Ana Mariana Silva Fernandes

MAPPING FISHING GROUNDS OF THE MULTIGEAR COASTAL FLEET IN SOUTHERN PORTUGAL

Faculdade de Ciências e Tecnologia

2022

Ana Mariana Silva Fernandes

Mapping fishing grounds of the multigear coastal fleet in southern Portugal

Master in Aquaculture and Fisheries

Under the supervision of:

Dr. Jorge Manuel Dos Santos Gonçalves, Centre of Marine Sciences (CCMAR), Fisheries, Biodiversity and Conservation research group, University of Algarve

Faculdade de Ciências e Tecnologia

2022

Declaração de autoria de trabalho

Declaro ser a autora deste trabalho, que é original e inédito. Autores e trabalhos consultados estão devidamente citados no texto e constam da listagem de referências incluída.

(Ana Mariana Silva Fernandes)

Acknowledgments

I would like to express my gratitude to the project TECPESCAS - Tecnologia da Pesca e Seletividade" (Mar2020 TecPescas project 16-01-04-FMP-0010 – IPMA/CCMAR) and the Algarve Center of Marine Science (CCMAR).

I would be amiss to attribute achievements in this thesis to my efforts alone, for there are many people to thank for the past years of my life at University of Algarve.

My academic supervisor Dr. Jorge Gonçalves and Pedro Monteiro for his role as co-supervisor are the first I have to acknowledge. To Jorge for the opportunity to work in this project, to welcome me with open arms and to introduce me to some researchers of the fisheries group. In addition, for all the insightful feedback, valuable knowledge and help that will serve me for the rest of my future in the field of research. To Pedro for providing an informal environment, a constant level of support and for teaching me much during the past years, especially about the QGIS software.

Thank you to Monika for all the help in collecting the on-board data and for the relentless sharing of all the information. Thank you, sensei.

I want to dearly thank my friends from the bachelor's and the master's degrees, especially Cheila for being the "friendly manta", for the uncontrollable laughter, the inspiring conversations and all the advice that will serve me for life. To the hometown friends who, despite the distance, have always supported me. A special thanks to Nuno for all the hours spent helping me. To Faro's friends because they were always there, in good times and bad. For dinners, dances, jam sessions and walks and all the hugs of warmth. To Victor for being the soundtrack of the writing afternoons.

To my family, for all the freedom they have given me, all the support, understanding and patience and for always being present in the most difficult moments. Without them none of this would be possible. I am deeply grateful for having you in my life.

This work is dedicated to the fishers, the true masters of the sea for the availability, wisdom and concern with us in the days when the sea did not surrender.

Abstract

Managing and monitoring fishing activities has been a major concern in recent years as overfishing and other negative impacts on the environment become increasingly known. The identification of fishing grounds is, therefore, a necessity, that can inform not only the fishing sector but also other maritime sectors. In this work, the fishing practices of the multigear coastal fleet in the southern coast of Portugal are analysed. A series of in-person interviews were performed on a sample of 40 vessels to identify core variables such as the vessel characteristics, fishing gear, species captured and fishing grounds. The fishing grounds indicated by the fishers were aggregated and a fishing intensity map was created. Observational and GPS data was further collected through on-board trips on a set of fishing vessels, which was used to compare with data collected in the interviews. GPS data was processed to identify events of searching, setting and hauling, as well as establish the average velocities for these events. According to one of the main objectives, it was possible to identify the main fishing grounds, which are located generically between one and eight nautical miles at 50 meters deep, highlighting an area between Lagos and Quarteira with greater fishing intensity. The fishing areas indicated by the fishers and those identified through GPS data display some agreement, as do the hauling and setting velocities and times. The same did not happened with the soaking duration in which there were differences between the soaking durations indicated on the interviews and those verified on-board. Evidence of a discrepancy between reported and real practices regarding gear, captures and fishing activities is also discussed, with an emphasis on the negative effects of such practices in fisheries and the environment. Some of the current issues being faced in fisheries are by-catch and discarding, Illegal, Unreported and Unregulated (IUU) fishing, and ghost-fishing. When these are not assessed and remain unknown, they contribute to lack of proper management and sustainability solutions. In the end, the main purpose is to create a clearer picture of what is occurring in the local environment and within the fisheries to produce valuable information (like maps of fishing grounds) and consistent sets of data that can be used for future management decisions.

Keywords: Target species, Fishing grounds, Gillnets, GPS data, Mapping, Management, Surveys, Trammel nets

Resumo

A gestão e monitorização da atividade piscatória é uma questão que tem vindo a tornar-se cada vez mais relevante nos últimos anos. Fatores como a sobrepesca, a perda ou descarte de equipamento em alto mar, a interação com os fundos marinhos e a pesca de espécies acessórias e as rejeições têm impactes negativos nos stocks e no meio ambiente. Como tal, a identificação dos bancos de pesca é um passo fundamental para alcançar esse objetivo, sendo que os resultados da mesma poderão informar não só o sector pesqueiro (e.g. administração, academia, associações de pescadores e armadores), mas também outros sectores marítimos no plano socioeconómico (e.g. aquacultura *offshore*, operações marítimo-turísticas) e de conservação e planeamento (e.g. estabelecimento e gestão de Áreas Marinhas Protegidas e Ordenamento do Espaço Marinho). No contexto desta necessidade, o presente estudo teve como objetivo prioritário a elaboração de mapas dos bancos de pesca da frota costeira polivalente e como objetivos secundários: (1) o conhecimento do *modus operandi* das embarcações, (2) a caracterização dos eventos de pesca usando dados de inquéritos, de observações feitas a bordo e de GPS e (3) a verificação de associações entre as espécies capturadas e os *métiers* usados.

Para isso, foram avaliadas as práticas piscatórias da frota polivalente portuguesa na costa sul de Portugal, entre os portos de Sagres e Vila Real de Santo António. Com este objetivo, foram realizados inquéritos junto de 40 embarcações nas quais foram identificadas as características gerais das mesmas (tais como comprimento, peso bruto, tripulação, etc.), as artes de pesca utilizadas, as espécies capturadas, os bancos de pesca utilizados, as velocidades e duração dos processos de calagem, alagem e tempo de imersão. A frota foi caracterizada em função das variáveis (licenças, artes de pesca utilizadas por região, espécies alvo por arte e aspetos técnicos como o comprimento e potencia das embarcações) obtidas nos inquéritos feitos nos portos de pesca. Estas variáveis foram comparadas com informação presente em bases de dados oficiais (e.g. *EU Fleet Register Database*) e foi avaliada a representatividade das embarcações incluídas nas entrevistas feitas aos pescadores. As artes de pesca foram relacionadas com as espécies capturadas e com a localização das zonas de pesca através de análise estatística (CCA, ANOVA, etc.). As zonas de pesca indicadas pelos pescadores foram

agregadas e foram criados mapas de intensidade de pesca, tanto para o conjunto das artes como, em separado para as redes e armadilhas. Para além dos inquéritos, foram também recolhidas informações de observações feitas a bordo das embarcações estudadas e registaram-se as variáveis chave identificadas anteriormente. Adicionalmente foram recolhidos dados GPS, sendo registadas a posição, tempo, direção e velocidade ao longo de todo o percurso. Os dados recolhidos a bordo foram por sua vez caracterizados e foram realizadas análises estatísticas sobre os mesmos, de maneira semelhante ao feito anteriormente. Adicionalmente, foi feito um caso de estudo dos barcos a operar com redes, no qual os dados GPS foram processados para identificação dos eventos de procura, alagem e calagem, bem como as velocidades a que os mesmos se processaram. Os dados dos embarques foram usados para validar os dados dos inquéritos.

Relativamente aos principais resultados e conclusões, as entrevistas feitas permitiram concluir que existem relações significativas entre espécies alvo e as técnicas de pesca utilizadas. De acordo com um dos principais objetivos estabelecidos para este estudo, foi possível identificar os principais bancos de pesca que se localizam genericamente entre a uma e as oito milhas náuticas a 50 metros de profundidade, destacando-se claramente uma área entre Lagos e Quarteira com maior intensidade de pesca. Também foi possível concluir que existe variabilidade espacial em função da arte de pesca utilizada, sendo que as redes são maioritariamente usadas entre Sages e Quarteira, enquanto as embarcações que usam armadilhas têm, de modo geral, uma área de pesca na mais extensa e são usadas ao longo de toda a costa Algarvia. Comparando as áreas identificadas nos inquéritos com aquelas identificadas nas saídas de pesca, verificou-se que existe alguma sobreposição.

A descrição dos *métiers* ajuda a entender a importância destas questões numa determinada frota. Relacionar as espécies desembarcadas com as características técnicas da arte de pesca, procedimentos da operação de pesca, o conhecimento dos pescadores e a informação recolhida a bordo permite a análise de potenciais *métiers* e a sua validação. Para saber as espécies associadas às diferentes embarcações, comparou-se as espécies quantificadas a bordo e as desembarcadas por arte de pesca. Em Sagres, redes de tresmalho com malhagens superiores a 100 mm capturaram principalmente tamboril, lagosta e sapateira. Já as redes de emalhar pescaram essencialmente pata-roxa. Em Portimão, foram utilizadas sacadas de longas dimensões que combinava redes de emalhar e de tresmalho que tem como alvo cherne, pargos, abróteas e faneca. Em Olhão, os

pescadores utilizaram diferentes conjuntos de redes de emalhar, com malhagens superiores a 100 mm, destinadas a tamboril e malhagens de 80 a 90 mm que capturaram pescada. Em relação às espécies desembarcadas, deve-se realçar também que essas informações não representam o cenário das pescas na totalidade, uma vez que existem muitas espécies rejeitadas por não estarem em bom estado ou subdimensionadas (abaixo do tamanho mínimo de desembarque). Combinando as operações de pesca com áreas de marcadas nos computadores de bordo e GPS, os pescadores revisitam as áreas que consideram locais produtivos, o que significa que várias áreas específicas estão sujeitas a pesca intensa. Os pescadores fazem o que podem para otimizar sua captura, apesar de alguns deles revelarem que veem uma mudança óbvia no tamanho e abundância de espécies, com uma diminuição destas variáveis desde a sua infância até agora.

Qualquer informação desconhecida sobre uma frota diminui a possibilidade de uma gestão adequada e eficaz. Por isso, é importante descrever as diferentes frotas de um país como Portugal, onde a indústria pesqueira tem uma elevada importância socioeconómica e impulsiona o turismo. Alguns dos atuais problemas da indústria pesqueira são a captura de espécies acessórias, a rejeição de pescado, a pesca ilegal, não declarada e não regulamentada e a *pesca fantasma*. O desconhecimento destes por falta de estudos contribui para a escassez de soluções adequadas de gestão e sustentabilidade. Sendo que, variáveis como as características das artes e das viagens de pesca e a descrição dos *métiers* pode ajudar a melhor compreender estes problemas numa determinada frota. Existem grandes desafios para a governabilidade da pesca polivalente costeira, relacionada com o sistema de governo em vigor. Estes incluem a falta de monitorização e avaliação, o baixo controlo e a fiscalização, o incumprimento das regras e regulamentos pelos pescadores e a falta de confiança dos pescadores nos órgãos de gestão. Este tipo de trabalhos pretende ajudar na criação de uma imagem mais clara do que se passa no ambiente local e dentro das pescas, para produzir informações valiosas (como mapas dos bancos de pesca) e conjuntos consistentes de dados que possam ser usados para futuras decisões de gestão.

Palavras-chave: Bancos de pesca, Dados GPS, Espécies alvo, Inquéritos, Gestão, Mapeamento, Redes de emalhar, Redes de tresmalho.

Table of contents

List of Figures

List of Tables

LIST OF ABBREVIATIONS AND ACRONYMS

AIS	Automatic Identification System
ANOVA	Analysis of variance
CCA	Canonical Correspondence Analysis
CFP	Common Fishery Policy
DGPA	Direção Geral das Pescas e Aquicultura
DGRM	Direção Geral de Recursos Naturais, Segurança e Serviços Marítimos
E	East
EBSA	Ecological and Biological Sensitive Areas
EU	European Union
FAO	Food and Agriculture Organization
FIX	Pots
GIS	Geographical Information Systems
GPS	Geographical Positioning Systems
GT	Gross Tonnage
IMO	International Maritime Organization
INE	Instituto Nacional de Estatística
KM	Kolmogorov-Smirnov
LOA	Length Overall
MPA	Marine Protected Area
MSFD	Marine Strategy Framework Directive
MSP	Marine Spatial Planning
N	North
NO	Number
PCA	Partial Correspondence Analysis
S	South
SIFICAP	Sistema Integrado de vigilância, Fiscalização e Controlo das Atividades da Pesca
TAC	Total Allowable Catch
VHF	Very High Frequency
VMS	Vessel Monitoring System
W	West

FPO	Traps and Pots
GNS	Gillnets
GTR	Trammel nets
GND	Drifnets
NO	Lift nets
LLD	Drifting Longlines
LHP	Rod
LLS	Longlines
DRB	Dredges
OTB	Bottom otter trawler
PS	Purse Seiners

LIST OF UNITS

h	Hour
nmi	Nautical mile
Km	Kilometre
m	Meter
kW	Kilowatts
Kn	Knots
t	Tonnes
kg	Kilograms

1. Introduction

1.1. Portuguese fisheries

Fishing is a well-marked activity in Portuguese cultural heritage. As a way of livelihood, it has a relevant socio-economic value, particularly for coastal communities that depend almost exclusively on this activity. In 2019, Portugal had the highest per capita consumption of fishery and aquaculture products of the European Union (European Union 2021). The importance of seafood in Portuguese food habits can be explained by its geography, marine living resources, social forces and politics. The country's location between temperate and subtropical biogeographical regions explains, in part, the high diversity of marine species (Briggs and 1946- 1974), of which about 360 are commercial species (according to DGRM- the Portuguese Directorate of Marine Resources in Leitão *et al.*, 2014).

Looking at the history of Portuguese landings since 1950 and according to Leitão *et al.* 2014), the catches increased from around 275 000 $t{\cdot}year^{-1}$ to a peak of just under 450 000 $t{\cdot}year^{-1}$ in 1964, before beginning a gradual but continuous decline to around 200 000 $t{\cdot}year^{-1}$ by the mid 2000s. Since then, total catches appear to have stabilized at this substantially reduced level of catch (Figure 1.1). This trend continued from 2010 to 2018, reaching the lower value of 189 722 t in 2010 and the higher of 226 396 t in 2017 (FAO, 2018). However, with several species showing signs of over-exploitation, there is cause for concern regarding fisheries. The decline in biomass is correlated to an increase in fishing effort, especially for higher trophic level species (Pauly and Palomares 2001; Watson and Pauly 2001). In addition, environmental variability has an influence on landings locally and in broad geographic areas (Watson and Pauly 2001) . Other negative effects associated with fishing, besides the reduction of the size of fish stocks, include a decrease of the mean size of the individuals and a reduction of the genetic pool which can lead to changes in the ecosystems and habitat degradation (Blaber *et al.*, 2000; Hilborn *et al.*, 2003; Pauly *et al.*, 2005).

Despite these alarming signs, Portuguese fisheries remain one of the most diversified, which can be illustrated by the fleet variety, the variety of gear as well as the number of different species captured. However, Portuguese fisheries depend on limited marine resources with low economic value (Garrido, 2018). Of these, the sardine (most common species), chub mackerel and the horse mackerel are the main representatives. On the other hand, the common octopus is ranked as the most valued landed fishing resource in 2016. In fact, the octopus fishery is especially important in the Algarve region, where octopus is the most landed species, representing 25-35% of the total landings (Silva *et al.*, 2018).

Yet, the trait that better characterizes Portuguese fisheries is the persistence of high consumption rates. In fact, between 2016 and 2018, for a production whose maximum has been limited 141 000 t (estimation of landings), the consumption reached more than thrice (about 650 000 t), which implies a deficit in the trade balance (European Commission, 2017; Garrido, 2018).

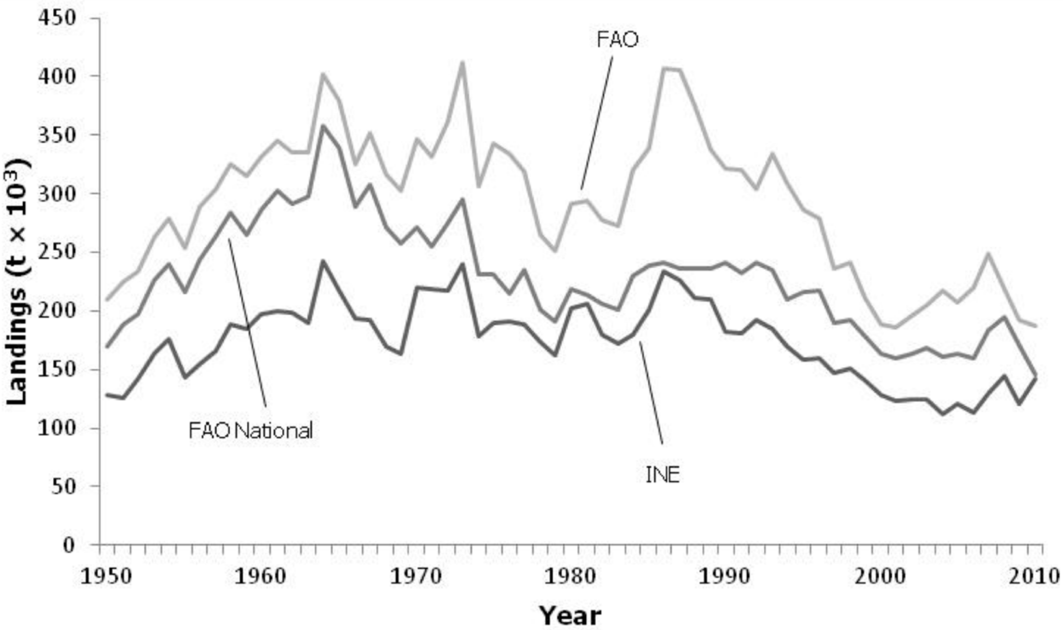


Figure 1.1 *- Comparison between national data (INE) for domestic portuguese mainland catches and FAO data adjusted by exclusion of clearly non-domestic taxa, 1950-2010 (Leitão et al., 2014).*

1.2. Portuguese fleet

In December of 2020, there were 7 718 vessels with a capacity in gross tonnage (GT) of 86 457 and potency of 345 249 kW. Traditionally, marine resources are mainly exploited by small-scale coastal and estuarine fisheries. The Portuguese fleet comprises mainly small vessels, of which 90% of the registered units have an overall length (LOA) smaller than 12 meters and reduced GT (INE, 2021).

As stated in the national legislation (Decree-Law No. 16/2015) the Portuguese fleet is classified according to its fishing areas, LOA and power. The local fleet is mainly comprised of open deck vessels with a LOA smaller than 9 m and a power no greater than 75 kW, that operate within the six nautical miles offshore, inside the jurisdiction zone of the port where they are registered in. The coastal fleet operates in the area limited by the parallel 48ºN to north, to the west by meridian 14ºW, to the south by the parallel 30ºN, and to the east by the African coast, by the line that joins Orão to Almeria and by the European coast; and in the area bordered to the north by the parallel 30ºN , to the west by the meridian 16ºW, to the south by the parallel 25ºN and to the east by the African coast; and also, in the Gorringe (Gettysburg), Josephine, Ampère, Seine and Dácia banks. This fleet is characterized by having a LOA between 9 and 33 m and a power equal or higher than 26 kW. Finally, the largest fishing vessels, which are characterized by having a gross tonnage higher than 100, can operate beyond 12 nmi of shore and have and a minimum autonomy of 15 days.

1.3. Multigear coastal fleet

In July of 2021, the Algarve multigear coastal fleet had a total of 186 vessels, with a LOA greater than 12 m and having valid licenses for static gear (DGRM, 2021). These fleet operate along the coast using mainly static gear (nets, longlines, pots and traps).

For Algarve fisheries, the most significant static gear are traps (Sonderblohm *et al.* 2017; Szynaka *et al.* 2021), longlines, gillnets (Erzini *et al.*, 2003) and trammel nets (Erzini *et al.* 2006; Borges *et al.* 2008). Traps encompass mostly pots, cages or baskets with variable shapes and dimensions, depending on the target species, local custom, and available materials (such as metal rods, wire netting, plastic, clay, etc.). These devices have one or more openings designed to encourage the entry of animals, which are then prevented from escaping either by particular aspects of their behaviour or by the design of the trap itself. They can be used with or without bait, depending on the target species.

Unbaited traps, such as clay or plastic pots, are made to resemble refuge and capture octopus by taking advantage of its behaviour. Baited traps are used to catch various predators' species of crustaceans, molluscs and demersal fishes. In order to accommodate more traps on the limited available space of the vessel, there are models that are designed in such a way that they can be stacked one upon each other (Slack-Smith, 2001). The most widely used traps in the Algarve are *covos* - metal frame, hard plastic netting, single entry traps for octopus - *armadilhas* - large, metal frame traps for catching cuttlefish and fish - and *murejona* - wire round traps for catching fish (Erzini *et al.*, 2008).

Regarding vessels operations, generally, traps can be set individually or in rows/strings connected to a mainline and are operated in a wide range of depths. When the fishing ground is reached and if the ship is in a downwind position, the buoy cable is launched and, consequently the mainline is dragged. As the mainline goes out, the various traps are dropped. In the end, a second buoy cable is thrown. The soaking time can last from one or two hours to a full day and usually fishers haul their traps every day. The gear can be hauled by a hydraulic system (Figure 1.2A), first by collecting one of the buoy cables and then by removing the mainline from the water. As the traps are hauled and stowed on the deck (Figure 1.2B), the species are withdrawn and if the vessel has enough space the procedure is repeated (Gaspar *et al.* 2014).

***Figure 1.2** - On the left (A) the hydraulic hauler that pull the main line and the traps. On the right (B) the deck of the vessel where the cages are stowed. This area is covered by a structured that do not allow the traps to fall from the boat.*

Gillnets are single or double netting panels while trammel nets are triple panel nets, usually made of monofilament (PA), which are set near the surface, in midwater or on the bottom with anchors or ballasts that oppose to the strength of the buoys and to the ocean currents. The rectangular nets have floats on the upper line (headrope) and in the inferior part (footrope) weights, which keeps the gear in a vertical position (FAO, 1978). Usually, the accumulated length of sets that can have different types of nets (for example, gillnets with trammel nets), varies between 2000 and 20 000 m. The number of nets combined in one set varies from 10 to 200. The height and the mesh size depend on the target species (Ordinance No.1102-H/2000). The fish can be retained by gills with gillnets or when using trammel nets, the entire body of the fish or part of it can also get entangled. Relative to the way that the gear is handled, the fishing operation begins with the release of the floater cable that has a weight or an anchor in the end. While the vessel is moving, the net is being dropped by one of the edges or by the stern of the vessel. As soon as the set is almost in the water, the captain reduces the velocity, and the other extremity of the cable is launched. The soaking time can last until 72 hours. During hauling, the nets are pulled with the help of a hauler, the fish are untangled from the net, and the is gear folded on the deck (Figure 1.3). This operation is done on one of the edges of the boat or on the bow, with the vessel facing the wind or against the direction of the currents. The fishing grounds of these vessels depend on the distance to the coast - vessels with a LOA greater than 9 m, fishes out of one mile distance; regarding vessels using trammel nets, to operate beyond the 15 nm, the nets must have mesh size greater than 240 mm (Ordinance No.1102-H/2000).

Figure 1.3 *- On the left top corner (A) is the hauler system pulling the net. On the top right (B) the sorting system and below, the deck area where the nets are kept after organized.*

While the government has access to information regarding the landed species, it is but a small part of the overall picture of how this multi-gear coastal fishing is affecting not only the environment but also the future of the fishery itself. This information does not provide details such as fishing operations and gear characteristics, meaning the *métiers* in this fleet are unknown. *Métiers* are valuable as they provide information on the fishing operations characterized by similar exploitation pattern, targeting similar species using similar gear during the same time of year and/or area (ICES, 2017). This knowledge gap prevents proper assessment of sustainability and management.

1.4. Monitoring systems

In order to monitoring fishing activity there are three main tools used in fisheries research. One relies on collected fishery data (like surveys, databases, scientific articles and logbooks) and the other two on monitoring systems like Vessel Monitoring Systems (VMS) and Automatic Identification System (AIS). For the first type of data, the georeferenced information is obtained through the realization of vessel transects or through the localization and identification of vessels from the coast (Horta E Costa *et al.*, 2013). Other studies have developed models built on data obtained from the fishermen community (Moreno-Baez *et al.*, 2012; Gaspar and Pereira, 2014; Ojeda-Ruiz *et al.*, 2015). For the second one, VMS and AIS are tools that allow the creation of a database with the fishing activity and the coordination between all the fiscal entities integrated in the Monitoring and Controlling System for Fisheries Activities (SIFICAP - *Sistema Integrado de vigilância, Fiscalização e Controlo das Atividades da Pesca*), instituted by Decree-Law No. 79/2001, of 5th March. However, due to confidentiality and protection concerns, VMS data are almost exclusive for judicial control and scientific purposes (Decree-Law No. 310/98).

At the European level, Portugal was a pioneer in the implementation of a continuous monitoring system for fishing vessels, named MONICAP. This system is integrated in a complex network, that uses a satellite positioning system (GPS) along with a communication technology (Inmarsat-C) to transmit the position, course and speed of the ship to the ground control centre, continuously and automatically. Using a computer, the control centre provides the real time surveillance of the fleet activity (Fonseca, 2012).

VMS appear in fisheries research in the EU as a revolutionary tool. This system collects fishing activity data in space and time with a frequency of 2 hours (Russo *et al.* 2014) and which is usually based on point-to-point satellite communications between the ship and the ground centres. VMS information should give the opportunity to assess more precisely the impacts of fishing activity geographically (Gonçalves *et al.*, 2015)

However, when treating a large volume of data and relating tracking data to fishing activity, this system poses a series of data management and methodological challenges. There is a need of build statistical tools to analyses VMS data and develop methods that fully satisfy and infer the hidden positions and behavioural state of fishing vessels (Hintzen *et al.*, 2012; Natale *et al.*, 2015). Despite the promising methodological developments and increasing number of tools (Russo *et al.*, 2011; Hintzen *et al.*, 2012; Russo *et al.*, 2014), the use of VMS data for scientific purposes is hindered by the difficulty of accessing control data for scientific purposes, often due to confidentiality and personal data protection concerns (Hinz *et al.* 2013).

AIS was introduced by the International Maritime Organisation (IMO) as a novel tool to improve maritime safety and avoid ship collisions (Resolution MSC.192 (79)). In contrast to VMS, AIS messages are broadcasted by the vessels omni-directionally and can be received by other ships in the neighbourhood, by ground-based receivers and by satellites (Figure 1.4.). The AIS system provides the possibility for ships to exchange near in real time kinematic information (position, speed, course, rate of turn, destination and estimated arrival time), static (vessel identifiers, dimensions, type and size of the ship) and voyage related information (destination, ETA, draught, etc.) (Mao et al. 2018).

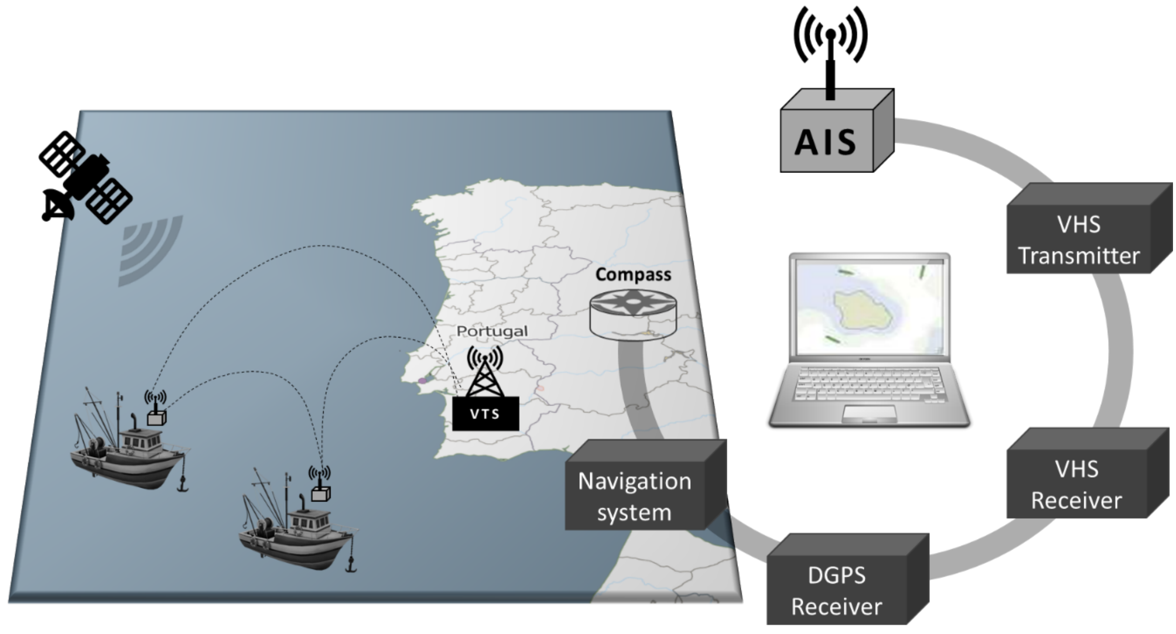


Figure 1.4 *- Automatic Identification system. On the map is shown how the VHFs are broadcasted by the AIS transceivers. On the right are the AIS integrated components (VHS transmitter and receiver, DGPS receiver, navigation system of the vessel and it compass) that provide information which are displayed on a screen. The VTS is a landed-based vessel traffic service that also have an AIS transceiver.*

There are still some difficulties that need to be overcome. AIS spatial coverage is limited to line-of-sight or, in specific cases, to ducting propagation of Very High Frequencies (VHF). The typical coverage range of AIS station or of an onboard transceiver is about 15-20 nmi, depending on various factors such as transceiver location/type or weather conditions. Moreover, in high traffic density areas there is the problem of message collisions which hinders the message detection by the satellite receiver (Natale *et al.* 2015; Tu *et al.* 2018). Despite this, AIS is a high-tech tool for navigation and for mapping fishing activities. An advantage offered by AIS lies in the time resolution of the messages. The system is integrated with a standardized VHF transceiver that broadcasts the information every 2 to 10 s and continuously collects it from other ships (Tu *et al*. 2018).

While VMS is compulsory for all EU vessels greater than 12 m, AIS system has been progressively extended in the EU to fishing vessels and has become mandatory since May 2014 for all fishing vessels with more than 15 m of length (EU Dir 2011/15/EU).

To keep track where the gears are set and where are the preferential fishing grounds, fishers use a combination of empirical knowledge, GPS and sonar data and controlling systems like the one represented in Figure 1.5.

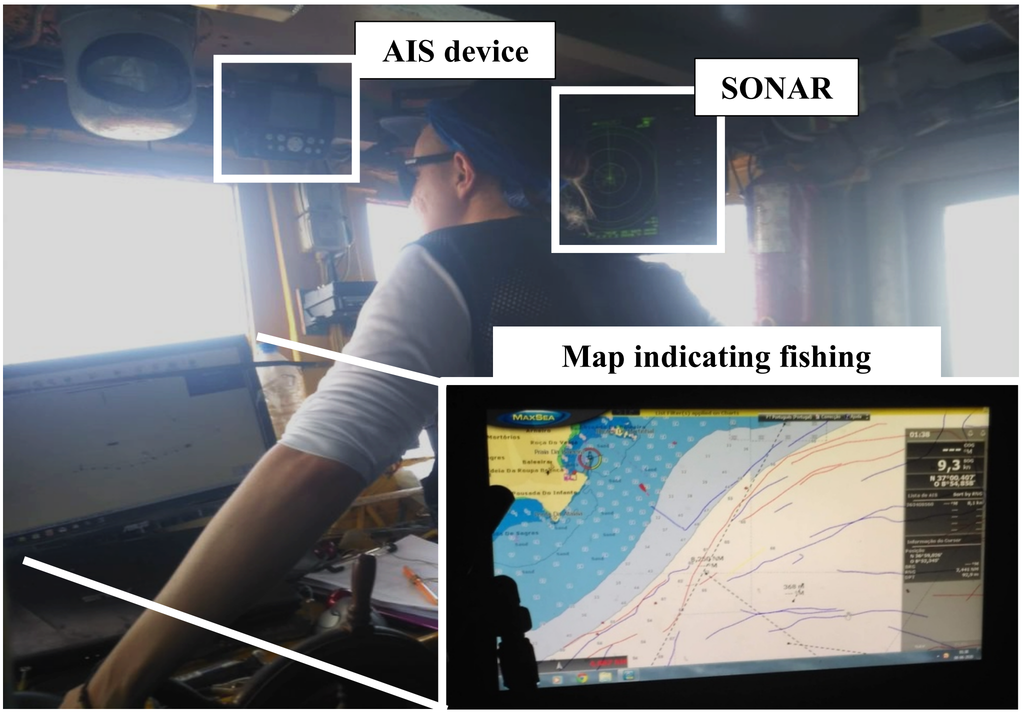


Figure 1.5 *- Captain's controlling and navigation area, where the AIS and SONAR devices are identified and the screen of the on-board computer augmented.*

1.5. Marine Spatial Planning

Nowadays, the increasing demand for high quality protein sources led to the ”Blue Revolution” bringing along new challenges in planning and managing the marine territory. Several activities compete economically and territorially with traditional fisheries, namely offshore aquacultures, maritime-touristic activities, renewable energies, mineral resources and fossil fuels extraction (European Commission, 2021; Gonçalves *et al.*, 2016). In order to prevent and minimize conflicts with other sectors, mapping fishing grounds can promote the enforcement of spatial management measures such as marine protected areas (MPAs) (Batista *et al.*, 2011; Gonçalves *et al.*, 2002), ecologically and biologically sensitive areas (EBSAs) as well as fisheries closure zones, consequently empowering the sustainable use of marine resources, optimizing the revenues and valuing the fishing products supporting the interests of this sector (Douvere, 2008).

Relative to MPAs, the establishing of it through participatory methods with the identification of ecosystem services and evaluation and mapping of the benefits produced are essential tools for outlining integrated management measures that establish commitments between the needs of different users and conservation objectives (Brander *et al.* 2015, Reuchlin-Hugenholtz and McKenzie 2015, Russi *et al.* 2016). Despite the growing demand for this type of information, a detailed characterization of the different activities – including georeferenced information and their socio-economic impact – is rarely available to inform and support the decision. The lack of socio-economic and geospatial information of the different activities supported by coastal ecosystems is one of the biggest obstacles to the integrated management of these ecosystems and their maritime planning (Halpern, 2012; Scholz *et al.* 2011).

Monitoring and mapping fishing areas is of great importance to detect changes in biodiversity and abundance of species as well as assess the effects of human impact on these environments. This can serve as a tool for Marine Spatial Planning as well for the conservation of habitats and marine biodiversity for future generations (Campbell *et al.*, 2014).

With one of the largest marine jurisdictions in Europe, the current protection of the Portuguese marine territory is far from achieving the 10% target for Marine Protected Areas (MPAs) (RCM No. 55/2018). Therefore, Portugal has a paramount effort ahead if it aims to fulfil the EU maritime polices. The considerable size of marine areas highlights the importance of establishing and ensuring an adequate organization of the maritime space (Frazão Santos *et al.* 2014).

Regarding the required connection between all sectors which impact and operate on the sea, an Integrated Maritime Policy has been developed. Since 2006, two National Ocean Strategies have been implemented in Portugal (RCM No. 163/2006; RCM No.12/2014). At European level, the Marine Strategy Framework Directive (MSFD) was transposed into national internal law (Frazão Santos *et al.* 2012) and the Portuguese government started a marine spatial planning (MSP) process (Portuguese Government, 2012; Frazão Santos *et al.*, 2014).

1.6. Legal and political framework

Relative to the exploitation of marine resources and ecosystem services, Portugal is in line with the Common Fisheries Policy (CFP) which aims to ensure that fishing is environmentally, economically and socially sustainable and provides a source of healthy food for EU citizens. Thus, it intends to promote a dynamic fishing industry and a fair standard of living for fishing communities. The CFP adopts a cautious approach when maximizing the catches by establishing limits to maintain fish stocks in the long term. Therefore, it seeks that fishing fleets become more selective in what they catch and reduce the discarding of unwanted fish (Regulation (EU) No. 1380/2013).

As part of the CFP, a quota system was created to manage the total catches, gear limitation, fishing time and areas restrictions. Annually, it is established a Total Allowable Catch (TAC) (Council Regulation (EEC) No 170/83) and the fisheries management is carried out through a top-down system based on several inputs and output control measures (Decree-Law No. 43/87), with little participation from the fishing industry in the decision-making process (Linke, 2015). However, due to fish specifications (e.g., reproduction season and life cycle) not all fishery types are under the CFP. The common octopus's fishery is excluded from quota regulations under the

Common Fisheries Policy (CFP) and consequently, the management of this fishery derive from research advice provided by the national fisheries research institute, local governmental and higher education research institutions. This is due to the huge annual fluctuations in octopus' populations, which implies that abundance varies from year to year. Aside from this, the fact that octopuses are terminal breeders and have non-overlapping generations also has implications for fisheries and the current fishery management under the CFP is very much focused on relatively long-lived fish and shellfish and thus, cannot be applied to octopus' fishery (Pita *et al.* 2021).

Management measures in place consist essentially of regulations defining a minimum landing weight and the gear used (Ordinance No. 1102-D/2000). The minimum landing weight for the common octopus is 750 g. A maximum of 3000 non-baited pots per vessel is stipulated by the legislation. Baited trap limits vary according to the length of the boat, in the case of vessels between 9 and 12 m in length and vessels over 12 m, the limits are 1000 traps and 1250 traps, respectively. The legislation also puts restrictions on the mesh size and dimension for different types of traps. Finally, there are spatial-temporal constraints on the fishery such as a minimum distance from shore at which the gear can be deployed (e.g., 1 nmi for vessels over 9 m in length using pots and/or traps). Regional rules have also been put in place, for example, in the Algarve south coast fishing grounds, isn't allowed the using of live bait (e.g., *Carcinus maenas*) (Ordinance No. 230/2012).

According to the Portuguese legislation (Ordinance No.1102-H/2000), trammel nets and gillnets also follow regulation measures that define the gear use. Vessels with a LOA higher than 9 m cannot operate at distance inferior of ¼ nmi from the coast. In the case of the fixed nets, the size of the net set depends on the overall length (LOA) and cannot exceed the 5000 m. There are some restrictions in specific areas like the São Vicente Cape (37º01' N) where the use, transport or having on board nets with a mesh size between 60 mm and 79 mm is forbidden. In depths ranging from 200 and 600 m the use of mesh sizes smaller than 220 mm is not allowed. In addition, depending on the mesh size, the existing catches on board must include a percentage higher than 70% of target species. The use of gillnets to capture of crustaceans is prohibited. Regarding soaking times, nets may not be immersed more than 24 hours, except if proven external factors prevented the fishers from taking them out, or 72 hours if the nets have a mesh size superior to 100 mm and are set in 300 m depths.

1.7. Objectives

This study aims to characterize and map the fishing grounds of coastal multigear fleet using survey data. The interviews were necessary to observe which *métiers* are active in the multi-gear fleet and to further explore the possibilities of combining the information from the landings and knowledges of fishers to understand what is occurring within the fisheries. For that, the work intends to:

1. Know the *modus operandi*, i.e., fishing behaviour, licenses that they have, and which are effectively the fishing gears being used, target species and fishing grounds;
2. Validate the data from the interviews by the on-board information collected and observed, fishers' comments and GPS data;
3. Do a characterization of the fishing events by identify the different fishing phases using GPS data, enquiry data and onboard observations (set netters case study);
4. Check if there are an association between the species captured and the *métiers* being used.

In the end, the main purpose is to create a clearer picture of what is happening to produce valuable fishing ground maps and consistent sets of data that can be used for future management decisions.

1.8. Thesis layout

This document is divided in six chapters. In the first chapter, Introduction, we present the historical evolution of Portuguese fisheries from the 1950s until the current status, including the legal and political framework of the multigear coastal fleet, monitoring systems, tools and techniques to assess the impact of fishing activity. The end of the chapter outlines the main objectives of the study in the context of the fleet characteristics identified in section one by presenting the fishing grounds selected in the interviews and creating a representation of what is happens in our study area and with the multigear coastal fleet.

Chapter two focuses on the characterization of the fleet through interviews to vessel captains. The methodology is outlined, and the results are analysed and discussed, including created maps of the fishing grounds identified by interviewees. Chapter three follows the same structure of chapter two, but this time related to the characterization of data collected on-board, highlighting the case study of set-net vessels, analysing fishing areas and characterizing the fishing events with GPS tracking data.

Chapter four relates and discusses chapters two and three, comparing data obtained through interviews and information collected on-board. The final chapter discusses the main conclusions and provides recommendations for future work.

2. Characterization of the fleet and mapping of fishing grounds

2.1. Introduction

In the last decade, two studies were conducted with the objective of assess the knowledge about the fishing grounds of Portuguese coast, namely the projects PRESPO (2009-2010) (Gaspar *et al.* 2010) and PescaMap (2015) (Gonçalves *et al.* 2015). The first one was carried out on the national level and the second was done on the Algarve coast. Both projects were based on the need to have geospatial information of fishing areas, which is necessary for maritime space planning and are in line with the guidelines of the current basic law of the Maritime Space Planning and Management National Policy (Law nº 17/2014 de 17 of April).

This section gives an understanding of our sample by characterizing the fleet defined below through the analysis of the interviews we have done in the main Algarve ports. It also explains how the data was acquired and at which locations. The spatial knowledge of fishing activities is usually scarce or of poor quality (Scholz *et al.* 2004). With the aim of enrich the limited existent data, on the sub-chapter 2.3.4. Fishing grounds the information obtained are discussed and the main purpose of this thesis, the identification and mapping of the fishing grounds, met.

2.2. Methodology

This chapter presents methodologies used by previous project such as PRESPO and PescaMap but applied to the multigear coastal fleet instead of the small-scale fisheries and the coastal fleet composed by purse seiners. Protocols for collection and use of key informants' knowledge using interviews have been described by Gonçalves *et al.* (2015), Silva *et al.* (2018) and Léopold *et al.* (2014), among other authors. For this work, we generalize their approach to the multigear coastal fleet and provide fishing intensity maps (see results section). For the mapping section, the methodologies used by Léopold et al. (2014) and Close and Hall (2006) were combined and adapted to collect, analyse and map fisher-based knowledge.

The definition of the fleet considered that the coastal multi-gear fleet is composed mainly by vessels that owned licenses to more than a single gear type and have a Length Overall (LOA) between 9 and 15 meters (with a few vessels above 15 meters). These vessels operate beyond the one nautical mile using a wide variety of passive gears (gill- and trammel nets, lines and hooks, traps, and pots) and by vessels catching a large variety of pelagic and demersal species.

- **Study area and data acquisition**

From November 2019 to March 2020 questionnaires were conducted between Sagres and Tavira on the main fishing ports (Figure 2.1). The captains of the vessels were informed about the objectives of the study. The choice to interview the skippers or captains was made to avoid mixing of bias from the fishers that worked on the vessels and because they are generally more knowledgeable regarding species as well as their gear characteristics. The interviews were conducted using *in situ* search where fishers were met by the landing dock during regular auction hours and when most of the vessels arrive from fishing. When it was difficult to encounter more vessels, we asked the local auction for vessel names, with the requirements that the vessels are more than 9 meters in length and the skippers owned licenses for more than a single fishing gear, for which a list with highlighted vessels was provided. However, this list did not signify currently active vessels. Final interviewing was conducted using the snowball effect, during which already interviewed fishers introduced or provided telephone numbers of their friends or colleagues (captains or skippers) who are also working in this fleet.

Figure 2.1 *- Study area (southern coast) highlighted from the Portuguese map. Bathymetrical lines and the main fishing harbours are also represented.*

The structured questionnaire (Annex 1) was divided into three sections. The first had information on vessel's characteristics (name, vessel registration, LOA, fishing licenses and changes in licenses). The second part intended to characterize the fishing activity with information about the trip (departure and landing ports, time of departure and arrival, trip duration, number of workers, mean number of trips by week, gears used, lost gears, navigation speed, setting and soaking times). In addition, information on fishing gear technical aspects, i.e., target species, number of traps/nets, setting and hauling speed, traps spacing, main line length, type of bait, mesh size of nets, depth of fishing and environmental aspects (e.g., bottom type) were collected. The third part aimed to assess fishermen's perception of the fishing grounds. For that, a grid map (Annex 2) of the southwest and south of the Algarve coast was presented to the fishermen and the main fishing areas were point out by the fishers. Besides the bathymetric, this map had information like the coastal line and the main fishing ports. On total 40 questionnaires on the multi-gear fleet were done.

2.2.1. Mapping technique

Since the vessels smaller than 12 meters do not possess the legal obligation of having monitoring systems and more than 50% of the captains said that the vessel did not have AIS or if it has it was turned off, the fishing ground maps for this fleet were built on surveys data. For that, a grid map of the Algarve coast was presented to the fishermen for them to select the preferential fishing areas. Besides the bathymetric lines this map includes information like the coastal line and the main fishing ports (Annex 2). The analysis contemplates the individual areas identified by each fisherman, taking into consideration that more than one area could be identified.

Following the methodology used by Gonçalves *et al.* (2015), the areas selected by the fishermen were converted into a vectorial format (shapefile) to be processed in geographic information system (GIS) software (QGIS 3.16.5 Hannover). For that, when fishing areas were selected on the grid map, a value of one was assigned to the respective cells. To the areas that were not marked (no fishing was occurring), a value of zero was attributed. Then, to calculate the total fishing area the matrixes produced were summed. and the fishing grounds used by all vessels was computed (Figure 2.2). To obtain the final maps, the individual fishing areas were transformed in raster format with the total study area and a resolution of ½ nm.

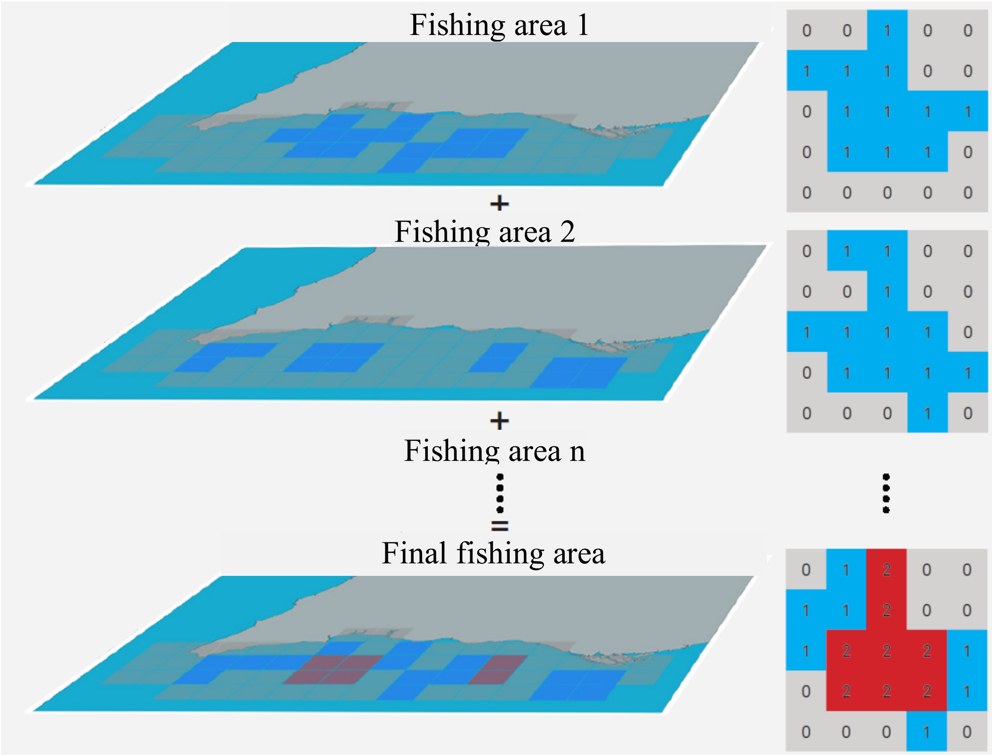


Figure 2.2 *- Example of the calculation methodology with spatial data in raster format to identify the fishing grounds. Adapted from: Gonçalves et al. (2016).*

2.2.2. Statistical Analysis

All the statistical analyses were carried out in R statistical software (R Core Team, 2020) and RStudio environment (RStudio Team, 2020). To evaluate the representativeness of sample a non-parametric test of Komogorov-Smirnov (KS) was performed. The null hypothesis was that the observed frequencies are equal to the expected ones and thus, the sample is representative. The alternative hypothesis is the opposed and was selected a significant level of 0.05. A partial canonical correspondence analysis (CCA) was performed to identify and measure the associations among the gear types, target species and sites. It was established a significance value of 0.01.

2.3. Results and discussion

2.3.1. Sample characterization

A total of 40 inquiries were performed. On the west coast, 16 interviews were conducted in the three ports of Sagres (4), Lagos (4), and Portimão (8). In the centre, 16 interviews were conducted in the ports of Olhão (11) and Quarteira (5). On the east coast, 8 interviews were conducted in the ports of Santa Luzia (7) and Tavira (1) (Figure 2.3). From the investigated vessels, traps (31) and pots (25) (FPO) are the most common licenses (40.3%), followed by longlines (LLS) (26.6%), which also includes hooks (17) and rod (1). Gillnets (GNS) which correspond to (19.1%) are divided according to mesh size into four classes. There were two licenses of gillnets with 35 mm to 40 mm of mesh (GNS (30-40 mm)), three of GNS (60-79 mm), five of GNS (80-90 mm) and other four of GNS (>100 mm) (4). Twelve GNS licenses did not specify which class they belonged to. Following gillnets were trammel nets (GTR) with mesh sizes bigger than 100 mm (12,9%) (18). In addition to these, two vessels had licenses for dredges (DRB) (Figure 2.4).

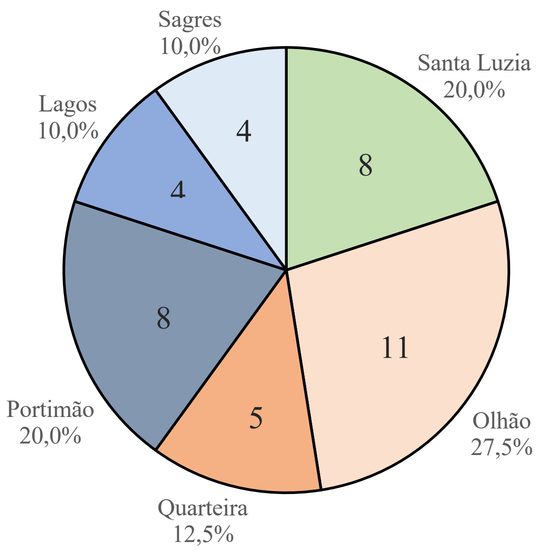


Figure 2.3 - Distribution of inquiries done in each port in Algarve coast West coast represented in blue, centre in orange and east coast in green.

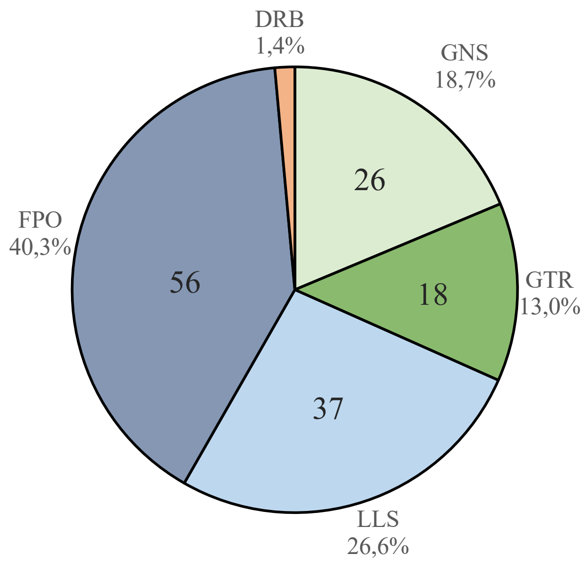


Figure 2.4 - Percentage of licenses from all interviews. LLS correspond to longlines, hooks and rods; FPO to traps and pots; GNS to gillnets; GTR to trammel nets and DRB to dredges.

In Sagres, LLS is the most common license (29,41%), while GTR, GNS and FPO are equally distributed with a percentage of 23,5% each. In Lagos, FPO is the main license (42,9%), followed by GNS and LLS (both with 28,6%). No vessel is licensed for GTR. In Portimão, the most frequent license is FPO (44,0%), followed by LLS (24,0%) and GNS and GTR (both with 16,0%). In Quarteira, FPO is also the most common license (35,0%), followed by LLS (25,0%), and GNS and GTR (both 20,0%). In Olhão, FPO represent 44,4% of all licenses, LLS 25,0%, GNS 22,2% and GTR 8,3%. In Santa Luzia, FPO and LLS are the most popular licenses (50,0 % and 30,8 %, respectively) while the least ones are GTR and GNS (11,5% and 7,7 %) (Figure 2.5).

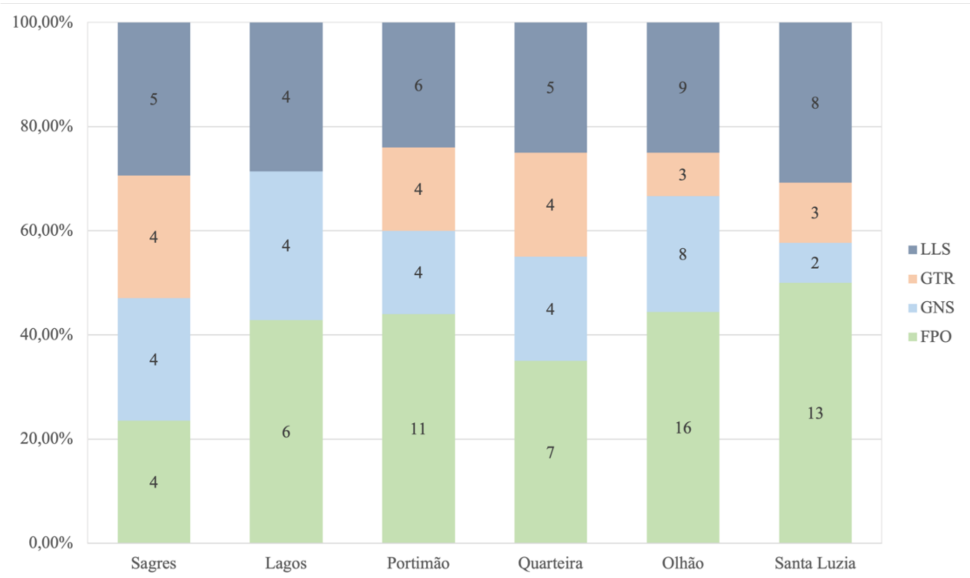


Figure 2.5 *- Distribution of licenses by port. The numbers inside the bars represent the absolute values of licenses.*

According to EU Fleet Register database there are 166 vessels belonging to the multi-gear coastal fleet and registered in our study area (EU Fleet Register, 2021). However, this value may include vessels that are operating outside and excludes vessels registered in other ports that work on our study region. On the other hand, it isn't possible to know if all the 166 vessels are active. When comparing the licenses from these vessels with our sample, there are some licenses which aren't present in our sample, namely driftnets (GND), lift netters (NO), drifting longlines (LLD), bottom otter trawl (OTB) and purse seiners (PS). Gillnets (GNS) and trammel nets (GTR) are approximately a third of the ones from EU Fleet database. Longlines (LLS) and, traps and pots (FPO) are well represented in our sample and are more than half of each license. Rod (LHD) and dredges (DRB) aren't so well represented (Figure 2.6). The KS statistical test presented for 10 degrees of freedom reject the null hypothesis (p-value < 0.05), concluding that the sample isn't representative. However, for a small data universe and by the fact that the number of active vessels from the database might be lower, the sample can be illustrative. In addition, nets and traps represents a third and more than half, respectively, of the expected values and thus, can represent the EU database.

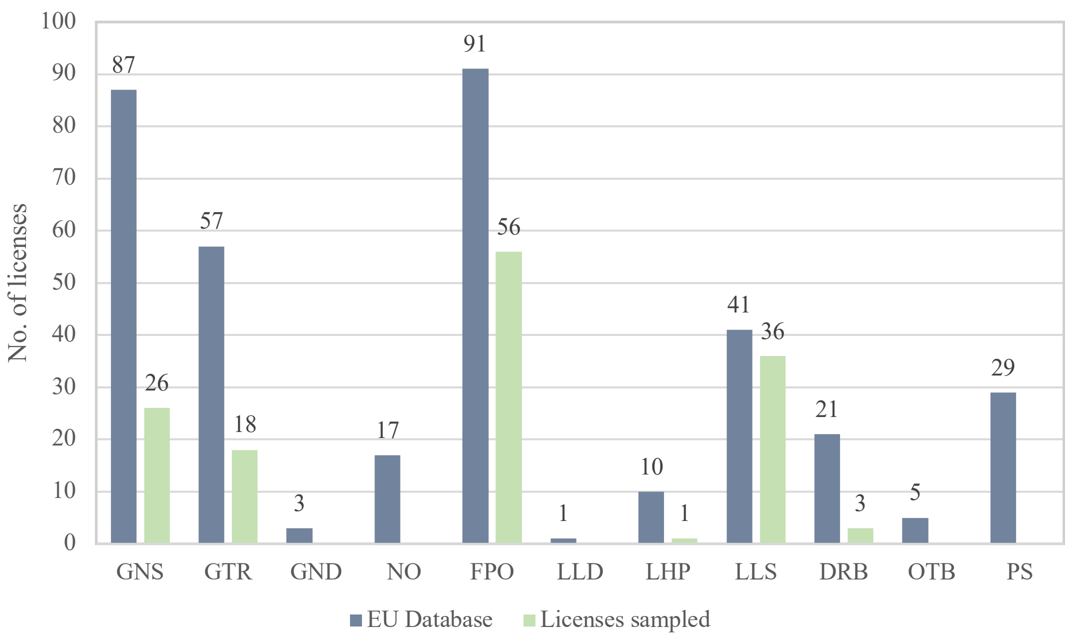


__Figure 2.6__ - Percentage of licenses (absolute values above the bars) of EU Fleet Register Database (blue) and from our sample (green). __GNS__ - Gillnets; __GTR__ - Trammel nets; __GND__ - Driftnets; __NO__ - Lift netters; __FPO__ - Traps and pots; __LLD__ - Drifting longlines; __LHP__ - Hand and Pole lines; __LLS__ - Set longlines; __DRB__ - Boat dredges; __OTB__ - Bottom otter trawl; __PS__ - Purse seiners.

2.3.2. Technical description of the vessels

Relative to the vessels sampled, the mean length was 11.9 m, the gross tonnage (GT) 10.8 t and the mean engine power 78.9 kW. The vessels with higher mean values of length and engine power were in the west, whereas the lowest values were in east (Table 2.1). This might be related to the maritime and atmospheric conditions that are turbulent and windier on the west coast and so the vessels need to be more robust and potent. From our sample the mean length is 12.0 m, the gross tonnage 10.8 t and the mean engine power 78.9 kW. From EU Fleet Register database, the mean length is 11.6 m, the gross tonnage 11.1 t and the mean engine power 79.4 kW. Most of the vessels interviewed are between 9.0 and 15.0 meters, which allows the vessel to hire more crew than small-scale or artisanal vessels, carry more catch and potentially conduct longer trips, and to set and haul more fishing gear. Although a few captains/skippers indicated that they operate two different gear types in a single trip (22.5%), most of the vessels use multiple sets of a single fishing gear during each fishing trip.

These values make sense for this type of fleet that does not use active gears (e.g., trawlers), don't have long trips, operate near the coast (between the 1- to around 12- nmi) and for the meteorological conditions of the southern coast which are relatively moderate all year.

Table 2.1 *- Mean technical characteristics (range in parenthesis) and number of vessels by region, of all the multi-gear vessels interviewed and of the EU Fleet Register database.*

Region	Length (m)	Gross tonnage (t)	Engine Power (kW)	No. of vessels
East	11.6 (9.0-13.0)	9.0 (5.2-14.0)	65.1 (44.0-92.0)	8
Centre	12.0 (9.0-16.5)	11.6 (4.4-26.8)	79.7 (37.0-137.2)	16
West	12.2 (9.9-17.0)	10.9 (5.2-16.7)	85.0 (44.7-110.3)	16
All sampled vessels	12.0 (9.0-17.0)	10.8 (4.4-26.8)	78.9 (37.0-137-2)	40
EU Fleet Database	11.6 (9.0-17.0)	11.1 (3.1-38.0)	79.4 (26.5-223.6)	166

Of the 40 vessels, 31 (77.5%) were using a single gear type per trip and the remainder nine vessels were setting and hauling two types of fishing gears during a single trip. Traps were the most used fishing gear in the three regions with a total of 28 being actively set. The *métier* in the west and centre regions are more diverse, while in the east traps are the main gear being used. Gillnets are more prevalent in the west where nine vessels are using it, with six vessels using the gear in the centre region (Figure 2.7).

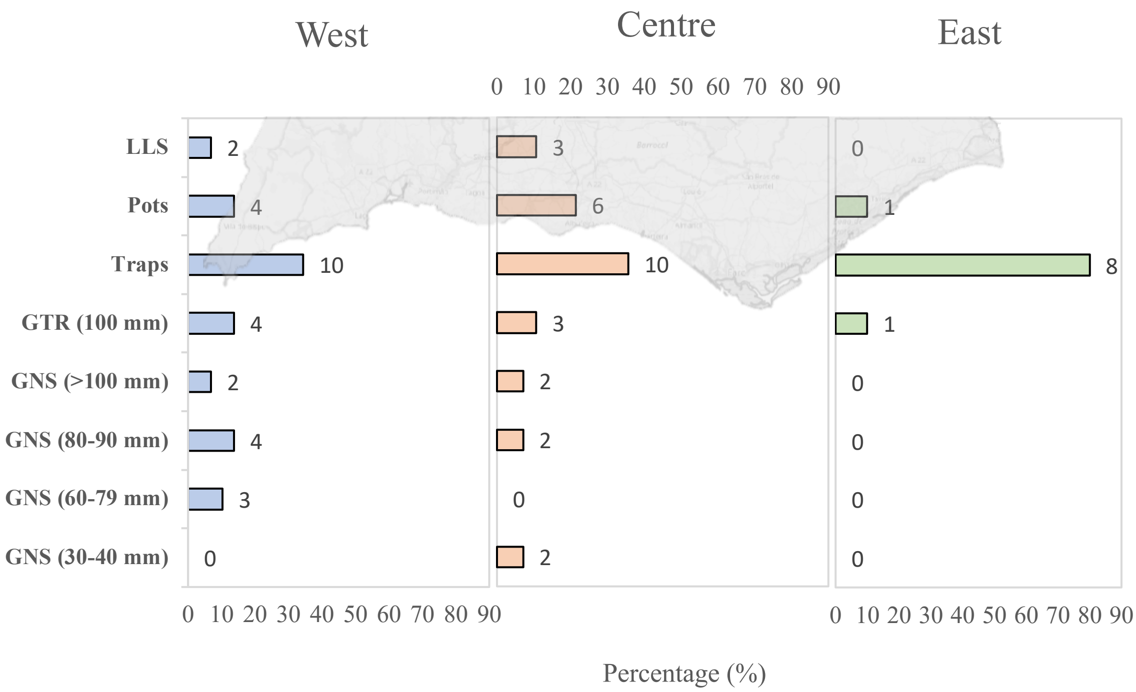


Figure 2.7 *- Percentage of gears being used by different vessels by region.* ***West*** *(n=29) includes the port of Portimão, Lagos and Sagres, the* ***Centre*** *(n=28) corresponds to Olhão and Quarteira ports and the* ***East*** *(n=10) to Santa Luzia port. Absolute values on the right of the bars.*

To describe the target species of each gear, the data were aggregate in table 2.2. Pots (FIX) were exclusively catching octopus (OCC). In addition to OCC, the 28 traps being use (FPO) were targeting *Spondyliosoma cantharus* (BRB), *Diplodus vulgaris* (CTB), *Conger conger* (COE). Two vessels using gillnets (35-40 mm) *Trisopterus luscus* (BIB), *Merluccius merluccius* (HKE), *Microchirus azevia* (MIA) and *Pagellus acarne* (SBA). Besides these species, the three gillnets used (60-79 mm) were also targeting for *Mullus surmuletus* (MUR), *Sarda sarda* (BON), and *Pagellus erythrinus* (PAC). For gillnets with mesh sizes of 80 – 99 mm (n=7), the target species were HKE, SBA, MUR, MIA *Dicentrarchus labrax* (BSS), *Lophius* spp (MNZ), *Raja* spp. (SKA), *Pagrus pagrus* (RPG), *Sparus aurata* (SBG) and *Solea* spp. (SOO). The gillnets (100-200 mm) (n=2) were targeting MNZ, MIA, MUR, RPG, SBA, SBG. Three gillnets with mesh sizes bigger than 200 mm were being use targeting *Lophius budegassa* (ANK), HKE, MNZ, *Raja brachyura* (RJH) and *Zeus faber* (JOD). Vessels working with trammel nets aim to catch *Helicolenus dactylopterus* (BRF), *Sepia officinalis* (CTC), *Argyrosomus regius* (MGR), *Solea solea* (SOL), *Diplodus sargus* (SWA), *Torpedo* spp. (TOE), BSS, MNZ, RPG, SBG, SOO and MIA. Two types of longlines were identified, with two gears with hook sizes between 1-8 and with three with the hook sizes between 9-13. COE, BRF, *Phycis phycis* (FOR) and *Polyprion americanus* (WRF) are targeted with both hook size ranges; CTB, PAC, RPG and SBA are exclusively targeted with 9-13 hooks.

Table 2.2 *- Gear type with mesh size or hook number (size), the targeted species and the number of métier being used by vessels [FAO Code:* ***ANK*** *= Blackbelly angler;* ***BIB****= Pouting;* ***BON*** *= Atlantic bonito;* ***BRB*** *= Black seabream;* ***BRF*** *= Blackbelly rosefish;* ***BSS*** *= European seabass;* ***COE****= Conger eel;* ***CTB*** *= Common Two-banded seabream;* ***CTC*** *= Cuttlefish;* ***FOR*** *= Forkbeard;* ***HKE*** *= Hake;* ***JOD*** *= John dory;* ***MIA*** *= bastard sole;* ***MGR*** *= Meagre;* ***MNZ*** *= Monkfishes nei;* ***MUR*** *= Red mullet;* ***OCC*** *= Octopus;* ***PAC*** *= Common pandora;* ***RJH*** *= Blonde ray;* ***RPG*** *= Red porgy;* ***SBA*** *= Axillary seabream;* ***SBG*** *= Gilthead seabream;* ***SKA*** *= Raja spp;* ***SOL*** *= Commun sole;* ***SOO*** *= Soles nei;* ***SWA*** *= White seabream;* ***TOE*** *= Torpedo rays* ***THS*** *= Bastard Soles;* ***WRF*** *= Wreckfish].*

Gear type	**Targeted species**	**No. of *gear***
FPO	BRB, COE, CTB, OCC	28
FIX	OCC	11
GNS (35-40) mm	BIB, HKE, MIA, SBA	2
GNS (60-79) mm	BIB, BON, HKE, MIA, MUR, PAC, SBA	3
GNS (80-99) mm	BSS, HKE, MIA, MUR, RPG, SBA, SBG, SKA, SOO	7
GNS (100-200) mm	MIA, MNZ, MUR, RPG, SBA, SBG	2
GNS > 200 mm	ANK, HKE, JOD, MNZ, RJH	3
GTR >100 mm	BRF, BSS, CTC, MGR, MIA, MNZ, RPG, SBG, SOL, SOO, SWA, TOE	7
H 1-8	BRF, COE, FOR, WRF	2
H 9-13	BRF, COE, CTB, FOR, PAC, RPG, SBA, WRF	3

To identify and measure the associations among the gear types, target species and sites, a partial canonical correspondence analysis (CCA) was performed. No variable was redundant among themselves since the Variance Inflation Factor for each of them was less than 10. The CCA present a total variance of 3.4 with 1.3 constrained (37% of variance of species is explained by the gear type) and 2.1 unconstrained (62% unexplained). The eigenvalues of X axis and axis Y are 0.65 and 0.30, respectively. According to the ANOVA, the CCA is significant ($p < 0.01$), the CCA terms (environmental variables) are significant ($p < 0.05$) and the CCA axes (CC1 and CC2) are also significant ($p < 0.01$). As mentioned before octopus are very related to traps (FPO). Species from the Scorpaenidae and Gadidae family like blackbelly rosefish and forkbeard, respectively, are linked to longlines (LSS). Sparidae namely (Common pandora, Axillary seabream and Red porgy), Merlucciidae (European hake), Soleidae (Thickback soles nei), and Lophiidae (Blackbellied angler, Monkfishes nei) are target by gillnets (GNS) and Sciaenidae (Meagre), Torpedinidae (Torpedo rays), Moronidae (European seabass), Scombridae (Atlantic bonito), Sepiidae (Common cuttlefish) are related to trammel nets (GTR>100). The gears in the west and centre regions are more diverse, while in the east, FPO is the only gear being used (Figure 2.8).

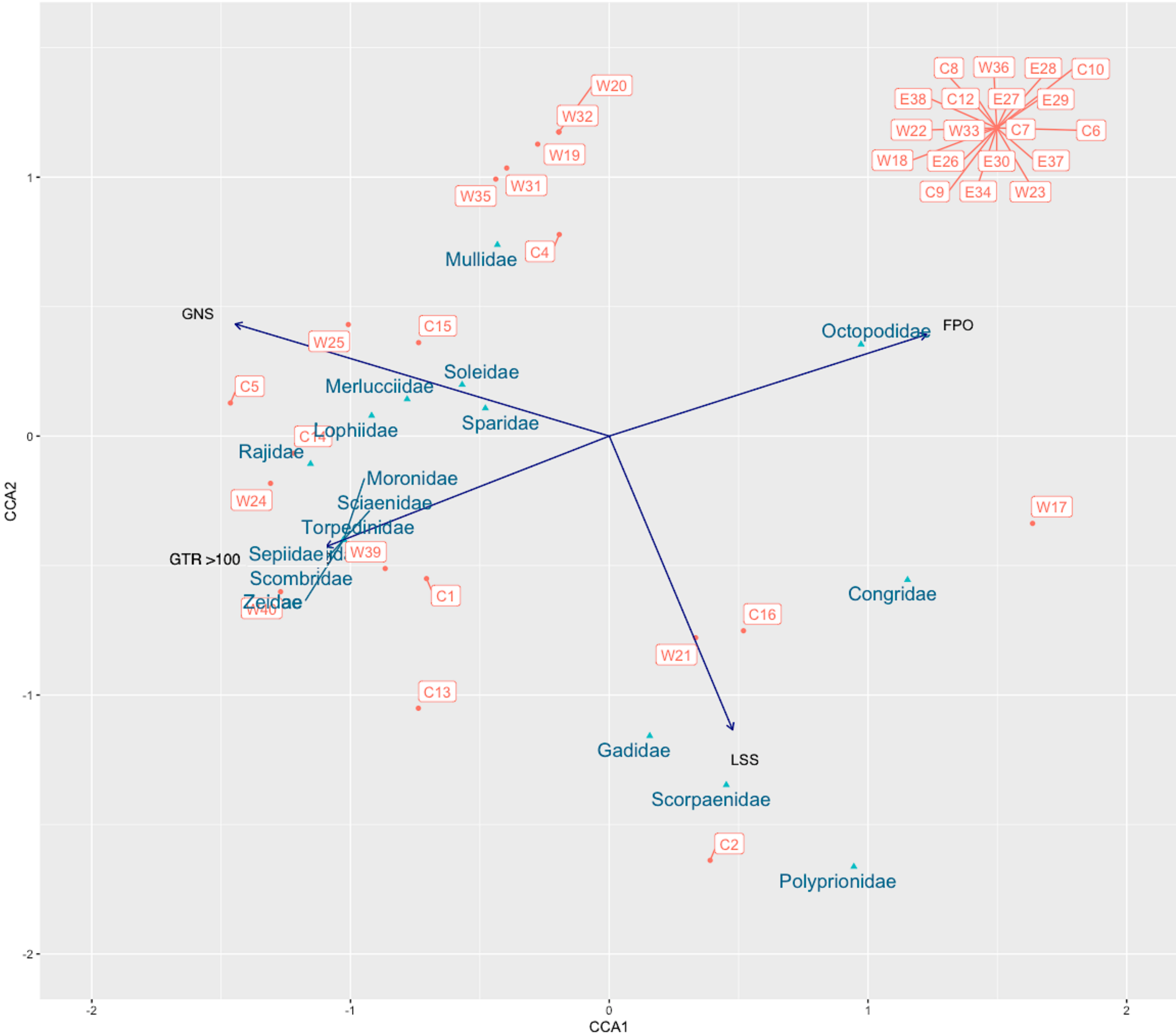


Figure 2.8 *- Triplot of families based on a canonical correspondence analysis (CCA) regarding gillnets (**GNS**), trammel nets (**GTR**), longlines (**LSS**) and traps and pots (**FPO**). The orange labels (●) correspond to the region where each interview was made - West (**W**), Centre (**C**) or East (**E**). The light blue triangles (▲) are the families represented.*

2.3.3. Trip Characteristics

To describe the trip, the vessels were grouped by gears set in a single trip, knowing that some vessels on the same trip used two different gear types (e.g., gillnets with trammel nets). In table 2.3, the different parameters are presented using value intervals according to the activity of various vessels. In general, the crews in this fleet were between two and seven workers. Usually, fishers go out to sea from three to six days a week when using nets. Regardless of how many different gears are set, vessels with pots and traps make two to five trips per week. Longline vessels go out one to five days a week. Vessels operating with only trammel nets and with gillnets and trammel nets on the same trip leave early between one in the morning and six. Those using only gillnets or traps can leave at any time of the day. Pots and longlines leave in the afternoon or late in the evening and hooks at ten in the night. The longest trip duration occurs for longlines, up to 96 hours, then for vessels using traps and longlines (until 48 hours) and then for traps or pots, up to 24 hours. This feature as the setting and hauling times depends on the vessel speed and on length of the net or the number of pots, traps or hooks. The setting speed for vessels operating with nets varies from one to eight knots and with traps and/or pots from 2.5 to eight knots. Longlines have lower setting speed values that vary from 1.5 to five knots. When comparing with the setting speed, the hauling speed has lower values for all gears set and vary from 0.5 to two knots for nets, from one to five for traps and/or pots and from 0 to 1.5 knots for longlines vessels. The lower values are due to the fact that it takes more time to take the fish from the cages and the process for longlines is more laborious and time-consuming. The setting duration for nets varies from 0.5 to 1.5 hours, while for vessels using traps and/or pots goes from 0.3 to three hours and for longlines from one to 12 hours. The longest soak times are for pots varying from a day to a five-day week. For vessels operating with nets the soaking time goes from four hours to almost three days, while longlines stay three to 24 hours underwater. Nets have the lower soaking times because fish damage is more likely for longer times (Savina *et al.*, 2016). Despite being illegal, when nets are left for longer periods, it is usually to use the damage fish as bait to catch species such as crabs and lobsters. This was observed on-board for at least one set netters and longliners also do that to catch bigger fishes. Finally, it is common for the vessels to be losing their gears, except when the gear being used is trammel nets. This might be correlated to the shorter soak times or, more likely, due to the fact of being a less used gear.

Table 2.3 - Enquiries results - selected characteristics of the fishing gear and activity.

Gears set in a single trip	No. of Workers	Trips per week	Time of Departure	Trip duration (h)	Setting Speed (Kts)	Hauling Speed (Kts)	Net(nm) / No. of Traps/Hooks	Setting duration (h)	Soak duration (h)	Mesh size (mm)/Hook no	Gear Loss
GNS	2-5	3-6	02:00-24:00	7-17	4.0-8.0	1.0-2.0	0.3-5.0	0.5-1.5	4-24	40-240	Common
GTR	3-5	4-6	04:00-04:30	8-10	5.0	1.0	2.7-5.4	0.5-1.0	8-24	100-120	Rare
GNS/GTR	3-7	4-5	01:00-06:00	9-15	1.0-7.0	0.5-1.0	0.8-5.4	0.5-1.5	10-24	40-200	Common
Pots	2-4	3-5	14:00-24:00	10-24	2.5-7.0	1.5-3.0	750-2500	0.7-1.5	24-120	NA	Common
Traps	2-5	2-5	01:00-24:00	8-24	3.0-8.0	1.0-5.0	800-2000	0.5-3.0	5-72	NA	Common
Traps/Pots	3-4	3-5	14:00-22:00	9-12	4.0-6.0	2.0-3.0	300-1250	0.3-2.0	24	NA	Common
LLS	3-4	1-5	17:00-22:00	17-96	1.5-5	0.0-1.5	900-5000	1.0-12.0	3-7	1-13	Common
Traps/LLS	4	3	NA	48	1.5-2.5	1.5	900-1000	3.0	24	NA/12	Common
Hooks	3	3	22:00	11	2.0	1.0	3000	1.5	5	12-13	Common
Total	**2-7**	**1-6**	01:00-24:00	7-96	1-8	0.5-5	150-12964	0.3-12.0	3-120.0	40-240/ 1-13	**Common**

2.3.4. Fishing grounds

When analysing the fishing intensity map (on a scale from one to eigth) (Figure 2.9) displaying the overlapping areas indicated by the fishers on the 40 interviews which includes nets and traps vessels and looking for substrate on figure 3.2, it is observed that in front of Lagos, Portimão, Albufeira and Quarteira, at 50 meters depth and from one to eight nautical miles from the coast line, there are higher values of fishing intensity ranging from six to eight where the fishing areas indicated on the interviews overlap. The fishers of these vessels fish on mix sediment, muddy sand or rocky spots. Between Carvoeiro and a Albufeira until the 50 meters depth there is an area of high ecological value, the bay of Armação de Pêra which was recently considered as one of the most productive areas and with higher biodiversity of the Algarve coast. This bay benefits from specific oceanographic conditions and of the larger rock reef of Portugal which creates a rich ecosystem (Henriques *et al*. 2018).

Most of the vessels operate between one to 12 nmi at depths of 50 to 150 meters in all type of substrate with rocks being the less common and muddy sand the most common. This makes sense taking into account the size and engine power of the vessels and the areas where this fleet can legally operate. Only two captains during the interviews mentioned that sometimes they fish 40 nmi from the coast inwards. In addition, in the west coast the fishing intensity is lower probably because captains have to consider the distance of the fishing grounds from the port and that the continental shelf is shorter. Also, it is worth mentioning that even if this work included interviews conducted in the west coast, there are few active vessels from these ports and so the results would not differ much.

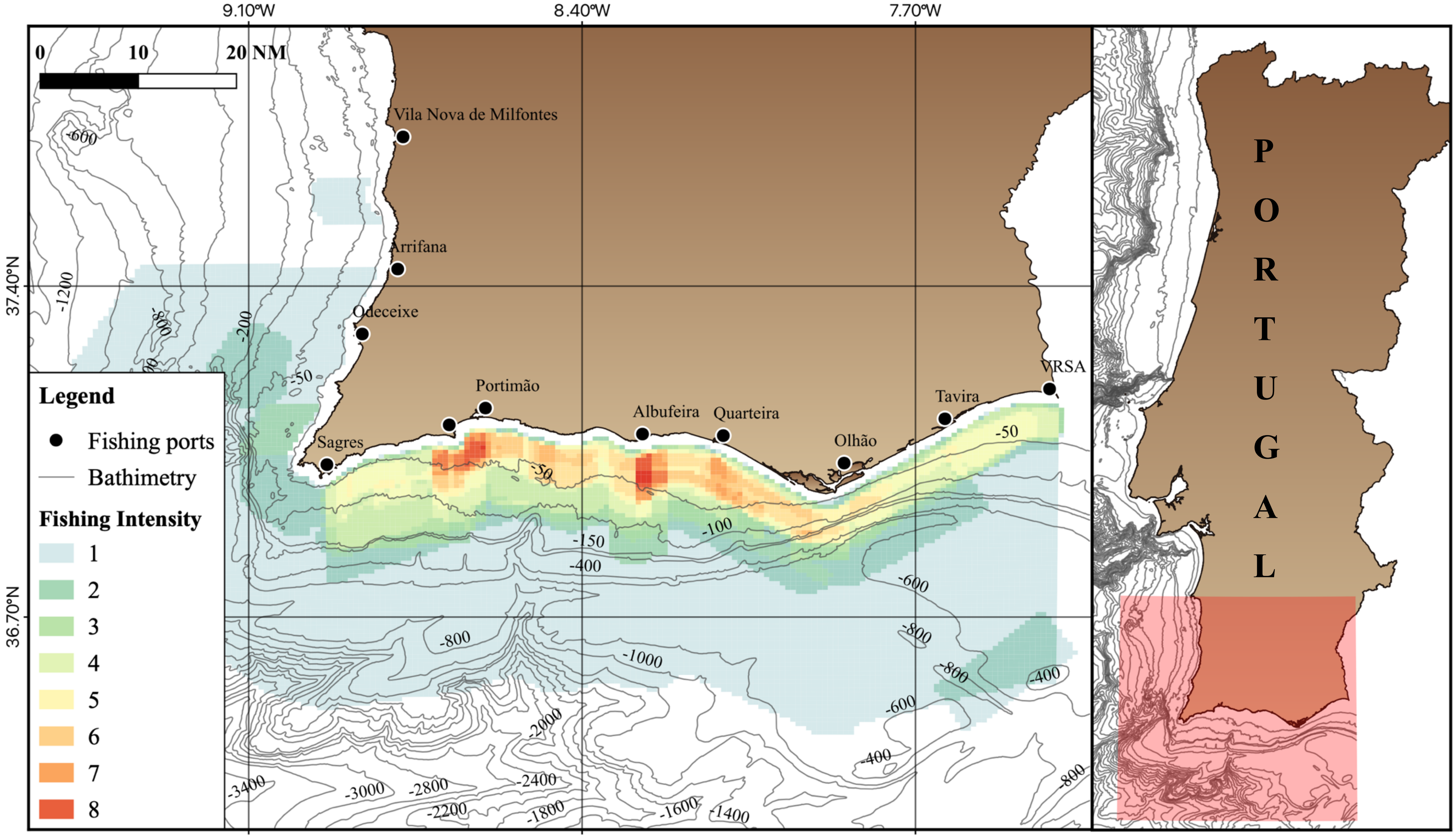


Figure 2.9 - Fishing intensity map displaying the overlapping areas indicated by the fishers on the 40 interviews. The fishing intensity varies from 1 to 8, where 1 is the lowest fishing intensity and 8 the highest. The study area relative to the Portuguese continental territory and the bathymetric lines and are also displayed.

Regarding the fishing intensity map of vessels operating exclusively with nets (Figure 2.10), it is observed that the main fishing grounds are concentrated in front of Lagos, Portimão Albufeira and Quarteira with the fishing intensity ranging from five to seven and the substrate and depths previous mentioned. These vessels are fishing mainly near the coast between the two- and six- nautical miles. These areas are favourable to species like gilthead seabream which is typically found at depths of 0-30 meters in small groups near seagrass or over sandy bottom and near estuaries (Lloris, 2005); European seabass that also prefer coastal waters and depths between 10 to 100 meters (Lloris, 2002); meagre which is found inshore and shelf waters in the entire water column between 15 to 300 meters depth (Schneider, 1990). As discussed before, the target species of vessels operating with nets are mainly from the families Sparidae, Merlucciidae, Soleidae, Rajidae and Lophiidae. Apart from some species of Sparidae that also are captured with traps, this type of fishe requires nets to get caught through different catch mechanisms. Small fish normally get gilled or wedged while larger fish are entangled and snagged (Gabriel *et al*., 2005).

On the other hand, vessels operate with traps along the Algarve coast mainly between Lagos and Armação de Pêra and from Albufeira to Vila Real de Santo António where the fishing intensity ranges from six to ten, being highest value in front of Albufeira (Figure 2.11). On the west side, between Lagos and Albufeira, the values can be explained by the high productivity of this zone discussed on the first paragraph. When comparing the two maps of each gear is possible to infer that there are a lot of traps vessels fishing in the east from Faro (Cabo de Santa Maria lighthouse) to VRSA and between 20- and 50-meters depth. The fishers of vessels operating on the east side prefer fine mud, muddy sand and sandy mud substrates. There are some rocky areas (like Pedra de Cacela) between Fuzeta and VRSA that serve as habitat to octopus and some Sparidae species. Santa Luzia is a well-known place for the octopus tradition and thus, it makes sense that the fishing intensity here is due to fishers were using exclusively pots or traps. This information is going to be confirm by the on-board data and discussed on the next chapter on the topic "Species captured".

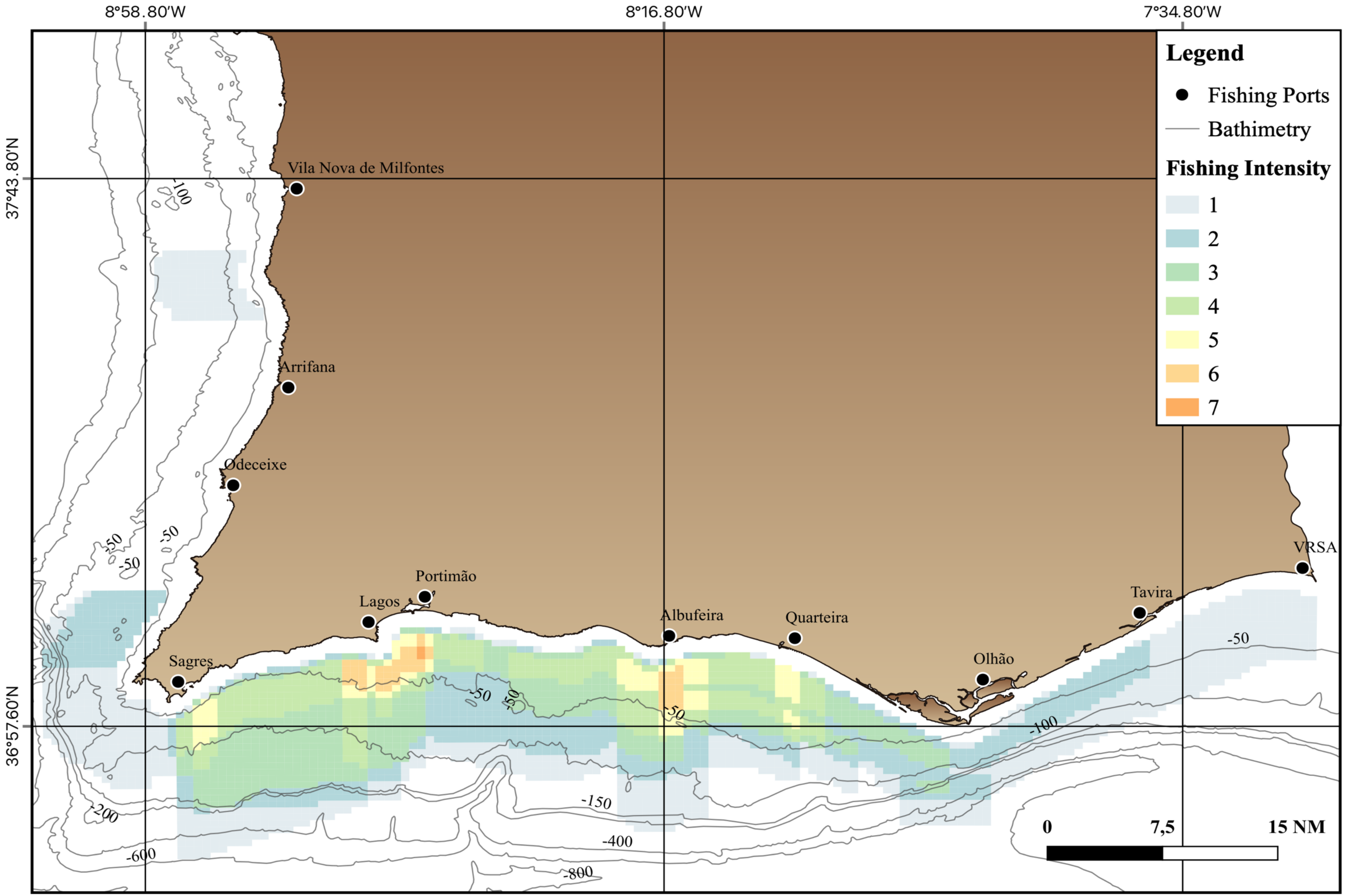


Figure 2.10 - Fishing intensity map displaying the overlapping areas indicated by the fishers of set netters. The fishing intensity varies from 1 to 7, where 1 is the lowest fishing intensity and 7 the highest.

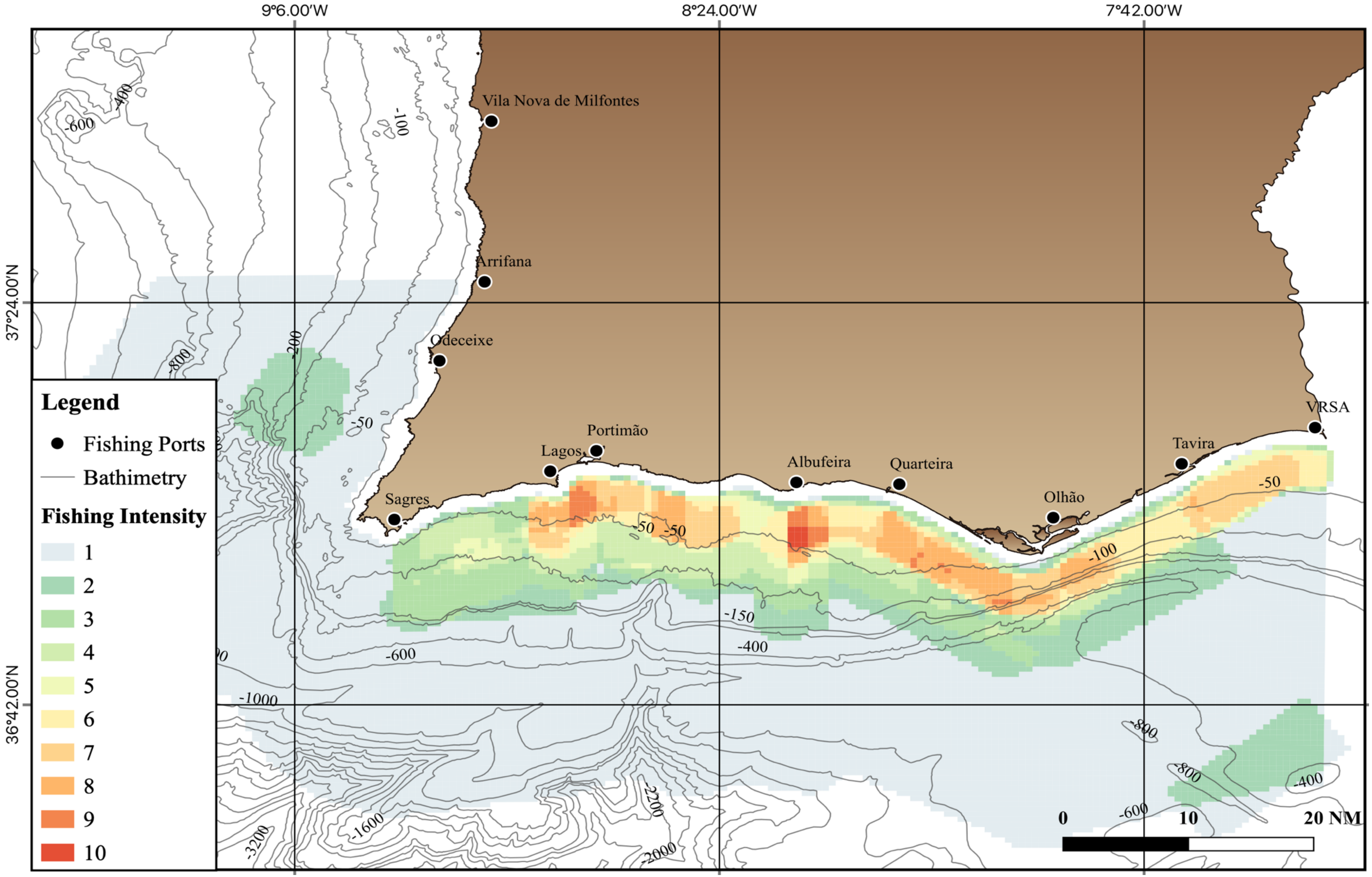


Figure 2.11 - Fishing intensity map displaying the overlapping areas indicated by the fishers of trap vessels. The fishing intensity varies from 1 to 7, where 1 is the lowest fishing intensity and 7 the highest.

3. Characterization of the on-board data – Set-Net fishery case study

3.1. Introduction

In the last decade, Geographic Information System (GIS) have been used and apply to monitoring the fishing activity. In Portugal, there were two projects that uses GPS data to map the fishing activity - PescaMap (Gonçalves *et al.,* 2015) and GeoCrust (Afonso-Dias *et al.*, 2002). From the last one emerges the *GeoCrust* software that use positioning data, vessels velocities given by the MONICAP system and captures of the trawler fleet to quantify and map the fishing effort of this vessels.

In this section, first the on-board notes, the information given by the fishers and the GPS data are analysed, as well as a characterization of the on-board and GPS data to validate the fishing inquiries and to identify the fishing events. Finally, the identification of associations among the gear types and species capture is done and compared with the landings weight at Docapesca.

3.2. Methodology

In order to validate the fishing inquiries, three vessels using nets of the 40 interviewed were selected to collected on board data. For the characterization of the on-board data, it is used the same approach as the previous section by considering the methodologies used by Léopold *et al.* (2014) and Close and Hall (2006) to collect and analyse fisher-based knowledge. For the processing of the GPS data, the procedures followed by Alvard *et al.* (2015) and Behivoke *et al.* (2021).

3.2.1. Data acquisition

- **Surveys and GPS data**

The selection of the three vessels was based on the size of the boat, gear used, trip duration, presence of monitoring devices (VMS and/or AIS devices) and on the captains that were more approachable on the interviews. The on-board survey forms (Annex 3) have three sections: one with basic information with the trip date and number and, vessel name; the second section includes information about the times of departure and arrival, setting, hauling, soaking and resting; the navigation, search, setting and hauling speed; gear being used, number of gears set, target species and bait; the third section had the catch information to count the species being caught. In case the vessel speed wasn't visible or the species caught was hard to identify this information was asked to the captains, otherwise they were noted by the onboard observers.

Apart from this, GPS data were collected by an on-board observer using a handheld GPS (GPSMAP® 78 series) with which coordinates were marked for the different fishing events (searching, setting and hauling) and recorded the track, position, direction and speed of the vessel at 5 s intervals.

- **Species captured**

The species captured were identified on-board with a help of an identification guide and of the fishers. They were annotated on a sheet that had information about the trip (e.g. vessel name, day, gear type, number of gears used). After each trip, the landing fish sorted by boxes per species and sizes is weighed. These values were obtained from the weighing made on Docapesca - Portos e lotas, SA from each region.

3.2.2. Detecting fishing activity

This topic focuses on fishing vessels using passive gear (gillnets and trammel nets) targeting species such as hake, monkfishes, spiny lobsters and edible crab, meagre and red porgy. On a typical fishing day, after leaving port, fishers navigate at relatively high speeds to fishing grounds, where the nets that have been set usually between 2 to 72 hours before are marked with surface marker buoys. When the skipper approaches a marker buoy, the speed of the vessel decreases to approximately 1 knot until close enough to hook the buoy and begin the process of hauling. The combination of the hauler (usually a rotating drum) used to retrieve each net at low speed, and the effects of wind and current (tide) acting upon the vessel determine the movement of the vessel. The relative influence of these factors will vary depending upon the type, size and configuration of the vessel. However, the vessel is normally positioned down wind or current to ensure that the net remains clear of the vessel during hauling. Afterwards, the skipper either travels to a new fishing ground or stays roughly in the same location and repeat this process. This cycle is repeated until the fishing trip is completed and the boat returns to port. Therefore, this methodology assumes that the fishing behaviour is highly dependent on the boat speed. By detecting variations on the frequency of speed and in the heading of the vessel, it is possible to identify which part of the route can be considered as fishing and non-fishing activity. This information might be relevant to artificial intelligence techniques to instruct the algorithms that classify the AIS data at which velocities occur the different fishing phases (Mazzarella *et al.* 2014; Natale *et al*. 2015).

3.2.3. Statistical Analysis

To identify and measure the associations among the gear types and families capture a canonical correspondence analysis was performed (CCA). It was established a significance value of 0.001. This analysis is done on the topic 3.3.4. Species captured.

3.3. Results and discussion

3.3.1. GPS data

Typical gear-specific trajectory patterns were reported in previous surveys using geolocation devices in small-scale and large-scale fisheries (Alvard *et al.*, 2015; de Souza *et al.*, 2016; Behivoke *et al.*, 2021). According to Behivoke *et al.* (2021), the shape of the vessel tracks varied according to fishing activity. Specifically, GPS track patterns corresponding to fishing hauls were characterized by thin loops or irregular segments that correspond to the drop of the net endpoints and are associated with dense groupings. In contrast, when the vessel is travelling from and to landing sites and fishing spots the track is straight and regular and occasionally it is possible to detect short incidental non-fishing events caused by sea conditions (e.g., tidal currents) and unpredictable, both environmental and human factors. The hauling phase is well represented in the track segment from one of the trips made. (Figure 3.1).

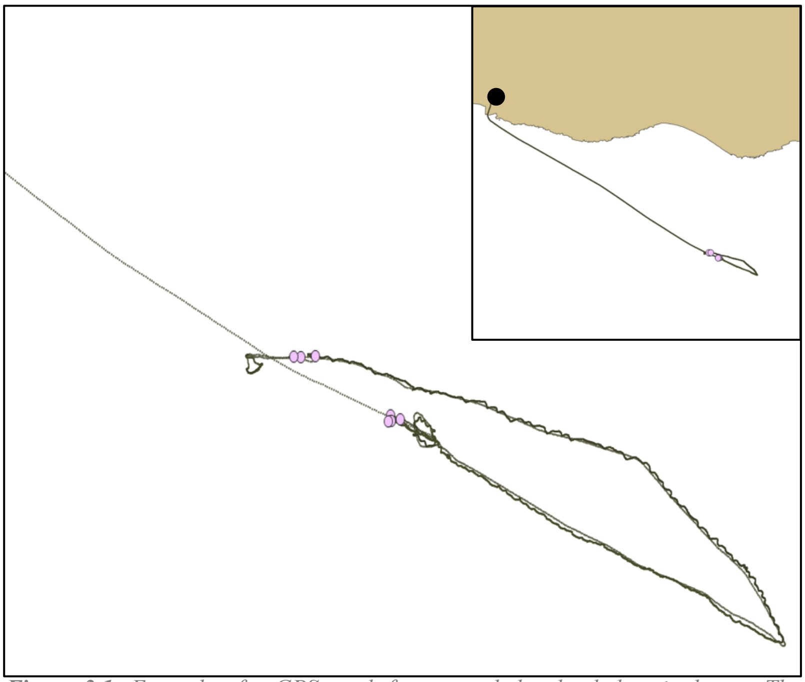


Figure 3.1- *Example of a GPS track from vessel that hauled a single net. The hauling moment was amplified to a better perception of the hauling phase. The pink dots were marked near the start and the end of the hauling. The black one is the fishing port and the brownish area is the land.*

- **GPS data and fishing grounds**

When analysing the map with the GPS tracks (Figure 3.2) it is possible to conclude that nets, due to the ocean currents, are usually set parallel to the coast to keep them from getting tangled and, usually between three and 12 nmi offshore. By comparing the substrate represented on the map, the target species mentioned on-board and the species captured (Figure 3.6) it is possible to infer that the fishing areas were chosen taking into account these variables. The type of substrate and the fishing areas corresponds to what the fishers had previous informed and to what was observed on board (e.g., rocks and shells stucked on the nets, corals and sponges entangled, and the dirty deck with mud).

In Sagres, the fishing event occurred mainly in areas of muddy sand with some rocky spots. Trammel nets (>100 mm) targeted species like monkfish (MON) and blackbelly angler fish (ANK) lobster (SLO) and edible crab (CRE). Each of these sets were single nets placed from six to nine nautical miles offshore from port, in depths that vary from 100- to 400-meters. Where the main substrate is muddy sand, the species fished were MON and ANK, while when fishing on rock substrate and deeper SLO and CRE. This makes sense taking in consideration the habitat preferences of these species. Gillnets were targeting hake (HKE) but caught mainly nursehound (SYT). These gears are the longest nets of this vessel and were set between 100-meters of depth on muddy substrate.

In front of Portimão, the substrate is mainly muddy sand and mixed sediment with some rocky areas. The fishing occurred closer to the shore (about six nautical miles) and at 50 meters depth. It was used long single set of trammel nets targeting meagre (WRF) and red porgy (RPG) and, GNS (60-79 mm) targeting Sparidae, pouting (BIB) and forkbeard fishes (FOR). While the first gear also caught SLO and CRE, the second one also fished auxiliary seabream (SBA) and red mullets (MUR).

In Olhão, the fishers used different sets of GNS (>100) targeting ANK and GNS (80-90 mm) targeting HKE, which was in fact what they captured. They were fishing close to the coast, up to the six nautical miles, on fine mud and muddy sand substrate and at depths between 150 - and 200-meters.

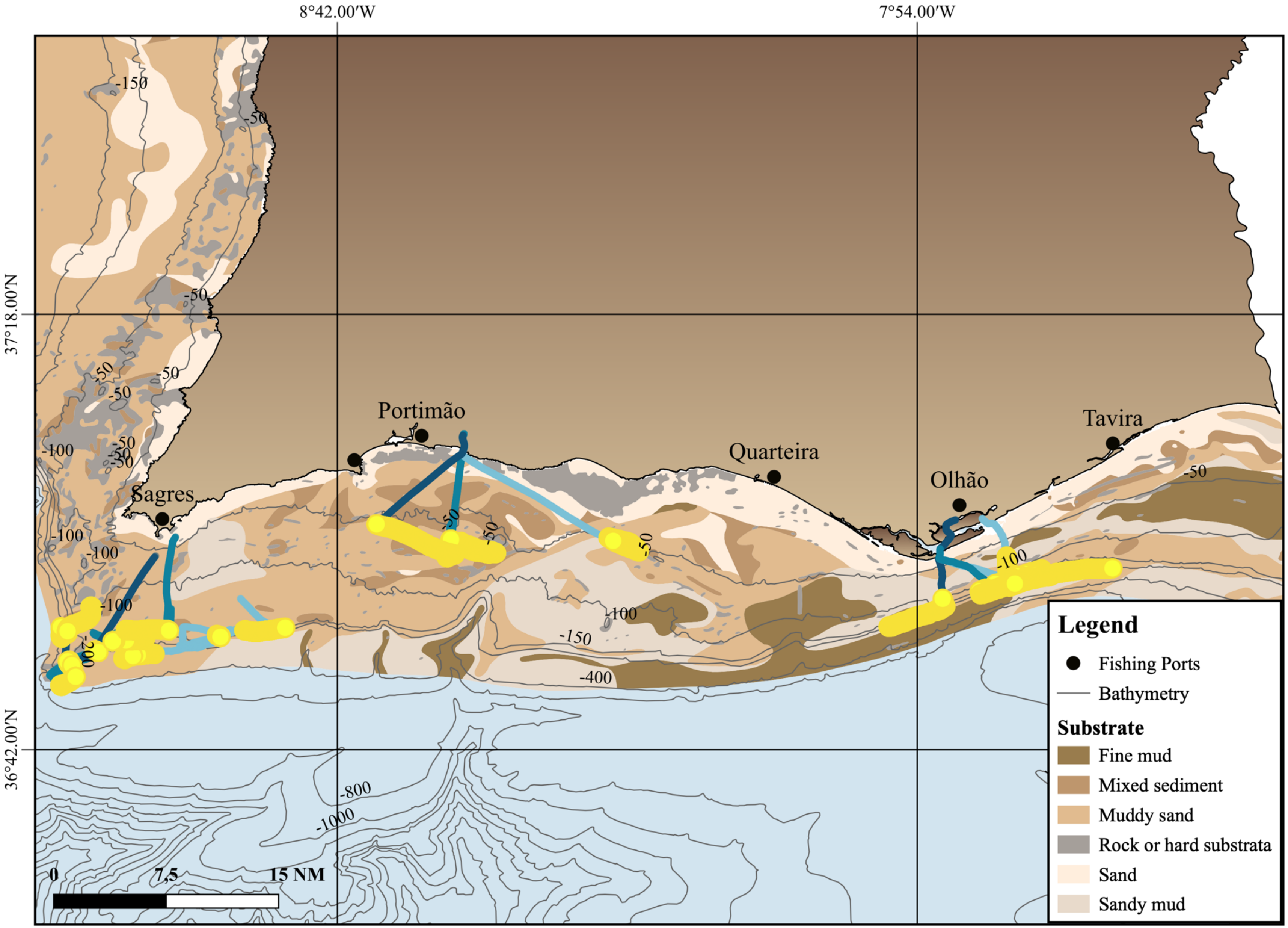


Figure 3.2 - GPS tracks of all trips made (n=9). Set netters tracks are blue and each variation of this colour correspond to a different trip. The fishing events are marked in yellow (locations where the fishers were hauling or setting the nets). The main ports are represented by the black dots (●) and, the bathymetry and the bottom substrate are also displayed. The different colours of the substrate represent the different types of it.

3.3.2. Trip characteristics

Similar to what was done on the interviews section the vessels were grouped by the gears set. In table 3.1 and 3.2, the different parameters are presented using value intervals according to the various vessels. Of the three vessels, three GNS with mesh size bigger than 100 mm and lengths that varies from 2.70 to 3.80 nmi were used. Vessels operating with it did trips of 10 hours, the setting duration were between 20 and 50 minutes, the soaking between 48 and 72 hours and the hauling between three to 05:40 hours. The lower values of setting are due to the fact the vessel operating with these nets had a sorting mechanical system that organize the nets after being haul and help on the setting. Three sets combining gillnets and trammel nets with the longer sets, ranging from 4.30 and 5.40 nmi, were used. These vessels had trip durations of 12 hours, setting duration ranging between two and four hours, soaking between one hour and half and eight and half hours and a hauling of six hours. The high values of setting and hauling are due to the use of longer nets. The gear of this vessel was set in the mornings and after one and half to eight hours of soaking took it from the water. Five GNS with a mesh size class of 80-90 mm and a length of three nautical miles were set. The trip of these boats took 10 to 16 hours, the setting took between half an hour and four and a half, the soaking range between four and 17 hours and the hauling from 02:20 and 02:40. Finally, trammel nets with mesh sizes bigger than 100 mm and a length of three nautical miles were the most used gear (seven times), and the vessels using it had trips of 13 to 16 hours, setting of one hour, soaking duration between 16 hours and 72 hours and hauling from one to two hours. The corresponding velocities of all these fishing phases are presented in table 4.2.

In general, the velocities and times depend on several factors. The setting time depend on the mechanical system and of the velocity itself. The hauling duration is related with the number of workers, net length, species caught (crabs and lobster are more difficult to take from the net) and if the net got stuck on rock or other fishing gears, as well as size and potency of the vessel. The soaking time depend on the species target (e.g., nets can be left for the weekend to fish get caught and become deprecated/predated by crabs and lobsters), bycatch species, landing dock working hours, number of gears on water and distance to the port. All the mentioned factors also influence the trip duration.

Table 3.1 - On-board data (gear type, number of times used and fishing activity phases duration) taken from the six trips done with three different tters.

Gear Type	Total no. gear	Trip Duration (h)	Setting Duration (h)	Soaking Duration (h)	Hauling Duration (h)
GNS (>100 mm)	3	10:00	00:20 - 00:50	48:00 - 72:00	03:00 - 05:40
GNS (60-79 mm)/ GTR	3	12:00	02:00 - 04:00	01:30 - 08:30	06:00
GNS (80-90 mm)	5	10:00 - 16:00	00:30 - 04:30	04:00 - 17:00	02:20 - 02:40
GTR (>100 mm)	7	13:00 - 16:00	01:00	16:00 - 72:00	01:00 - 02:00
Total	18	10:00 - 16:00	00:20 - 04:30	01:30 - 72:00	01:00 - 06:00

Table 3.2 - On-board data (gear type, net length and fishing activity phases velocity) taken from the six trips done with three different set netters.

Gear Type	Net Length (NM)	Navigation Speed (kn)	Setting Speed (kn)	Searching Speed (kn)	Hauling Speed (kn)
GNS (>100 mm)	2.7-3.8	8.0	5.0	-	1.0 - 2.0
GNS (60-79 mm)/ GTR	4.3-5.4	7.0 - 8.0	4.0 - 5.0	6.0	2.0
GNS (80-90 mm)	3.0	8.0 - 10.0	5.0 - 9.0	2.0 - 8.0	2.0
GTR (>100 mm)	3.0	9.0 - 10.0	7.0 - 9.0	2.0 - 8.0	2.0
Total	1.1 - 3.0	7.0 - 10.0	4.0 - 9.0	2.0 - 8.0	1.0 - 2.3

3.3.3. Fishing events

The exploratory analysis of the GPS data allowed the characterization of typical activity during a fishing day. This information combined with the data obtained from the interviews permitted the identification of the different fishing phases. According to this information, set-net vessels navigate with speeds between seven and ten knots and search for the nets with a speed between two and eight knots. When setting, the speed varies from one to eight knots and when hauling from zero to two knots. The setting takes between 0.5 to 1.5 hours, the hauling between 1 to 6 hours and the soaking between 1.5 to 72 hours. Thus, it is possible to infer that the boat speed varies according to fishing factors (as mentioned before) as well as non-fishing factors like tidal current, wind strength and direction (Behivoke *et al.* 2021) .

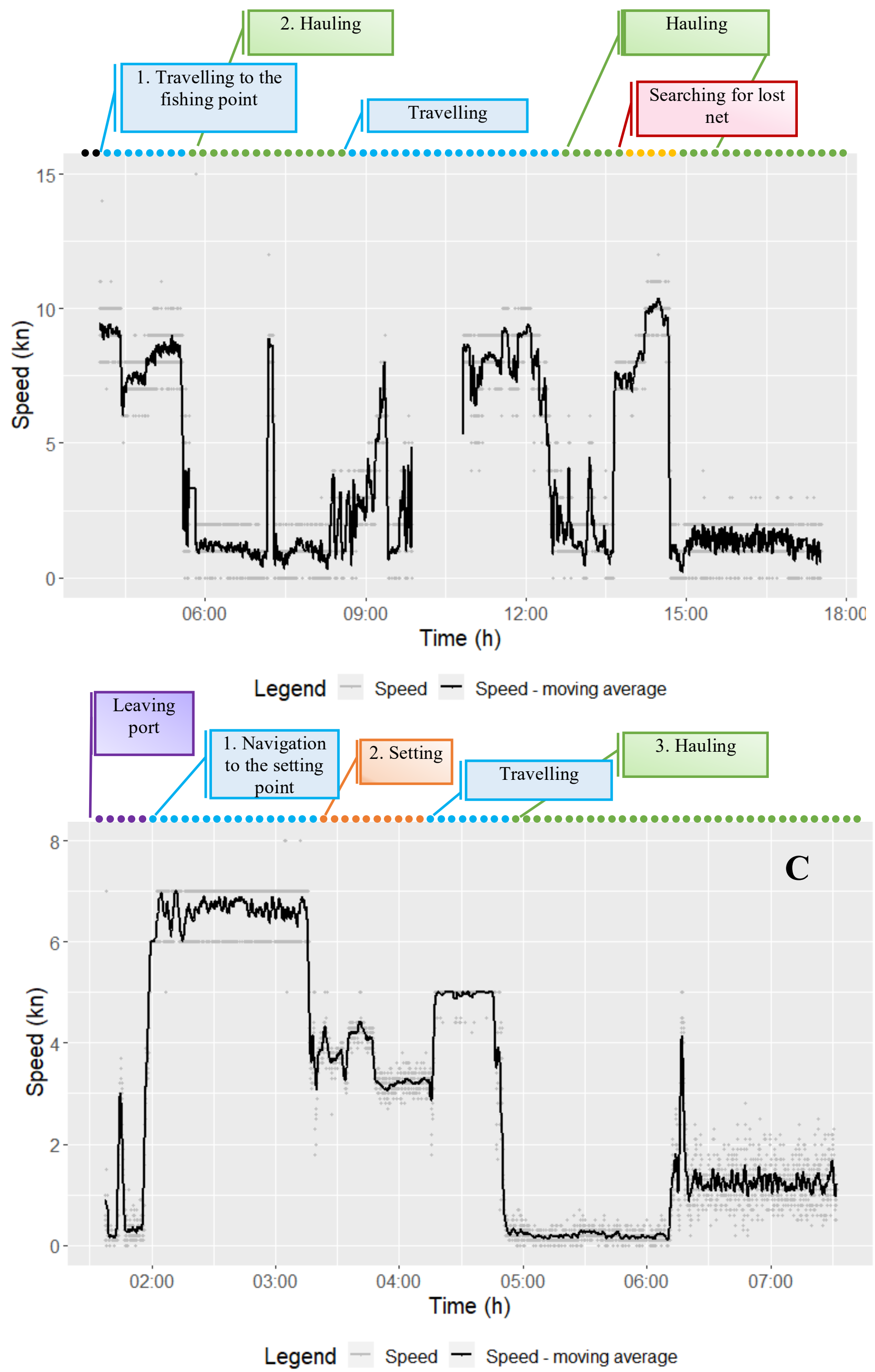
Having this in account and looking to the fishing profiles of the three vessels selected to go on-board, it is note-worthy that vessels operating with the same type of gear can have different behaviours. The first vessel (Figure 3.3A), on the first trip, hauled two trammel nets and one gillnet with a mesh size of 80 mm. It is possible to observe that from 04:00 to 05:38, the vessel was travelling to the fishing point with an average speed of 8.1 knots (*SD* = 1.1). At 05:39, it starts to collect the nets from a previous trip by travelling slowly toward west at an average speed of 1.1 knots (*SD* = 0.5). Around 07:18, at the average speed of 1.8 knots (*SD* = 2.4) , the fishers start to take the second net from the ocean. At 08:45 the vessel starts to move faster to the next fishing ground, and it goes from average of 3.2 knots (*SD* = 2.1) to 8.2 knots (*SD* = 0.9). Then the speed decrease until 12:48, when the third haul start at a mean speed of 3.5 knots (*SD* = 2.9) eventually stabilizing at mean velocity of 1.4 knots (*SD* = 0.6). Around 17:00 the vessel finishes hauling. During this haul, the nets got lost and the vessel increased the speed between 13:30 and 14:30 when looking for them. In addition to this, there is a significant portion of time where there is a large variance in speed (between 9:15 and 11:00) that cannot be identified as a single phase, during which the vessel scoured the area for one end of the setting line. It is important to note that, due to technical issues, these results aren't very clear. The plot described presents three discontinuities due to the loss of the GPS signal. The first one is between 05:42 and 05:49, the second the time jumps close to an hour from 09:52 to 10:49 and the third between 17:11 to 17:14, without any significant speed change. It is also relevant to note that, unlike the next two vessels, a large portion of time was spent searching for the setting lines endpoints, which not only makes the interpretation of the data more complicated, but also presents a challenge for identifying travelling and hauling/setting events.

The second vessel (Figure 3.3B) displays a different scenario, where the instantaneous speed at each fishing period doesn't vary as much as the previous vessel. This vessel as the following one only hauled a single gillnet with a mesh size of 220 mm. This trip started around 02:30 with a relatively constant speed of 7.9 knots (*SD* = 0.6) while travelling to the fishing points. At 03:30 they arrived at the fishing site and the vessel began searching for the buoy at an average velocity of 1.8 knots (*SD* = 1.5). After retrieved it, the fishers started to slowly collect the main line while hauling the nets at a velocity of 1.5 knots (*SD* = 1.5). At 07:45 the vessel travels back to the port with an average speed of 6.7 knots (*SD* = 2.2).

Finally, the plot of the third vessel (Figure 3.3C) also hauled a long single net but this one was composed of gillnets (60mm) and trammel nets (220mm). From the speed plot we can distinguish four levels of speeds: very low speed (less then 1 knot) in the periods between 01:30 and 02:00 (vessel leaving the port area) and between 04:45 and 06:15, when the vessel was hauling the net at average speed of 0.2 (*SD* = 0.1); low speed (*Mean* =1.2, *SD* = 0.4) in the period between 06:20 and 07:30 (vessel continues to hauling), and high speeds (*Mean* = 6.6, *SD* = 0.5), in the rest of the journey, corresponding to the navigation periods when the vessel is travelling to the fishing locations. From 03:19 and 04:15, it's the only high-speed period that corresponds to the setting of the net and the average speed goes from an average of 3.6 knots (*SD* = 1.7) to 4.5 knots (*SD* = 1.4).

From the analysis of the three plots, it is possible to identify two main fishing phases that are common to all the vessels: travelling to the fishing zone at which the vessels navigate at an average speed of 7.5 knots (*SD* = 1.1) and hauling at a mean velocity of 1.2 knots (*SD* = 0.9). On the plot B it was also identified the searching phase at an average speed of 1.8 knots (*SD* = 1.5) and on the graph C the setting phase at mean speed of 4.1 knots (*SD* = 1.6). This information is mainly relevant to artificial intelligence techniques to instruct the algorithms that classify the AIS data at which velocities occur the different fishing phases (Mazzarella *et al.* 2014; Natale *et al.* 2015).

However, it is possible to appraise that the identification of the fishing events isn't a trivial task. This depends on multiple factors since different fishing events can occur at the same speed, on a single trip can occur unexpected occurrences (like being stop by the maritime authority, losing the GPS signal, nets stuck on rocks or other fishing gear or vessel incidents) and depending on the *métier* and the *modus opperandi* of the fishers the plot of the events of vessels using nets can have different traits. There is a need to combine the data from these graphs with other information like on-board notes, interviews and GPS direction and position to obtain a more reliable result.



A

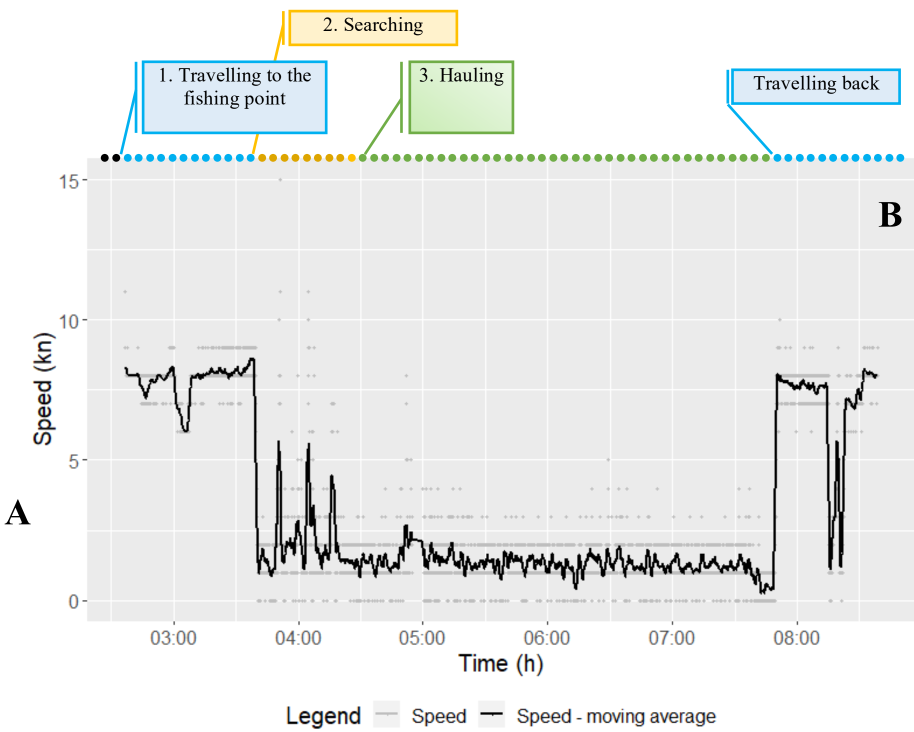


Figure 3.3 *- Instantaneous speed (kn) and average speed (kn) of three different set netterss. The grey dots indicate the instantaneous speed in knots, while the black lines indicate the average speed (kn). The moving averages were calculated using 20 contiguous elements. The main fishing phases are identified by the following colour scheme: blue represents the navigation phase, yellow the searching of the nets, orange the setting and green the hauling phase. The red box shows an interruption in the hauling phase to search for the fishing net and the purple box indicates the moment the vessel left the port.* ***Plot A*** *- the fishers hauled two trammel nets and one gillnet (80 mm) and two fishing phases were identified on the plot: travelling to the fishing point (1) and the fishing event or hauling (2). From 09:52 to 10:49 the data was not recorded by the GPS.* ***Plot B*** *- one single gillnet (220 mm) was hauled and. three fishing phases were represented on the plot: travelling to the fishing point (1), searching for the nets (2) and hauling (3).* ***Plot C*** *- one long set pulled composed of gillnets (60 mm) and trammel nets (220 mm) were used and three different fishing phases were identified: travelling to the fishing point (1), setting the nets (2) and hauling (3).*

3.3.4. Species captured

To identify and measure the associations among the gear types and species captured a partial canonical correspondence analysis (CCA) was performed (Figure 3.4) and a histogram (Figure 5.5) was constructed. No variable was redundant among themselves since the Variance Inflation Factor for each of them was less than 10. The CCA present a total variance of 3.6 with 3.0 constrained (85% of variance of species is explained by the gear type) and 0.54 unconstrained (15% unexplained). The eigenvalues of X axis and axis Y are 0.28 and 0.16, respectively. According to the ANOVA, the CCA is significant ($p < 0.001$), the CCA terms (environmental variables) are significant ($p < 0.01$) and the CCA axes (CC1 and CC2) are also significant ($p < 0.001$).

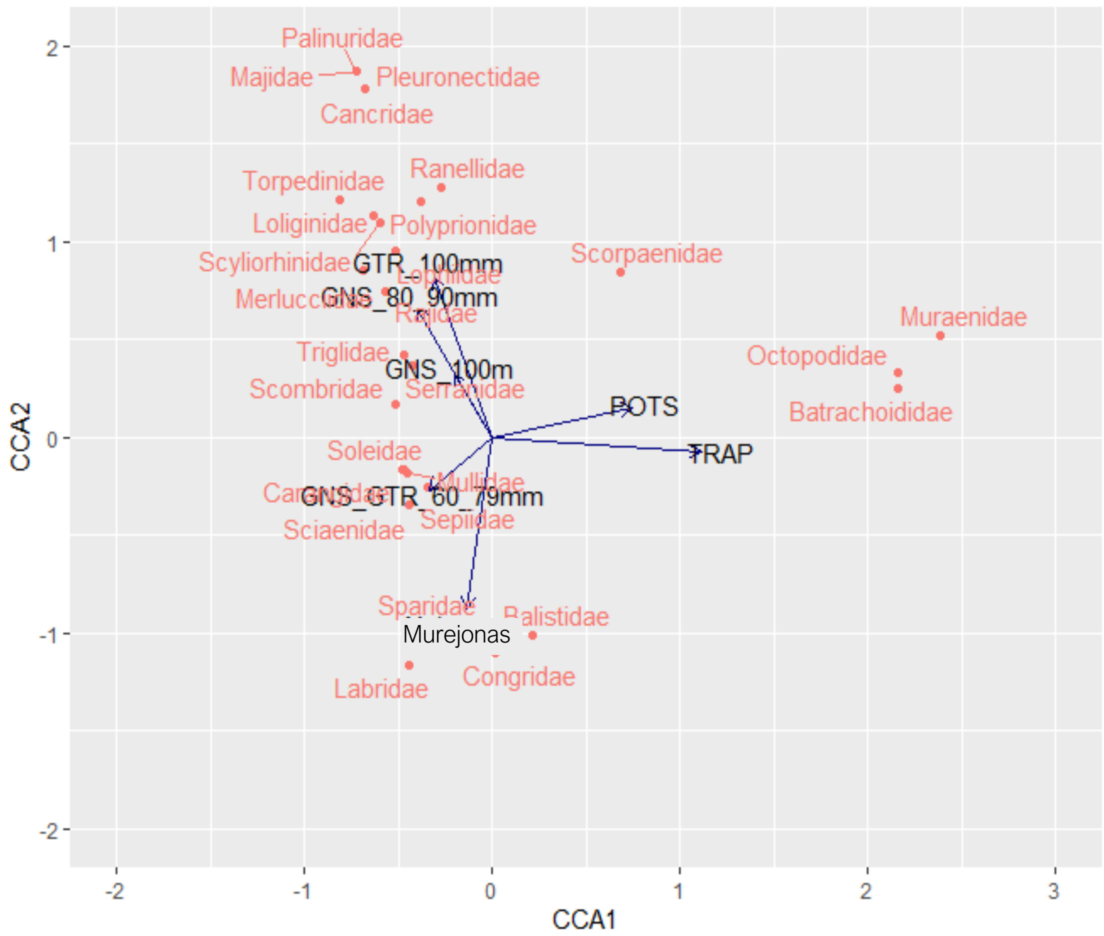


Figure 3.4 - Triplot of families captured based on a canonical correspondence analysis (CCA) regarding gillnets (GNS) of different mesh sizes classes (60-79, 80-90 and more than 100 mm), trammel nets (GTR 100 mm), a combination of GNS and GTR and traps, pots and murejonas. The orange dots correspond to the families represented.

As illustrate by figure 3.5 and the CCA plot octopus are very related to traps and pots. Traps also linked to Sparidae, Batrachoididae and Scorpaenidae. In general, gillnets are more diverse in terms of species caught. GNS with mesh sizes of 80-90 mm are related to Scyliorhinidae, i.e., nursehound sharks (SYT), Scombirdae and Merluciidae (hake - HKE) families. The main family linked to gillnets (>100 mm) is Lophiidae, particulary blackbelly angler fish (ANK). Pleuronectidae (sole species), Lophiidae (monkfish - MON and ANK) and Ranellidae (Knobbed triton - KRJ) families are related to trammel nets with mesh sizes superior to 100 mm. Finally, the sets combining gillnets (60-79 mm) and trammel nets caught a variety of species belonging to the Sparidae (e.g., Axillary seabream-SBA and red porgy-RPG), Gadidae (Pouting-BIB and forkbeard fishes-FOR), Scombridae, Mullidae (Red mullets - MUR) and Carangidae (Lobsters-SLO and edible crab-CRE) families. When comparing nets, trammel ones are more selective then gillnets due to the technical aspects of the gears, soaking times and setting areas.

It is possible to observe that these results are similar and correspond to the species landings weighted (Figure 3.6). The deviations correspond to species that weren't landed and weight on Docapesca and probably the fishers brought them home or sold in parallel markets. In addition, some fish were not distinguished from other on the weight receipts and thus, were registered as the same species. This happened for common pandora and blackspot seabream that were list as axiliary seabream.

Octopus (OCC) were the main species landed with a total weigh of 885 kg, being that traps were the gear that caught higher quantities. Apart from the 28 kg of OCC, murejonas also caught 67 kg of conger (COE) and the remaining species were from the Sparidae family (around 18 kg including main species). The 324 kg of nursehound sharks (SYT) were caught with gillnets (80-90 mm). However, according to the on-board notes the targets species of this vessel when using gillnets were hake (HKE) and wreckfish (WRF). When this vessel was operating with trammel nets the target species were monksfish (MON), blackbellied anglerfish (ANK), edible crab (CRE) and lobster (SLO), which were caught with the weights of 292 kg, 112 kg, 8 kg and 6 kg, respectively. Gillnets of 60-79 mm caught (and targeted) a variety of Sparidae species - 82 kg of axiliary seabream (SBA), 21 kg of common pandora (PAC), 20,7 kg of common two-banded seabream (CTB) - of Gadidae species, namely 119 kg of pouting (BIB) and 40 kg of forkbeard fish (FOR) - and of Mullidae family 53 kg of red mullets (MUR).

Regarding the species landed, it also worth to mentioned that this information does not represent the whole picture of captures since there are a lot of discard species that weren’t in good conditions (were predated by other fishes or parasites) or were undersized, by-cacth like corals, echinoderms and sponges and ghost-fishing. Thus, the fishing ground identify are also habitat of discarded species that weren’t weighted.

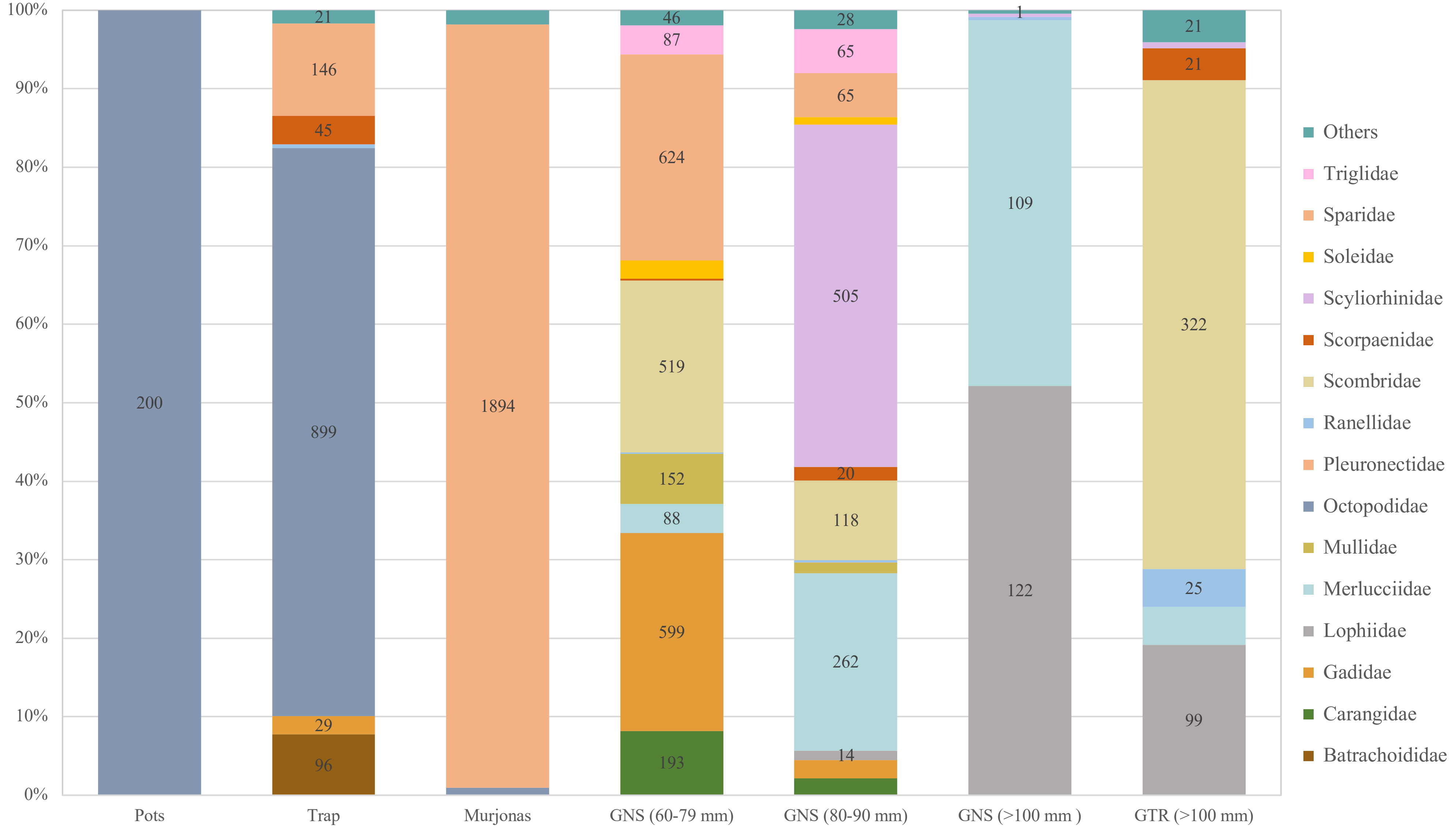


***Figure 3.5** - Families distribution per gear type set by three different set netters. The absolute values of the main representative families are displayed over the bars. The families with less than 13 individuals caught were grouped in the 'Others' category.*

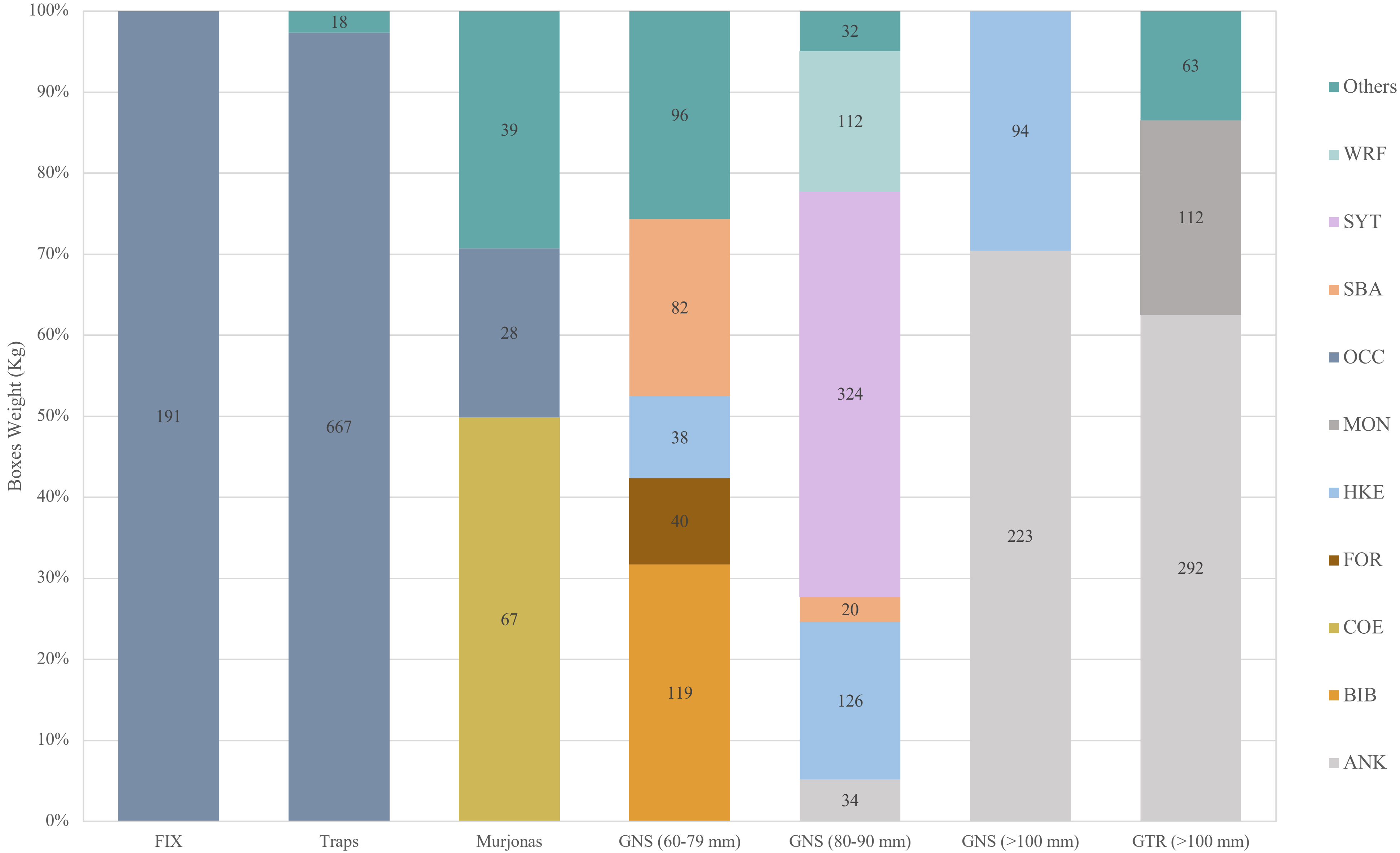


Figure 3.6 *- Weight (kg) per box of species land. Values obtained from Docapesca, SA weighing.*

4. General Discussion

- **Enquiry data validation with onboard observations**

Regarding fishing operations and their impacts, something that should be of concern is the fact that the majority of the vessels stated that it is common to lose fishing gear regardless of the type, including vessels which stated they discard fishing gear in the ocean. Beyond the obvious environmental impacts of pollution, the loss of fishing gear can result in ghost fishing, i.e., the capture of individuals by lost and unused fishing gear, resulting in the decrease of fisheries without consumption. Therefore, the loss of gear impacts both the target species, as it leads to an increase in competition, and non-commercial species, through by-catch (Erzini *et al.* 1997, Santos *et al.*, 2003, Erzini *et al.*, 2008). In this way the continuous loss of gear can lead to large environmental impacts.

Combining their fishing operations with marking areas on their computers/GPS, the fishers are revisiting areas that they consider "good fishing" spots, meaning that they are doing intensive fishing in several specific areas.

Relatively to Illegal, Unreported and Unregulated (IUU) fishing, some fisherman reported (and was observed on-board) passing excessive catch to other vessels not going to sea, effectively circumventing their assigned fishing quota. This adds another mechanism to the already large potential for underreporting catch.

Any unknown information regarding a fleet decreases the chance of proper and effective management. It is thus important to be able to describe the different fleets within a country, especially ones such as Portugal where the fishing industry has high socio-economic importance and drives tourism sector. Therefore, a next step to further validate the *métiers* as well as the fishing operations is the analysis and conjugation onboard observations and GPS data with the inquiries data and consequently, a case study for vessels operating with nets was presented.

The fishing grounds identified in the interviews represent the area covered by all the vessels for all their trips, and is, therefore, not expected to significantly correlate with location data collected on the trips. Nevertheless, it is possible to verify that the vessels stayed within the previously identified areas throughout the majority of their course, without significant deviations. The only noteworthy deviation occurred for one of the trips of Sagres, where the vessel coursed through an area not identified as fishing grounds in the interviews. The most likely reason for this deviation is an inaccuracy in the identification of fishing grounds by the fishers.

According to the interviewed vessels, the boats operating with nets tend to haul them after a few hours of being set (maximum soak time is 24 hours) and they tend to leave port early in the morning to haul at dawn. Both gillnets and trammel nets are often hauled within a day and the duration of the trip is no longer than 16 hours. When comparing this information, with the one obtained from the onboard and GPS data, just the trip duration and the departure hours are in accordance with the later. Soaking duration can last until three days and just one of the vessels operate as was mentioned above, having a soak time between one hour and a half and 08:30 hours. From all the 18-gear set, the mean underwater time is 10:30 hours. Another mechanism mentioned on the previous section occurs when nets are left for a long soaking time (usually over a weekend) for the by-catch to get caught. The by-catch is later predated by the targeted species. As previously, such methods can lead to a large loss of individuals without real consumption, resulting also in an environmental loss.

The intervals of velocity of the different fishing phases as well as the net length correspond to the ones stated on interviews. However, on on-board, a captain stated that he was using one nautical mile long net and after checking the GPS track and calculating the length with setting and velocity times it was concluded that the real length was 5.4 nmi.

The fishers do what they can to optimize their catch, despite some of them disclosing that they see an obvious shift in size (smaller individuals especially of Sparidae) and abundance in species (less species) they have been catching since their childhood.

In contrast to nets and with only information based on interviews, pots and traps are left in the water anywhere from a few hours to an entire week. While pots (not baited) are less problematic as individuals can escape, traps are baited and prevent most catch from escaping as the entrance of the trap is designed to minimize escapement. The baiting of traps attracts by-catch and undersized commercial catch, increasing the potential for overexploitation and discarding. Apart from the increasing of by-catch, another potential result of long soak times (Erzini *et al.* 2008) is the premature death of undersized individuals, which may compromise the maintenance of populations. This heavy fishing of octopus using baited traps happens mainly because of targeted for its first sale price (Pita *et al.* 2015, Sonderblohm *et al.* 2016). In fact, the yield of common octopus more than doubled, from an average annual catch of 4,000 tonnes between 1970–1986 to 8,800 tonnes from 1987 to 2013. As landings have continued to rise in response to increasing effort, it appears that common octopus catches in Portugal remain at sustainable levels

(Baeta *et al.* 2005). Whether this will continue to be the case in the long-term is unclear. Nowadays, in terms of quantities landed and particularly in terms of commercial value, it is an increasingly important socio-economic fishery resource, which plays a major role in providing employment and income to coastal fishing communities. In Santa Luzia there are also a cultural and traditional aspects that emphasize its importance to the region. This was observed when in all the interviews performed there, the fishers were using exclusively pots or traps.

- **Control and law enforcement**

In Portugal, control and law enforcement are carried out by the maritime police and harbour authorities, while the armed forces (navy and air force) monitor and control at sea. However, the effectiveness of this at sea is very insufficient, due mostly to lack of human resources to patrol large areas. This means that the number of traps and nets deployed is in practice under no control. There is also limited enforcement on land, reducing the efficacy of the minimum landing weight legislation. According to fishers, particularly in times of difficulties, compliance with rules and regulations is negligible.

As reported by the fishers themselves and observed by the researchers at the port, there are an excessive amount of static gear in the water, which leads to conflicts among fishers. The accumulated investment in fishing gear tends to be increasingly unbalanced, as some fishers continuously invest in gear (mostly low-cost plastic pots) due and deploy all this gear in the water to secure fishing areas. Some static gear users accuse others of occupying all of the fishing grounds. Simultaneously, encroaching on mobile gear areas results in accusations of foul play.

There are major challenges remain for the governability of multigear coastal fishery, related to the governing system in place. These include lack of a viable level of monitoring and assessment, poor control and enforcement, lack of respect for rules and regulations by fishers and lack of trust of fishers in management bodies. In addition, the low levels of organization, trust and cooperation between fishers themselves result in them having a limited influence on the decision-making process.

4.1. Conclusions and future work

- Nets are usually set parallel to the coast, between 3 and 12 nmi and the fishing grounds are mainly in areas of muddy sand with some rocky spots and between depths of 50 m to 200 m.
- In general, the velocities and times depend on several factors. The setting time depend on the mechanical system and of the velocity itself. The hauling duration is related with the number of workers, net length, species caught and unexpected incidents, as well as size and potency of the vessel. The soaking time depend on the species target, landing dock working hours, number of gears on water and distance to the port. All these the factors also influence the trip duration.
- Significant differences were identified between the soaking durations indicated on the interviews and verified on-board.
- Despite the information from the enquiries were mostly in concordance with the onboard and GPS data, identify the different phases of the fishing events isn't a trivial task.
- The fishing areas indicated by the fishers and those identified through GPS data display some agreement.
- The species identify and register onboard were about the same of the landings, however it was observing the discard of several individuals which leads to a miscounting of captures.
- Some of the current issues being faced in fisheries are overfishing, by-catch and discarding, Illegal, Unreported and Unregulated fishing, and ghost-fishing. When these are not assessed and remain unknown, they contribute to lack of proper management and sustainability solutions.
- The trip and gear characteristics are variables that affect the issues mentioned above.
- Being able to describe the *métiers* can assist in better understanding how significant these issues are within a particular fleet. Pairing landings information with fishers' knowledge allows for the examination of potential *métiers* and the validation of them.
- With regard the coastal multigear fleet, the fishing intensity maps created in this study are an innovation which contains valuable information that can be used for future management decisions.

Future work

- Identify the fishing events and the fishing grounds of Octopus fishery by the validation of the interview's information with observations, GPS and on-board data.
- Map fishing effort and catch per unit of effort (CPUE).
- Collect socio-economic data such as the value and yield of commercial species and cross them with fishing grounds to find out which areas are more profitable having in consideration the fishing time and the quantity of captures.
- Create algorithms that can easily identify fishing events with data from satellite tracking devices.
- The current fisheries monitoring system and stock assessment practices in Portugal have long been identified as inadequate for the management and thus, tools like VMS and AIS can improve this information to be applied in marine spatial planning.
- Evaluate how the monitoring of fisheries carried through tracking devices (VMS and AIS), fishing logbooks, dock-side monitoring and digital record keeping at auctions can be expanded to fishing vessels lacking monitorization.
- Implement more research programs (national fish-auction sampling programs and stock assessment research cruises) to provide further support for management advice and guide legislation.

5. References

Afonso-Dias, M., Simões, J. M., Pinto, C. & Sousa, P. 2002. Use of satellite GPS data to map effort and landings of the Portuguese crustacean fleet (Geocrust). Study project 99/059. Tech. Rep., Universidade do Algarve.

Alvard M., D. Carlson, and E. McGaffey. 2015. Using a Partial Sum Method and GPS Tracking Data to Identify Area Restricted Search by Artisanal Fishers at Moored Fish Aggregating Devices in the Commonwealth of Dominica. PLoS ONE, 10(2):e0115552.

Arce-Acosta, M., Ramírez-Rodríguez, M. and De-la-Cruz-Agüero, G. 2018. Small scale fisheries operative units in the west central region of the Gulf of California, Mexico. Ocean & Coastal Management, 160:58-63.

Baeta, F., Pinheiro, A., Corte-Real, M., Costa, J. L., de Almeida, P. R., Cabral, H., & Costa, M. J. 2005. Are the fisheries in the Tagus estuary sustainable? Fisheries Research, 76, 243–251.

Batista, M. I., F. Baeta, M. J. Costa, and H. N. Cabral. 2011. MPA as management tools for small-scale fisheries: The case study of Arrábida Marine Protected Area (Portugal). Ocean & Coastal Management 54(2):137–147.

Behivoke, F., M. P. Etienne, J. Guitton, R. M. Randriatsara, E. Ranaivoson, and M. Léopold. 2021. Estimating fishing effort in small-scale fisheries using GPS tracking data and random forests. Ecological Indicators 123:107321.

Blaber, S., D. P. Cyrus, J.-J. Albaret, C. V. Ching, J. W. Day, M. Elliott, M. S. Fonseca, D. E. Hoss, J. Orensanz, I. C. Potter, and W. Silvert. 2000. Effects of fishing on the structure and functioning of estuarine and nearshore ecosystems. ICES Journal of Marine Science 57(3):590–602.

Borges, Erzini, Bentes, Costa, Gonçalves, Lino, Pais, and Ribeiro. 2008. By-catch and discarding practices in five Algarve (southern Portugal) *métiers*. Journal of Applied Ichthyology 17(3):104–114.

Brander, L., Baulcomb, C., van der Lelij, J. A. C., Eppink, F., McVittie, A., Nijsten, L. and P. van Beukering. 2015. The benefits to people of expanding Marine Protected Areas. VU University, Amsterdam, The Netherlands.

Briggs, J. C. 1974. Marine zoogeography. McGraw-Hill, New York.

Campbell, M.S., Stehfest, K.M., Votier, S.C. and Hall-Spencer, J.M. 2014. Mapping fisheries for marine spatial planning: Gear-specific vessel monitoring system (VMS), marine conservation and offshore renewable energy. Marine Policy, 45, pp.293-300.

Castro, J., Marín, M., Pérez, N., Pierce, G.J. and Punzón, A. 2012. Identification of *métiers* based on economic and biological data: The Spanish bottom otter trawl fleet operating in non-Iberian European waters. Fisheries Research. 125: 77-86.

Close, C. H., and G. B. Hall. 2006. A GIS-based protocol for the collection and use of local knowledge in fisheries management planning. Journal of Environmental Management 78(4):341–352.

Douvere, F. 2008. The importance of marine spatial planning in advancing ecosystem-based sea use management. Marine Policy 32(5):762–771.

Erzini, K., Monteiro, C.C., Ribeiro, J., Santos, M.N., Gaspar, M., Monteiro, P. and Borges, T.C., 1997. An experimental study of gill net and trammel net 'ghost fishing' off the Algarve (southern Portugal). Marine Ecology Progress Series. 158: 257-265. 10.3354/meps158257.

Erzini, K., Costa, M.E., Bentes, L. and Borges, T.C., 2002. A comparative study of the species composition of discards from five fisheries from the Algarve (southern Portugal). Fisheries Management and Ecology, 9(1):31-40.

Erzini, K., J. M. S. Gonçalves, L. Bentes, P. G. Lino, J. Ribeiro, and K. I. Stergiou. 2003. Quantifying the roles of competing static gears: comparative selectivity of longlines and monofilament gillnets in a multi-species fishery of the Algarve (southern Portugal). Scientia Marina 67(3):341–352.

Erzini, K., Gonçalves, J.M., Bentes, L., Moutopoulos, D.K., Casal, J.A.H., Soriguer, M.C., Puente, E., Errazkin, L.A. and Stergiou, K.I., 2006. Size selectivity of trammel nets in southern European small-scale fisheries. Fisheries Research, 79(1-2):183-201.

Erzini, K., L. Bentes, R. Coelho, P. G. Lino, P. Monteiro, J. Ribeiro, and J. M. S. Gonçalves. 2008. Catches in ghost-fishing octopus and fish traps in the northeastern Atlantic Ocean (Algarve, Portugal). Fishery Bulletin 106(3):321–327.

European Commission. 2021. The EU blue economy report 2021. Publications Office, Directorate-General for Maritime Affairs and Fisheries. https://data.europa.eu/doi/10.2771/5187

European Union. 2021. The EU Fish Market. Directorate-General for Maritime Affairs and Fisheries. Brussels.

Falsone, F., Scannella, D., Geraci, M.L., Vitale, S., Colloca, F., Di Maio, F., Milisenda, G., Gancitano, V., Bono, G. and Fiorentino, F. 2020. Identification and characterization of trammel net *métiers*: A case study from the southwestern Sicily (Central Mediterranean). Regional Studies in Marine Science. 39: 101419.

FAO. 1978. FAO catalogue of fishing gear designs. London, Fishing News Books Ltd., pp. 1–160.

FAO. 2020. FAO yearbook. Fishery and Aquaculture Statistics 2018/FAO annuaire. Statistiques des pêches et de l'aquaculture 2018/FAO anuario. Estadísticas de pesca y acuicultura 2018. Rome/Roma.

Fleet Register Database (2020) Fleet Register. Available at: https://webgate.ec.europa.eu/fleet-europa (Accessed: 10 December 2020)

Fonseca, Paulo. 2012. Sistema MONICAP de monitorização das embarcações - aplicações no âmbito do apoio à gestão das pescas. Revista da Marinha.

Frazão Santos, C., Z. Gonçalves Teixeira, J. Janeiro, R. Sousa Gonçalves, R. Bjorkland, and M. Orbach. 2012. The European Marine Strategy: Contribution and challenges from a Portuguese perspective. Marine Policy 36(5):963–968.

Frazão Santos, C., T. Domingos, M. A. Ferreira, M. Orbach, and F. Andrade. 2014. How sustainable is sustainable marine spatial planning? Part II – The Portuguese experience. Marine Policy 49:48–58.

Gabriel, O., K. Lange, E. Dahm, and T. Wendt. 2005. Fish Catching Methods of the World Fourth Edition.

Gaspar, M.B. and Pereira, F. 2014. Pequena pesca na costa continental: caracterização socioeconómica, descrição da atividade e identificação de problemas. IPMA, projeto PRESPO, 272p

Gonçalves, E. J., M. Henriques, and V. C. Almada. 2002. Use of temperate reef-fish community to identify priorities in the establishment of a Marine Protected Area.

Gonçalves, J.M.S., Stergiou, K.I., Hernando-Casal, J.A., Puente, E., Moutopoulos, D.K., Arregi, L., Soriguer, M.C., Fernández, C.V., Coelho, R. and K. Erzini. 2007. Discards of trammel nets in southern European small-scale fisheries. Fisheries Research, 8 (1-3): 5-14.

Gonçalves, J.M.S., Monteiro, P., Oliveira, F., Costa E., Bentes, L. 2016. Bancos de pesca de cerco e da pequena pesca costeira do Sotavento Algarvio. Pescamap Sotavento: Mapeamento de bancos de pesca e demais actividades marítimas no Sotavento Algarvio - Vol. I. Relatório final No. 1/2016 - PescaMap Sotavento. Universidade do Algarve, CCMAR, Faro, 109 pp.+anexos.

González-Álvarez, J., García-de-la-Fuente, L., García-Flórez, L., Fernández-Rueda, M. and Luis Alcázar-Álvarez, J. 2016. Identification and Characterization of *Métiers* in Multi-Species Artisanal Fisheries. A Case Study in Northwest Spain. Natural Resources, 7, 295-314. doi: 10.4236/nr.2016.76026.

Halpern, Benjamin & Diamond, Jordan & Gaines, Steven & Gelcich, Stefan & Gleason, Mary & Jennings, Simon & Lester, Sarah & Mace, Amber & McCook, Laurence & McLeod, Karen & Napoli, Nicholas & Rawson, Kit & Rice, Jake & Rosenberg, Andrew & Ruckelshaus, Mary & Saier, Bettina & Sandifer, Paul & Scholz, Astrid & Zivian, Anna. 2012. Near-term priorities for the science, policy and practice of Coastal and Marine Spatial Planning (CMSP). Marine Policy. 36. 198-205. 10.1016/j.marpol.2011.05.004.

Halkos, G., Roditi, K., Matsiori, S. and Vafidis, D. 2018. Small-scale fishery of the Eastern Mediterranean Sea: A case study in the Kalymnos Island, Greece.

Henriques, N.S., Ressurreição, A., Oliveira, F., Monteiro, P., Rangel, M., Bentes, L., Lino, P., Jacob, J., Afonso, C.M.L., Moura, D., Berecibar, E., Horta e Costa, B., Gonçalves, J.M.S. 2018. Baía de Armação de Pêra: Informação de base dos valores naturais e dos usos do espaço marinho. CCMAR, Universidade do Algarve, Fundação Oceano Azul, Faro, Portugal. 84p.

Hilborn, R., T. A. Branch, B. Ernst, A. Magnusson, C. V. Minte-Vera, M. D. Scheuerell, and J. L. Valero. 2003. State of the World's Fisheries. Annual Review of Environment and Resources 28(1):359–399.

Hintzen, N. T., F. Bastardie, D. Beare, G. J. Piet, C. Ulrich, N. Deporte, J. Egekvist, and H. Degel. 2012. VMStools: Open-source software for the processing, analysis and visualisation of fisheries logbook and VMS data. Fisheries Research 115–116:31–43.

Hinz, H., L. G. Murray, G. I. Lambert, J. G. Hiddink, and M. J. Kaiser. 2013. Confidentiality overfishing effort data threatens science and management progress. Fish and Fisheries 14(1):110–117.

Horta e Costa, B., Gonçalves, L., Gonçalves, E. J. 2013. Vessels' site fidelity and spatio-temporal distribution of artisanal fisheries before the implementation of a temperate multiple-use marine protected area. Fisheries Research, 148: 27-37.

ICES. 2017. Report of the Working Group on Mixed Fisheries Advice (WGMIXFISH-ADVICE), 22–26 May 2017, Copenhagen, Denmark. ICES CM 2017/ACOM:18. 128.

Instituto Nacional de Estatística. 2021. Estatísticas da Pesca: 2020. INE, Lisboa.

Leitão, F., V. Baptista, D. Zeller, and K. Erzini. 2014. Reconstructed catches and trends for mainland Portugal fisheries between 1938 and 2009: implications for sustainability, domestic fish supply and imports. Fisheries Research 155:33–50.

Léopold, M., N. Guillemot, D. Rocklin, and C. Chen. 2014. A framework for mapping small-scale coastal fisheries using fishers' knowledge. ICES Journal of Marine Science 71(7):1781–1792.

Linke, Sebastian. 2015. Co-management in fisheries – Experiences and changing approaches in Europe. Ocean & Coastal Management. 104. 170-181. 10.1016/j.ocecoaman.2014.11.017.

Lloris, D. 2002. A world overview of species of interest to fisheries. Chapter: *Dicentrarchus labrax*. FIGIS Species Fact Sheets. Species Identification and Data Programme-SIDP. FAO-FIGIS, 3.

Lloris, D. 2005. A world overview of species of interest to fisheries. Chapter: *Sparus aurata*. Retrieved on 08 July 2005, from www.fao.org/figis/servlet/species?fid=2384. 3p. FIGIS Species Fact Sheets. Species Identification and Data Programme-SIDP, FAO-FIGIS

Mao, S., E. Tu, G. Zhang, L. Rachmawati, E. Rajabally, and G.-B. Huang. 2018. An Automatic Identification System (AIS) Database for Maritime Trajectory Prediction and Data Mining:241–257.

Mazzarella, F., M. Vespe, D. Damalas, and G. Osio. 2014. Discovering Vessel Activities at Sea using AIS Data: Mapping of Fishing Footprints. Discovering vessel activities at sea using AIS data: mapping of fishing footprints. In Information Fusion (FUSION), 2014 17th International:1–7.

Moreno-Baez, M., Cudney-Bueno, R., Barron, J.O., Shaw, W. W., Pfister, T. J., Torre-Cosio, Loaiza, R. M., Rojo. 2012. Integrating the spatial and temporal dimensions of fishing activities for management in the Northern Gulf of California, Mexico. Ocean & Coastal Management, 55:111-112.

Natale, F., M. Gibin, A. Alessandrini, M. Vespe, and A. Paulrud. 2015. Mapping fishing effort through AIS data. PLoS ONE 10(6):1–16.

Ojeda-Ruiz, M. A., Ramírez-Rodríguez, M., Cruz-Aguero, G. 2015. Mapping fishing grounds from fleet operation records and local knowledge: The Pacific calico scallop (*Argopecten ventricosus*) fishery in Bahia Magdalena, Mexican Pacific. Ocean & Coastal Management, 106:61-67.

O'Shea, T., Jones, R., Markham, A., Norell, E., Scott, J., Theuerkauf, S., and T. Waters. 2019. Towards a Blue Revolution: Catalyzing Private Investment in Sustainable Aquaculture Production Systems. The Nature Conservancy and Encourage Capital, Arlington, Virginia, USA.

Pauly, D., and M. L. D. Palomares. 2001. Fishing Down Marine Food Webs: An Update. Waters in Peril 279(February):47–56.

Pauly, D., R. Watson, and J. Alder. 2005. Global trends in world fisheries: impacts on marine ecosystems and food security. Philosophical Transactions of the Royal Society B: Biological Sciences 360(1453):5–12.

Pita, C., Pereira, J., Lourenço, S., Sonderblohm, C. and Pierce, G.J. 2015. The traditional small-scale octopus' fishery in Portugal: framing its governability. Jentoft S., Chuenpagdee R. (eds) Interactive Governance for Small-Scale Fisheries. MARE Publication Series, 13:117-132.

Pita, C., K. Roumbedakis, T. Fonseca, F. L. Matos, J. Pereira, S. Villasante, P. Pita, J. M. Bellido, A. F. Gonzalez, M. García-Tasende, E. Lefkaditou, A. Adamidou, D. Cuccu, P. Belcari, A. Moreno, and G. J. Pierce. 2021. Fisheries for common octopus in Europe: socioeconomic importance and management. Fisheries Research 235.

QGIS Development Team. 2021. QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.osgeo.org

Ressurreição, A., Rangel, M., Oliveira, F., Monteiro, P., Bentes, L., Pontes, J., Henriques, N.S., Andrade, M., Afonso, C.M.L., Sousa, I., Guimarães, M.H., Andrade, M., Horta e Costa, B., Gonçalves, J.M.S. 2020. AMPICvalue - Mapeamento e valoração das atividades suportadas pela costa de Lagoa, Silves e Albufeira e desenvolvimento de um processo participativo com vista ao estabelecimento de uma Área Marinha Protegida de Interesse Comunitário (AMPIC). CCMAR, Universidade do Algarve, Fundação Oceano Azul, Faro, Portugal. 162p.

Reuchlin-Hugenholtz, E., McKenzie, E. 2015. Marine protected areas: Smart investments in ocean health. WWF, Gland, Switzerland.

RStudio Team. 2020. RStudio: Integrated Development for R. RStudio, PBC, Boston, MA URL http://www.rstudio.com/.

Russi, Daniela & Pantzar, Mia & Kettunen, Marianne & Gitti, Giulia & Mutafoglu, Konar & Kotulak, Monika & Ten Brink, Patrick. 2016. Socio-Economic Benefits of the EU Marine Protected Areas.

Russo, T., L. D'Andrea, A. Parisi, and S. Cataudella.. 2014. VMSbase: An R-Package for VMS and Logbook Data Management and Analysis in Fisheries Ecology. PLoS ONE 9(6):e100195.

Savina, Esther & Karlsen, Junita & Frandsen, R. & Krag, Ludvig & Kristensen, Kasper & Madsen, Niels. 2016. Testing the effect of soak time on catch damage in a coastal gillnetter and the consequences on processed fish quality. Food Control. 70. 10.1016/j.foodcont.2016.05.044.

Santos, M.N., Saldanha, H.J., Gaspar, M.B. and Monteiro, C.C. 2003. Hake (*Merluccius merluccius* L., 1758) ghost fishing by gill nets off the Algarve (southern Portugal). Fisheries Research. 64(2-3):119-128.

Schneider, W., 1990. FAO species identification sheets for fishery purposes. Field guide to the commercial marine resources of the Gulf of Guinea. Prepared and published with the support of the FAO Regional Office for Africa. Rome: FAO. 268 p.

Scholz, A., K. Bonzon, R. Fujita, N. Benjamin, N. Woodling, P. Black, and C. Steinback. 2004. Participatory socioeconomic analysis: drawing on fishermen's knowledge for marine protected area planning in California. Marine Policy 28:335–349.

Scholz, A., Steinback, C., Kruse, S., Mertens, M., and Silverman, H. 2011. Incorporation of spatial and economic analyses of human-use data in the design of marine protected areas. Conservation Biology, 25: 485–492.

Silva, P., Cabral, H., Rangel, M., Pereira, J., Pita, C., 2018. Ready for co-management Portuguese artisanal octopus fishers' preferences for management and knowledge about the resource. Mar. Policy 0–1. https://doi.org/10.1016/j.marpol.2018.03.027

Slack-Smith. R. J. 2001. Fishing with Traps and Pots. FAO Training Series. Food and Agriculture Organization of the United Nations, Rome. 62 pp.

Sonderblohm, C., Guimarães, H., Rainha, R., Gonçalves, J.M.S., Pereira, J., Gaspar, M. Erzini, K., Rangel, M. 2016. Livro verde sobre a pesca do polvo no Algarve. Programa PROMAR - Direcção Regional de Agricultura e Pescas do Algarve (DRAP Algarve). Centro de Ciências do Mar (CCMAR), Universidade do Algarve GOBIUS Comunicação e Ciência. 48p. ISBN: 978-989-20-7231-9

de Souza, E. N., K. Boerder, S. Matwin, and B. Worm. 2016. Improving fishing pattern detection from satellite AIS using data mining and machine learning. PLoS ONE 11(7):1–20.

Szynaka, M. J., K. Erzini, J. M. S. Gonçalves, and A. Campos. 2021. Identifying Métiers Using Landings Profiles: An Octopus-Driven Multi-Gear Coastal Fleet. Journal of Marine Science and Engineering 2021, Vol. 9, Page 1022 9(9):1022.

Tu, E., G. Zhang, L. Rachmawati, E. Rajabally, and G. bin Huang. 2018. Exploiting AIS Data for Intelligent Maritime Navigation: A Comprehensive Survey from Data to Methodology. IEEE Transactions on Intelligent Transportation Systems 19(5):1559–1582.

Watson, R., and D. Pauly. 2001. Systematic distortions in world fisheries catch trends. Nature 414(6863):534–536.

6. Annexes

ANNEX I - Inquérito modelo efetuado à frota costeira

*A informação deste inquérito será analisada pelo **CCMAR (Centro de Ciências do Mar)** da Universidade do Algarve, no âmbito da tese de mestrado: "Mapeamento dos bancos de pesca da frota polivalente costeira". Com a finalidade de ser utilizado como ferramenta para mapear e caracterizar a pesca polivalente costeira, o presente questionário tem como principal objetivo integrar os interesses do setor das pescas no planeamento e gestão do meio marinho. Todos os dados recolhidos são para uso exclusivamente científico e como tal, é **garantida a confidencialidade** e anonimato das suas respostas.*

Inquérito nº __________**Inquiridor:** ____________________________**Hora:**____________**Porto:**____________________________**Data:**_____/______/______

1. Identificação:

1.1. Responsabilidade na embarcação: Armador ☐ Mestre ☐ _________________☐ Anos de atividade __________________ Nº de pescadores________

2. Dados referentes à embarcação:

2.1. Embarcação: _____________________________________ Matrícula: _________________________Potência_______________ **CFF**_____________

Dispositivos__________________ (Diário de bordo, VMS, AIS, …) Dias de pesca por semana/mês_____________ Capturas por dia de pesca (CPUE)__________

3. Dados referentes à atividade:

3.1. **ARMADILHAS** Áreas de pesca__________________________________ Época__________________

Espécie alvo _________________________________

Nº Caçadas/armadilhas ________Tipo ___________Espaçamento entre armadilhas ______________ Profundidade ________ e________

Tipo de fundo preferencial ________________

3.2. **Hora**: Saída/Chegada porto_________/_________ Largada ____________Tempo de imersão ____________ Alagem____________ **Descanso**_______________

Posição: Porto____________________ Largada_________________Imersão__________________________Alagem_____________________________________

Velocidade: Navegação _______________Pesquisa______________ Largada _________________________Alagem______________________________________

3.3. Espécies mais capturadas

3.4. Arte Secundária____________________ Espécie alvo_____________________ Malhagem________ Tamanho______/______ Nº Covos/panos de rede______

3.5. Áreas de pesca______________________Época_________________Tipo de fundo preferencial _______________Profundidade ______ e______

3.6. **Espécies mais capturadas**

3.7. **REDES DE EMALHAR** Áreas de pesca __________________________ Época________________________ Espécie alvo _________________________ Nº de redes na caçada_______________________ Tipo __________ Tamanho_________/_________Malhagem_________________

3.8. Tipo de fundo preferencial _______________Profundidade ______ e______

3.9. **Hora**: Saída/Chegada porto__________/________ Largada ___________Tempo de imersão ___________ Alagem___________ **Descanso______________**

Posição: Porto____________________

Largada________________Imersão_________________________Alagem___________________________________

Velocidade: Navegação **______________**Pesquisa_____________ Largada ________________________Alagem_____________________________________

3.10. Espécies mais capturadas

3.11. Arte Secundária______________________ Espécie alvo ___________________ Malhagem_______ Tamanho______/______ Nº Covos/panos de rede________

3.12. Áreas de pesca________________________ Época___________________ Tipo de fundo preferencial ________________Profundidade _______ e__________

3.13. **Espécies mais capturadas**

4. **REDES DE TRESMALHO** Áreas de pesca ____________________________ Época_______________________ Espécie alvo ___________________________ Nº de redes na caçada_________________________ Tipo ___________ Tamanho_________/__________Malhagem___________________

4.1. Tipo de fundo preferencial ________________Profundidade ______ e______

4.2. **Hora**: Saída/Chegada porto_________/_________ Largada ____________Tempo de imersão ____________ Alagem____________ **Descanso**_______________

Posição: Porto______________________

Largada_________________Imersão___________________________Alagem_______________________________________

Velocidade: Navegação _______________Pesquisa______________ Largada

__________________________Alagem____

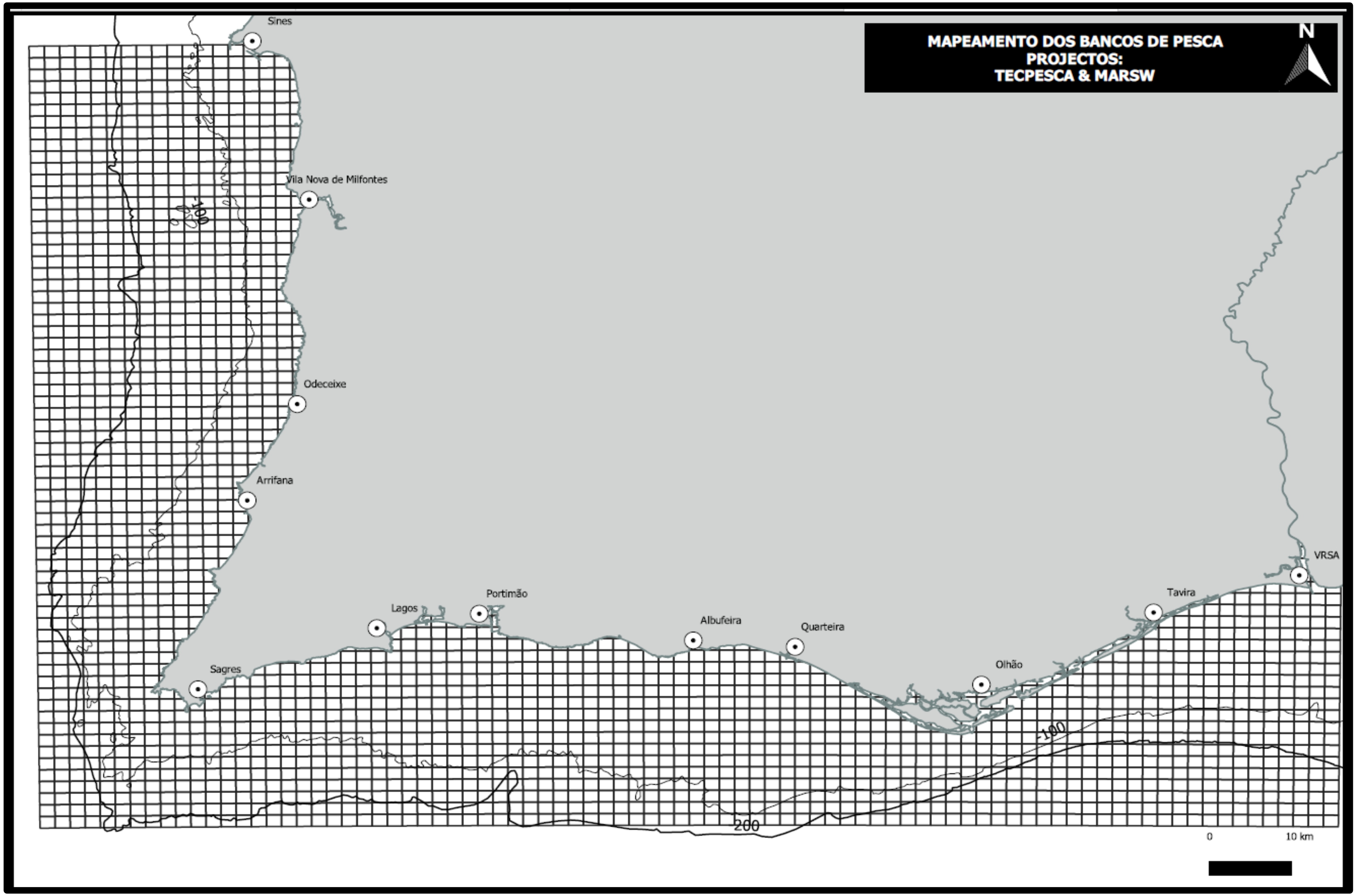
4.3. Espécies mais capturadas

4.4. Arte Secundária______________________ Espécie alvo ___________________ Malhagem_______ Tamanho______/______ Nº Covos/panos de rede________

4.5. Áreas de pesca________________________ Época___________________ Tipo de fundo preferencial ________________Profundidade _______ e__________

4.6. **Espécies mais capturadas**

ANNEX 2 - Grid map



ANNEX 3 - Sheet with onboard data

Basic Info.
Observer(s): 1. ____________________ 2. ________________________
Date: ___/___/_______ Vessel name: _____________ Regis. # ____-____-___ Trip No.:______

Time
Departure: _____:_____ Arrival: _____:_____ Set: _____:_____ Haul: _____:_____
Soak Time: ______h Resting: _____:_____

Speed
Navigation:____________Search:______________Setting:_____________Hauling:_________
___

Gear
Type: Gear No. Set: 1 2 3
Traps: Traps: Cage Pots
Nets: Nets: Gill Trammel
Line: Line: Long-line Long-line Hand-lineHand-line

Specifications (Hook No., Mesh Size): __________mm Bait: _______________

Catch info.
*Alive, Dead, Injured_

No.	SPP	Discard	Reason Dis	Condition/Sample	Coor/WP
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					
17.					
18.					
19.					
20.					
21.					
22.					