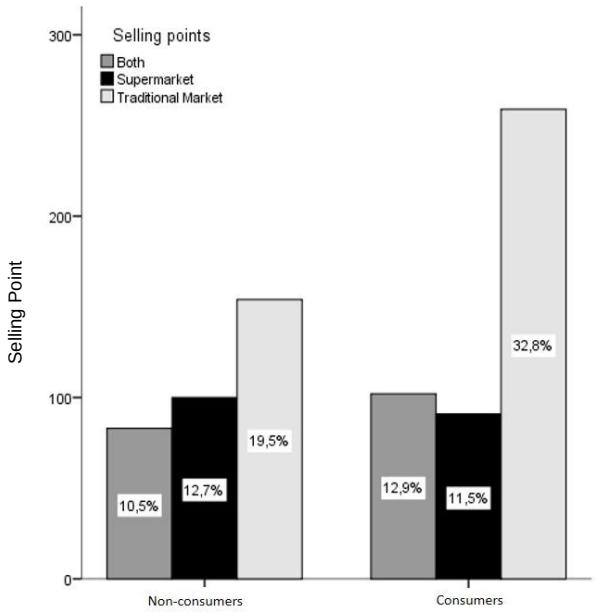

Figure 18 – Consumer and non-consumer's distribution by selling points. Global approach.

The local approach revealed that there is no relation between chub mackerel consumption and selling points for Aveiro, Peniche and Lisbon (Aveiro: $\chi^2_{(2)} = 2.890$, *p*-value = 0.236; Peniche: $\chi^2_{(2)} = 3.394$, *p*-value = 0.183; Lisbon: $\chi^2_{(2)} = 1.230$, *p*-value = 0.541). In opposition, Olhão showed a significant association between selling points and chub mackerel consumption (Olhão: $\chi^2_{(2)} = 33{,}481$, *p*-value = 0.000) – Fig.19. Thus, consumers were influenced by the selling points (traditional markets and supermarkets), meaning that their purchase fish at traditional markets preferably.

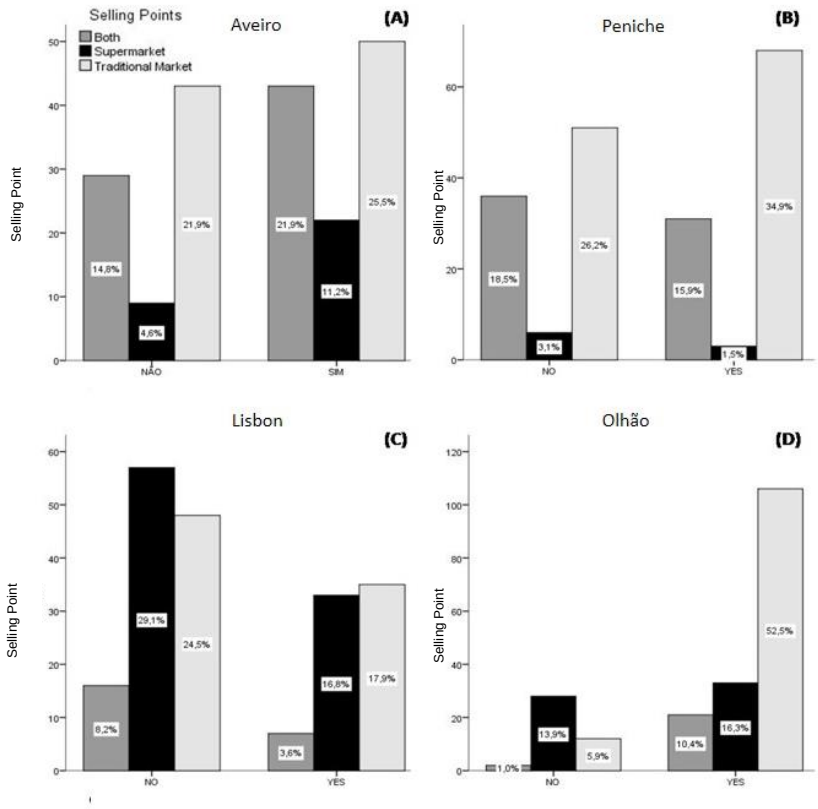

Figure 19 – Consumer and non-consumer's distribution by selling points. Regional approach: (A) Aveiro, (B) Peniche, (C) Lisbon, (D) Olhão.

Consumer's attitude and residence area

Results from consumption and residence analysis showed a significant association ($\chi^2_{(2)}$ = 70.782, *p*-value = 0.000) between these variables. Additionally, it is possible to observe that both Olhão and Lisbon were preponderant for that association (Fig. 20). Hence, consumers were influenced by their residence area (Aveiro, Peniche, Lisbon, and Olhão). Consumers from Olhão were more influenced to consume chub mackerel, while non-consumers from Lisbon showed to be more influenced into not consuming this species.

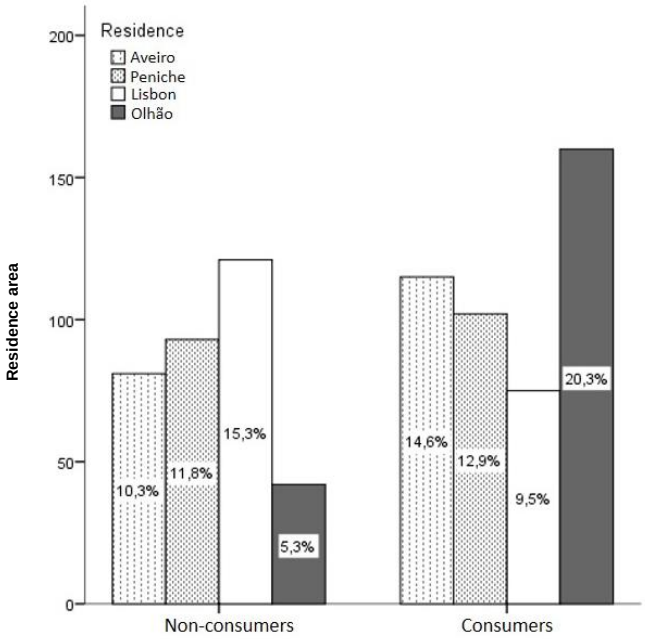

Figure 20 – Consumer and non-consumer's distribution by residence area.

Consumer's attitude and Docapesca campaign

Global approach results revealed a significant relation between the Docapesca campaign and chub mackerel consumption (Fisher's Exact Test[3], *p*-value=0.000), thus confirming the Docapesca campaign influenced chub mackerel consumption (Fig.21).

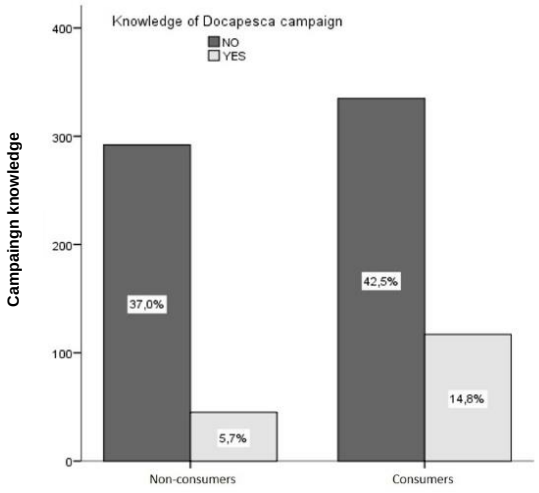

Figure 21 – Consumer and non-consumer's distribution by Docapesca campaign knowledge. Global approach.

Regarding regional approach, both Peniche and Lisbon revealed no significant relation between chub mackerel consumption and Docapesca campaign knowledge (Fisher's

[3] Computed only for a 2x2 table

Exact Test: p-value$_{Peniche}$ = 0.879; p-value$_{Lisbon}$ = 0.566). Therefore, at these regions chub mackerel consumption are independent from campaign, meaning that it didn't influence species consumption (Fig.22).

Aveiro and Olhão regions presented statistical significant dependency (Fisher's Exact Test: p-value$_{Aveiro}$ = 0.003; p-value$_{Olhão}$ = 0.019), meaning that chub mackerel consumption was influenced by the Docapesca campaign (Fig.22).

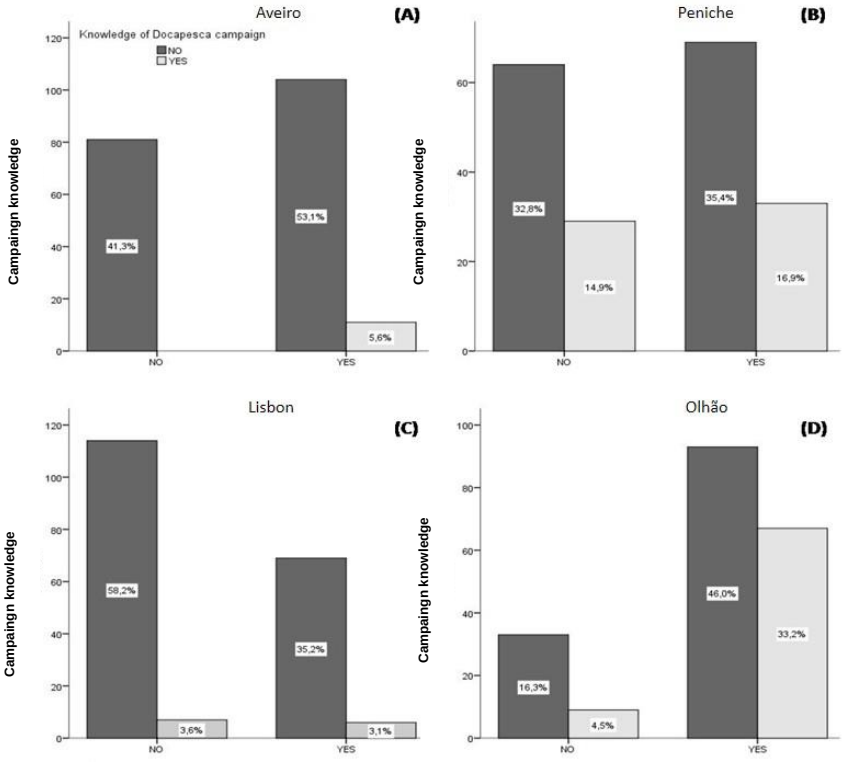

Figure 22 – Consumer and non-consumer's distribution by Docapesca campaign knowledge. Regional approach.

6 Discussion

Results revealed some concerns regarding sustainability of chub mackerel's stock. According to MSY results for the four considered models, sustainable yield has either been, or will soon be surpassed. This is an unsustainable indicator regarding the resource and it is necessary to apply measures to prevent stock collapse and to ensure its health. Some considerations have to be kept in mind regarding data, namely that biomass data used in this study regards estimation of chub mackerel biomass between 2007 and 2009, assessed by an acoustic pelagic campaign from IPMA. The same report assigned a good environmental state (GES) to chub mackerel, although researchers alert for the lack of data and the need for stock assessment. At the moment, there is no update data available regarding chub mackerel's effective biomass or any direct stock assessment campaign. This raises more concerns since chub mackerel was always harvested, although data from landings misrepresents total catches. Chub mackerel was a bycatch species from fisheries targeting sardine and its constant and low landings supplied mainly the canned industry. Until now, it hasn't been possible to know if the increase in chub mackerel landings corresponds to an increase in real catches, which would be very important to assess and therefore understand the real fishing effort applied to this resource for a longer period of time. To prevent that happening, CFP included a discard ban hopefully implemented until 2019. These kind of measures are extremely important to bring more accuracy on real catches. A primary TAC (Total Allowable Catch) could be established as a first measure while investments are made in directed campaigns to assess chub mackerel stock and data collection. Such TAC should be assessed according to the precautionary approach, established by CFP.

Considering that, in the last fifteen years, chub mackerel landings have been increasing, results displayed two main indicators as follows: (1) chub mackerel seems to have grown in commercial interest, this can be concluded by its growing business volume, which is a positive indicator from a trades point of view; (2) the growth in value is exclusively a consequence of the increase in tonnes landed, which represents a negative indicator for the resource and the environment.

The increase in chub mackerel tonnes landed relates at 65% with the decrease in sardine tonnes landed, with the remaining 35% related to other factors. One of which can be Docapesca's promoting campaign focusing on chub mackerel consumption. Nevertheless, results on surveys showed that this campaign didn't achieved as many consumers as it was expected. Facing these and the fact that purse seine fisheries have a lot to achieve in having a multi-target-species, some management measures could be

applied. Such measures should focus on two perspectives - first sale price in auction, and promoting consumption - sharing the same goal: to create a regulated market for chub mackerel supported by the simple economic basis of supply and demand influencing transaction prices. To begin, the government should offer incentives to settle a fair trade price in auction. Auction sales stand on the principle that fish lose quality as time progresses, therefore their continuous loss in value. This method sometimes leads fishermen to sell their fish at a price which will not pay operational costs. For example, in August 2015, chub mackerel was transacted at Cascais' fishery auction at € 0.03 (INE, 2015), which is an unreasonable and unfair value for both fishermen and the resource alike.

Promoting chub mackerel consumption, as part of a management plan, could lead to an increase in demand for this species. By promoting the demand and assuring that stock is safeguarded by TAC, a market will most likely be generated around chub mackerel ruled by supply and demand laws, as established above as goal.

Also, and in line with The National Strategy to the Sea, by promoting and investing in new technology concerning inventive new products recreated from under-valued products, other new market opportunities will certainly be opened. With a good stock assessment and the resource safe guarded, chub mackerel seems to be a great product to invest in.

Although sardine landings have decreased dramatically in the last years, this species contribution to total purse seine transactions remained constant corresponding to about 50% of the total value in sales, as consequence of the great increase in first sale price in auction. This corroborates the idea that a good management between supply and demand should be promoted in order to generate better profit to fishermen rather than landing great volumes in tonnes.

During the last few years, chub mackerel reached 10% of the total landed value, accompanied by a slight decrease in sardine proportion. Also, as displayed in the results, chub mackerel is suitable not only to cover total vessel expenses as well as to generate profit. Once more, it is important to guarantee stock sustainability and stock-health beforehand.

On a general approach, chub mackerel consumers can be characterized as being middle age individuals, on average 52 years old. Regardless of the fact that there were a higher number of female respondents, it was not possible to draw any conclusions about gender, since women are more likely to purchase groceries for the family.

With regards to consumer profile, chub mackerel consumers state their preferences in consuming it fresh, and they mostly have practiced this since earlier in their lives, certainly for more than 10 years. Those who had knowledge about the chub mackerel promoting campaign felt more encouraged to continue in consuming this species, mostly due to its benefits for health. Some of the consumers also highlighted the fact that, it's not only good for their health, but it is also inexpensive, which definitely contributed for their continued choice of chub mackerel.

As a rule, the Docapesca campaign did not reach as many individuals as it could, having the majority of consumers, and also non-consumers, revealed they did not have any knowledge about this campaign. However, and most of the time, those who did know about the campaign did not actually notice who the promoting institution was. They claimed that they did indeed hear something about chub mackerel and its benefits for health, regarding its omega 3 content, especially on TV, but they did not know who was behind this campaign. However, this is still a positive sign, since the main goal of the Docapesca was precisely to increase attention on this species. On a regional approach, there are some relevant facts that need to be highlighted to ensure more effectiveness in promotional campaigns. Olhão is the region where chub mackerel is more traditionally routed, where the majority of the respondents have been consumers of chub mackerel for a very long time. This could be partially explained by the fact that Olhão is predominantly a fishing town, with most residents, or at least their relatives, being fishermen, and chub mackerel was not easily sold, which led them to self-use their surplus catches. Olhão residents show a preference in consuming it fresh, and they have various ways of cooking it. Peniche is also a fishing community, but displayed rather different results. The local population is more willing to consume other species than chub mackerel, and mostly state that this is a species they would prefer discarding rather than consuming. However, traditional market sellers indicated more demand for chub mackerel, especially by younger consumers, and they relate this to the Docapesca campaign. In fact, Peniche was one of the regions where this campaign deployed strongest efforts. In Aveiro, there is some tradition in consuming chub mackerel, yet not as markedly as in Olhão. Fish sellers state that the demand for chub mackerel is far related with the offer. When available, consumers tend to purchase chub mackerel, especially due to its low price, when compared with other species. Results for Lisbon revealed interesting data, which was to be expected from a large city, with the public being more prone to experiment with their food choices. Canned chub mackerel showed to be much appreciated. Nevertheless, these results for Lisbon reveal a small recent group of new consumers, who have been consuming chub mackerel for around 1 to 5

years, and decided to include this species in their feeding habits, mostly due to certain specific aspects, such as increased availability, lower price and health benefits.

Therefore, consumers appear to be willing to include chub mackerel in their habits, especially if it represents benefits for health and their savings. These are very important findings, since it enables to continued promotional campaigns and their adjustment to consumers. Two campaigns targeting two consumers groups could be lead: one focused in housekeepers, promoting the species' variability in ways to cook and health benefits; and other focused in shortly time young-adult people looking for more easy-to-eat options.

The economic crisis may be harnessed to promote healthy and inexpensive goods, especially concerning sea food products, and purse seine products, such as chub mackerel.

In light of the above, a SWOT (Strengths, Weakness, Opportunities and Risks) analysis was designed for chub mackerel exploitation (Tab. 16).

Table 16 – SWOT analysis on chub mackerel commercial sustainable exploitation

STRENGTHS	**WEAKNESS**
Low first price in auction. New group of consumers, based in its accessible price. Health benefits. Fast growing early maturing species.	Lack of stock assessment. Lack of collection data. Lack of Total Allowable Catch. Low interest in some parts of the country.
OPPORTUNITIES	**RISKS**
Prone to generate profit to fishermen. Can work as an affordable feed-stock for the agro-alimentary industry. Potential to generate new creative food products. Funds from EMFF[4] to support sustainable fisheries.	Overfishing. Stock collapse.

To conclude, chub mackerel has potential to be an alternative choice to consumers and to generate profit to fisheries. This is observable by the receptivity of the market to this

[4] European Maritime and Fisheries Fund.

new species, and its potential to improve fish marketing. Nevertheless, and most importantly, there is a strong risk of stock collapse if measures aren't applied, which is not desirable since the goal is to try to multi-specify purse seine. Thus, creating a market around this species seems to be the viable way to make it an alternative, while safeguarding the resource. The first measure to be taken should be the establishment of a Total Allowable Cache in order to achieve sustainability of the resource.

Demand for seafood continues to increase due to increasing population and the growing realization of the health benefits of its consumption. Creating systems that lead to sustainability is a global imperative. According to the new CFP, governments should promote responsible consumption levels that respect the ecological limits of the marine ecosystems. It is necessary to call out consumers and instil into them some responsibilities. Thus, it is necessary to inform them, so they may act more actively, and rationally, concerning this issue.

Nevertheless, global fish dependency can also be seen as an opportunity, especially for Portugal, regarding chub mackerel, for example, and its variability in ways-to-eat, as it is presented in this study. Portugal can profit from maximizing this species' landings, while promoting its consumption and gastronomic versatility amongst consumers, and while reaching for new external-market. These profits can be either from relaying more national consumption on national production or even from external trade offs and incomes. These would, most likely, decrease national consumption dependency on external markets, while contributing to improve exports. Even so, it is imperative to ensure sustainable exploitation of the stock. Stock assessment and data collection should be prioritized.

The concept of MSY, and its use in fisheries management, should take into account natural fluctuations such as temperature, especially regarding the latest data concerning global environmental changes, which is widely known as having influence in fish migration and biological patterns. Nevertheless, it should be used as one tool, along with others, in marine resources management.

7 Final Remarks

If well managed, resources from the EU's highly productive waters have the potential to sustain long-term, stable fish supply and jobs, while creating social and economic benefits for the community (NEF, 2014), therefore the advice for an imperative need of stock assessment of chub mackerel.

Chub mackerel may constitute an alternative option for purse seine fisheries, if well managed. This type of fishery relies heavily on sardines and, as demonstrated above, this stock is reaching critically low levels, with catches reaching a point when they cease to be sustainable. Awarding subsidies to fishermen so they may halt their activities, to prevent sardine catches, has proven to not be a viable alternative. Alternatives shouldn't be supported financially by government, they should be provided by diversifying catches and well-managed resources.

Consumers appear to be receptive to accepting and adding new species to their feeding habits, especially if these represent health benefits and financial savings. More assertive campaigns might increase chub mackerel consumption. If such consumption becomes a habit, it is expectable that the demand for this species will most likely increase. Providing consumers with other alternative species allows fishermen to reap more profits from their catches. Nevertheless, it is important to maintain prices to the consumer, since this appeared to be a positive selective factor while ensuring the resource's renewability. This could be accomplished through measures that keep retailers from overpricing fish bought at auction.

In August 2015 the quota for Iberian sardine was met in almost every Portuguese port, and some of them were instructed to hold their caches, such as Peniche and Nazaré, which led to losses amongst fishermen.

According to a ship-owner from Peniche, a change in sardine habits is noticeable in recent years, with delays both in maturation and fattening, in relation to historical previous results. Fishermen have also been noticing that fatter (i.e. higher value) sardines now occur predominantly from late August until October, as opposed to early June, which used to be considered 'normal'.

Purse seine fishermen also complain about rules imposed on seine fisheries, especially when compared to trawlers. For example, purse seiners are not allowed to harvest during the weekends, and this might cause them to miss an opportunity for trawlers, which are allowed to harvest during the weekends and harvest sizeable sardine landings.

Fishermen now consistently complain of measures adopted by governments, claiming these mimic those measures that were taken for land ownership reforms in the 1970s. It is of major importance to take multi-criteria action regarding fisheries management and invest in more integrated models, to ensure greater profits from a well-managed renewable resource. The very same ship-owner interviewed above claims that, if he had been awarded an individual fishing quota, he would have preferred to delay his catch to

September-October, when yields were shown to be double of what he achieved in June. However, the inexistence of individual quotas, and a system where a common quota is shared by all fishermen from the PO (Producer Organization), drove him to catch as much as possible earlier in the season, fearing there would be little left later on. This reasoning is at the foundation of the ITQ system, which allows stakeholders to manage their resources in a more efficient fashion.

Also, with a more ecosystem-based MSY, regarding environmental aspects, such as temperature combined with growth rate, would probably be associated with a more environmentally-friendly approach. Also, if given another species stock to explore as an alternative for a lower biomass of sardine, such as chub mackerel, with previously stock safeguarding, will represent even more alternatives for fishermen to manage their ITQs. Fishermen will likely safeguard sardine stocks, exchanging their catch by that of chub mackerel in out-of-phase periods, ensuring maximum profitability from both stocks, internalising the externalities derived from the common property of fisheries.

These fishery management approaches should be followed by several campaigns targeting consumers, which would land some of the responsibility of choices taken in them as well. Consumers should have access to quality information regarding seafood products, including stocks status.

Campaigns, such as the one Docapesca is conducting on the promotion of chub mackerel consumption, are a positive measure, although it has been established that these campaigns need to increase in effort, so they may reach substantially more consumers than those they have reached thus far. Nevertheless, consumers are increasingly more concerned about their choices and their health benefits, and also the global financial crisis calls for more low cost alternatives, maintaining all health benefits.

Government should also encourage innovative new ways to approach new market opportunities, also as a mean to increase exports and reduce the trade difference between seafood imports and exports, contributing to reduce national fish dependency.

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Appendix

Appendix 1 –Questionnaire

Tese de Mestrado
Estudo dos desembarques de cavala (*Scomber colias*, Gmelin, 1789): importância para a pesca de cerco

Inquérito ao consumo

Zona: Aveiro ___ Peniche ___ Lisboa ___ Olhão ___

Local: Mercado tradicional ___Grandes superfícies ___

Idade: ____ **Género:** M ___ F ___

1 – Costuma consumir peixe fresco?

Sim___ Não___

2 – Consome cavala em fresco ou em conserva?

Sim___ Não___

3 – Se sim. Prefere consumir cavala fresca ou em conserva?

Conserva___ Fresca ___

4 – Há quanto tempo é consumidor de cavala?

Menos de 1 ano __ Mais de um ano __ Mais de 5 anos __ Mais de 10 anos__

5 – Onde costuma comprar o peixe que consome?

Mercado tradicional ___ Grandes superfícies ___

6 – Teve conhecimento de alguma campanha promovida pela Docapesca sobre o consumo de cavala?

Sim ___ Não ___

7 – Em caso afirmativo. Essa campanha convenceu-o a incluir cavala na sua alimentação?

Sim ___ Não ___

Obrigada

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