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Master Program in Information Management

BI SOLUTION,
IN SUPPORT OF THE PORTUGUESE NAVY´S FISHERY SURVEILLANCE

JOÃO ANTÓNIO OSÓRIO BEJA

Dissertation report presented as partial requirement for obtaining the Master's degree in Information Management

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Instituto Superior de Estatística e Gestão de Informação
Universidade Nova de Lisboa

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by

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Dissertation report presented as partial requirement for obtaining the Master's degree in Information Management, with a specialization in Business Intelligence.

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Epigraph

"The oceans, seemingly limitless, invoke in us a sense of awe and wonder and also, sometimes, fear. They cover 70 percent of the surface of our planet and yet they are still the least explored. Hidden beneath the waves, right beneath my feet there are creatures beyond our imagination. With revolutionary technology we can enter new worlds and shine a light on behaviours in ways that were impossible just a generation ago.
We've also recognised an uncomfortable fact – the health of our oceans is under threat, they are changing faster than ever before in human history […] Never has there been a more crucial time to reveal what is going on under the surface of the seas […]
[…] we will journey across the globe, from the warm waters of the tropics to the coldest around the poles to bring us a new understanding of life beneath the waves."

The venerable narrator David Attenborough,

2017,

In "Opening intro titles episode 1 - Blue Planet II – BBC"

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Abstract

Illegal Unreported and Unregulated (IUU) fishing poses challenges that go beyond economic and environmental impacts. It disrupts evidence-based fisheries management and undermines the fair competition faced by law-abiding fishers in terms of resource access and market opportunities. The increased recognition of IUU fishing as a significant threat has prompted the need for effective measures to combat it. Governments, international organizations, and non-governmental organizations are now actively working to address this issue and develop strategies to mitigate the negative impacts of IUU fishing on global interests.

To address these challenges, the implementation of a Business Intelligence (BI) solution, using Power BI™, is proposed. This BI solution aims to enhance the reporting and analysis capabilities of the Portuguese Navy (MP) and the National Maritime Authority (AMN), when dealing with data from the Integrated Surveillance, Inspection, and Control System of Fishing Activities (SIFICAP), and other fisheries inspection data. By centralizing and transforming decentralized data sources into actionable information, the BI system facilitates decision-making at various organizational levels, enabling more effective preparation of on-site sea inspections.

The thesis focuses on describing how the maritime surveillance effect on fisheries-related infringements can be measured using the BI system. The goal is to ensure that relevant and timely information is available to the right individuals within the organization, thereby improving decision-making processes and enhancing the effectiveness of surveillance, inspection, and control activities in combating all fisheries infringements.

Keywords:

IUU fishing; Ocean sustainability; Deterrence effect, Business intelligence

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Abbreviations

AIS - Automatic Identification System

CDS - Chief of the Defence Staff

CPF - Common Fisheries Policy

DGAM - Directorate-General of Maritime Authority

DGRM - Directorate-General for Natural Resources, Safety and Maritime Services

EFCA - European Fisheries Control Agency

ETL - Extract, Transform and Load

EEZ - Exclusive Economic Zone

EU - European Union

FAO - Food and Agriculture Organization

FPIs - Fishery Performance Indicators

GFW - Global Fishing Watch

GPS - Global Positioning Data

IUU - illegal, unreported, and unregulated fishing

LO - Landing Obligation

MCS - Monitoring, Control, and Surveillance

MONICAP - Portuguese acronym for, Continuous monitoring of fishing activity

MP - Maritime Police

MPA - Marine Protected Areas

MSY - Maximum Sustainable Yield

NMA - National Maritime Authority

PN - Portuguese Navy

PSMA - Port State Measures Agreement

PNSS - Portuguese National Strategy for Sea

PSM - Port State Measures

SADAP - Decision Support System for Patrol Activity

SAM - Maritime Authority System

SGDs - Sustainable Development Goals

SIFICAP - Portuguese acronym for, Integrated System for Inspection, Information and Control of Fishing Activities

SRQ - Start Research Question

TACs - Total Allowable Catches

UNCLOS - United Nations Convention on the Law of the Sea

VMS - Vessel Monitoring System

VTS – Vessel Traffic Service

WTO - World Trade Organization

1 Introduction

1.1 Framework

The ocean is the planet´s largest ecosystem, covering about 71 % of the Earth´s surface. It plays a vital role in supporting life on our planet, providing a habitat for a wide variety of marine species, and contributing to global climate regulation (FAO, 2022, p. 1).

Fish is fished every day, and in every ocean of the planet. An immense volume is captured and processed to keep up with the insatiable appetite of global demand leading to overfishing of the oceans. Government subsidies are keeping fishing boats fishing even when there are too few fish left for fishing to be profitable. While some subsidies aim to promote sustainable fishing practices and support small-scale fishermen, others can contribute to overfishing, depletion of fish stocks, and ecological damage. Subsidies given to large industrial fishing boats and other ill-advised subsidies can contribute to illegal, unreported, and unregulated (IUU) fishing (World Trade Organization WTO, 2022, pp. 5 and 7). Recognizing the need to address harmful fishing subsidies, the World Trade Organization (WTO)[1] has been engaged in discussions on this topic for several years.

The European Fisheries Control Agency (EFCA) plays a crucial role in promoting a sustainable fisheries management, combatting IUU fishing, and safeguarding marine resources among the European Union (EU) member states and beyond. EFCA's wide range of activities support the implementation of the Common Fisheries Policy (CFP) and address international fisheries challenges, through operational coordination, international cooperation, fostering compliance culture, and participation in the European Coast Guard Cooperation (Donatella F., 2023, pp. 5, 8).

The Portuguese National Fisheries Authority is the Directorate-General for Natural Resources, Safety and Maritime Services (DGRM), that has implemented an Integrated System for Surveillance, Inspection, and Control of Fishing Activities, known as SIFICAP[2]. This system is an important instrument in the efforts to prevent and eliminate illegal fishing, unreported, and unregulated (IUU) fishing. Under the terms of the Portuguese law (Decree Law No.79, 2001), the Portuguese Navy (PN) and the National Maritime Authority (NMA) as participating entities in the Integrated System SIFICAP, contribute to the maritime surveillance efforts aimed at combating fisheries-related infringements.

[1] WTO - The World Trade Organization (WTO) was established on January 1, 1995, following the signing of the Marrakesh Agreement in 1994. This agreement replaced the General Agreement on Tariffs and Trade (GATT), which had been in place since 1948. The WTO's mission is to promote free and fair trade by facilitating negotiations, reducing trade barriers, and enforcing trade rules and agreements. is the world's largest international economic organization, with 164 member states representing over 98% of global trade and global Gross Domestic Product.

[2] SIFICAP – Portuguese acronym for Integrated System for Inspection, Information and Control of Fishing Activities (Decree Law No.79, 2001)

Over-capacity of existing fishing fleets, overfishing, some traditional fishing practices, lack of fish alternatives, and high demand for fish products by wealthy populations contribute to IUU fishing (Borit M., 2009, p. 15).

Eliminating fisheries-related infringements is fundamental to safeguard the oceans and the livelihoods of people who depend on fishing. Sustainable fishing practices involve several key aspects. Strengthening control and surveillance measures are essential steps towards achieving sustainable fishing. By doing so, Member States can ensure the long-term viability of fisheries, protect marine biodiversity, and support the livelihoods of fishing communities.

The goal of increasing maritime surveillance efforts is to improve detection rates, enhance the capacity to enforce fishing regulations, and act as a deterrent to potential IUU fishing operators (Borit M., 2009, p. 21). It sends a strong signal that illegal activities are being monitored and increases the risks associated with engaging in infringing fishing practices.

1.2 Problem

From our literature review, the lack of well identified relations between surveillance measuring metrics and the effect of this surveillance on the occurrence of fisheries-related infringements is a research gap. The *Main Research Question* (MRQ) of this thesis addresses the research gap that was identified, and can be formulated as:

- How can the Portuguese Navy (PN) and the National Maritime Authority (NMA) as participating entities in the Integrated System SIFICAP, measure the maritime surveillance effect on the occurrence of fisheries-related infringements?

1.3 Topic´s relevance

With the vast amount of available data, it can be difficult to extract meaningful information and translate it into actionable knowledge. Integrating tools that can merge data from various sources and provide comprehensive analysis is indeed crucial for effective decision-making.

Business intelligence solutions can play a significant role in this process by providing tools and techniques for data integration, analysis, and visualization. These solutions help identify patterns, correlations, and trends within datasets, enabling decision-makers to gain valuable insights and make informed decisions. Overall, the integration of data management, analytics, and business intelligence solutions can significantly enhance the decision-making process and support efforts to combat illegal fishing more effectively. By transforming data into actionable information, decision-makers can be better equipped to tackle the challenges associated with illegal fishing and ensure more sustainable fisheries management.

The output of this thesis is to understand to what extend measuring metrics can help to achieve a deterrent effect with the fishing vessels inspections at sea, conducted by PN and NMA as participating entities in SIFICAP. This thesis provides valuable insights into how we can effectively measure the impact of maritime surveillance on fisheries-related infringements. The results can inform evidence-based decision-making, policy development, and resource allocation to enhance the control and surveillance measures in place, ultimately contributing to sustainable fisheries and the protection of marine ecosystems.

For these reasons the title of the present research work is: BI solution, in the support of the fishing surveillance of the Portuguese Navy.

1.4 Goals

The main goal in this thesis is to produce a BI solution in support of the Portuguese Navy’s fishery surveillance. This BI solution is important to improve decision making in maritime surveillance planning.

To achieve this goal, we need to:

- Analyse and visualise large-scale geo-referenced maritime surveillance data.
- Develop surveillance and deterrence indicators.
- Develop various tools to enable planning decisions for maritime surveillance activity.

1.5 Methodology

The research approach in this study follows a pragmatic perspective, aiming to obtain practical results and insights. The research utilizes inductive reasoning, which involves drawing general conclusions from specific observations and data analysis. Critical thinking is applied to evaluate the information gathered and make informed interpretations.

The study employs a case study design, focusing on a specific object of study within a real work context. The scope of the research is defined by the consultation, analysis, and structuring of data, which are spatially located and analysed within a specific time frame. The content of the research is aligned with the domain and area of research, ensuring relevance and applicability to the research context.

The data collected is examined and interpreted to derive meaningful insights and draw conclusions. The main goal is to contribute to the existing knowledge and address practical issues within the research domain.

After performing a comprehensive literature review, we took the sequence of steps shown in **Error! Reference source not found.**.

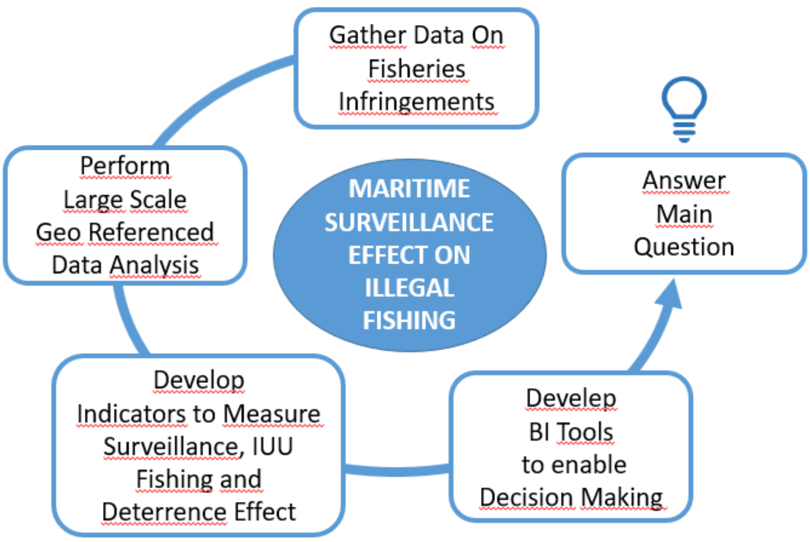

Figure 1 - Sequence of work performed.

1.6 Structure

The first chapter of this thesis, named “Introduction”, presents the problem to be solved, the topic´s relevance, methodology and goals, and structure of the document. The “Literature review” chapter describes the concept of fisheries-related infringements at sea, previous work in thesis area and in the analysis of large-scale geo referenced data. The third chapter, “Indicators for measure surveillance effect” identifies possible indicators and metrics for surveillance, IUU, and the deterrence effect. The fourth, “BI Solution to report fishery surveillance” describes the Extract-Transform-Load (ETL) process, and the development of the BI solution in Power BI™. The “Conclusion” chapter summarizes the overall result and answers the research questions. It also points to some possible future work in this area.

2 Literature review

2.1 Fisheries in a sustainability way

The Fishery Performance Indicators (FPIs) are introduced as a tool for assessing the performance of individual fisheries and establishing links between enabling conditions, management strategies, and triple bottom line outcomes (economic, community, and ecological sustainability) (Anderson et al., 2015, pp. 1–3). The analysis of 61 fishery case studies from industrial and developing countries demonstrates the importance of tracking economic and community outcomes alongside resource status. Developed countries generally offer better community services and generate more economic benefits from their fisheries. They excel in harvests, post-harvest assets, and value-added processing, which contribute to higher-value products and successful trade. These differences in performance are associated with disparities in enabling conditions such as national economies, infrastructure, governance, and environmental regulatory performance.

The FPIs outcome (Anderson et al., 2015) provide a valuable tool for comparing and analysing fishery performance, enabling lessons to be drawn from successful fisheries and identifying areas where stakeholders and communities are not adequately supported. The tool leverages variations in management strategies and enabling conditions across different fisheries, allowing for natural experiments that can inform effective management approaches. The data from FPIs can be used to test hypotheses and supplement the framework with additional indicators related to sociological or ecological variables. With further case studies, outcomes can be linked to specific contexts and management strategies, ultimately contributing to science-based approaches for maximizing the potential benefits of ocean resources.

The case study conducted in Cartagena, Spain, in (Hernández Aguado et al., 2016) focuses on the assessment of fisheries sustainability using an integrated multicriteria participatory framework. The framework considers six dimensions: Ecological, Economic, Social, Technological, Ethical, and Institutional. The modified 'Rapfish' technique is utilized as a decision-making tool, while cognitive mapping helps assess the perceived linkages among indicators. Traditionally, fisheries sustainability has predominantly been defined based on ecological considerations, particularly maintaining catch levels. However, in (Adrianto et al., 2005) argues that sustainability should also encompass human and social goals, including the fulfilment of basic human rights such as access to food and livelihood. (Lam & Pitcher, 2012) emphasizes the application of justice principles to balance ecological impacts with human rights fulfilment.

The results of the Aguado study, emphasize the significance of establishing new social networks to gather knowledge from stakeholders and develop measures that cater to the environmental, social, and economic demands of the fishing community (Hernández Aguado et al., 2016). It is suggested that the formulation of common goals can promote social justice within the sector without increasing fishing effort, and prioritizing indicators which is crucial to enhance the sustainability of fisheries in Cartagena. In terms of sustainability policy, Aguado advocates for incorporating the importance and linkages of indicators into decision-making processes. This entails considering different perspectives within the same fishery system and leveraging knowledge from diverse sources. The analysis of Cartagena's fisheries serves as an initial step towards a more participative and socially just approach to fisheries management, aiming to enhance overall sustainability. Aguado's work highlights the complexity of fishery systems and the necessity of moving beyond ecological considerations alone to achieve true sustainability. By integrating multiple dimensions and involving stakeholders in the decision-making process, a more comprehensive and socially just approach to fisheries management can be fostered.

The United Nations 2030 Agenda for Sustainable Development encompasses seventeen Sustainable Development Goals (SDGs) that aim to address a range of social, economic, and environmental challenges.

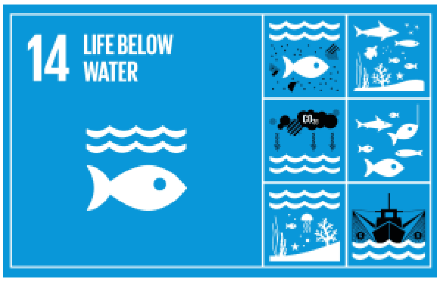

Figure 2 - SDG logo "14 - Life below water"

One of the SDGs is the Goal 14 referred to as "Life below water", specifically focuses on various aspects of marine conservation, sustainable fisheries, and the mitigation of ocean-related challenges. Within Goal 14, there are seven specific targets and 4 general targets (United Nations, 2022, pp. 54 and 55). The target 14.4 is aiming "by 2020, effectively regulate harvesting and end overfishing, IUU fishing and destructive fishing practices". And the 14.4.1 indicator is specific to evaluate the "Proportion of fish stocks within biologically sustainable levels" (United Nations Statistics Division, 2020, pp. 16 and 17).

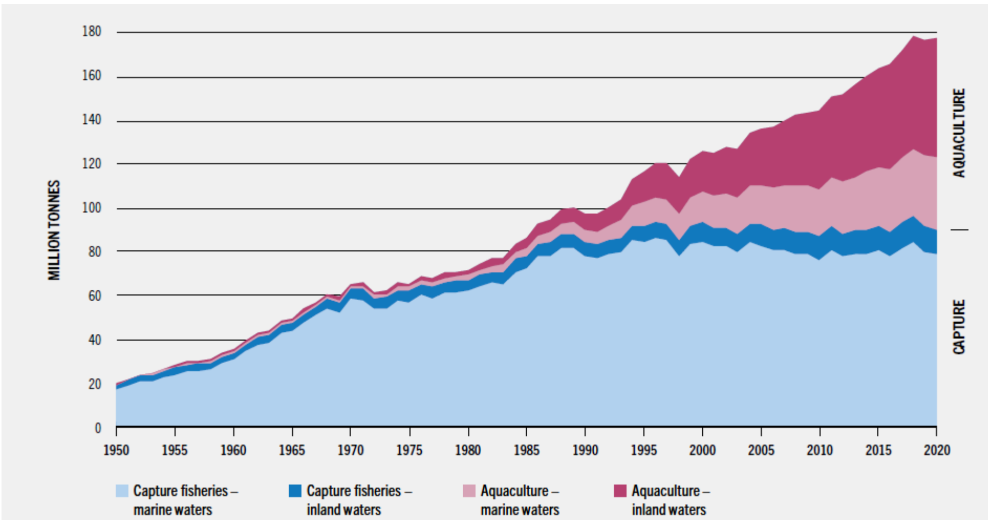

Figure 3 - World capture fisheries and aquaculture production (FAO, 2022, p. 4)

In 2020, the total world production of aquatic animals was estimated to be 178 million tonnes, which was slightly lower than the 2018 record high of 179 million tonnes (Figure 2). Out of the total production, capture fisheries contributed 90 million tonnes (51 percent), while aquaculture accounted for 88 million tonnes (49 percent) (FAO, 2022, p. 1).

Accordingly with the same report, marine waters accounted for 63 percent (112 million tonnes) of the total production, with 70 percent coming from capture fisheries and 30 percent from aquaculture. Inland waters contributed 37 percent (66 million tonnes) of the total production, with aquaculture contributing 83 percent and capture fisheries contributing 17 percent.

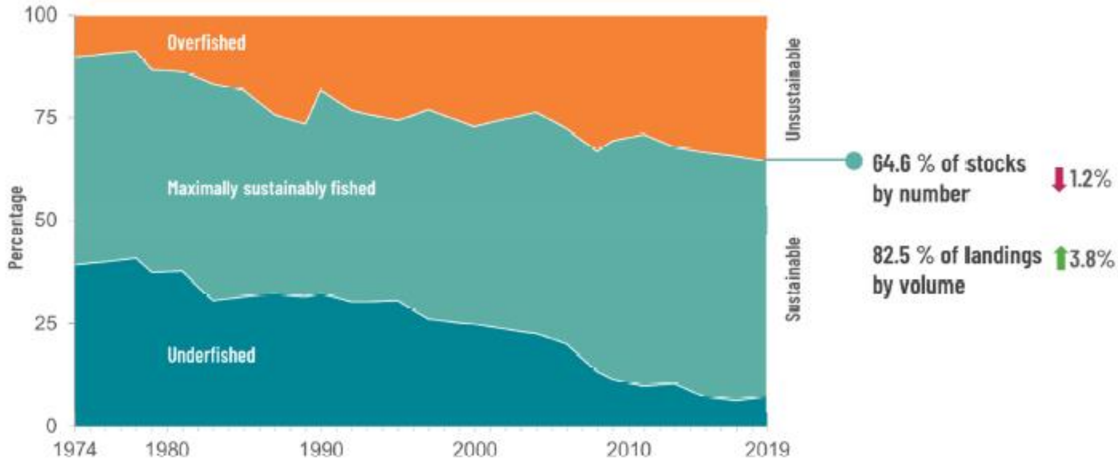

Figure 4- Global trends in the state of the world´s marine fishery stocks, 1974-2019

The Food and Agriculture Organization (FAO) 2022 report assessment considers the abundance of stocks and the volume of their catch, estimated in 82.5 percent of the fishery landings in 2019 were from biologically sustainable stocks (FAO, 2022, p. 3). This weighted assessment shows a 3.8 percent improvement from the previous assessment, indicating that a larger proportion of the fishery landings came from stocks that are considered biologically sustainable (FAO, 2022, p. xvi).

In 2019, only 64.6 percent of fishery stocks were estimated to be within biologically sustainable levels. This means that these stocks were being harvested at a rate that allowed them to replenish and maintain their populations. However, this figure represents a decrease of 1.2 percent compared to 2017, indicating a decline in the overall sustainability of fishery stocks (FAO, 2022, p. 46). The percentage of stocks fished at biologically unsustainable levels has been increasing over time. In 1974, it was 10 percent, but by 2019, it had risen to 35.4 percent. This means that a significant portion of fishery stocks is being harvested at a rate that exceeds their natural replenishment capacity, risking overfishing and potential population declines.

The statistics highlight the urgent need for improved fisheries management and conservation efforts to reverse the trend of declining fishery stocks and increasing unsustainable fishing practices. Sustainable fisheries management, including science-based decision-making, effective catch limits, and ecosystem-based approaches, is crucial to ensure the long-term viability of fish stocks, protect marine biodiversity, and sustain the livelihoods of those dependent on fisheries.

Under the 'Blue Transformation' initiative, the FAO is committed to provide existing and emerging knowledge and tools to its members and partners. This support is aimed at maximizing the contribution of aquatic food systems to various important aspects, including food security, nutrition, and the availability of affordable and healthy diets. Integrating different strategies and approaches, the 'Blue Transformation' has three main objectives (FAO, 2022, p. 110):

1. Sustainable aquaculture expansion and intensification:
   Promoting sustainable practices in aquaculture, the Blue Transformation helps meet the increasing global demand for aquatic food while minimizing negative environmental impacts. Sustainable aquaculture reduces the pressure on wild fish stocks and helps curb IUU fishing, providing a responsible and reliable source of seafood.
2. Effective management of all fisheries:
   The objective of effective fisheries management aligns with efforts to combat IUU fishing. By implementing science-based management measures, such as setting fishing quotas, regulating fishing gear and methods, and establishing protected areas, fisheries can be managed sustainably. Effective management reduces overfishing, enhances the health of fish stocks, and creates a level playing field for fishers, discouraging IUU activities.
3. Upgraded value chains:
   Upgrading value chains in the fisheries and aquaculture sectors includes improving traceability, promoting fair trade practices, and ensuring the social, economic, and environmental viability of aquatic food systems. These measures contribute to curbing IUU fishing, improving transparency and accountability throughout the supply chain. Traceability systems help identify and eliminate illegally caught or unreported seafood, ensuring that only legally sourced products reach the market.

The conservation and restoration initiatives of aquatic habitats, including coastal areas, mangroves, and coral reefs, to maintain biodiversity and enhance the resilience of aquatic food systems, and mostly are known as Marine Protected Areas (MPA) (Di Franco et al., 2016). While MPAs are valuable for the conservation and restoration of aquatic habitats, their protection from illegal fishing activities is essential. Effective enforcement, community engagement (Fisherman), stakeholder cooperation and international collaboration (presence of fishermen within the management board), and innovative monitoring technologies for sustainable fishing, are some key issues to safeguarding MPAs and the fisheries resources they support. The Dehens study[3] (Dehens & Fanning, 2018, pp. 43, 55) emphasizes the importance of vigilance and adaptability for MPA managers and stakeholders, particularly in response to external threats like invasive species. It also highlights the need for coordination and collaboration between MPA management and surrounding watershed partners, especially when the MPA boundary is relatively small. This research suggests four key actions to enhance MPA effectiveness through assessing legitimacy: Tracking Legitimacy Indicators, Using a Legitimacy Indicator Framework, Community Leadership and Trust, and site-specific context.

[3] Dehens Study - Musquash MPA is a small, coastal MPA located in the Bay of Fundy, in New Brunswick, Canada

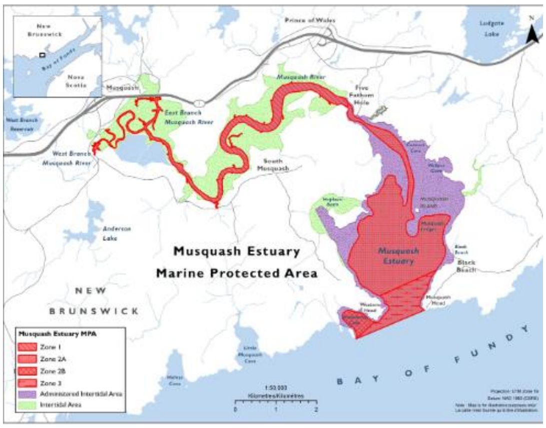

Figure 5 - Canada, Musquash Estuary Marine Portected Area

Source: (Fisheries and Ocean Canada (DFO), 2019)

SDG 14.4 highlights the importance of effectively regulating harvesting, ending overfishing, IUU fishing, and destructive fishing practices. The adoption of effective Monitoring, Control, and Surveillance (MCS) measures is essential to ensure compliance with conservation and management measures (Lubchenco & Haugan, 2023, p. 586). MCS measures enhances compliance with conservation and management measures established to regulate fishing activities. Monitoring and enforcing these measures, such as fishing quotas, gear restrictions, protected areas, and closed seasons, MCS helps prevent overfishing, IUU fishing, and destructive practices that harm marine ecosystems (Lubchenco & Haugan, 2023, p. 349).

MCS involves the use of various technologies, such as satellite monitoring, vessel tracking systems, and aerial surveillance, to monitor fishing activities in real-time. It allows authorities to track vessel movements, identify suspicious behaviour, monitor the use of different registered gear type, and detect potential violations of fishing regulations. The study explored learning-based and regime-based methods for fishing gear recognition using Vessel Monitoring System (VMS) data and applied these methods to detect abnormal VMS patterns of fishing vessels in Indonesian fisheries. Effective monitoring and surveillance help detect and deter IUU fishing and destructive practices (Marzuki et al., 2018). MCS measures include control and enforcement mechanisms to ensure compliance with fishing regulations. This involves inspections, patrols, and enforcement actions to detect and respond to non-compliance (Temple et al., 2022). Control measures may include boarding and inspecting fishing vessels, verifying catch documentation, and checking for compliance with licensing and registration requirements. Enforcement actions can range from fines and penalties to vessel seizures and prosecution.

Achieving SDG 14.4 requires the active involvement and voluntary actions of ocean fishery stakeholders, including coastal states. Coastal states have a responsibility to act in implementing MCS measures within their jurisdictions to regulate fishing activities effectively. This involves engaging with stakeholders, including fishers, industry representatives, and civil society, to promote responsible fishing practices and raise awareness about the importance of sustainable fisheries (FAO, 2022, p. 160).

MCS measures are most effective when there is international cooperation and collaboration. Coastal states can work together through regional fisheries management organizations, international agreements, and information sharing mechanisms to enhance MCS efforts. Sharing best practices, exchanging data and information, and coordinating enforcement activities, coastal states can collectively combat overfishing, IUU fishing, and destructive practices on a global scale.

Maritime surveillance plays a crucial role in supporting the objectives of the 'Blue Transformation' initiative aimed by FAO. Monitoring fishing vessels and their activities, surveillance systems can identify, and track vessels engaged in illegal fishing practices, such as unauthorized fishing in protected areas, overfishing, or using prohibited fishing gear, helps in detecting and combating IUU fishing activities.

Effective maritime surveillance enables the monitoring of compliance with fisheries regulations and fishing quotas. Using a collection data system on fishing activities and vessel movements, surveillance systems can help ensure that fishing operations adhere to sustainable fishing practices and comply with national and international regulations. This helps maintain the health and abundance of fish stocks, contributing to the long-term sustainability of aquatic food systems. Monitoring and protecting Marine Protected Areas (MPA), by closely monitoring vessel movements and activities within MPA, surveillance systems can identify any unauthorized fishing or other detrimental activities and take appropriate actions to prevent damage to these ecologically important areas. Protecting MPA is crucial for preserving biodiversity, restoring fish stocks, and maintaining healthy marine ecosystems.

Maritime surveillance also contributes to ensuring security and safety at sea for fishing vessels and maritime workers. By monitoring vessel movements and providing real-time information on potential risks, surveillance systems can support search and rescue operations, prevent illegal activities, and enhance the overall safety and security of fisheries and aquaculture operations. Integrating maritime surveillance into the 'Blue Transformation' initiative, FAO can strengthen its efforts to promote sustainable and responsible practices in aquatic food systems. Effective surveillance helps combat illegal fishing, ensures compliance with regulations, protects marine ecosystems, and enhances the overall resilience and sustainability of aquatic food systems.

2.2 World overfishing

Overfishing is when the fishing pressure on a particular species or population is too high, leading to the depletion of fish stocks and negatively impacting the overall health of the ecosystem (FAO, 2022, p. 55).

However, overfishing as a “broad definition” (Sumaila & Tai, 2020, p. 2) . Firstly, occurs when more fish are harvested than nature can replenish sustainably. This means that the fishing pressure exceeds the reproductive capacity of the fish populations, leading to population declines and potential collapse. Secondly, overfishing often targets high trophic level and valuable fish species. This selective fishing of top predators can disrupt the natural balance of the marine food web. Removing large numbers of these important species can have cascading effects on the entire ecosystem, affecting the abundance and distribution of other species and potentially leading to ecosystem imbalances. Thirdly, harmful fishing gears and practices can disturb and damage ocean habitats. Certain fishing techniques, such as bottom trawling or using destructive gear, can cause physical damage to seafloor habitats, coral reefs, and other sensitive ecosystems. This destruction of habitats further undermines the health and resilience of marine ecosystems.

In fact, the increased demand for fish and seafood products, driven by factors such as population growth, changing dietary preferences, and globalization of the seafood market, puts pressure on fisheries to meet consumer needs. Modern fishing technologies, such as large-scale commercial fishing vessels, sonar systems, and advanced gear, enable more efficient and effective fishing operations. If not properly regulated, these technologies can lead to increased fishing capacity and intensify the fishing pressure on fish stocks. Inadequate fisheries management, including weak regulations, insufficient monitoring and enforcement, and the absence of sustainable fishing practices, can contribute to overfishing. Without proper measures in place, fish stocks can be exploited beyond sustainable levels. Overfishing can occur due to various factors such as high demand, technological advancements, and lack of effective management.

Beyond overfishing, climate change impacts on fish and ocean life (Sumaila & Tai, 2020, p. 3) . Ocean acidification due to high level of CO2 on the ocean reduces the amount of carbonate, a key building block in seawater. Changes in temperature (Ocean warming) that go beyond an organism’s optimal range will initiate physiological responses that may affect biological performance including growth, reproduction, and survival. Climate-related impacts may also lead to shifts in phenology (timing of seasonal biological events). Taking measures to mitigate climate change are also crucial for the long-term health of marine ecosystems. To promote the long-term sustainability of marine ecosystems it´s necessary these measures and recognizing the interconnectedness of overfishing, climate change, and marine ecosystem health. Sustainable fisheries management practices and global cooperation are key in ensuring that future generations can continue to benefit from the valuable goods and services provided by the oceans (Sumaila & Tai, 2020, p. 6).

In a global effort to tackle the worldwide overfishing there are some key actions that can be addressed by governments, such as setting catch limits, implementing effective fisheries management, establishing protected areas, promoting sustainable fishing practices, enhancing international cooperation, and raising awareness and consumer choices (World Trade Organization WTO, 2022).

2.3 Illegal, unreported, and unregulated (IUU) fishing

The IUU fishing is widely recognized as one of the biggest and most serious environmental crimes globally (Petrossian, 2018). IUU fishing refers to fishing activities that violate national or international laws and regulations, including fishing without proper authorization, exceeding quotas, using prohibited gear or methods, or fishing in prohibited areas (See Annex C).

The findings from the Global Fishing Watch (GFW) 2017 report, provide valuable insights into the prevalence of transshipment activities in the fishing industry (Global Fishing Watch, 2017). The GFW report identified 694 vessels that could conduct transshipments at sea during the 2017 year. These vessels have the infrastructure and capacity to transfer catch between fishing vessels or from fishing vessels to refrigerated cargo vessels. The instances where transshipment-capable vessels were moving at a slow speed for a sufficient duration to indicate a potential transshipment event. This suggests that these vessels were engaged in activities related to the transfer of catch at sea. The report also highlighted several instances where fishing vessels were near transshipment-capable vessels for a significant duration, indicating the possibility of engagement in transshipment activities. This suggests a potential link between fishing vessels and transshipment operations.

These findings highlight the scale and frequency of transshipment activities within the fishing industry during the given timeframe. Transshipment at sea can pose challenges for monitoring and enforcement efforts, as it can facilitate the obfuscation of catch origin, quantities, and compliance with regulations. Reports such as these provide valuable information to policymakers, fisheries management authorities, and law enforcement agencies, helping them identify areas and vessels where transshipment activities are prevalent. This data can be used to inform targeted monitoring, enforcement, and regulatory measures aimed at combating IUU fishing and promoting sustainable fishing practices.

It is worth noting that GFW continues to monitor and analyse fishing vessel movements using AIS data, contributing to ongoing efforts to improve transparency, traceability, and sustainability in the global fishing industry (Figure 4).

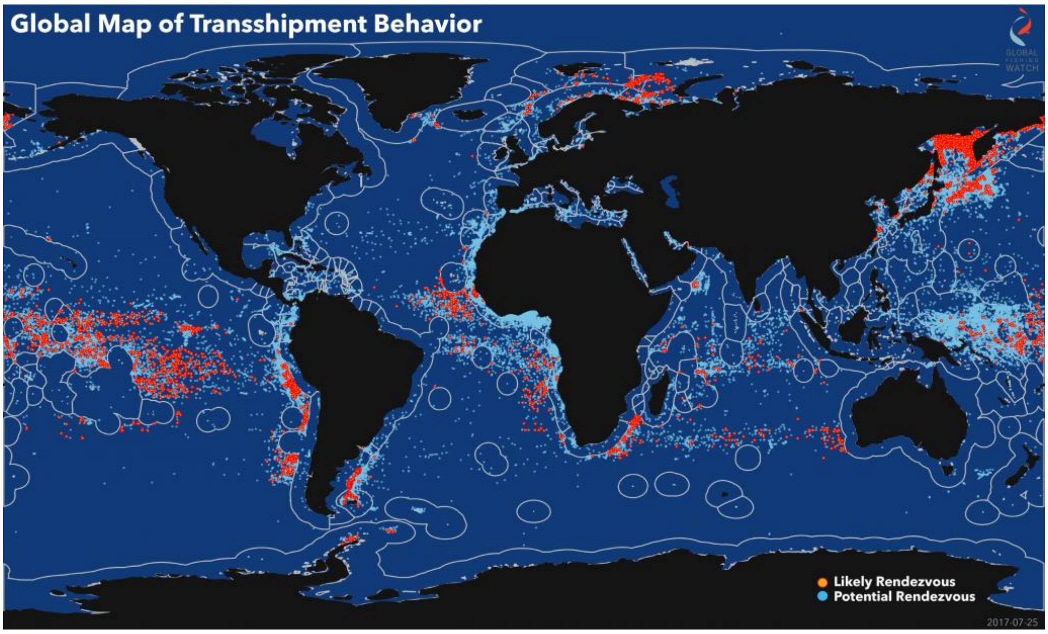

Figure 6 - Potential transshipment events at sea, January 2012 to December 2017

Source: (Global Fishing Watch, 2017)

Important methods and patterns are commonly employed by perpetrators of IUU fishing (Petrossian, 2018). Identifying these practices and patterns allows for monitoring authorities and law enforcement officers in detecting some key points related to these methods.

Transshipment at sea, where catch is transferred between vessels, is a common method used in IUU fishing (Lubchenco & Haugan, 2023; Walton et al., 2022, p. 6). This practice allows perpetrators to obscure the origin and quantity of the catch, making it harder to trace and monitor their activities.

IUU fishing vessels often exploit flags of convenience, registering their vessels in countries with weak regulations or enforcement measures. They may also deliberately fail to comply with regulations and fishing quotas, disregarding sustainable fishing practices. Ports of convenience, when IUU fishing vessels take advantage of ports that offer little inspection or enforcement, enabling them to offload and trade their illegally caught seafood without thorough scrutiny. These ports may have weak regulations, limited resources, or corruption issues (Lubchenco & Haugan, 2023, pp. 561, 562).

Vessel Monitoring System (VMS) and Automatic Identification System (AIS) manipulation take place, most of all when perpetrators of IUU fishing may deactivate or manipulate their VMS or AIS to avoid detection and monitoring by authorities. This makes it challenging to track their movements and activities and it´s designated by dark activity (Bunwaree, 2023, p. 180).

IUU fishing operations often employ complex networks of ownership, making it difficult to identify the true beneficiaries and individuals responsible for these illegal activities. This can involve multiple layers of shell companies, flag changes, and hidden ownership structures (Lubchenco & Haugan, 2023, p. 562).

IUU fishing vessels may carry fraudulent ship's documents to misrepresent their identity, registration, or catch documentation. This helps them evade authorities and conceal their illegal activities. IUU fishing operations are not limited to large-scale industrial fleets. Perpetrators often infiltrate small artisanal fisheries, taking advantage of limited monitoring and enforcement capacities in these areas (Lubchenco & Haugan, 2023, p. 564).

In the absence of effective MCS measures, many countries may have limited knowledge of the extent of IUU fishing within their Exclusive Economic Zones (EEZs) and adjacent waters (Agnew & Barnes, 2004, pp. 19, 26). To combat IUU fishing effectively (Hutniczak, 2018, pp. 34–36, 55, 84–86), it is essential to strengthen monitoring and enforcement capacities, enhance international cooperation, and promote transparency and traceability throughout the seafood supply chain. This includes implementing stringent port controls, improving vessel monitoring systems, promoting information sharing among countries, and supporting initiatives such as catch documentation schemes. Combating IUU fishing requires a comprehensive approach involving government agencies, regional fisheries management organizations, industry stakeholders, and civil society to address these practices and safeguard the sustainability of fisheries resources.

There are three key opportunities for action to combat IUU fishing (Lubchenco & Haugan, 2023, pp. 579, 580): Adopt global transparency in fisheries, enact tighter controls at ports, and enhance collaboration. Advancements in tracking methods, such as satellite-based vessel monitoring systems (VMS) and electronic catch documentation and traceability systems, offer powerful tools for fisheries management. To track fishing vessel movements and trace fish catch throughout the value chain, is required these technologies and integrating them with existing regulations. This enhanced transparency, combined with public awareness of authorized vessels and fishing areas, can significantly improve compliance with regulations and deter IUU fishing.

Port states play a crucial role in preventing the entry of IUU-caught fish into the market. Ratifying and implementing the FAO's Port State Measures (PSM) Agreement (FAO, 2022, pp. 102, 128, 133, 143) is essential for all port states. The agreement requires parties to establish stricter controls on foreign-flagged vessels seeking to use their ports, enabling them to detect and prevent the trade of IUU products. Countries can effectively block illegally caught fish from entering the supply chain by strengthening port inspections and documentation requirements. IUU fishing is a transboundary issue that requires collaboration among nations at regional and international levels. Governments, businesses, financial institutions, scientific establishments, and civil society organizations need to work together to develop and implement solutions. Collaborative efforts can include information sharing, joint surveillance and enforcement operations, capacity building initiatives, and the development of common policies and regulations. By pooling resources, expertise, and data, collaborative approaches maximize impact and minimize costs in combating IUU fishing.

Data-enabled technology (Lubchenco & Haugan, 2023, p. 583) plays an important role in combating IUU fishing, and the International MCS Network. Is a global network that aims to enhance cooperation, coordination, and information exchange among national organizations and institutions responsible for fisheries related MCS activities. It provides a platform for countries to collaborate and share best practices, data, and technological innovations to improve the efficiency and effectiveness of their MCS efforts. Is a platform for capacity-building activities, technology and innovation enable real-time monitoring, analysis, reporting, detect and deter IUU fishing activities.

2.4 Common Fishery Policy and the National Fisheries Authority

The Common Fisheries Policy (CFP) of the European Union has several objectives, one of which is to ensure the exploitation of living aquatic resources in a sustainable manner from economic, environmental, and social perspectives (Regulation EU 1380, 2013). The CFP was implemented by the European Community in 2002 and grants powers to the EU to address various aspects related to fisheries management. Establishing measures for the sustainable management of fish stocks, including setting fishing quotas, implementing fishing effort limitations, and promoting responsible fishing practices, striving the reduce of bycatch and protecting sensitive habitats, minimizing the negative environmental effects of fishing activities, and defining the conditions under which fishing vessels can access EU waters and resources, including licensing requirements and allocation of fishing opportunities are some examples of how the CFP legislation is in forced.

The introduction of Maximum Sustainable Yield (MSY) as the management target in the Common Fisheries Policy (CFP) legislation aimed to achieve sustainable fishing levels for all stocks, progressively implemented between 2015 and 2019 (Borges, 2018, p. 1). The objective was to ensure the conservation of fish stocks in the North-East Atlantic. Under the CFP, Total Allowable Catches (TACs) are set annually through negotiations between EU member states (MSs) and the European Commission. These negotiations involve representatives from each EU member states who advocate for their national interests in the Council. While scientific advice on fishing opportunities informs the negotiation strategy, national domestic interests can often influence the final decisions.

Prior to 2015, TACs were primarily focused on limiting the amount of fish landed rather than the amount caught. However, since 2015, several TACs have started to reflect catches due to the phased introduction of the Landing Obligation (LO) outlined in Article 15 of Regulation (EU) No 1380/2013 (Regulation EU 1380, 2013). The LO requires that all catches of TAC-regulated species in the North-East Atlantic must be landed and accounted for by 2019 (Borges, 2021), and the LO, also known as the discard ban, aimed to address the issue of discarding unwanted catches at sea. By requiring the landing and accounting of all catches, the LO aimed to promote more sustainable fishing practices and reduce wasteful discards. The implementation of the LO and the transition to catch-based TACs marked a significant shift in fisheries management within the EU. It sought to align fishing activities with the principle of sustainability and the objective of achieving MSY. By accounting for all catches, including previously discarded fish, the LO aimed to provide a more accurate representation of the actual fishing mortality and enable better management of fish stocks.

The EU fishing fleet operates globally, but most catches are concentrated in the North-East Atlantic region (Commission & Fisheries, 2022, p. 19). The EU fishing industry primarily targets several key species, namely Atlantic herring, European sprat, blue whiting, and mackerel. These species collectively make up 42% of the total EU landings. When it comes to the leading Member States in terms of fishing volume (excluding the United Kingdom, which has left the EU), Denmark, Spain, the Netherlands, and France emerge as the prominent players. These four countries combined account for 58% of all EU catches (Commission & Fisheries, 2022, p. 20). It is worth noting that these rankings may be subject to change over time due to various factors, including shifts in fish stocks, fleet dynamics, and fishing practices. This information underscores the significance of the North-East Atlantic for EU fishing activities and highlights the importance of these key species to the EU fishing industry. The involvement of specific Member States, particularly Denmark, Spain, the Netherlands, and France, further emphasizes their substantial contributions to the overall EU fishing volume.

Total catches of world's main producers (2019)
(volume in tonnes live weight and percentage of total)

China	14 169 893	15.15 %
Indonesia	7 524 705	8.05 %
India	5 477 100	5.86 %
Russia	4 983 145	5.33 %
Peru	4 851 310	5.19 %
EU-28	**4 824 384**	**5.16 %**
United States	4 803 630	5.14 %
Vietnam	3 429 029	3.67 %
Japan	3 230 560	3.45 %
Norway	2 472 399	2.64 %
Chile	2 376 682	2.54 %
Philippines	2 056 669	2.20 %
Myanmar	1 951 120	2.09 %
Bangladesh	1 895 619	2.03 %
Mexico	1 581 127	1.69 %
Thailand	1 542 465	1.65 %
Others	26 348 963	28.18 %
Total	93 518 800	100.00 %

Table 1- Total Catches of world´s main producers

(Commission & Fisheries, 2022, p. 21)

The EU was responsible for catching 4,8 million tonnes of fish, during 2019, registering 72,9% of the catches in the Northeast Atlantic Ocean area, highlighting Spain, Denmark, and France as the first three fleets of the European ones to catch the largest volumes (Commission & Fisheries, 2022, p. 20). However, in terms of fish consumption (in kilograms per capita), the EU country that consumes the most fish or aquaculture products is Portugal (60 kg per capita), followed by Spain (46 kg per capita), Denmark (43 kg per capita) and France (33 kg per capita) (Commission & Fisheries, 2022, p. 45).

Portugal	59.91
Spain	46.02
Denmark (**)	42.56
France	33.26
Luxembourg	32.84
Italy	31.21
Ireland	25.50
Sweden	25.16
Cyprus	24.34
EU-28	**23.97**
Finland	23.77
Belgium	23.31
Croatia	20.82
Netherlands (*)	20.60
Greece	20.37
UK (***)	20.13
Estonia (*)	16.00
Lithuania	13.90
Poland (*)	13.11
Austria	13.09
Germany (*)	13.08
Slovenia	12.18
Latvia (*)	10.46
Slovakia	9.69
Romania	8.11
Bulgaria	7.45
Hungary	6.28
Czechia (*)	6.00

Norway	54.56
Japan	46.74
China	40.42
EU-28	**23.97**
United States	22.9
Canada	22.33
Russia	20.74
World average	**20.66**
Brazil	9.04
India	7.63
Turkey	5.09

Table 2- Consumption of fisheries and aquaculture products in 2019

Quantity in live weight (Kg / in habitant / Year)

Left side: European Union – Right side: Top 10 World Ranking (Commission & Fisheries, 2022, p. 45)

In Europe, and particularly in Portugal, there has been a growth in the aquaculture sector, but it has not yet reached sufficient production values to contribute to a sustainable supply of fish to reduce catches at sea, where Portugal is also included, thus arising the need for efficient and effective monitoring of fishing activity in national waters (Commission & Fisheries, 2022, p. 26). Currently, the independent monitoring and control of fishing activity is becoming increasingly relevant when there is an increasing overexploitation of animals and populations of living marine resources in decline, particularly in coastal, offshore, and high seas fisheries (Ewell et al., 2020).

The Portuguese National Strategy for Sea (PNSS) 2021-30 as outlined in Portuguese government document (Resolution of the Council of Ministers No.68, 2021), focuses on promoting sustainable development, maritime security, and responsible fisheries practices. Through information sharing, traceability measures, and surveillance mechanisms, the strategy aims to address challenges such as IUU fishing, ensure the authenticity of fish products, and foster cooperation among stakeholders in the maritime sector. The PNSS 2021-30, serves as a framework for the future program of the European Maritime, Fisheries, and Aquaculture Fund. It is further detailed in Portuguese document law as an action plan (Resolution of the Council of Ministers No.120, 2021) and aligns with the guiding principles of the United Nations Agenda 2030 for sustainable development, as well as the CFP. One of the key aspects of this strategy is the promotion of information sharing in maritime situational awareness. This aims to enhance cooperation and collaboration across sectors and transnational partnerships to ensure maritime security. The strategy emphasizes technical and operational cooperation in various areas, including maritime and port activities, fostering synergies, joint responses, and liaison mechanisms. These efforts focus on preventing and suppressing illegal acts, exchanging information, and monitoring and surveillant the sea. Another important component of the strategy is the encouragement of fish traceability. This involves promoting locally produced fish in Portugal and utilizing technologies like molecular identification tracing or blockchain to ensure the authenticity and transparency of fish products. By implementing robust traceability measures, the strategy aims to prevent IUU fishing practices and combat misleading marketing of fish. The strategy also emphasizes the use of surveillance and monitoring means at sea and on land to enhance fisheries management and enforcement efforts. By employing these measures, the goal is to improve compliance with regulations and prevent IUU fishing activities.

The control, inspection, and enforcement system in the field of fisheries, established by the EU regulation, has been in force since the beginning of 2010 (Regulation EU 1224, 2009). In line with this regulation, the Directorate-General for Natural Resources, Safety and Maritime Services (DGRM)[4] has implemented an integrated system designated by the acronym SIFICAP (Decree Law No.79, 2001). This system is part of the control system applicable to the Common Fisheries Policy established by the EU and it considers the specific reality of fishing activities in Portugal. Advanced information technologies are used to maximize the commitment of resources, both human and material, and to enhance collaboration among participating entities. Through SIFICAP, better interconnection and collaboration between various entities involved in the control and enforcement process are established. The system allows access to information obtained from various data files, which are essential for statistical analysis and efficient implementation of administrative and judicial proceedings resulting from inspections. By leveraging advanced technologies and optimizing data management, SIFICAP aims to improve the effectiveness of monitoring, reporting, and control of fishing activities. The system plays a vital role in ensuring compliance with fisheries regulations and promoting sustainable fishing practices. SIFICAP serves as a valuable tool for the National Authority for Fisheries in Portugal to monitor and enforce fisheries regulations, promoting sustainable fishing practices, and ensuring compliance with the Common Fisheries Policy of the EU.

MONICAP[5] has evolved from a Portuguese pilot project to a mandatory and widely adopted system for monitoring fishing vessels (DGRM, 2018). This system primarily operates as a satellite VMS, using a mobile device installed on board fishing vessels known as the “Blue Box” or continuous monitoring equipment. The device receives global positioning data (GPS) and communicates with the Portuguese Vessel Traffic Service (VTS) centre and fisheries control and surveillance centre, through Inmarsat satellites. MONICAP has significant benefits, which were quickly recognized and adopted by national legislation in the European Union, as well as by third countries and Regional Fisheries Management Organizations. Currently, is mandatory for all Union vessels over 12 meters in length, regardless of their operational area (Regulation EU 1224, 2009). The integration of MONICAP into the SIFICAP system strengthens the overall monitoring, reporting, and control framework for fisheries activities (Decree Law No.79, 2001). It enhances the ability to detect and deter illegal, unreported, and unregulated (IUU) fishing practices, supports traceability efforts, and contributes to the sustainable management of fishery resources.

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[4] DGRM - Directorate-General for Natural Resources, Safety and Maritime Services is the National Authority for Fisheries in Portugal, since 2012 (Decree Law No. 49-A, 2012).

[5] MONICAP – Portuguese acronym for, Continuous monitoring of fishing activity

2.5 NMA & PO Navy Maritime surveillance

The National Maritime Authority (NMA) operates within the SAM (Maritime Authority System) framework (Decree Law No43, 2002). It is responsible for coordinating activities at the national level conducted by the PN (Mostly at sea), and Maritime Police (MP) (Land and sea) as an operational structure, and Directorate-General of Maritime Authority (DGAM) as a central structure of the NMA (Decree Law No44, 2002). DGAM, in turn, directs, coordinates, and controls the activities of the Central Services, Maritime Departments (North, Centre, South, Azores, and Madeira), and Port Captaincies. DGAM oversees the Maritime Departments, which are regional bodies with coordination and assistance responsibilities for the actions and services of the Captaincies. The main mission of the Maritime Departments is to ensure the execution of maritime surveillance and vigilance activities within their respective areas.

The PN, as a branch of the Portuguese Armed Forces, has its primary mission (Decree Law No185, 2014, p. 3) [6] to participate in the military defence of the Republic, in accordance with the Constitution and the law. The PN's activities include fulfilling international commitments, engaging in humanitarian and peacekeeping missions, protecting national interests and life, and undertaking other missions assigned by the Chief of the Defence Staff (CDS). While the PN's main mission is military defence, it also operates in non-military spheres. This includes missions related to public authority at sea, scientific research, and preservation of the marine environment. Although these non-military missions are not the PN's primary focus, they have significant importance and are carried out by Navy units.

The PN, together with the NMA, fulfils its role in surveillance, inspection, and control of fishing activities. This is carried out through the local maritime police commands and the corps of maritime police officers, which are legally competent entities[7] (Decree Law No.79, 2001). Their responsibilities include coordinating surveillance and inspection of fishing activities and marine cultures within areas under national sovereignty and jurisdiction, to better conserve and manage resources. The collaboration between the PN and the NMA, along with their respective departments and entities, plays a crucial role in ensuring maritime surveillance, control of fishing activities, and the conservation and management of marine resources. In the context of fishing activities, the concept of inspection is commonly referred to as fisheries surveillance. Fisheries surveillance involves the monitoring and control of fishing activities to ensure compliance with applicable regulations and management measures (Mourinha, 2012, p. 98).

The MCS activities are conducted through various measures and approaches to ensure compliance with fisheries regulations and sustainable fishing practices (Cremers et al., 2020). The specific methods and techniques employed may vary depending on the country and jurisdiction. However, it is by combining various MCS techniques, that maritime fisheries authorities work towards effective and sustainable management of fisheries resources.

The VMS involves the use of satellite-based technology to track the location and movement of fishing vessels (Dupont et al., 2020), by installing tracking devices on fishing vessels, authorities

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[6] Decree Law No185/2014, changed by (Decree Law No19, 2022)

[7] SIFICAP Entities – DGRM, PN, NMA, Air Force, Coastal Control Unit from National Republican Guard, Azores Regional Fisheries Inspection, Madeira Regional Directorate for Fisheries.

can monitor vessel positions in real-time, verify fishing activities, and detect any unauthorized or suspicious behaviour (Orofino et al., 2023, p. 679). The remote sensing technologies, including satellite imagery, can be used to monitor and analyse fishing activities from a distance (Drakopulos et al., 2022, pp. 1, 2, 5). Satellite imagery can identify and track vessels, detect changes in fishing patterns or areas, and assist in identifying potential illegal or unsustainable fishing practices. The value of active vessel patrols and the limitations of relying solely on satellite monitoring for fisheries surveillance is quite important for the MCS vessel analysis. While satellite surveillance provides valuable information on vessel movements and patterns, it does not replace the need for active patrols and inspections at sea (Rowlands et al., 2019). Active vessel patrols complement satellite surveillance by providing on-site presence and the ability to conduct direct inspections of vessels. Patrols allow fisheries authorities to verify compliance with regulations, inspect fishing gear, measure catch quantities, and ensure adherence to fishing restrictions and conservation measures (Millar, 1995) (Cremers et al., 2020). The On-site inspections conducted onboard of fishing vessels to verify compliance with regulations, enhanced to check fishing gear, measure catch quantities, examine logbooks, documentation, ensure compliance with size limits catches, catch quotas, and other management measures. Inspections may also include verifying compliance with safety standards and crew welfare requirements.

The aerial surveillance involves the use of aircraft, drones, or helicopters equipped with advanced technologies to monitor fishing activities (Millar, 1995, pp. 3, 7, 8) (Rowlands et al., 2019). Aerial surveillance provides a comprehensive view of fishing areas, enabling authorities to detect illegal fishing practices, identify unauthorized vessels, and monitor compliance with fishing regulations over large areas. The EMS involves the use of onboard cameras closed-circuit television (CCTV) and sensors to monitor fishing activities (Orofino et al., 2023, pp. 676, 677). These systems record and analyse data on fishing operations, catch handling, and compliance with regulations. EMS can provide valuable information for audits, verification, and investigations.

Fisheries authorities often collaborate with other stakeholders, such as fishers´ associations, industry representatives, and regional organizations, to gather information and enhance monitoring capabilities (Drakopulos et al., 2022). They may also encourage reporting mechanisms where fishers, crew members, or the public can report suspected illegal fishing activities.

Gathering and collect data and analyse data on fishing activities, catch reports, vessel registrations, and other relevant information requires MFA information systems (Orofino et al., 2023, p. 683). Advanced information systems and databases help in managing and analysing these data, identifying trends, and assessing compliance with regulations.

Maritime surveillance data can be used to map shipping density in different areas of the world (Dupont et al., 2020). These studies provide valuable information on the patterns and intensity of fishing activities, which can aid in understanding maritime traffic dynamics, assessing risks, and informing maritime spatial planning efforts. With fishing density maps can assess fishing effort and fishing activity. These data can provide insights into fishing patterns, identify high-pressure fishing areas, and contribute to fisheries management strategies, such as evaluating the effectiveness of fishing regulations and identifying potential areas of overfishing. By examining the spatial overlap of activities such fishing, offshore installations, and conservation areas, researchers can identify potential conflicts, evaluate cumulative impacts, and inform decision-making processes to mitigate adverse effects. Combining these MCS techniques, MFA promote compliance with fisheries regulations and work towards effective and sustainable management of fisheries resources.

For Mourinha, oversight On-site inspections[8] as an element of MCS activities falls between legislation and procedural decision, and its effectiveness and efficiency of fisheries compliance and enforcement efforts can be assessed through various measures (Mourinha, 2012, p. 101) (Mourinha, 101). Compliance refers to the degree to which individuals and entities adhere to applicable regulations, while efficiency pertains to optimizing the resources expended to achieve compliance (Cohen & Felson, 1979). Rationalist theories of compliance, such as Becker's mode, provide insights into the factors influencing potential offenders´ behaviour (Becker, 1968). According to Becker's model, potential offenders consider three key factors (Mourinha, 2012): the probability of being detected, the probability of being convicted, and the severity of the applicable coercive measures. Increasing any of these factors can potentially deter offenses and improve compliance. One approach to reducing offenses is to increase the severity of the penalties prescribed by law. Harsher sanctions, such as fines, license revocations, or other legal consequences, can act as deterrents by raising the perceived costs of non-compliance. Enhancing the number and effectiveness of enforcement activities can contribute to improved compliance. This involves allocating adequate resources for monitoring, surveillance, and inspections to increase the chances of detecting non-compliance and taking appropriate enforcement actions. Swift and timely sentencing plays a role in deterring potential offenders. When offenders perceive a higher probability of being sentenced in a timely manner, they may be less likely to engage in non-compliant behaviour.

Assessing the effectiveness and efficiency of compliance and enforcement efforts involves evaluating the extent to which these factors influence compliance levels and resource optimization (Abusin & Hassan, 2014, pp. 240–242, 250). This assessment may involve measuring compliance rates, quantifying the allocation of resources, evaluating the frequency and effectiveness of enforcement actions, and considering the timeliness of legal proceedings. However, it's important to note that compliance is a complex issue influenced by various factors beyond just rational calculations of risks and penalties. Socio-economic factors, cultural norms, stakeholder engagement, education, and awareness also play significant roles in shaping compliance behaviour (Ali, 2010, P115). Therefore, a comprehensive approach to fisheries compliance and enforcement should consider these broader dimensions in addition to the rationalist theories of deterrence.

2.6 Economic Exclusive Zone

The Exclusive Economic Zone (EEZ) is a concept established under the United Nations Convention on the Law of the Sea (UNCLOS) in 1982 (United Nations Organization, 1982). It grants coastal states exclusive rights over the exploration and exploitation of natural resources in the oceanic area extending up to 200 nautical miles (370 km) from their land coast. This

[8] On-site inspections - Here it is understood as the product of any legislative process, regardless of who is the entity that issues it

jurisdiction extends to various activities such as fishing, energy production, and the management of marine resources. By defining the boundaries of the EEZ, UNCLOS aimed to reduce disputes over offshore enterprises and promote cooperation among nations. Beyond the limits of the EEZ lies the high seas, which are considered international waters accessible to all countries. The establishment of EEZs expanded the traditionally recognized territorial waters, which were set at 12 nautical miles (22 km) from the coast. Within their EEZs, coastal states have certain rights and responsibilities. They have the authority to conserve and manage fisheries, as well as regulate the production of energy from sources like water and wind. Additionally, coastal states can exercise control over activities related to artificial islands, research stations, and marine preservation.

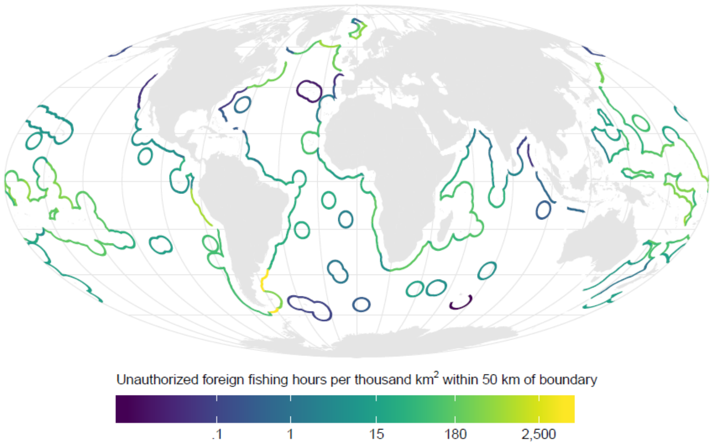


Figure 7 - Unauthorizing foreign fishing hours per thousand Km^2 within 50 Km of boundary

In a study conducted by Englander on the deterrence effect of exclusive economic zones (EEZs) on unauthorized foreign fishing (Englander, 2019). The study utilized GFW data to analyse the fishing activities inside and outside of EEZs and determine the impact of EEZs on deterring unauthorized foreign fishing. According to the study, there is a significant deterrence effect of EEZs on unauthorized foreign fishing. Unauthorized foreign fishing was found to be 81% lower inside EEZs compared to just outside EEZs. This implies that the existence of EEZs plays a crucial role in deterring unauthorized foreign vessels from engaging in fishing activities within these zones.

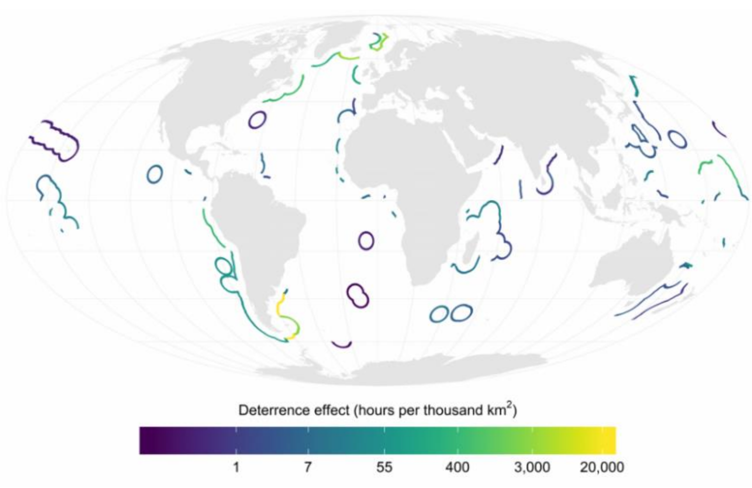


Figure 8- EEZ Deterrence effect (Hours per Thousand Km^2)

The study also identified specific countries and EEZ-sea regions that effectively enforce their EEZs and deter unauthorized foreign fishing. These regions include Argentina, Iceland, Norway, the Faroe Islands, the Falkland Islands, Canada, the Marshall Islands, and Peru. These countries' EEZs contribute to protecting vulnerable species such as the Argentine Angelshark, Greenland Shark, and Atlantic Halibut. However, it is noted that many EEZ-sea regions do not deter unauthorized foreign fishing effectively. Only 10 EEZ-sea regions account for 97% of the global deterrence effect, while the remaining regions either have small deterrence effects or do not deter unauthorized foreign fishing at all. Some EEZs in Africa, for example, were found to have slightly higher unauthorized foreign fishing effort just inside their EEZ boundaries.

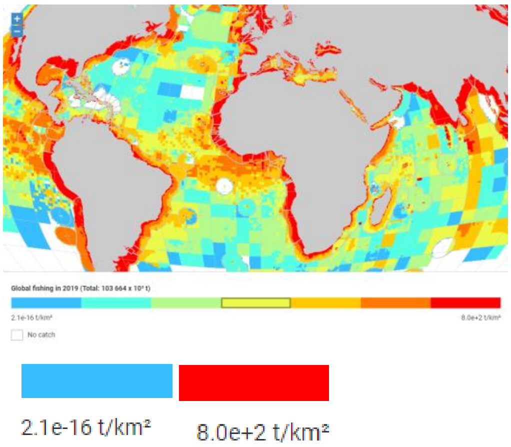


Figure 9 - Global fishing in 2019 (All fishing countries)

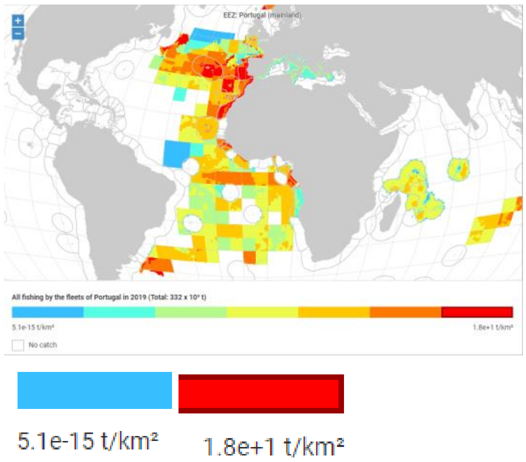


Figure 10 - Global fishing in 2019 (Portugal)

Source: (Sea Around Us, 2019)

In this study it is interesting to observe the comparison of the EEZ of Portugal with the other coastal nations of the world and that for an average of fish in the EEZ of Portugal in the year 2019 presents a value of 1.8 tons/Km2. It is noteworthy however that the number of unauthorized fishing hours per Km^2 within 50 km of the EEZ border is almost non-existent, except in the Madeira EEZ slightly higher, and the dissuasive effect of IUU fishing is only registered in the continental EEZ and northern Madeira EEZ.

The study suggests that the deterrence effect of EEZs depends on the value of the fishery resources near the high seas boundaries of these zones. Countries with valuable fisheries resources are more likely to invest in enforcement measures to protect their interests, such as increasing the presence of patrol vessels and aircraft for monitoring and control. These findings have implications for the design of other conservation and management institutions. For instance, proposed marine protected areas on the high seas may face greater challenges in enforcement due to their remote locations and potential limitations on catch. The study emphasizes the importance of considering the costs and benefits of enforcement when designing conservation measures, as economic incentives influence the decisions made by enforcement entities and ultimately impact conservation outcomes.

2.7 Fishery infringements or crime and its deterrence

Crime theory encompasses various perspectives and frameworks that seek to explain the causes and motivations behind criminal behaviour (Mora, 2010, pp. 10–14). The routine activities theory and the rational choice perspective, which both focus on the opportunity element in crime theory These theories help us understand why individuals engage in illegal activities and provide insights into how infringements or crime can be prevented and controlled. Besides the valuable insights for understanding the causes of crime and developing strategies for crime prevention, they underscore the significance of situational factors and individual decision-making processes in shaping criminal behaviour, assessing the design of targeted interventions to reduce criminal opportunities and discourage potential offenders.

Routine activities theory was developed by (Cohen & Felson, 1979), posits that the occurrence of certain types of crime depends on the convergence of three elements: a motivated offender, an appropriate target, and the absence of a capable guardian[9] became known as "The Chemistry for Crime".

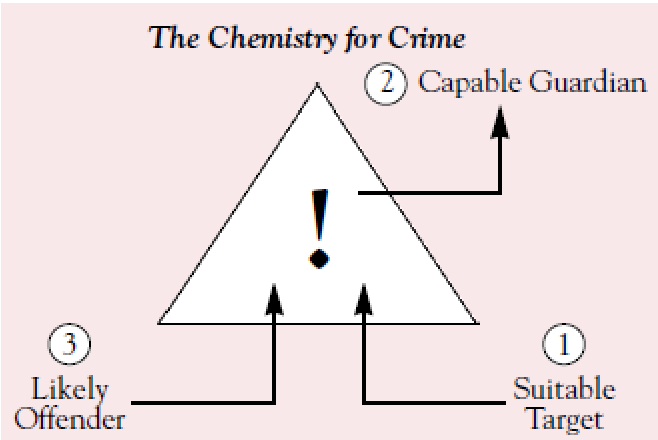


Figure 11 – The Chemistry for Crime, Source: (Felson & Boba, 1998)

Rational choice perspective was developed by (Clarke, 1997), the rational choice perspective focuses on the offender's decision-making process. It assumes that criminal behaviour is an intentional act undertaken to benefit the offender. According to this perspective, offenders weigh the potential rewards and risks before committing a crime. The theory emphasizes that the opportunity for crime, perceived benefits, and perceived costs influence an individual's decision to engage in illegal activities.

Both theories recognize that crime is the result of an assessment of opportunities and costs by the offender. They highlight the importance of reducing opportunities for crime by strengthening the presence of capable and eliminating or minimizing the motivation for offenders. By addressing these factors, crime prevention efforts can be more effective.

There are some key tenets of environmental criminology and its policy implications, studied by Petrossion and Clarke (Petrossian & Clarke, 2020, p. 3). It highlights the importance of situational and environmental factors in shaping criminal behaviour, and it advocates for the design and implementation of targeted measures that reduce crime opportunities and vulnerabilities. Due to a lack of punishment, environmental criminology focusses more on prevention, offering a

[9] Capable Guardian - The term "Guardian" does not necessarily refer to a law enforcement officer or an enforcer. This can include factors such as surveillance cameras, security measures, community members, or even the physical environment that makes the crime more difficult or risky to commit. It highlights that the presence of suitable targets and the lack of effective guardianship contribute to the opportunity for crime (Mora, 2010, p. 11).

nuanced approach to policy solutions instead of contributing to more effective crime reduction efforts. The main points, are:

- Crime is purposive and committed to benefit the offender: Environmental criminology recognizes that criminal behaviour is a purposeful act undertaken to serve the interests or desires of the offender. Criminals engage in illegal activities to gain some form of personal benefit, whether it be financial gain, power, or other incentives.
- Opportunity plays an important role in every form of crime: Environmental criminology emphasizes that crime is influenced by situational factors and the availability of opportunities. Criminals are more likely to commit a crime when they perceive a favourable environment or circumstances that allow them to carry out their illegal acts.
- Crime is highly concentrated where opportunities are the greatest: This premise suggests that crime tends to occur in locations or situations where opportunities for criminal behaviour are abundant. Areas with high population density, economic disparities, or poor security measures may provide greater opportunities for criminal activity.
- All crime can be reduced by design and management measures that reduce crime opportunities: Environmental criminology posits that crime can be effectively reduced by implementing measures that modify the physical and social environment to reduce opportunities for criminal behaviour. By targeting the underlying conditions and situations that facilitate crime, such as improving lighting, enhancing security measures, or altering the layout of public spaces, the likelihood of criminal acts can be diminished.
- Measures must be closely tailored to highly specific but recurring forms of crime: Environmental criminology recognizes that different types of crime have their own unique characteristics and opportunity structures. To effectively prevent and address specific forms of crime, interventions and preventive measures should be customized to address the specific factors and conditions associated with each type of crime.

Focusing on MCS capability, PSM, and deployment of an enforcement fleet, policymakers and stakeholders can prioritize interventions and allocate resources to address specific vulnerabilities and enhance the effectiveness of measures to combat illegal fishing (Petrossian & Clarke, 2020, p. 8). This approach allows for targeted efforts to strengthen MCS capacity, improve enforcement mechanisms, and implement relevant international agreements, all of which can significantly reduce illegal fishing activities and protect fishery resources.

Hatcher (Hatcher & Pascoe, 2006), suggests that the decision to commit an infringement, such as exceeding the allowed catch quota, is determined by the potential benefits and risks involved in the action, considering uncertainties and potential gains. The decision-making process is driven by the perceived expected gain obtained through the infringement action. Kuperan (Kuperan & Sutinen, 1998), identifies a strong relationship between the infringement of legal regulations, specifically exceeding catch quota limits, and the perception of reduced expected gain. Fishermen may choose to exceed catch quotas if they perceive that the benefits of doing so outweigh the potential penalties or costs associated with compliance.

Nye (Nye, 2000, p. 136) argues that dissuasion, which aims to discourage individuals from committing infractions, has been a strategy used throughout history and is not unique to the

Cold War period. Dissuasion often relies on instilling fear in potential offenders to deter them from engaging in illegal activities.

According to Sutinen (Sutinen et al., 1990), the perceived probability of being detected and convicted has a greater impact on deterrence than the severity of the penalty itself. The perception of the risk of getting caught and the subsequent likelihood of facing legal consequences play a significant role in an individual's decision-making process when considering whether to commit an offense. The longer the period between detection and conviction, the lower the perceived cost of the offense, potentially reducing the deterrent effect. Sutinen suggests, the maximum deterrent period for achieving compliance with fisheries laws and regulations is defined as one year. This implies that law enforcement programs and processes that swiftly address potential infractions, leading to timely detection, conviction, and penalty, have a greater deterrent effect. Conversely, delays in the legal process may reduce the perceived cost of the offense and weaken deterrence.

Garoupa (Garoupa, 1997) references the marginal deterrence theory proposed by Stigler (Stigler, 1970). The theory suggests that the sanctioning system should provide clear incentives for individuals to choose the least harmful act when faced with multiple harmful options. In the context of fisheries, this implies that the penalties for infractions should be structured in a way that encourages compliance and discourages more severe violations. By understanding the psychological factors that influence deterrence and implementing a well-designed sanctioning system, policymakers can strive to achieve greater levels of compliance and deter potential offenders in the fisheries sector.

When there is increased pressure on illegal fishing activities, such as enhanced enforcement efforts, the costs associated with evasive actions tend to rise for the remaining illegal vessels (Milliman, 1986). As the risk of detection and penalties increase, offenders may need to invest more resources or adopt more sophisticated tactics to avoid getting caught.

Abusin (Abusin et al., 2012, p. 521), adds that higher fines associated with infractions can lead to a reduction in the number of violations. The prospect of facing significant financial penalties acts as a deterrent for potential offenders, as the potential costs outweigh the benefits of illegal activities. Abusin, also notes that the profits obtained from illegal fishing are a result of finding an optimal balance between evasive efforts and the rate of infractions committed by the offender. This indicates that offenders engage in a cost-benefit analysis, weighing the risks and rewards of their illegal activities.

Kuperan (Kuperan & Sutinen, 1998), suggests that the increased pressure felt by transgressor fishermen is related to their perception of a higher probability of being detected. When the risk of being caught and facing legal consequences is perceived as greater, offenders may be more inclined to invest in evasive actions or reconsider engaging in illegal fishing altogether. The dynamics between these factors can inform the development of effective strategies and policies to combat illegal fishing and promote compliance with fisheries regulations.

The probability of detection influences the evasive actions taken by offenders to avoid being caught by patrol vessels or other enforcement authorities (Milliman, 1986). As the probability of detection increases, offenders may engage in more elaborate and costly evasive actions to escape detection and continue their illegal activities. Abusin & Hassan, (2014) points out that the variability of the probability of detection can be influenced by factors outside the control of offenders. For example, the inherent fear of the risk of being apprehended can impact the perception of the probability of detection, influencing offenders' decision-making processes and behaviors. The probability of detection is jointly determined by the characteristics of each individual offender and the resources allocated to law enforcement in response to illegal acts (Garoupa, 1997). The level of enforcement expenditure and the effectiveness of enforcement efforts play a significant role in shaping the perceived risk of being detected and the overall deterrence effect. Ensuring an appropriate balance between enforcement expenditure and the probability of detection is crucial for maintaining a deterrent effect and promoting compliance with fisheries regulations.

Higher penalties are associated with a lower number of infractions (Furlong, 1991). The severity of the penalty acts as a deterrent, discouraging potential offenders from engaging in illegal fishing activities. It is important to align the value of the penalty with the expected gains resulting from the infractions it aims to dissuade. Hatcher & Pascoe, (2006) argue that increasing the value of penalties associated with repressing illegal fishing may be counterproductive, especially in precarious sectors like fishing. The effectiveness of penalties can be compromised if they impose significant financial burdens on fishermen without addressing the underlying reasons for non-compliance. Care should be taken to ensure that penalties are proportionate and do not have unintended negative consequences.

The income, is influenced by various factors such as fish abundance in different fishing grounds, plays a crucial role in the decision-making process of fishermen regarding compliance with fishing regulations (Kuperan & Sutinen, 1998). The potential economic gains from fishing activities, particularly in specific fishing zones, can influence the choices made by fishermen. One of the key decisions made by fishermen is the choice of fishing zone (Mistiaen & Strand, 2000). Factors such as fish abundance, market demand, and revenue potential influence the selection of fishing grounds. The availability of resources and income opportunities in a specific fishing zone can determine whether fishermen choose to operate in that area or abandon it. In conclusion the increased revenue in a specific fishing zone influences the choice to operate in that zone (Curtis & Hicks, 2000). Conversely, a decrease in revenue may lead to the abandonment of that fishing zone. Economic considerations, including revenue potential, profitability, and resource availability, impact the decisions made by fishermen regarding fishing zone selection. By aligning penalties with the potential gains from illegal fishing, addressing underlying economic factors, and promoting sustainable income opportunities, policymakers can work towards compliance and sustainable fishing practices.

The decision-making process in fisheries is dynamic, meaning that it is influenced by numerous variables that vary over time and space (Jagers et al., 2012) (Rei et al., 2017). Fishermen must continually assess and adapt to changing conditions, such as fish abundance, environmental factors, market demand, and regulatory measures. These dynamics can impact catch rates and ultimately affect profitability. The decision support variables that influence fishermen's choices and potential infractions, include factors related to time, such as seasonality, fishing effort, and temporal restrictions; factors related to space, such as fishing grounds, fishing zones, and spatial management measures; and factors related to uncertainty, such as fluctuating fish stocks, market conditions, and regulatory changes. The interplay of these variables adds complexity to the decision-making process.

2.8 Summary

The importance of establishing social networks and common goals to promote social justice, enhance sustainability, and involve stakeholders in decision-making processes, is emphasized in different research studies as the FPIs provide a valuable tool for comparing and analysing fishery performance, identifying successful fisheries, and areas lacking support. SDG 14 focuses on marine conservation, sustainable fisheries, and the mitigation of ocean-related challenges. SDG 14.4 aims to regulate harvesting, end overfishing and destructive practices, while SDG 14.4.1 measures the proportion of fish stocks within sustainable levels.

Improved fisheries management and conservation efforts are urgently needed to reverse declining fishery stocks and unsustainable fishing practices. Science-based decision-making, effective catch limits, and ecosystem-based approaches are crucial for long-term viability, biodiversity protection, and sustaining livelihoods. The FAO's 'Blue Transformation' initiative aims to provide knowledge and tools for maximizing the contribution of aquatic food systems to food security, nutrition, and affordable diets. The initiative focuses on sustainable aquaculture expansion, effective fisheries management, and upgraded value chains.

IUU fishing is considered a serious environmental crime with significant negative impacts on marine ecosystems, fish stocks, and coastal communities. IUU fishing involves fishing activities that violate national or international laws and regulations, often employing deceptive practices to avoid detection and enforcement efforts. To combat IUU fishing effectively, robust MCS measures are essential. These measures involve the use of various technologies and strategies to monitor, track, and enforce fishing activities.

International cooperation, information sharing, and coordination among coastal states and regional fisheries management organizations are vital to combat overfishing, IUU fishing, and destructive practices on a global scale.

The CFP introduced MSY as the management target to achieve sustainable fishing levels. The LO aimed to address discarding by requiring the landing and accounting of all catches. The Portuguese National Strategy for Sea focuses on sustainable development, responsible fisheries practices, and surveillance mechanisms. Maritime surveillance, including VMS, satellite imagery, aerial surveillance, and information systems, plays a crucial role in monitoring fishing activities, enhancing compliance, and preventing IUU fishing.

Deterrence theories, such as routine activities theory and rational choice perspective, help explain criminal behaviour and provide insights into preventing and controlling infringements or crimes in fisheries. Swift and timely sentencing increased perceived risks of detection, and addressing economic factors can enhance deterrence. EEZs have a significant deterrence effect on unauthorized foreign fishing, reducing it by 81% compared to just outside EEZs. Effective fishery enforcement requires the presence of capable guardians, comprehensive monitoring, reporting, and control systems, and the allocation of resources to detect, convict, and penalize offenders promptly.

Despite the decision-making process in fisheries is dynamic, meaning that it is influenced by numerous variables that vary over time and space, the importance of sustainable fisheries management, effective enforcement measures, international cooperation, and stakeholder engagement are crucial for achieving the goals of marine conservation, ending overfishing, and combating illegal fishing practices. Fisheries indicators for MCS measuring is quite highlighted for enable effective management approaches and can be supplemented with additional indicators to test hypotheses and enhance sustainability.

3 Indicators for measure surveillance effect

The focus of this paper is to address the central question of: How can the effect of maritime surveillance on the occurrence of fisheries-related infringements be measured? It´s crucial to identify the indicators that can effectively measure the impact of surveillance on such infringements.

3.1 Concept

As mentioned by Ribeiro (Ribeiro, 2010, p. 15), the process of strategy formulation is intertwined with a complex set of variables and their operationalization. Chapter 2 of the source examines the dynamic and complex variables that underpin the strategies adopted by initiatives such as the FAO Blue Transformation initiative, the EU CPF framework law and its regulations, the Portuguese National Strategy for Sea, Portuguese laws, and Portuguese MCS SIFICAP.

Caldeira argues (Caldeira, 2009, p. 15), that strategic, activity, and budget plans play a significant role in outlining the appropriate path towards fulfilling the corporate mission. However, it is through the monitoring process that the indicators, which best reflect the elements of these plans, are consolidated (Caldeira, 2009, p. 16). Reporting is a key component of the monitoring process, as it involves documenting and presenting crucial business information such as business results, impact assessments, and achieving visibility through reports, tables, or graphics.

One of the preferred tools for monitoring performance is management by objectives, which relies on monitoring results. It enables effective management (Caldeira, 2009, p. 17), by identifying objectives or benefits associated with indicators, including deviations and their causes, future restrictions, corrective or preventive actions, adjustments to goals and responsibilities, and fostering interaction among stakeholders while reinforcing the corporate image.

Chiavenato (Chiavenato & Sapiro, 2003) suggests that operationalizing the control and feedback function involves four phases: identifying what needs to be measured, setting standards based on strategic objectives, rigorously measuring performance, comparing achieved results with expectations (standards), and identifying deviations, followed by taking corrective action to address identified deviations and reinforce positive aspects of the process. The feedback function, as emphasized by (Ribeiro, 2010, p. 201), is crucial in providing and updating the necessary information for decision-makers responsible for adjusting the control mechanism.

Performance measurement involves quantifying actions taken by management, and it is a crucial process for evaluating how well an operation is fulfilling its performance objectives to satisfy customers, as described by Slack (Slack et al., 2010, p. 609). It allows for judging the effectiveness of an operation, indicating whether it is performing well, poorly, or somewhere in between. When selecting performance measures, there is a need to strike a balance between having a few key measures that are simple but may not capture the full range of organizational objectives, and having many detailed measures that are complex and challenging to manage but provide a more detailed understanding of performance. The key is to ensure that there is a clear link between the overall strategy of the operation and the detailed measures used to support each key performance indicator. This alignment ensures that the performance measures effectively reflect the operation's strategic objectives.

The specific objective that emerges as a performance measure for maritime control and surveillance of fisheries offences, is the deterrence indicator.

3.2 Characteristics for a good indicator

The concepts underlying the management indicators can provide clear and objective information, allowing for effective performance analysis and decision-making, are for Caldeira (Caldeira, 2022, pp. 14, 15) in a gathered way: Indicator name; Objective with clarification of the purpose and way of expressing the information that the indicator represents; Indication of whether the indicator is a KPI; What algorithm is used, what is the result and the conditions for obtaining this result; Quantification of the target; Deviation between the target and the result obtained; Performance is a way of presenting the result by comparing indicators with different units of measurement; Qualitative assessment obtained according to the performance and deviation recorded. Caldeira defines also that an indicator can integrate a total of fifteen characteristics, which classify it as a good indicator although it is difficult to find indicators with all these characteristics (Annex D). However, even without all the characteristics, it is always a viable indicator to be included in the performance analysis.

In the context of key performance indicators (KPIs) (Peterson & demystified, 2006, p. 14) argues, that it is crucial to avoid overwhelming stakeholders with irrelevant data that provides little value. KPIs should be: (1) Hierarchical, tailored, meaningful, and actionable, (2) Focus on the most critical information that directly impacts areas of responsibility, (3) Be open to suggestions, fostering better decision-making, and driving performance improvement. In addition, PN surveillance indicators of fishing vessel activities can be used as a measure of the effect of surveillance on compliance with fisheries legislation (EFCA, 2021, p. 4). The indicators are tailored to the legal framework defined by the EU and, with the appropriate adaptation to the Portuguese fishing fleet, defined by the DGRM and in line with the EFCA: (1) Non qualification to exercise fishing activity; (2) Illegal use of fishing gear; (3) Fishing activity in an unauthorised area; (4) Non-compliance with the general regulation of fishing activity.

The "SMART" criteria, (Doran, 1981) in the context of management objectives, can be adapted and applied to the development of indicators, including those related to combating illegal fishing. The SMART criteria provide a framework for creating indicators that are effective, practical, and meaningful (Annex E).

3.3 General surveillance fishery indicators

For enhance the surveillance measure, were identified five indicators to conduct the beginning of the present analysis. The indicators, are:

- Inspections
  Number of inspections conducted at sea, how many of them are detected:
  - Legal: detected with on the legal normative compliance.
  - Illegal: detected with infractions on the legal normative compliance.
- Fishing vessels
  All the fishing vessels inspections are validated by the PN name as the survey vessel, date, time, geographic position, fishing vessel name, national registered number, and the result of the inspection (Legal or infraction).

Note: One inspection has only one fishing vessel associated, but one fishing vessel could have one or more inspections.

- Violation code

  The violation code represents non-compliance with the legal obligation for fishing activity. There are fourteen codes to aggregate different types of noncompliance (Annex F).
- Fishing Gear

  On inspection, which gears are registered to the fishing vessel. For the grouping types of gear, it´s used an equivalent table from EU CFP legal framework and the different types registered in Portuguese inspections.
- Geographic Position, Captaincy or Zone

  Every geographic position where the inspection was made, are set in the twenty-eight captaincy areas identified in the table 1 of the annex of document law (DL265), entitles to visualise in a geographic map:
  - The position related to other inspections of same fishing vessel and other vessels in the same period and space zone (North, Centre, South, Madeira, and Azores Islands).
  - The visualization on the map the position of the type of result of the inspection.
  - According to the analysis request, all information obtained in the indicators should interact between all indicators.

In analysing the results of indicators, it is necessary to allow the operator carrying out the analysis to develop in a top-down manner from the general to the particular and to change according to curiosity or research interest. In this case, allow the analysis to develop:

- Inspection by Result
- Vessels by Result
- Areas by Result
- Result by Violation Code (I – XIV)
- Fishing gear by Result
- And Interaction with each indicator

The work by Pingguo He, (Pingguo He, 2021, p. 4) provides a comprehensive classification and definition of various types of fishing gear. According to He, the term "fish" encompasses all aquatic animals caught by fishing gear, which includes not only fish but also Crustacea and Mollusca, unless otherwise specified. To define fishing gear, He adopts the definition provided in Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL). According to this definition:

“A fishing gear is any physical device or part thereof, or combination of items that may be placed on or in the water or on the seabed with the intended purpose of capturing or controlling for subsequent capture or harvesting marine or freshwater organisms.”

By adopting this definition, Pingguo He establishes a clear and inclusive understanding of fishing gear, encompassing a wide range of tools, equipment, and devices used in fishing activities. This comprehensive definition allows for a better understanding and approach of the different types of fishing gear and their specific purposes in capturing or controlling aquatic organisms, although is the EU fishing gear code that this study will follow.

To establish the fishing gear indicator, is established in smaller groups by an equivalent terms and types, to group the different Portuguese fishing gear types following the EU fishing gear code in the annex G.

The relevance of eventual correlation between fishing gear type and deterrence effect level, and violation code, would give different insight about patterns of fishing activities, by date and zone of fishing activity.

3.4 Fishery deterrence model

Measuring the deterrent effect of enforcement actions for fishery infringements, is crucial in assessing what indicators would support MCS actions in deterring future non-compliance and illegal activities. These indicators could include metrics such as the reduction in the number of repeat offenses, the decrease in the incidence of non-compliance, the increase in voluntary compliance, or the change in attitudes and perceptions of stakeholders towards compliance and enforcement. It may also discuss different indicators that have been proposed or used in previous studies to measure the deterrent effect of enforcement actions and explore the conceptual framework or methodology that will guide the research in identifying and analysing the relevant indicators.

Underscore the importance of recognizing the dynamic nature of illegal fishing, by implementing appropriate sanctions, and developing deterrence models that account for the repeated nature of the fisheries infringements, it´s relevant to seek among various aspects of repeated illegal fishing and find the right approach to address non-compliance (Abusin, 2015, p. 2107) (Vulperhorst et al., 2019, p. 15). A model of deterrence can be useful in combating illegal fishing. Deterrence refers to the use of penalties, enforcement measures, monitor repeated fishery offenses and other strategies to discourage individuals and entities from engaging in illegal fishing (Lubchenco & Haugan, 2023, p. 285) (Garoupa, 1997, p. 278). By creating a credible threat of detection and punishment, deterrence aims to dissuade potential offenders and encourage compliance with fishing regulations and conservation measures.

A well-designed deterrence model considers various factors that influence the decision-making process of fishers, such as the expected benefits from illegal fishing, the perceived risk of detection and punishment, and the potential long-term consequences. It considers the dynamic nature of illegal fishing and the repeated actions of offenders.

3.5 Deterrence effect indicator

From the analysis of the previous indicators, it is possible to create a variable that represents the differences between the groups of results that are intended to be discriminated from the inspection result indicator, whose value is legal or illegal, being a necessary condition: obtaining the result of two consecutive inspections of the same fishing boat. Thus, it is attainable to create the deterrence effect level, with the grouping of sequences of the of inspections result to measure the how high or low is the compliance or not in legal fisheries activity. The table 3, and figure 12, illustrate better the “Deterrence effect level formulation”.

Sequence 1ª Inspection	Sequence 2ª Inspection	Deterrence Effect Level (DEL) Type	Deterrence Effect Level (DEL) Category
Legal	-	Not applicable	Single Inspection
Illegal	-	Not applicable	First (1^{st}) Inspection
Legal	Legal	DEL 1	High
Illegal	Legal	DEL 2	Medium High
Legal	Illegal	DEL 3	Medium Low
Illegal	Illegal	DEL 4	Low

Table 3- Deterrence effect level formulation

However, if the analysis is conducted in period of a fishing vessel which has only one inspection registered in all data at the present situation, there is no deterrence effect possible to assess (Figure 12 – Line 1: Single inspection). And as the in case, when the period selected for the analysis is setting only the first inspection, because the analysis always needs a sequence of two followed inspections to categorize the deterrence effect level (Figure 12 – Line 2: First [1^{st}] inspection). In this line 2, the period for analysis is set on data, that has no information before the first inspection. Thus, in line 3, although the period is set for only one inspection, the system, can analyse the deterrence effect level, because there is information before moment set with only one inspection.

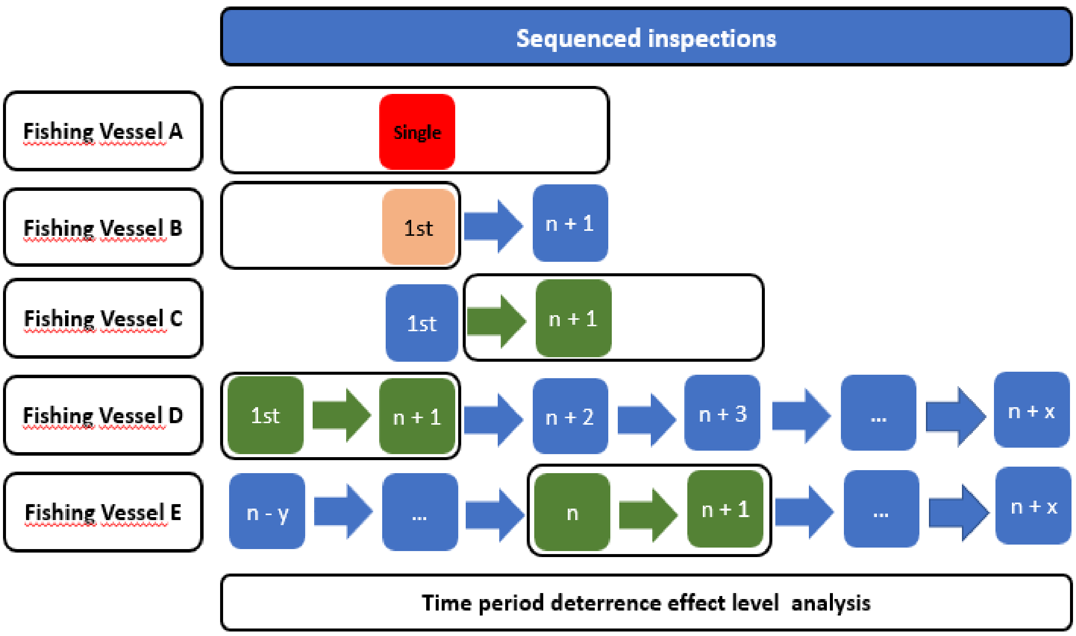


Figure 12 – Deterrence effect level for the sequence analysis inspections, on each fisshing vessel inspected

The cases in lines 4 and 5, quite simple to understand that in each situation there is always information before on the period set for the analysis the deterrence effect level.

Fishing Vessel	Insp 1	Insp 2	Insp 3	Insp 4	Insp 5	Insp 6
Vessel A	I	L	L	L	L	L
Date	23MAR	27ABR	21JUN	10NOV	26NOV	27DEZ
Deterrence Effect Level	DEL 2	DEL 1	DEL 1	DEL 1	DEL1	
Vessel B	L	L	I	I	I	I
Date	12MAR	18MAI	02JUL	14AGO	26OUT	08NOV
Deterrence Effect Level	DEL 1	DEL3	DEL 4	DEL 4	DEL 4	
Vessel C	I	L	I	L	L	I
Date	11FEV	26MAI	02JUN	12JUL	12SET	27OUT
Deterrence Effect Level	DEL 2	DEL 3	DEL 2	DEL 1	DEL 3	
Vessel D	L	I	I			
Date	27MAR	26OUT	21NOV			
Deterrence Effect Level	DEL 3	DEL 4				

Table 4- Example for DEL analysis in four fishing vessels

In table 4, the deterrence effect level enhances the number of infracts in a sequence. For instance, the vessel B, between 12th March and 18th of May shows a high level of deterrence effect, because in both inspections the result was legal. Between 18th of May and 2nd of July, it was not so good, because the inspection on 2nd of July the result was illegal, and shows a medium high DEL. And worst, was the next sequence between because all the next inspections were illegal. Which shows the lowest DEL. Which is the same to say, that the type of fisherman that repeats several times de noncompliance in the regulations for the fishing activity.

With DEL, the analysis in the table 4, and considering that all the first inspections were as the table are showing, can be simpler of reading only the DEL analysing, and can summarized for the period of the four vessels, as follows:

- Vessel A: In six inspections, one was illegal and shows 5 times high DEL;
- Vessel B: In six inspections, four were illegal, has in sequence one high DEL, one medium low DEL, and three low DEL;
- Vessel C: in six inspections, three were illegal, has in sequence one medium high DEL, one medium low DEL, one medium high DEL, one high DEL, and one medium low DEL.
- Vessel D: In three inspections, two were illegal, has in sequence one medium low DEL and one low DEL.

So, as much information gather on dataset, as better the deterrence effect level can show, mainly if a is registered the minimum of two inspections. Having single inspection is better of having nothing, because with just one more inspection is achievable the deterrence effect level.

In the analysis is missing a wide broad analysis for see the relationship between the DEL with the fishing gear, the violation code, and the geographic zone that DEL interacts or on the other hand how does the other variables interact with the DEL.

The deterrence effect level measures the effectiveness of surveillance efforts in deterring fisheries infringements by assessing the impact of enforcement actions on reducing non-compliance and illegal activities. To measure the deterrence effect level, various indicators and metrics can be used, depending on the specific context and goals of the monitoring program.

The deterrence effect indicator metric is the reduction in the number of repeat offenses. This can be measured by tracking the proportion of fishing vessels or individuals that engage in repeat infringements over a specific period. A decrease in the rate of repeat offenses indicates that enforcement actions have had a deterrent effect on potential offenders.

Monitoring the overall incidence of non-compliance with fisheries regulations can provide insights into the deterrence effect. By comparing the rate of non-compliance before and after enforcement actions, it is possible to determine whether the presence of surveillance has reduced the occurrence of infringements.

Assessing the attitudes and perceptions of stakeholders towards compliance and enforcement can provide indirect indicators of the deterrence effect. Surveys or interviews can be conducted to gather feedback on perceived risks, penalties, and the effectiveness of surveillance measures. Positive changes in attitudes and perceptions indicate a potential deterrence effect.

For that it´s necessary to requires other kind of tools that can analyse in a dynamic way the five indicators interacting with the Deterrence Effect Level, such as Business Intelligence tools.

3.6 Summary

The importance of selecting appropriate indicators, monitoring performance, and select tools to measure the deterrent effect of enforcement actions in fisheries control and surveillance, require a well-defined strategy and the analysis of various factors to gain insights into the effectiveness of these actions.

Management by objectives is a preferred tool for monitoring performance and enables effective management by identifying objectives and associated indicators, deviations, future restrictions, corrective actions, and fostering stakeholder interaction. The deterrence indicator emerges as a specific objective for monitoring the performance of maritime control and surveillance of fisheries offences. Foster indicators that possess as much as the fifteen characteristics are to be considered good indicators, although it is difficult to find indicators with all these characteristics.

The chosen fishery indicators for the analysis include the number of inspections conducted at sea, fishing vessels' general characteristics (Date time, name and registered number), type of infraction, fishing gear, and geographic positions of inspections. The correlation between fishing gear type and the deterrence effect level, as well as the violation code, can provide insights into patterns of fishing activities by date and fishing zone.

Monitoring the reduction in repeat offenses and the overall incidence of non-compliance with fisheries regulations are two key metrics that can be used to measure the deterrence effect in surveillance of fisheries infringements. By tracking the proportion of fishing vessels or individuals that engage in repeat infringements over a specific period, you can assess the effectiveness of enforcement actions in deterring potential offenders. If there is a decrease in the rate of repeat offenses, it indicates that the presence of surveillance and enforcement measures has had a deterrent effect, discouraging individuals from committing further infringements.

Similarly, by monitoring the overall incidence of non-compliance with fisheries regulations, you can evaluate whether the presence of surveillance has reduced the occurrence of infringements. By comparing the rate of non-compliance before and after enforcement actions, you can assess the impact of surveillance efforts in promoting compliance and deterring potential offenders.

A well-defined strategy is essential for targeting a narrow range of key performance indicators, and the monitoring process, reporting, and management by objectives play crucial roles in evaluating performance and facilitating corrective actions.

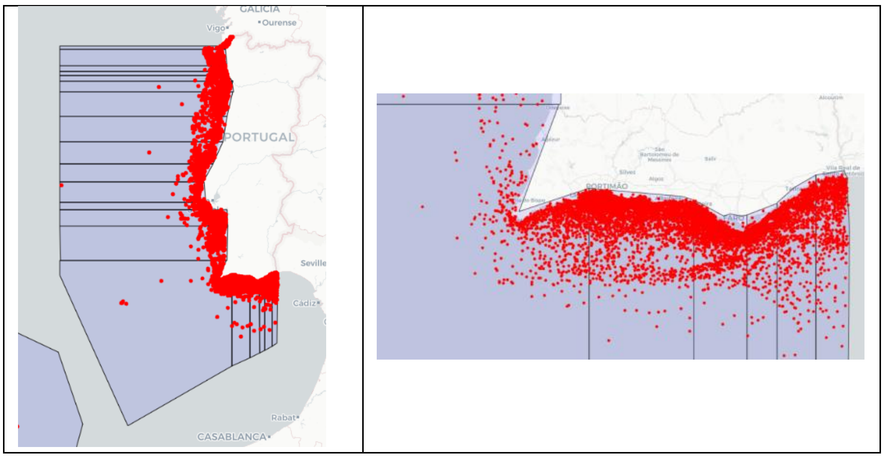
Analysing the relationship between the deterrence effect indicator and fishing gear, violation code, and geographic zone requires the selection of Business Intelligence (BI) tools, such as Tableau, Power BI, or QlikView. These BI Tools, provide advanced data visualization, analysis capabilities, interactive dashboards, reports, and visualizations that facilitate the understanding and interpretation of data, including the measurement and a comprehensive assessment of deterrent effects.

4 Business Intelligence Solution to report fishery surveillance

Once described the indicators that describe how to measure the effect of maritime surveillance related to infractions in fishing activity, to which the development of the Business Intelligence solution will respond, follows the description of a brief description of: (1) Data source, (2) Data process and transform data, (3) Model definition, and (4) Report – Power BI, requiring the BI solution.

4.1 Data source

The data source has as basis the data collected by, during fisheries inspections made ate sea by PN. The PN database to gather the fisheries inspection information is designated as decision support system for patrol activity (SADAP – Portuguese Acronym).



4.2 Data processing and transformation

To process the raw data into useful information are made three transformations, which one is using the Python code for get a useful dataset to load the power BI, and the third one is python code also, but to get a report information about density map of fisheries inspection activity three main zone of Portugal: Continental cost, Madeira and Azores Islands.

4.2.1 Transform 1

To get the DEL for each inspetion made, it´s used a python script to assign the DEL in each record of dataset. Using the file source and the Python script designated is got the outputfile, that will be used in other python scripts and for the BI tool.

File source	Python Script	Outputfile
BDados_FISCREP_2022.xlsx	Friscrep.ipnb Annex A	dataset_cat1.xlsx

Previewn in Jupiter notebook:

Out[10]:

	Nome	GDH (AAAAMMDD)	Resultado (âmbito CN)	Categoria
4174	COSTA SUL	2010-03-23	Presumível infrator	1ª Fiscalização
4175	COSTA SUL	2010-08-01	Presumível infrator	Type 4
4176	COSTA SUL	2010-08-25	Legal	Type 2
4177	COSTA SUL	2010-10-09	Presumível infrator	Type 3
4178	COSTA SUL	2010-10-17	Presumível infrator	Type 4

4.2.2 Transform 2

To preform the geo referenced identification of each record with the result of inspection and its DEL associated to the EEZ jurisdictional area, is set the EEZ zones for the twenty eight capitancies in the Portugal continental coast, Madeira and Azores Islands.

To visualise in the Jupiter notebook the points that define the polygons of the areas that limit the zones of jusisdiction of the Portuguese EEZ, it was necessary to create the file in QGis with the extension shapefile (shp). The name of the file is: Capitanias.shp.

Using the file source and the Python script designated is got the outputfile, that will be used in other python scripts and for the BI tool.

File source	Python Script	Outputfile
BDados_FISCREP_2022.xlsx Capitanias.shp	Fiscrep com Categorias e Capitanias.ipnb (ANNEX B)	intersected_geometry.csv

Previewn in Jupiter notebook:

Latitude (decimal)	Longitude (decimal)	Categoria	geometry	Capitania
37.083833	-8.493333	1ª Fiscalização	POINT (-8.49333 37.08383)	Portimão
37.095000	-8.548667	Type 4	POINT (-8.54867 37.09500)	Portimão
37.096667	-8.513333	Type 3	POINT (-8.51333 37.09667)	Portimão
37.112833	-8.562333	Type 3	POINT (-8.56233 37.11283)	Portimão
37.103000	-8.533833	Única Fiscalização	POINT (-8.53383 37.10300)	Portimão

4.2.3 Transform 3

To vizualize a density map with help of Pytho script, is set the

File source	Python Script	Outputfile
categorias_1.xlsx Capitanias.shp intersected_geometry.csv	Capitanias.ipnb (ANNEX C)	heatmap.html

4.2.4 Resume of Transformation

Overall Tranformation data in output information

Process	File source	Python Script	Outputfile	Source for power BI
1	BDados_FISCREP_ 2022.xlsx	Friscrep.ipnb Annex A	dataset_cat1.xlsx	Yes
2	BDados_FISCREP_ 2022.xlsx Capitanias.shp	Fiscrep com Categorias e Capitanias.ipnb (ANNEX B)	intersected_geo metry.csv	Yes
3	categorias_1.xlsx Capitanias.shp intersected_geo metry.csv	Capitanias.ipnb (ANNEX C)	heatmap.html	No

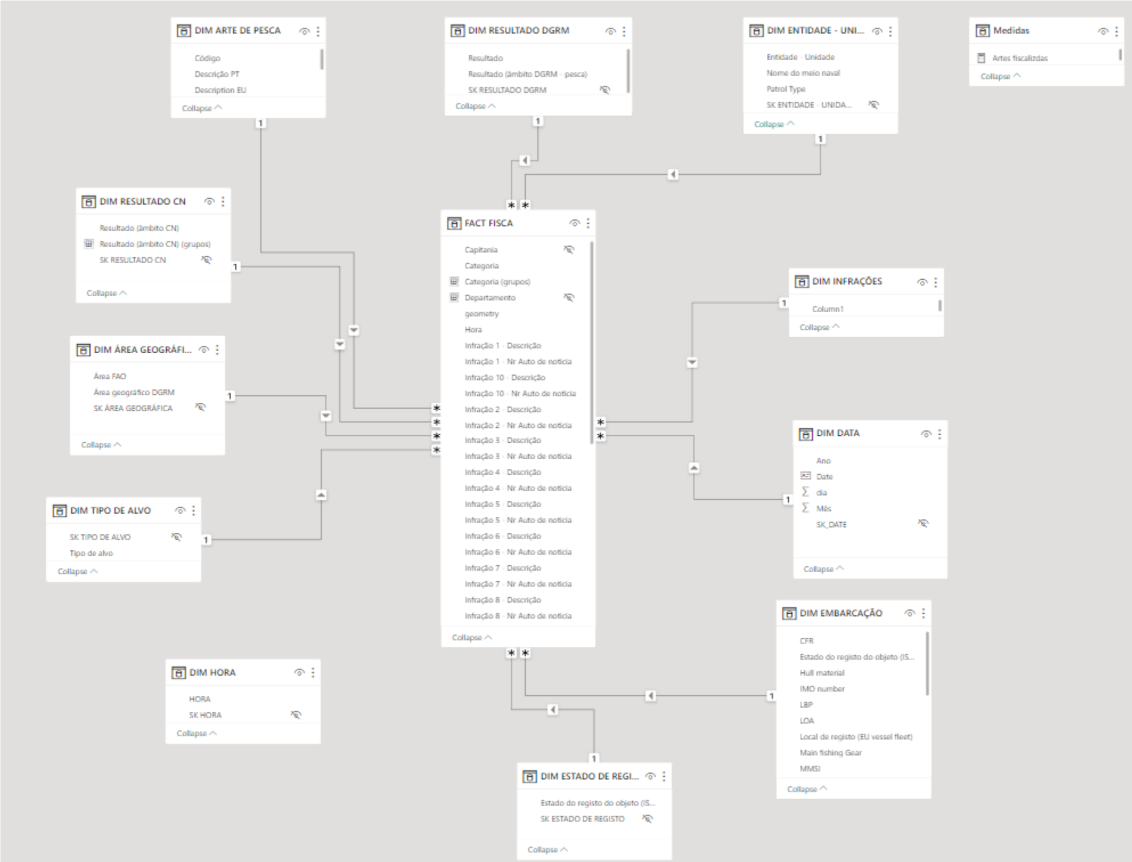
The python code and BI solution developed are available on Github.

4.3 Model

4.3.1 Dimensional Model – Star Schema

The option in the BI tool solution is developed in the Star Schema dimensional model idealized by Ralph Kimball. This model presents added value in terms of performance of the Reports that will consult the Data Warehouse and also presents a stable basis for backups and recovery - "A star schema hosted in a relational database is a good physical Foundation for building an OLAP cube and is generally regarded as a more stable basis for backup and recovery."

The design of our dimensional model followed the methodology developed by Ralph Kimball, called "Four-Step Dimensional Design Process" (Kimball, 2013). This methodology follows four fundamental steps: Select the business process, Declare the grain, Identify the dimensions and, Identify the facts (Kimball, 2013).



4.3.2 Grain detail

This step refers to the definition of the granularity, i.e. what each row of the fact table represents individually - what is the level of detail associated with the measures of the fact table (Kimball, 2013, p.71). In the specific case of our model, the granularity of the fact table will be "Inspections Result", i.e. each row of our fact table represents the sale of a product. The granularity of the fact table "Evaluations" will be the evaluations, i.e. each row of this fact table represents the evaluation of a product made on a given date.

4.3.3 Dimensions

Following the methodology defined by Raph Kimball, we designed the dimensions based on the questions they should answer: "who, what, where, when, why, and how" (Kimball, 2013, p. 72). Thus, the dimensions identified for our model are the following:

Who - DimClients

When - DimCalendar, DimCampaigns and DimMetereology

What - DimProducts

Following the methodology defined by Raph Kimball, we designed the dimensions based on the questions they should answer: "who, what, where, when, why, and how" (Kimball, 2013, p. 72). Thus, the dimensions identified for our model are the following:

Who – Dim_Fishing Vessel Name

When – Dim_Date

What – Dim_InspectionsResult

As already mentioned at the beginning of this chapter 3, we opted for the Star Schema model in the design of the Dimensional Model (presented below), not only because it was a recommendation and is widely used, but also because it brings with it performance gains when executing queries for reporting purposes (Kimball, 2013). In this way it could lead our solution to be a good and efficient decision support system in the future.

4.3.4 Facts

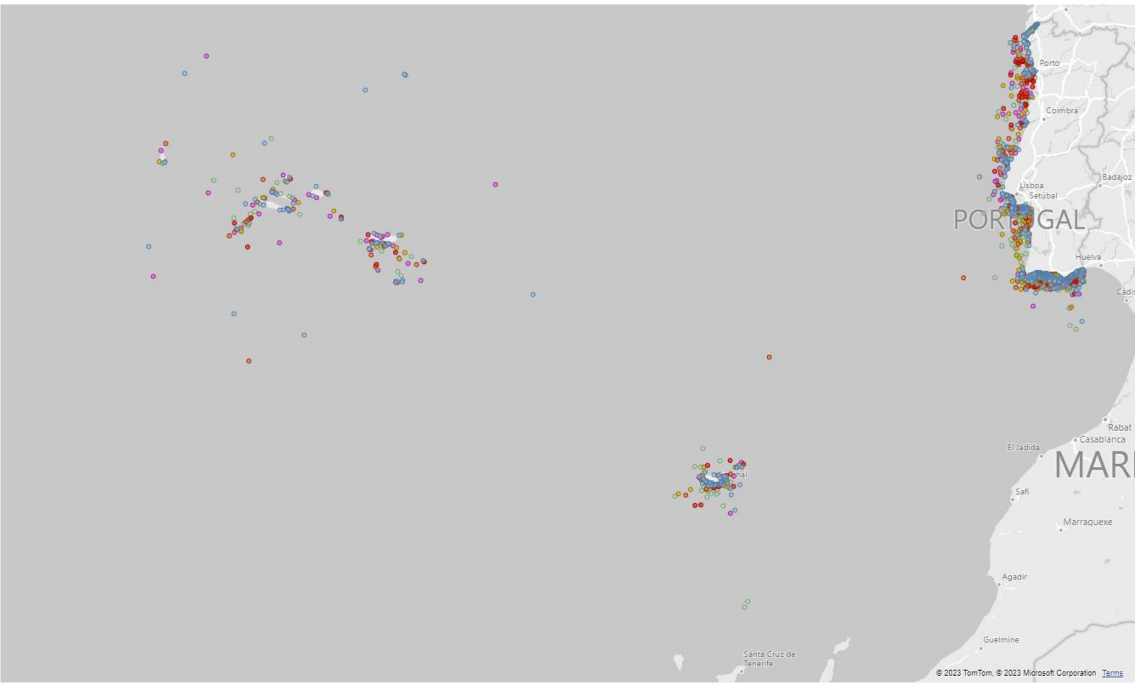
In this work the fact table is called "FACT FISCA".

It is composed of dimensions, analysis measures, and Surrogate Keys that relate it dimensions: Captaincy, Category, Department, Geometry, Infraction, Geographic coordinates (LAT&Long).

4.4 Report – Power BI

The report is dived in five analysis screens:

(1) Overall Statistics
(2) Fisihng Vessels, Gear, Infractions
(3) Repeated inspections
(4) Infractions by capitancy
(5) Vessel & Zone Detail


PORTUGAL
Porto
Coimbra
Lisboa
Setúbal
Badajoz
Huelva
Rabat
Casablanca
El Jadida
Safi
Marraquexe
Agadir
Guelmine
Santa Cruz de Tenerife
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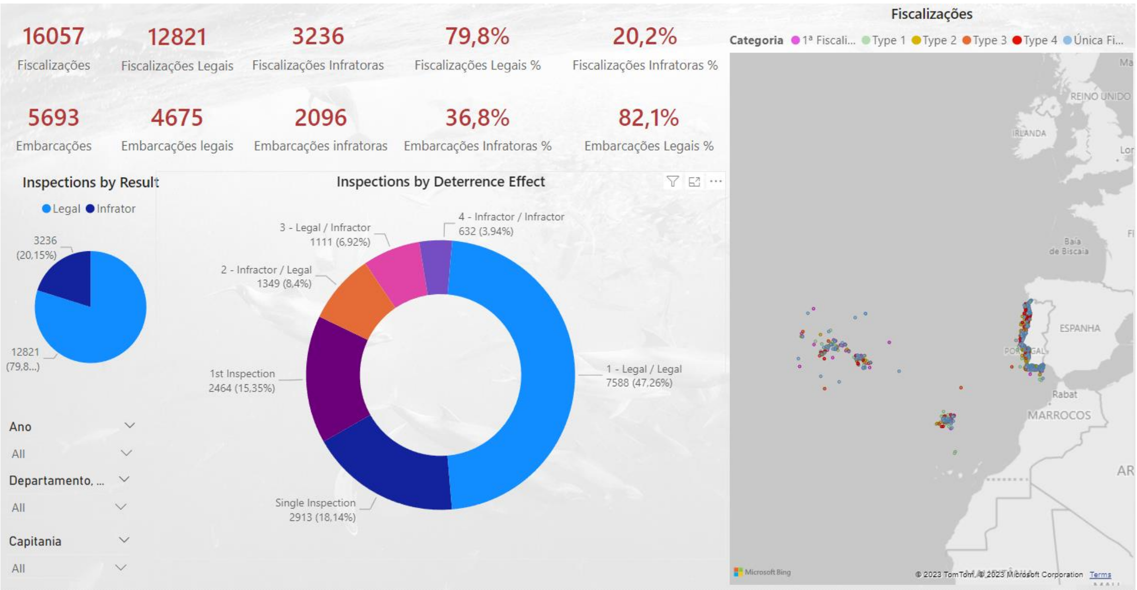
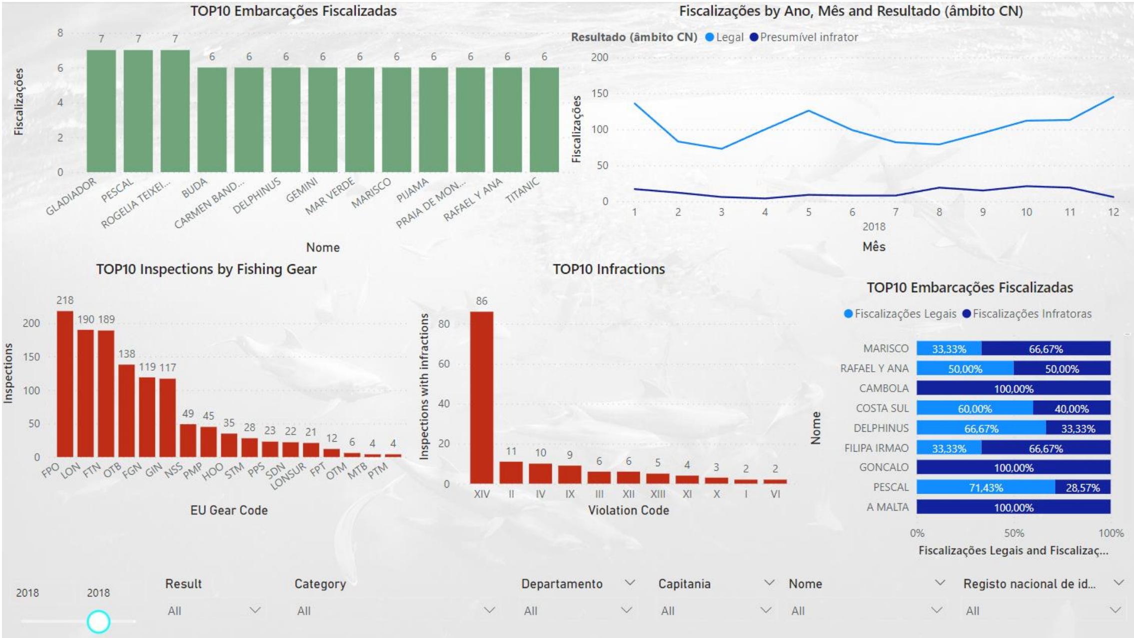
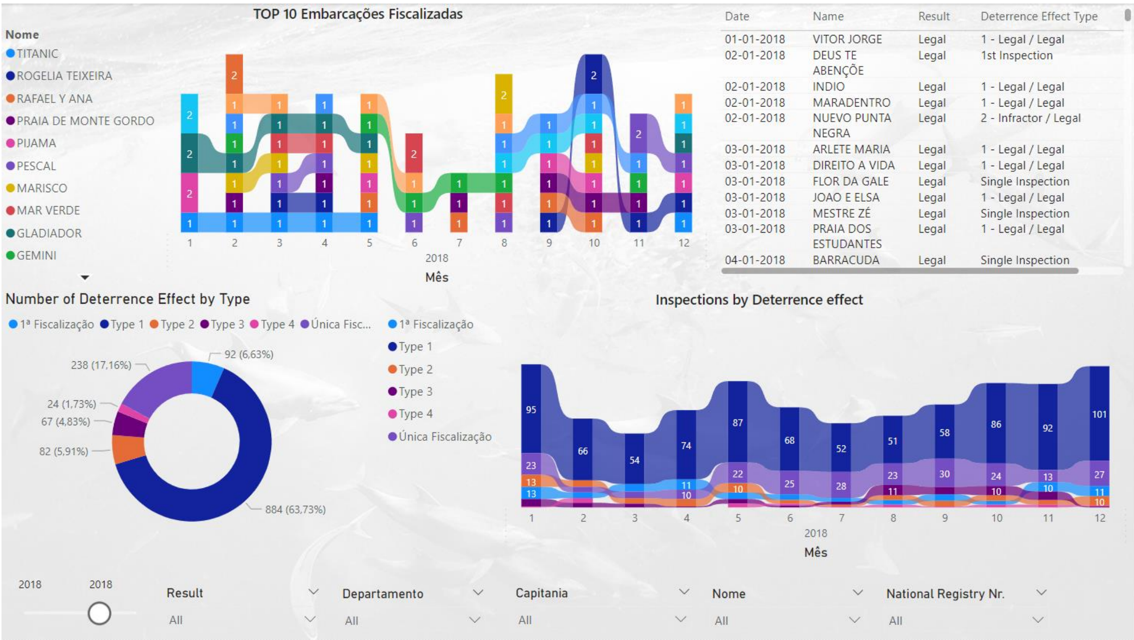
A2


16057
Fiscalizações
12821
Fiscalizações Legais
3236
Fiscalizações Infratoras
79,8%
Fiscalizações Legais %
20,2%
Fiscalizações Infratoras %
5693
Embarcações
4675
Embarcações legais
2096
Embarcações infratoras
36,8%
Embarcações Infratoras %
82,1%
Embarcações Legais %
Inspections by Result
Legal Infrator
3236 (20,15%)
12821 (79,8...)
Inspections by Deterrence Effect
4 - Infractor / Infractor 632 (3,94%)
3 - Legal / Infractor 1111 (6,92%)
2 - Infractor / Legal 1349 (8,4%)
1st Inspection 2464 (15,35%)
Single Inspection 2913 (18,14%)
1 - Legal / Legal 7588 (47,26%)
Ano
All
Departamento, ...
All
Capitania
All
Fiscalizações
Categoria 1ª Fiscali... Type 1 Type 2 Type 3 Type 4 Única Fi...
REINO UNIDO
IRLANDA
Baía de Biscaia
ESPANHA
PORTUGAL
Rabat
MARROCOS
Microsoft Bing
© 2023 TomTom, © 2023 Microsoft Corporation Terms

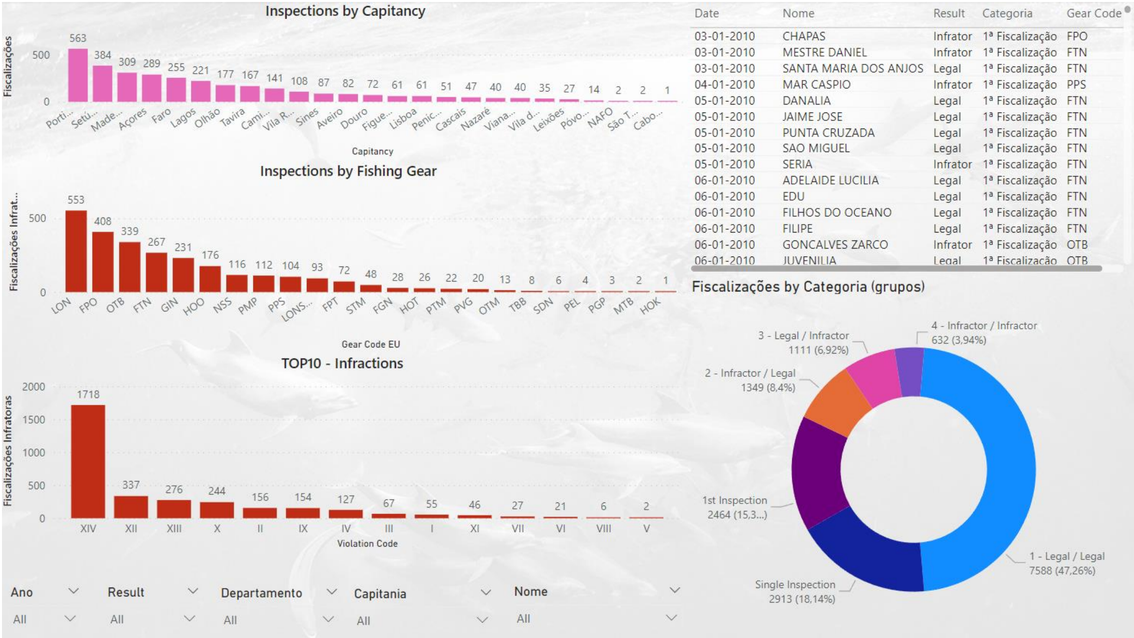
A3


TOP10 Embarcações Fiscalizadas
Fiscalizações
GLADIADOR
PESCAL
ROGELIA TEIXEI...
BUDA
CARMEN BAND...
DELPHINUS
GEMINI
MAR VERDE
MARISCO
PIJAMA
PRAIA DE MON...
RAFAEL Y ANA
TITANIC
Nome
Fiscalizações by Ano, Mês and Resultado (âmbito CN)
Resultado (âmbito CN) Legal Presumível infrator
2018
Mês
TOP10 Inspections by Fishing Gear
Inspections
EU Gear Code
TOP10 Infractions
Inspections with infractions
Violation Code
TOP10 Embarcações Fiscalizadas
Fiscalizações Legais Fiscalizações Infratoras
MARISCO
RAFAEL Y ANA
CAMBOLA
COSTA SUL
DELPHINUS
FILIPA IRMAO
GONCALO
PESCAL
A MALTA
Fiscalizações Legais and Fiscalizaç...
Result
Category
Departamento
Capitania
Nome
Registo nacional de id...
All

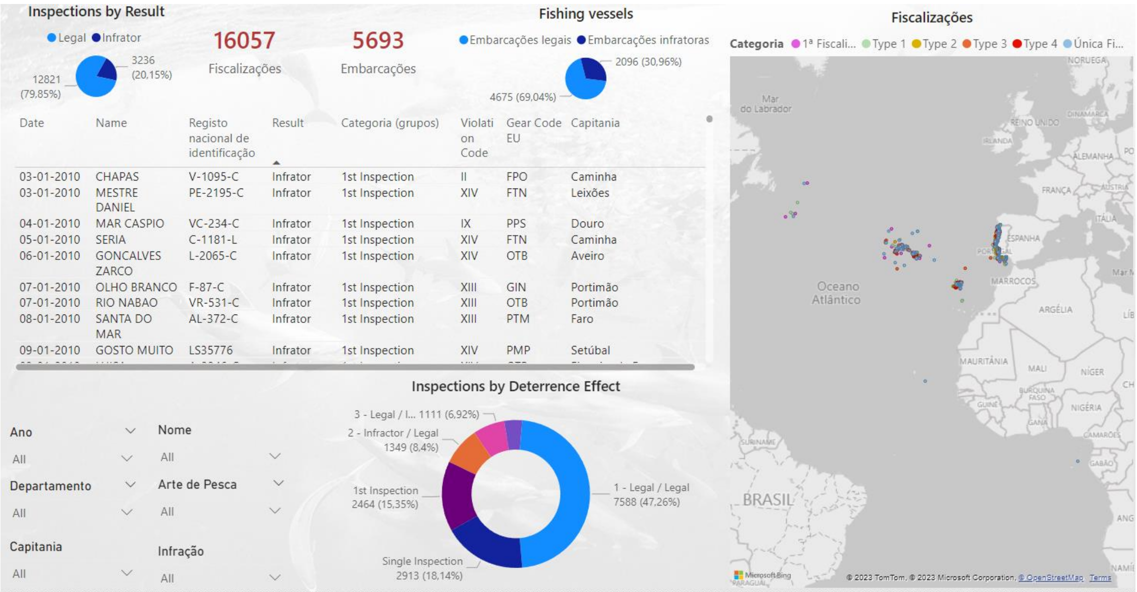
A4


TOP 10 Embarcações Fiscalizadas
Nome
TITANIC
ROGELIA TEIXEIRA
RAFAEL Y ANA
PRAIA DE MONTE GORDO
PIJAMA
PESCAL
MARISCO
MAR VERDE
GLADIADOR
GEMINI
2018
Mês
Date Name Result Deterrence Effect Type
01-01-2018 VITOR JORGE Legal 1 - Legal / Legal
02-01-2018 DEUS TE ABENÇOE Legal 1st Inspection
02-01-2018 INDIO Legal 1 - Legal / Legal
02-01-2018 MARADENTRO Legal 1 - Legal / Legal
02-01-2018 NUEVO PUNTA NEGRA Legal 2 - Infractor / Legal
03-01-2018 ARLETE MARIA Legal 1 - Legal / Legal
03-01-2018 DIREITO A VIDA Legal 1 - Legal / Legal
03-01-2018 FLOR DA GALE Legal Single Inspection
03-01-2018 JOAO E ELSA Legal 1 - Legal / Legal
03-01-2018 MESTRE ZÉ Legal Single Inspection
03-01-2018 PRAIA DOS ESTUDANTES Legal 1 - Legal / Legal
04-01-2018 BARRACUDA Legal Single Inspection
Number of Deterrence Effect by Type
1ª Fiscalização Type 1 Type 2 Type 3 Type 4 Única Fisc...
92 (6,63%)
238 (17,16%)
24 (1,73%)
67 (4,83%)
82 (5,91%)
884 (63,73%)
1ª Fiscalização
Type 1
Type 2
Type 3
Type 4
Única Fiscalização
Inspections by Deterrence effect
2018
Mês
Result
Departamento
Capitania
Nome
National Registry Nr.
All

A5

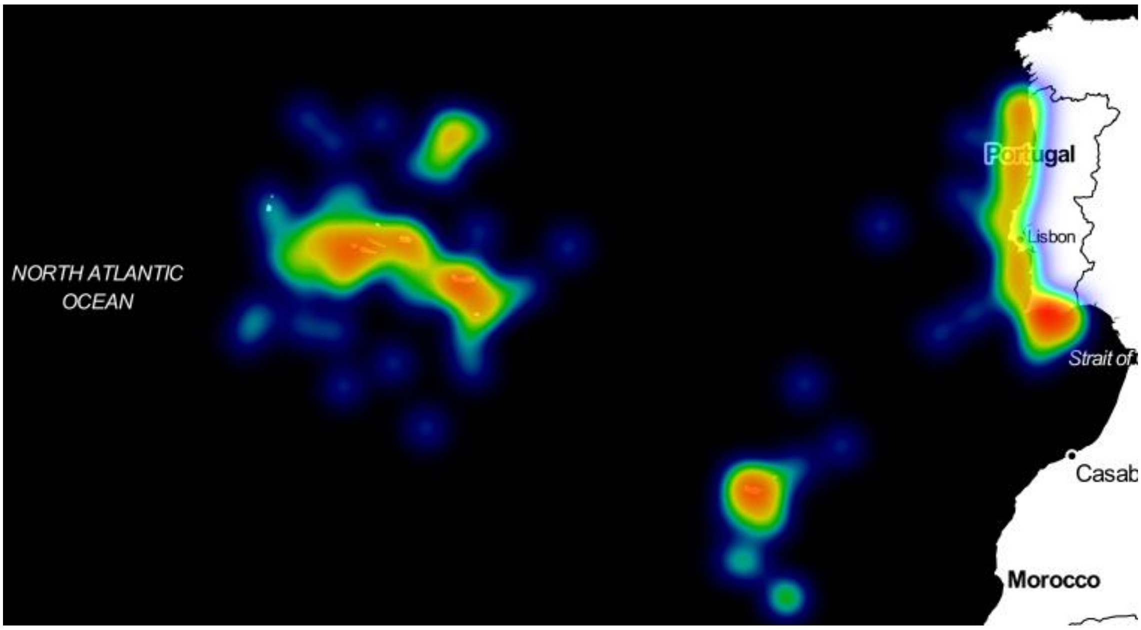


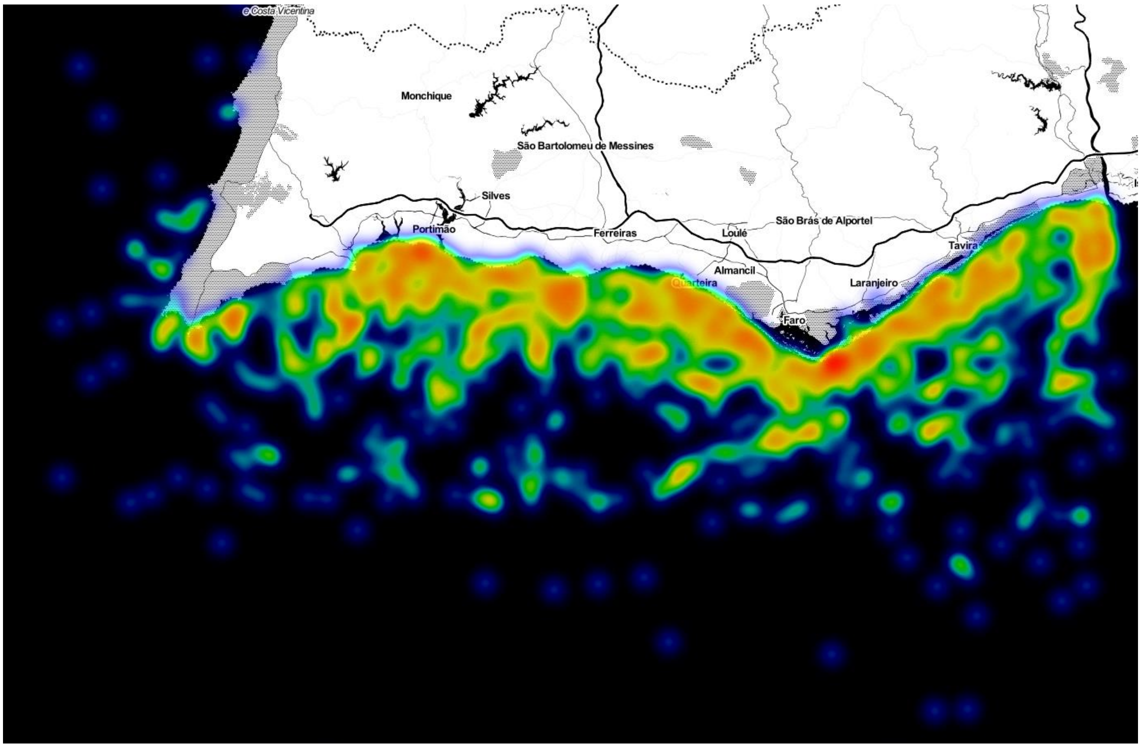
A6



4.5 Heat Map Reporting

To have a clear ideia of overall geographic distribution of illegal fishing and surveillance, we developed the following Heat Map, using the Python library Follium.





4.6 Summary

In this thesis we developed a power BI solution that helps the PN and NMA understand what is going on the fisheries surveillance at sea.

5 Conclusions.

the methodology of this study developed three derivative questions, which are able to answer:

How does the capacity for large-scale geo-referenced, data analysis and visualisation contribute for a maritime surveillance in illegal and fishery infringements?

What are the indicators to measure the deterrent effect of enforcement actions?

What are the BI tools to enable planning decisions for maritime surveillance activity?

the main question elaborated in

How to measure the maritime surveillance effect on the occurrence of fisheries-related infringements?

The python code and BI solution developed are available on Github.

5.1 Future work

The present BI solution is a clear step forward for the PN and MNA capability for managing MCS of fishery infringements. However, a continuous use of this tool will certainly reveal shortcomings and possible improvements, both to the user interfaces and to the indicators use. We foresee that use of machine learning will enable predictions of future activities and better identification of problematic vessel and geographic areas. Crossing the information we used in this thesis with other information, such as meteorological and oceanographical information, information on calendar (work days, holidays and festivities), landing total catches registered, market prices, and fishing effort can provide further insights and better predictions of future activities.

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APPENDIX

APPENDIX A – Methodology analysis model

Table 5 - Methodology analysis model

BI solution, in support of the Portuguese Navy's fishery surveillance					
Research Domain		**Domain**	Management Kowledge		
		Area	Business Intelligence (BI)		
Study´s object			Use of BI systems to support decision making		
Delimitation		**Space**	Portuguese Economic Exclusive Zone		
		Time	2010 – 2022 (Except 2011 and 2013)		
		Content	Fishery Indicators and BI tools (Power BI)		
General Objective			Propose inputs for the application of a BI solution for decision support in maritime surveillance planning.		
Central Question			How to measure the maritime surveillance effect on the occurrence of fisheries-related infringements?		
Methodology	Inductive reasoning	Qualitative and quantitative		Research Design - Case Study	
Specific Objective	Derived Questions	Concepts	Dimensions	Indicators	Data collection techniques
SE1: Describe the ability to analyse and visualise large-scale geo-referenced maritime surveillance data.	DQ1: How does the capacity for large-scale geo-referenced, data analysis and visualisation contribute for a maritime surveillance in illegal and fishery infringements?	▪ Geo visuals analytics ▪ Maritime surveillance	▪ Georeferenced and Large-scale data ▪ Visualization tools ▪ Big data Analysis ▪ Maritime Control and Surveillance	▪ AIS ▪ VMS ▪ VTS ▪ Satellite images	▪ Documentary analysis ▪ Open sources
SE2: Identify and depict surveillance and deterrence indicator.	DQ2: What are the indicators to measure the deterrent effect of enforcement actions?	▪ Fishery infringements ▪ Maritime surveillance ▪ Deterrence effect	▪ Fishing activity ▪ Fishery infringements ▪ IUU fishing ▪ Deterrence Theory	Fishing: - Activity - Infractions - Repeat offenders. - Sequence of infractions - Time and space (EEZ)	▪ Documentary analysis ▪ Open sources
SE3: Suppress the lack of tools to enable planning decisions for maritime surveillance activity	DQ3: What are the BI tools to enable planning decisions for maritime surveillance activity?	▪ Holistic comprehensive intelligence ▪ Analytical trends Decision making	▪ BI Tools ▪ Extract, Load and Transform (ETL) ▪ Data analysis ▪ Dashboards ▪ Power BI	Management information on BI accessed	▪ Documentary analysis ▪ Open sources

APPENDIX B – Definitions and concepts

Flag State

The State in which a ship or vessel is registered, regardless of other factors such as the port of origin, the port in which it is based, or the nationality of the owner, captain, or crew, is responsible for any loss or damage caused to the coastal State due to non-compliance with the applicable laws and regulations. According to the rules of International Law, the flag State (referred to as "EB" in the provided text) bears the responsibility in such cases. When a coastal State seizes or detains ships or vessels within its sovereign waters or jurisdiction, it is required under the rules of International Law to promptly notify the flag State of the actions taken and any subsequent sanctions imposed. Flag States must effectively exercise their jurisdiction and control in administrative, technical, and social matters concerning vessels flying their flag. This includes maintaining an accurate and up-to-date register of ships registered under their flag and exercising their jurisdiction in accordance with their domestic laws (United Nations Organization, 1982).

RFMO

An RFMO (Regional Fisheries Management Organization) is an inter-governmental organization that meets two criteria. Firstly, it has the authority under international law to establish legally binding conservation and management measures for fisheries. Secondly, the geographical scope of its authority includes a portion of the high seas. RFMOs serve as platforms for states to fulfill their cooperative responsibilities regarding fisheries in the high seas.

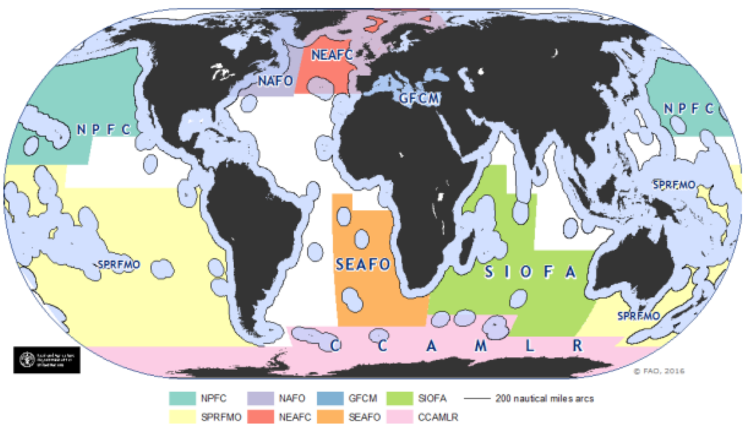
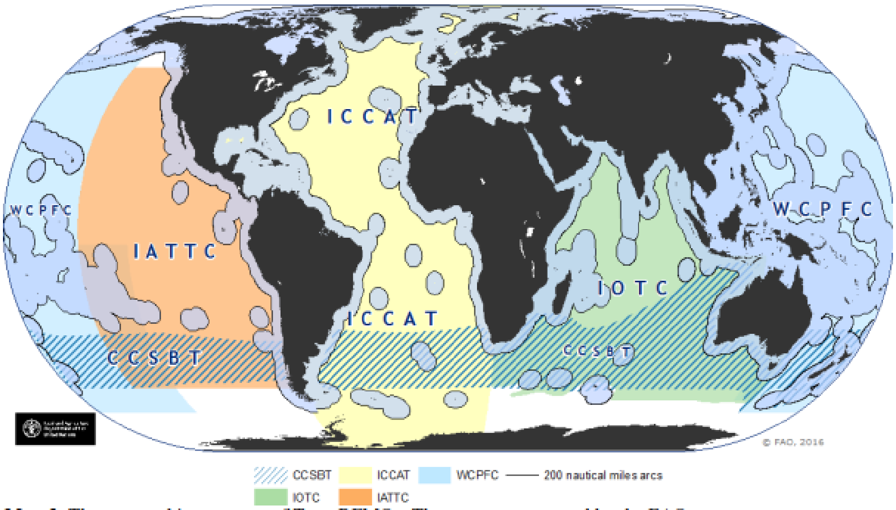


Figure 13 - The geographic coverage of General RFMO (Map1)



Map 2. The geographic coverage of Tuna RFMOs. The map was prepared by the FAO.

Figure 14 - The geographic coverage of Tuna RFMO (Map2)

There are three main types of RFMOs:

- General RFMOs: These organizations cover a wide range of species, excluding tuna. They focus on the conservation and management of various fish species in specific regions.
- Tuna RFMOs: These RFMOs are specifically dedicated to the conservation and management of tuna and tuna-like species. They aim to ensure sustainable tuna fisheries and regulate fishing activities in the relevant areas.
- Specialized RFMOs: These organizations are established to address specific regional or species-specific fisheries. They focus on the conservation and management of specific species or groups of species in particular regions.

The primary goal of RFMOs is to promote sustainable fisheries practices, protect marine ecosystems, and ensure the long-term viability of fish stocks in their respective areas of jurisdiction. They achieve this through the adoption of binding measures, cooperation among member states, and scientific research and data collection.

APPENDIX C – Illegal, unreported, and unregulated fishing

IUU fishing is also a major threat to marine biodiversity, which needs to be tackled. In 2001, FAO approved an International Action Plan to Prevent, Prevent and Eliminate Illegal, Unreported and Unregulated Fishing, which the European Union subscribed to (FAO, 2001).

Illegal, unreported, and unregulated (IUU) fishing is a broad term that captures a wide variety of fishing activity. IUU fishing is found in all types and dimensions of fisheries; it occurs both on the high seas and in areas within national jurisdiction. It concerns all aspects and stages of the capture and utilisation of fish, and it may sometimes be associated with organized crime. Reference to broad activities classified as illegal, unreported, and unregulated fishing are included in the IPOA-IUU as follows (FAO, 2001):

1. "Illegal fishing" means fishing activities:
   - Conducted by national or foreign vessels in waters under the jurisdiction of a State, without the permission of that State, or in contravention of its laws and regulations.
   - Conducted by vessels flying the flag of States that are parties to a relevant regional fisheries management organisation but operate in contravention of the conservation and management measures adopted by that organisation and by which the States are bound, or relevant provisions of the applicable international law; or
   - in violation of national laws or international obligations, including those undertaken by cooperating States to a relevant regional fisheries management organization.

2. 'Unreported fishing' means fishing activities:
   - which have not been reported, or have been misreported, to the relevant national authority, in contravention of national laws and regulations; or
   - are undertaken in competence of a relevant regional fisheries management organisation which have not been reported or have been misreported, in contravention of the reporting procedures of that organisation.

3. "Unregulated fishing" means fishing activities:
   - in the area of application of a relevant regional fisheries management organization that are conducted by vessels without nationality, or by those flying the flag of a State not party to that organization, or by a fishing entity, in a manner that is not consistent with or contravenes the conservation and management measures of that organization; or
   - in areas or for fish stocks in relation to which there are no applicable conservation or management measures and where such fishing activities are conducted in a manner inconsistent with State responsibilities for the conservation of living marine resources under international law

IUU fishing undermines national and regional efforts to conserve and manage fish stocks and, therefore, inhibits progress towards achieving the goals of long-term sustainability and responsibility. Moreover, IUU fishing greatly disadvantages and discriminates against those fishers that act responsibly, honestly and in accordance with the terms of their fishing authorizations. If IUU fishers target vulnerable stocks that are subject to strict management controls or moratoria, efforts to rebuild those stocks to healthy levels will not be achieved, threatening marine biodiversity, food security for communities who rely on fisheries resources for protein and the livelihoods of those involved in the sector.

APPENDIX D – Features of a good indicator

Indicators are crucial in performance monitoring as they provide the necessary information to assess progress and measure the effectiveness of actions taken. By using indicators, organizations can track their performance over time, compare it to established targets or benchmarks, and make informed decisions based on the results. Indicators serve to quantify and evaluate complex concepts or outcomes, making them easier to understand and measure. They provide a clear and objective basis for assessing performance, identifying areas of success, and highlighting areas that may need improvement.

Caldeira, (Caldeira, 2022, p. 16) considers these factors when selecting indicators for performance monitoring can help ensure that the indicators are meaningful, practical, and useful for assessing progress and driving improvement:

Fifteen characteristics of a good indicator

1. Relevance of indicators for management
2. Credibility of the result
3. Acceptable effort to determine the result
4. Simplicity of interpretation
5. Simplicity of the calculation algorithm
6. In-house data source
7. Automatic calculation
8. Possibility to audit data sources efficiently
9. Aligned with monitoring frequency
10. Possibility to calculate in extraordinary moments
11. Protected from external effects
12. Does not generate perverse effects
13. Possibility of benchmarking
14. Up to date
15. Possibility to have a target

APPENDIX E – SMART criteria adapted for illegal fisheries.

The break down each component of the SMART criteria, (Doran, 1981) and its relevance to developing indicators for addressing fishing infringements:

Specific:

Indicators should be specific and clearly defined, focusing on aspects or goals related to combating fishing offenses. For example, instead of a general indicator like "reducing illegal fishing," a specific indicator could be "reducing the number of known IUU fishing vessels operating with illegal gear."

Measurable:

Indicators should be measurable, meaning that they should allow for the collection of reliable data to track progress or changes over time. Measurable indicators related to illegal fishing might include the number of infract inspections reported and prosecuted, the volume of confiscated illegal catch, or the percentage of vessels complying with fishing regulations.

Assignable:

Indicators should be assignable, meaning that specific responsibilities and accountabilities can be assigned to relevant stakeholders for monitoring and achieving the indicator. This helps ensure that actions and measures are taken to address illegal fishing effectively. Assignable indicators could involve assigning responsibilities to law enforcement agencies for investigating and prosecuting infraction fishing cases. E.g. The owner of fishing licence and fishing vessel if necessary.

Realistic:

Indicators should be realistic and attainable, taking into consideration the available resources, capacities, and limitations. Realistic indicators related to illegal fishing might consider the enforcement capabilities, surveillance technologies, and available funding for monitoring and combating infringements fishing activities.

Time-related:

Indicators should be time-related and include a specific time frame for achieving the desired outcomes or targets. This helps in tracking progress and evaluating the effectiveness of interventions. Time-related indicators related to illegal fishing might include reducing the percentage of IUU fishing incidents by a certain percentage within a specified period. Mostly, Fishing assessment are reported at least for one year performance.

APPENDIX F – Violation code to identify the non-compliance legal fishing activity

Table 6 - Violation code to identify the non-compliance legal fishing activity

Violation Code	Description
I II	MISSING LOGBOOK INCORRECTLY COMPLETED LOGBOOK
III IV V	FISHING GEAR PROHIBITED FISHING IN A PROHIBITED OR NO-GO AREA FISHING PROHIBITED DUE TO EXCESSIVE ENGINE POWER OR TONNAGE
VI VI VIII	UNDUE CATCHES BY DIRECT FISHING UNDUE CATCHES BY BY-CATCH UNDUE CATCHES OF FISH SMALLER THAN THE LEGAL MINIMUM SIZE
IX	ACTIVITY CARRIED OUT WITHOUT A LICENCE OR AUTHORISATION
X XI	IMPROPER LIGHT SIGNAL AND/OR IDENTIFICATION OF FISHING GEAR IMPROPER LIGHT SIGNAL AND/OR IDENTIFICATION OF VESSELS
XII XIII	DOCUMENTS: INVALID CERTIFICATES DOCUMENTS: NON-EXISTENT/INVALID MARITIME REGISTRATION
XIV	OTHER: LACK OF OTHER DOCUMENTS ON BOARD, LACK OF SOLAS SAFETY EQUIPAMENT LIKE, PYROTECHNICS, LACK OF LIFE-SAVING APPLIANCES, EXPIRED FIRE EXTINGUISHERS, ETC).

APPENDIX G - Fishing Gear equivalent codes between and European Union

In accordance with, COMMISSION REGULATION (EC) No 1639/2001 of 25 July 2001 establishing the minimum and extended Community programmes for the collection of data in the fisheries sector and laying down detailed rules for the application of Council Regulation (EC) No 1543/2000.

Note: * Are the main groups in the EU Gear Code

Table 7- Fishing Gear equivalent codes between Portuguese and European Union

Description PT	PT Gear Code	EU Gear Code	Description EU
Artes de pesca do meixão	MEX	FGN	Passive gears,Fixed nets,Fixed nets,
Redes de emalhar e enredar	GN0	FGN	Passive gears,Fixed nets,Fixed nets,
Barreira, Barragem, Estacada	FWR	FGN	Passive gears,Fixed nets,Fixed nets,
Rede de emalhar de deriva "Volanta"	GND	FGN	Passive gears,Fixed nets,Fixed nets,
Rede de emalhar envolvente	GNC	FGN	Passive gears,Fixed nets,Fixed nets,
Nassa, Covo, Murejona	FPO	FPO*	Passive gears,Pots and traps,
Armadilhas	F0	FPO*	Passive gears,Pots and traps,
Armação	FPN	FPO*	Passive gears,Pots and traps, ,
Armadilhas	ARM	FPO*	Passive gears,Pots and traps, ,
	FP0	FPO*	Passive gears,Pots and traps,
	FPS	FPO*	Passive gears,Pots and traps, ,
Armadilha aérea	FAR	FPO*	Passive gears,Pots and traps, ,
FPO	FPO	FPO*	Passive gears,Pots and traps,
	FPO-C4	FPO*	Passive gears,Pots and traps,
Armação	FNP	FPO*	Passive gears,Pots and traps,
	F0-GN0	FPO*	Passive gears,Pots and traps,
	FPNS	FPO*	Passive gears,Pots and traps,
Alcatruz	FPA	FPT	Passive gears,Pots and traps,Fish traps (2),
Rede de tresmalho	GTR	FTN	Passive gears,Fixed nets,Fixed nets,Trammel nets
Rede mista de emalhar-- tresmalho	GTN	FTN	Passive gears,Fixed nets,Fixed nets,Trammel nets
Emalhar/Tresmalho	RED	FTN	Passive gears,Fixed nets,Fixed nets,Trammel nets
	GNR	FTN	Passive gears,Fixed nets,Fixed nets,Trammel nets
	GRT	FTN	Passive gears,Fixed nets,Fixed nets,Trammel nets
	LLD	FTN	Passive gears,Fixed nets,Fixed nets,Trammel nets
Rede de emalhar fundeada	GNS	GIN	Passive gears,Fixed nets,Fixed nets,Gill nets

Description PT	Gear Code PT	Gear Code EU	Description EU
Navio de Pesca à Linha	PLI	HOK*	Passive gears,Gears using hooks, ,
	LDD	HOK*	Passive gears,Gears using hooks, ,
Palangre fundeada	LLS	HOO	Passive gears,Gears using hooks,Other gears using hooks,
Palangre fundeada	LSS	HOO	Passive gears,Gears using hooks,Other gears using hooks,
Linha de corrico	LTL	HOT	Passive gears,Gears using hooks,Other gears using hooks,Troll line
	COR	HOT	Passive gears,Gears using hooks,Other gears using hooks,Troll line
Linha simples e de vara manual	LHP	LON	Passive gears,Gears using hooks,Longlines,
Linhas e Anzóis	L0	LON	Passive gears,Gears using hooks,Longlines,
Linha simples e de vara mecanizada	LHM	LON	Passive gears,Gears using hooks,Longlines,
Salto e Vara	SVA	LON	Passive gears,Gears using hooks,Longlines,
Palangreiro	PAL	LON	Passive gears,Gears using hooks,Longlines,
	LZZ	LON	Passive gears,Gears using hooks,Longlines,
	LHO	LON	Passive gears,Gears using hooks,Longlines,
Linhas e Anzóis	LSD	LON	Passive gears,Gears using hooks,Longlines,
Palangre derivante	LLD	LONSUR	Passive gears,Gears using hooks,Longlines,Surface longlines
Artes de pesca de recreio	EMR	PGP*	Passive gears,Polyvalent passive gears, ,
	C1	PGP*	Passive gears,Polyvalent passive gears, ,
	RG	PMP*	Polyvalent gears,Combining mobile & passive gears, ,
	MISC	PMP*	Polyvalent gears,Combining mobile & passive gears, ,

Description PT	Gear Code PT	Gear Code EU	Description EU
Ganchorra	GAN	MTB	Mobile gears,Demersal trawl and demersal seiner,Bottom trawl,Other multirig trawl
	DBR	MTB	Mobile gears,Demersal trawl and demersal seiner,Bottom trawl,Other multirig trawl
Draga rebocada por embarcação "Ganchorra"	DRB	NSS	Mobile gears,Beam trawl,North Sea < 221kW,
Redes de arrastar	OTB	OTB	Mobile gears,Demersal trawl and demersal seiner,Bottom trawl,
Rede de arrasto pelo fundo de camarões	TBS	OTB	Mobile gears,Demersal trawl and demersal seiner,Bottom trawl,
Redes de arrastar	OTB0	OTB	Mobile gears,Demersal trawl and demersal seiner,Bottom trawl,
Rede de arrastar pelo fundo	OTB1	OTB	Mobile gears,Demersal trawl and demersal seiner,Bottom trawl,
	OTD	OTB	Mobile gears,Demersal trawl and demersal seiner,Bottom trawl,
	OTP	OTB	Mobile gears,Demersal trawl and demersal seiner,Bottom trawl,
	OTC	OTB	Mobile gears,Demersal trawl and demersal seiner,Bottom trawl,
	OYB	OTB	Mobile gears,Demersal trawl and demersal seiner,Bottom trawl,
Rede de cerco dinamarquês	SDN	SDN	Mobile gears,Demersal trawl and demersal seiner,Danish seiners,
Rede de cerco escocês	SSC	SSC	Mobile gears,Demersal trawl and demersal seiner,Scottish seiners,
Rede com retenida operada por uma embarcação	PS1	STM	Mobile gears,Pelagic trawls and seiners,Pelagic trawl,Single trawler
	PSI1	STM	Mobile gears,Pelagic trawls and seiners,Pelagic trawl,Single trawler
Rede de arrasto pelo fundo de vara	TBB	TBB*	Mobile gears,Beam trawl, ,

Description PT	Gear Code PT	Gear Code EU	Description EU
Rede de cerco com retenida	PS	OTM	Mobile gears,Pelagic trawls and seiners,Pelagic trawl,
Rede de arrasto pelágico com portas	OTM	OTM	Mobile gears,Pelagic trawls and seiners,Pelagic trawl,
	PSA	OTM	Mobile gears,Pelagic trawls and seiners,Pelagic trawl,
	P3	OTM	Mobile gears,Pelagic trawls and seiners,Pelagic trawl,
Rede de sacada operada de embarcação	LNB	PEL	Mobile gears,Pelagic trawls and seiners,Pelagic seiner and purse seiner,
Redes de sacada	LN0	PEL	Mobile gears,Pelagic trawls and seiners,Pelagic seiner and purse seiner,
Redes de cercar	PS0	PPS	Mobile gears,Pelagic trawls and seiners,Polyvalent,
Cercador	ARR	PPS	Mobile gears,Pelagic trawls and seiners,Polyvalent,
Rede de cerco sem retenida "Lâmpara"	LA	PPS	Mobile gears,Pelagic trawls and seiners,Polyvalent,
	ALA	PPS	Mobile gears,Pelagic trawls and seiners,Polyvalent,
Redes envolventes--arrastantes	SB0	PPS	Mobile gears,Pelagic trawls and seiners,Polyvalent,
Rede envolvente--arrastante de parelha	SPR	PPS	Mobile gears,Pelagic trawls and seiners,Polyvalent,
	PRE	PPS	Mobile gears,Pelagic trawls and seiners,Polyvalent,
Cercador	CER	PPS	Mobile gears,Pelagic trawls and seiners,Polyvalent,
Rede de cerco com retenida operada por duas embarcações	PS2	PTM	Mobile gears,Pelagic trawls and seiners,Pelagic trawl,Paired trawlers
Artes de pesca diversas	MIS	PVG	Polyvalent gears
Arpão	HAR	PVG	Polyvalent gears
Draga de mão	DRH	PVG	Polyvalent gears
	FUN	PVG	Polyvalent gears
Polivalente	POL	PVG	Polyvalent gears
	LTD	PVG	Polyvalent gears
	LHG	PVG	Polyvalent gears
	NAC	PVG	Polyvalent gears

APPENDIX H – Python code for Transformation 1

```
In [1]: import pandas as pd

        # Caminho do arquivo
        caminho_arquivo = r'BDados_FISCREP_2022.xlsx'

        # Lendo o arquivo em um DataFrame
        df = pd.read_excel(caminho_arquivo)

In [2]: pd.set_option('display.max_columns', None)

In [3]: df.head(2)
```

import pandas as pd

Caminho do arquivo

caminho_arquivo = r'BDados_FISCREP_2022.xlsx'

Lendo o arquivo em um DataFrame

df = pd.read_excel(caminho_arquivo)

Exportar o DataFrame para um arquivo CSV

df.to_excel(r'dataset_cat1.xlsx', index=False)

```
In [11]: # Exportar o DataFrame para um arquivo CSV
         df.to_excel(r'dataset_cat1.xlsx', index=False)
```

APPENDIX I – Python code for Transformation 2

```
In [30]: import pandas as pd
         import geopandas as gpd
         import matplotlib.pyplot as plt
         import seaborn as sns
         import folium
         %matplotlib inline
```

```
In [16]: # Caminho do arquivo
         caminho_arquivo = r'BDados_FISCREP_2022.xlsx'

         # Load shapefile using geopandas
         shp_path = r'Capitanias.shp'
         shapefile = gpd.read_file(shp_path)

         # Lendo o arquivo para DataFrame
         df = pd.read_excel(caminho_arquivo)
```

```
In [17]: pd.set_option('display.max_columns', None)
```

```
In [18]: df.head(50)
```

```
In [34]: intersected.to_csv(r'intersected_geometry.csv', index=False)
```

APPENDIX J – Python code for Transformation 3

In [1]:
```
import pandas as pd
import geopandas as gpd
import matplotlib.pyplot as plt
import seaborn as sns
%matplotlib inline
```

In [2]:
```
pd.set_option('display.max_columns', None)
```

In [75]:
```
# Load CSV file with geographic coordinates
coords_path = r'categorias_1.xlsx'
df = pd.read_excel(coords_path, )

# Load shapefile using geopandas
shp_path = r'Capitanias.shp'
shapefile = gpd.read_file(shp_path)
```

In [76]:
```
df.head(20)
```

In [110…
```
# Save the map as an HTML file
map_html = 'heatmap.html'
m.save(map_html)
```