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**Analysis of Cultural and Provisioning Ecosystem
Services Use: A Comparative Study of Artificial Reefs,
Rocky Areas, and Sandy Bottoms in the Algarve**



UNIVERSIDADE DO ALGARVE

Faculdade de Ciências e Tecnologia

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2024

Declaration of authorship of the work

I declare to be the author of this work, which is original and unprecedented. Consulted authors and works are rightfully cited in the text and are included in the list of references.

Faro, September 2024

Ana Maria Madiedo Camelo

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DEDICATION

This thesis is dedicated to my parents, whose unwavering love, guidance, and unconditional support have been the cornerstone of my journey. Without their encouragement and belief in me, reaching these academic goals and experiencing this transformative journey would not have been possible. Their confidence in my abilities, along with their constant motivation, made this entire endeavor achievable and fulfilling.

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ABSTRACT

Artificial reefs are human made structures that are deployed in the seabed to provide multiple economic, social and ecological benefits. Artificial reefs have emerged as a highly effective strategy to provide ecosystem services, such as habitat protection, restoration, and recreation. Despite their acknowledged benefits, there remains a limited understanding of how these reefs are currently being used by the local communities. The present study aims to identify and analyze the use of provisioning and cultural ecosystem services provided by the artificial reefs located in the south coast of Portugal, in comparison with rocky areas and sandy bottoms. To achieve this, a satellite dataset comprising automatic identification system (AIS) records with nine months of hourly location data for recreational and fishing vessels (including purse seiners and multi-gear) was utilized to identify and analyse high-density areas. Statistical tests were conducted to further assess the data. The results indicate that, within the selected study area, sandy bottoms are the most intensively used habitat for fishing activities, with multi-gear vessels being the predominant type, proving to be a significant type of habitat that provides essential ecosystem services. In contrast, artificial reefs were found to be used for recreational and fishing activities, but with lower density values, while rocky areas were the least used ones.

Keywords: Artificial reef, ecosystem services, fishing vessels, recreational vessels, rocky areas, sandy bottoms.

RESUMO

Os recifes artificiais são estruturas feitas pelo homem que são implantadas no fundo do mar para proporcionar múltiplos benefícios económicos, sociais e ecológicos. Os recifes artificiais surgiram como uma estratégia altamente eficaz para fornecer serviços ecossistémicos, tais como a proteção do habitat, a restauração e a recreação. Apesar dos seus benefícios reconhecidos, continua a haver uma compreensão limitada da forma como estes recifes estão atualmente a ser utilizados pelas comunidades locais. O presente estudo tem como objetivo identificar e analisar a utilização dos serviços ecossistémicos de aprovisionamento e culturais fornecidos pelos recifes artificiais localizados na costa sul de Portugal, em comparação com áreas rochosas e fundos arenosos. Para o efeito, foi utilizado um conjunto de dados de satélite que consiste em registos do sistema automático de identificação (AIS) com nove meses de dados horários de localização de embarcações de recreio e de pesca (incluindo cercadoras e polivalentes) para identificar e analisar áreas de elevada densidade. Foram efectuados testes estatísticos para avaliar melhor os dados. Os resultados indicam que, na área de estudo seleccionada, os fundos arenosos são o habitat mais intensivamente utilizado para atividades de pesca, onde as embarcações polivalentes são o tipo predominante, demonstrando que este é um habitat importante que fornece serviços ecossistémicos essenciais. Em contraste, verificou-se que os recifes artificiais são utilizados para atividades recreativas e de pesca, mas com valores de densidade mais baixos, enquanto as áreas rochosas foram as menos utilizadas.

Palavras-chave: Embarcações de pesca, embarcações de recreio, fundos arenosos, recife artificial, serviços ecossistémicos, zonas rochosas.

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List of Abbreviations & Acronyms

ANOVA	Analysis of Variance
AIC	Akaike Information Criterion
AIS	Automatic identification system
CICES	Common International Classification of Ecosystem Services
EEA	European Environment Agency
Df	Degree of freedom
FCT	Portuguese Foundation for Science and Technology
GIS	Geographic Information System
IPMA	Portuguese Institute for Sea and Atmosphere
MEA	Millenium Ecosystem Assessment
MMSI	Maritime Mobile Service Identity
MUSA	Underwater Museum of Art
SCUBA	Self-Contained Underwater Breathing Apparatus
Sig	Significance Level
SPSS	Statistical Package for the Social Sciences

1 INTRODUCTION

Over time, there has been a growing awareness of the importance of nature and how it can provide multiple benefits to human beings. Specifically, regarding marine ecosystems, humanity has been using these resources since the beginning of time, whether for obtaining food, shelter, engaging in recreational activities and others (Barbier, 2017). These multiple benefits had been designated “Ecosystem services” and currently their high value to humanity is widely recognized (Daily, 1997; Costanza et al., 1997; Buonocore et al., 2021).

Due to the high demand for resources and intensity of activities done in the different types of marine ecosystems, it has been evidenced increasing environmental impacts such as habitat loss, changes in biodiversity, physicochemical alterations, and more (Barbier, 2017). This significant habitat degradation has led to the development of tools and new methodologies that allow to mitigate the impacts, restore and protect natural resources, and enhance their productivity. These efforts aim to ensure the continued provision of those named ecosystem services (Danovaro et al., 2021).

One example of a tool implemented are the artificial reefs, which are structures designed and deployed on the seabed with the aim to simulate the natural conditions of a natural reef and promote the increase of fish density as well as the presence of other marine organisms (Pickering et al., 1999). These types of structures had been the main subject of different research, revealing numerous uses and benefits that can be associated with the deployment of artificial reefs.

1.1 Artificial reefs

The concept of artificial reefs has changed and adapted over the years (Lee et al., 2018). There is no consensual origin of these structures. One of the earliest records of artificial reefs dates back to 1600s, where it was evidence of stones used as anchors to create fishing ground for catching tuna in the Mediterranean Sea. During this period, it was also evidenced an increase in marine life in

sunken ships and their surrounding areas, which made these sunken ships to be seen as artificial reef structures as well (Fabi et al., 2011; Ramm et al., 2021).

Another evidence of the beginning of artificial reefs was found in Awaji, Japan. In this area, the fishing community perceived an increase in fish population and fishing ground in the surrounding areas of a sunken ship. After these perceived benefits, they began to adopt the concept of artificial reefs. Over time, more projects started to be developed to intentionally sink vessels, and new technical designs were included in the deployed structures (Pickering, 1996).

Nowadays, artificial reefs are defined as human-made structures that are deployed in the seabed aiming to mimic the characteristics of natural reefs (Baine, 2001), and are being used as a coastal management resource tool to mitigate the impacts produced by anthropic activities such as trawling, habitat destruction, and others (Carr & Hixon, 1997).

1.1.1 Artificial reefs in Europe

In Europe, between 1980 and 1990 the use of artificial reefs significantly increased (Monteiro and Santos, 2000). Until the end of 1990s, in comparison to the rest of the world, Europe had deployed 57% of purpose-build reefs, where most of them were deployed as a protection tool to inhibit trawling activities (Sánchez-Jerez and Ramos-Esplá 2000; Ramm, 2021). The Mediterranean Sea is the area of Europe with the highest concentration of artificial reefs, primary deployed as a fishery management tool. The OSPAR (i.e., Oslo and Paris Conventions) Maritime Area, is also a region with high concentration of artificial reefs, followed by the Baltic and Black seas, where multiple structures had been deployed as a conservation and restoration tool to reduce the impact of anthropic activities in the ecosystems (Fabi et al., 2011).

1.1.2 Artificial reefs in Portugal

Specifically in Portugal, from 1990 onwards, were progressively deployed seven artificial reefs along the Algarve south coast (Figure 1), by the Institute of Marine Research (now IPMA). These were implemented as a management measure, taking into consideration the intensive fishing in the

area, the presence of highly productive estuarine systems and the lack of natural reefs that provided refuge for the juveniles (Monteiro and Santos, 2000). One of the most important estuarine-lagoon systems is Ria Formosa, which functions as a nursery for multiple fish species which migrate to the open coastal waters, to then be potentially caught by fishermen.

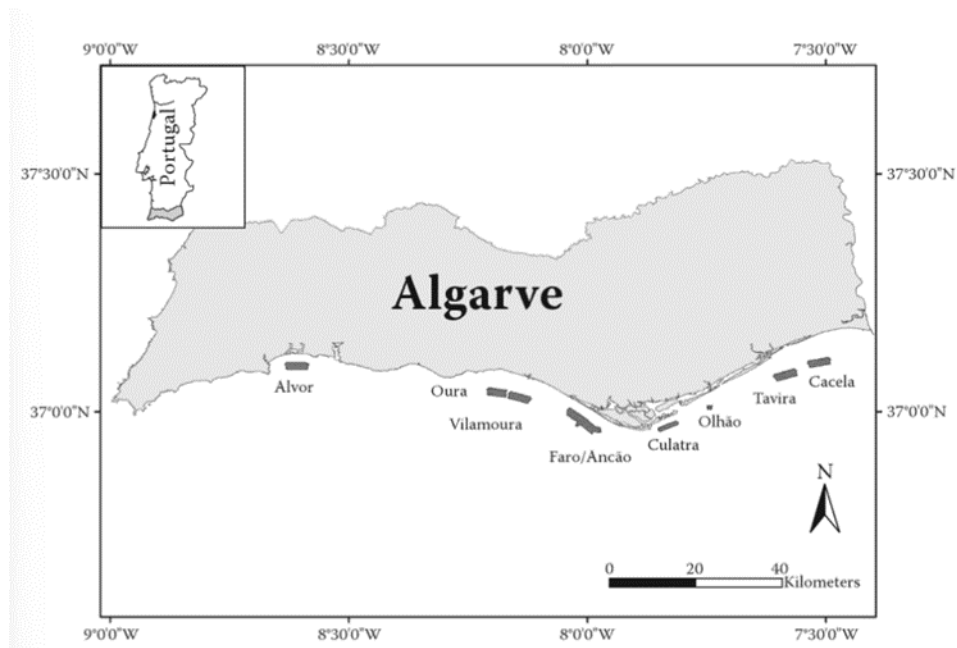


Figure 1. The Algarve is southernmost region in Portugal mainland and offshore is where most of cubic, parallelepipedal and octagonal artificial reef modules are located. Source: Retrieved from Santos et al. (2011). Note: Despite intended, Culatra AR was not deployed

The first artificial reefs were deployed off Faro and off Olhão, which were made of concrete modules and with two distinct purposes. The ones allocated closer to the shore (cubic modules), where there is the most abundance of fish, were deployed to create shelter for fingerlings that migrate from Ria Formosa lagoon. The other were deployed further offshore into deeper waters, with the aim of attracting fish and their activity in the area (parallelepipedal and octagonal modules), (Santos and Monteiro, 1997). About 14 years after the deployment of these artificial reefs, it was found an increase of species availability and diversity, creating habitat to support diverse benthic and pelagic species. At the same time, the artificial reefs contributed to an increase in catch rates from 20 up to 40% (Santos and Monteiro, 2007).

In Nazaré, off the west coast of Portugal, in 2010 it was deployed an artificial reef to benefit the fishing activities, as well as to encourage the resilience of some marine organisms and to promote

tourism as well as educational activities in the area. After its implementation, it was found that the concentration of phytoplankton was the same as the control site, which indicated the structures were being colonized and assimilated into the ecosystem. Moreover, there was an increase of macroinvertebrates, indicating that the artificial reefs contributed to enhance biological diversity. Concerning fishing communities, smaller vessels were the ones that used the area around the artificial reefs the most and obtained benefits from it. Prior to the reef's deployment, the most predominant species were sandy bottom related (e.g., flatfishes). However, after the reef deployment, there was an increase in species diversity, related to the refuge provided by the artificial reefs (Ramos et al., 2021).

1.2 Ecosystem services

The concept of ecosystem services has evolved over time and has experienced multiple classifications and adaptations before the formalization of the concept. Westman (1977), was one of the first authors to introduce the term “services” within the context of benefits obtained from nature. His research aimed to assign value to the benefits people received from nature, which were considered priceless.

Ehrlich & Ehrlich (1981) in their book “*Extinction: the causes and consequences of the disappearance of species*” were the first ones to define the concept of “ecosystem services”. These authors emphasized the importance of different species and how they contribute to the adequate function of the ecosystems, as well as their role to support human life. The connection between these two factors gave origin to the term of ecosystem service.

The term “Ecosystem Services” has come to a formalization and has been adopted for environmental policies. According to the Millenium Ecosystem Assessment (MEA, 2005), ecosystem services are direct and indirect benefits provided by the ecosystems to people. MEA considers four types of ecosystem services: provisioning, cultural, supporting and regulating. In 2009 the European Environment Agency (EEA) developed the Common International Classification of Ecosystem Services (CICES) with the aim of creating a framework to classify and

describe the ecosystem services, that could be used across different contexts of management and policymaking (EEA, 2009). According to the latest version (CICES 5.1), the ecosystem services were classified in three main categories: Provisioning, Regulation and Maintenance, and Cultural (**Table 1**). Additionally, it includes a hierarchy to better understand each of the services according to a section, division, group, class and class type (Haines-Young & Potschin, 2012).

Table 1. *Definition and classification of ecosystem services according to CICES 5.1. Source: Adapted from Haines-Young & Potschin (2012).*

Ecosystem Service	Definition
Provisioning	All nutritional, non-nutritional material and energetic outputs from living systems as well as abiotic outputs (including water).
Cultural	All the non-material, and normally non-rival and non-consumptive, outputs of ecosystems (biotic and abiotic) that affect physical and mental states of people.
Regulation and Maintenance	All the ways in which living organisms can mediate or moderate the environment that affects human health, safety or comfort, together with abiotic equivalents.

1.2.1 Ecosystem services and natural reefs

Natural reefs are structures formed by rocks, corals, and other biological materials, making them vital for multiple marine organisms. They serve as breeding grounds, provide shelter and food for different species, and are within the most productive and biodiverse ecosystems of the world (Connell, 1978). These structures have been known for their ability to provide numerous ecosystem services, and some examples of the perceived benefits are described below.

1.2.1.1 Provisioning

Within the multiple services provided by natural reefs, it has been found that they can provide medicinal resources. An example of this was found in the Caribbean and Indian Ocean reefs, where multiple compounds have been identified for their potential use in treating leukaemia, breast, and liver cancer (Bruckner, 2002). Specifically, in the case of the Coral Triangle region, the importance

of this area has been identified for harvest of fish where it has been found to be the highest value derived from these reefs, mainly in the Solomon Islands, where more than 90% of the communities benefit from fishing activities in the reefs (Albert et al., 2015).

1.2.1.2 Cultural

The natural beauty of coral reefs makes them attractive destinations for recreational activities such as snorkelling and diving. Studies indicate that these ecosystems not only contribute to attracting tourism but also hold significant value for local communities, who utilize these spaces for recreational fishing, snorkelling, and SCUBA diving (Johns et al., 2013; Seller, 2013; Lachs and Oñate-Casado, 2020). In Queimada Grande Island (Brazil), there had been perceived multiple cultural ecosystem services associated with spearfishing and recreational diving, with the rhodolith bed being a major attraction for tourists (Niz et al., 2023). Similarly, a study by Jarvis et al. (2017) estimated an annual income of \$8.7 billion from the cultural services provided by the Great Barrier Reef in Australia, predominantly related to reef-based tourism activities such as fishing, spearfishing, and diving.

1.2.1.3 Regulation and maintenance

Natural reefs are recognized for their ability to provide regulation and maintenance ecosystem services, including carbon sequestration, water quality improvement, erosion control, coastal protection, and others. An example of this are oyster reefs, which have been found to protect other vital ecosystems such as seagrasses and mangroves by reducing the impact of waves in those areas. Coral reefs also contribute to shoreline protection and the reduction of erosion by diminishing the impact of waves and tides (Johns et al., 2013). In addition, oyster reefs serve as natural filters, capable of trapping organic matter and various contaminants from the water column. They can effectively remove potential toxins that may affect other marine organisms and humans (Leard et al., 1999; Mann et al., 2009). Furthermore, coral reefs have proven to provide significant biological support, offering shelter to multiple species of pelagic juvenile fish (Spurgeon, 1992). Additionally, their physical characteristics play a key role in providing shelter for multiple species from predators (Steele, 1999).

1.2.2 Ecosystem services and artificial reefs

There are multiple types of artificial reefs such as sunken vessels, artistic sculptures and specially designed structures that mimic the conditions of natural reefs, among others. These are created with specific features to replicate the ecological functions of natural reefs. Similar to natural reefs, artificial reefs contribute to providing a wide range of ecosystem services, some of which are

described below.

1.2.2.1 Provisioning

The provisioning service is mostly related to the noticeable increase of fish resources derived from artificial reef deployment. These fish resources can be sought after by fishermen to be sold as food (protein from the sea). In this scope it can be described in brief some examples.

Ramos et al., (2006a) studied the usage of the artificial reef off Olhão. According to the results, it was evidenced that the surrounding areas of the reef were used mostly for commercial and recreational purposes, the first ones being the most predominant. These patterns could be related to an increase in catches around the area, translating into economic advantages for the fishing community (Whitmarsh et al., 2008).

To assess the efficacy of artificial reefs in enhancing local fisheries, Santos et al. (2011) studied the colonization rate and composition of fish assemblages. Four months after deploying the Faro/Ancão artificial reef, an increase in diversity and biomass was observed in the fish assemblage, with one-third of the biomass consisting of adult fish. This outcome highlights the positive contribution of artificial reefs, demonstrating their capacity to accelerate fish aggregation (with two to three times higher density). This highlights the efficiency of artificial reefs as a viable management tool, creating a potentially positive impact on local artisanal fisheries (if negative externalities created are negligible).

Around the world it can be found some other examples of artificial reefs used to either enhance fish resources or prevent the negative effects derived from fishing. For example, in the Philippines, artificial reefs were deployed to counteract the depletion of fisheries resources due to over-fishing. A similar case was studied in Senegal where there was some evidence of a decline in demersal fish resources. With assistance from Japan, it was developed a project with artificial reefs that were deployed at 20m offshore from the coast, using concrete blocks. After a year of its deployment, it was found an increase of group fish gathered around the reef and according to the testimony of the fishermen from the villages around. This resulted in a rise in the fish catch as well as an increase in

its diversity (Watanuki and Gonzales, 2006).

During the 1980s Japan spent the equivalent of about US\$10 million per year to construct and deploy artificial reefs in benefit of the fisheries. It was found that over 50% of the fishermen in the East and West Shimamaki (Hokkaido, North Japan) used the reef regularly. At the same time, there was an increase in catching of flatfish, scorpionfish and octopus. About 30% of the population of fisherman recognized that they had perceived a benefit of catch increase since the implementation of artificial reefs in the area (Polovina and Sakai, 1989).

1.2.2.2 Cultural

Artificial reefs have proven to provide cultural ecosystem services related to recreational activities, as they contribute to the improvement of underwater landscape as an additional benefit that results from the increase of biodiversity. This had led to the encouragement of activities such as SCUBA diving and angling around the artificial reefs, as it is the case of the Great Barrier reef in Australia, or other reputed places to practice the activity such as Jamaica and Penghu (Chen et al., 2013). More recently Ilieva et al. (2019) described cultural services provided by intentionally submerged structures comprising cubic structures, four shipwrecks (two service vessels and two tanker warships).

A study presented by Ramos et al. (2006b) made a comparative analysis of diver's preference for diving location. The study revealed that, on average, the sunken vessel situated off Faro ranked as the second most visited spot, following natural reefs. This reflects the role of artificial reefs in promoting ecotourism activities, as they attract divers and help to mitigate the potential mechanical damage that may occur in natural reefs due to diving activities.

Artificial coral reefs attract divers due to the increase in fish populations nearby, relieving pressure on natural reefs. In Israel, according to the study presented by Belhassen et al. (2017), the artificial reefs in Eilat exhibited higher diver density compared to the adjacent natural reefs. The research also highlighted that artificial reefs are considered more favorable for training purposes, which reflected their attractiveness to the diving community.

Among the various types of artificial reefs, artistic installations stand out, featuring sculptures

crafted from eco-friendly materials that attract corals and foster the presence of diverse marine species. In Cancun, Mexico, there is an underwater museum named MUSA (Underwater Museum of Art) which contains around 400 sculptures. The deployment of these artworks serves to reduce pressure on natural reefs in the region, attracting divers and promoting ecotourism (EI Gohary, 2013). A similar initiative is started in 2013 in Sharm El Sheik (Egypt), where a project intended to submerge Pharaonic Egyptian sculptures. The objective of this museum was to increase the tourism activities in the area as well as to benefit the overall ecological conditions of the ecosystem conditions (*Op. cit.*).

In Sri Lanka, an underwater museum has been established along the coastal area of Galle. This museum features a collection of statues designed and crafted by navy sailors using eco-friendly materials. The deployment of these statues serves a dual purpose: firstly, to boost diving tourism activities, and secondly, to foster the colonization of diverse marine species, thereby enhancing the overall marine life in the area. In addition to the museum, there are multiple shipwrecks that are considered cultural heritage for the local communities. This cultural heritage not only contributes to the attraction of tourists, but also inspires individuals to engage in dive trails (Fernando and Rathnayake, 2020).

1.2.2.3 Regulation and maintenance

Regarding the supporting ecosystem services, artificial reefs can be used as a rehabilitation tool to reduce the impact of anthropic activities. Between 2002 and 2004, Falcão et al. (2007) studied the influence of artificial reefs in the biogeochemical process in the south coast of Portugal. The study revealed that artificial reefs played an important role in enhancing sediment biomass, facilitating nutrient regeneration, and consequently, promoting increased productivity. It was verified that the high presence of several species of fish, combined with the organic matter they produced, was deposited in the sediments. It was later found that this material was reintegrated into the food chain, stimulating biological colonization.

These artificial reefs contribute essential nutrients, including nitrogen and phosphorus, which settle

in sediments. Nitrogen and phosphorus together, support the growth of phytoplankton, acting as primary producers. Artificial reefs promote biological production throughout the water column. The study observed high concentrations of nutrients (ammonium, nitrates, phosphate, and silicates) in the areas surrounding the base of the reefs, contributing to a greater presence of primary producers. Two years after deployment, the Faro-Ancão artificial reefs have shown an increase in nutrient cycling that positively impacted the entire trophic chain (*Op. cit.*).

The study conducted by Santos et al. (2011) revealed that artificial reefs strategically placed near the shore (as observed in the section of *artificial reefs in Portugal*) play a crucial role in safeguarding juvenile marine life. The deployment of these reefs led to a substantial increase in biomass colonization, with an astounding 88% of the population consisting of juveniles that directly relied on the accumulated biomass within the assemblages. Moreover, these artificial reefs served as protective shelters, providing a refuge for juveniles to escape predators and shielding them from the strong currents prevalent in the area. In terms of biomass enhancement, a notable increase in the density of some fish species, namely sea bass (*Dicentrarchus labrax*) and white seabream (*Diplodus sargus*) was identified, constituting 75% of the total exploitable biomass.

Studies conducted in diversified geographies, namely Florida, Thailand, and the Caribbean focused on investigating the erosion control ecosystem services provided by artificial reefs. In these regions, Reef Ball™ artificial reefs were strategically employed as restoration tools and coastal erosion protection measures, after a tsunami and hurricane event. Located offshore as breakwaters, these artificial reefs played a crucial role in stabilizing beaches by contributing to wave attenuation and refraction. Following the deployment of these artificial reefs, it was evidenced how they reduced the erosion of the areas of study. In the Caribbean, specifically in Gran Dominicus (Dominican Republic) there was clear evidence of accretion, leading to an increase in the shoreline by up to 13 meters in certain areas. Moreover, an additional 44.25 m³/m of sand was deposited without causing adverse effects on the adjacent beaches (Harris, 2009).

Another case study took place in the Dutch Wadden Sea, involving the installation of biodegradable artificial reefs aimed at enhancing accretion and stabilization within a tidal flat. About 3 years after

its implementation, it was evidenced a reduction of 30% of the height of the waves coming into the area of study. Additionally, the artificial reefs played a significant role in promoting sand accretion in the targeted area (Marin-Diaz et al., 2021).

The Neva Bay estuary, an extension of the Gulf of Finland, faces consistent pressure due to ongoing industrial and domestic discharge. This continuous influx has resulted in various adverse effects, including the increase of water turbidity, diminished presence of bottom plants, and a decline in fauna and fish populations. Additionally, toxic substances have been introduced into the trophic chain. In response to these environmental impacts, a project was initiated to deploy artificial reefs aimed at fostering the growth and attraction of encrusting animals and plants with water-filtering capabilities. This filtration capacity was anticipated to contribute significantly to the enhancement of water quality (Antsulevich, 1994).

1.2.3 Ecosystem services and other types of sea bottoms

1.2.3.1 Rocky areas

Rocky areas provide similar benefits to coral reefs and are sometimes identified as rocky reefs, depending on the complexity of their habitat. These habitats are characterized by their substrate where they are dominated by rock formation (Anderson, 1950). These areas have been found to supply provisioning ecosystem services, as their complex structure shelters multiple species and promotes fish diversity (Dominici-Arosemena and Wolff, 2006). Additionally, rocky areas contribute significantly to nutrient cycling and coastal protection from storms (Pellowe et al., 2023). In Cabo Pulmo, located in the Baja California peninsula, the high presence of rocky areas has provided shelter to filter-feeding species and has played a crucial role in maintaining nutrient balance. Additionally, there had been perceived benefits related to supporting ecosystem services, as rocky areas can be eroded and contribute to sand formation. They also serve as essential elements for cultural services, attracting tourism for activities such as diving and snorkelling (Sánchez-Rodriguez et al., 2015).

1.2.3.2 Sandy bottoms

Sandy bottoms are composed by particles made of fragments of biological materials, minerals and rocks (Gray and Elliott, 2009). These habitats play a crucial role in supporting diverse marine life, with higher biomass of piscivorous and planktivorous fish observed in these areas (Cordero-Umaña and Santidrian-Tomillo, 2020). Sandy bottoms also contribute to carbon sequestration. For example, a study done in the English North Sea, found that this type of substrate contains 1.74 Mt of organic carbon and has the capacity to capture 1.32 kt/yr (Burrows et al., 2021). Additionally, sandy areas

indirectly promote water filtration, as bivalve species like *Mya arenaria L.*, a filter-feeder with significant biomass in sandy environments, contribute to improve water quality through their filtering activity (Forster and Zettler, 2004). Similar benefits had been observed in *Ditrupa arietina*, a dominant macrofauna filter-feeding found in the sandy bottoms in Gulf of Lions and the Mediterranean Sea (Riisgård et al., 2002)

1.3 Research objectives

In this thesis it is aimed to relate some ecosystem services to areas off the Algarve coast. For that purpose, a general and some specific objectives were identified as follows.

1.3.1 General objective

Identify and analyse the presence of provisioning and cultural ecosystem services provided by the Oura, Vilamoura and Faro artificial reefs, in comparison with the different types of habitats nearby (sandy bottoms and rocky areas).

1.3.2 Specific objectives

- i. Identify areas of high density/intensity of fishing and recreational vessels for the sandy bottoms, rocky areas and artificial reefs.
- ii. Analyse the spatial distribution patterns of fishing and recreational vessel activities around the Oura, Vilamoura, and Faro artificial reefs compared to nearby sandy bottoms and rocky areas.

1.4 Research questions

- i. How do artificial reefs compare to rocky areas and sandy bottoms in terms of the use of provisioning and cultural ecosystem services?
- ii. Do fishing and recreational vessels choose the area to develop their activities according to the type or habitat (artificial reefs, sandy bottoms or rocky areas)?
- iii. How do distance to the coast and proximity to different habitats influence vessel preferences for operating in specific areas?

2 METHODOLOGY

2.1 Study Area

The Algarve, located in the south coast of Portugal, is one of the main tourism destinations of the country and is well known for its beaches as well as the associated marine recreational activities, such as diving, angling, dolphin watching and others (Valle et al., 2011). Apart from tourism activities, the Algarve has some large fishing communities, specifically in Fuzeta, Olhão and Quarteira (OECD, n.d.) and the tradition related to fisheries had always been an important part of the economic activities in the region (Valadas -Monteiro, 2014).

Considering the artificial reefs of interest (Faro-Ancão and Oura-Vilamoura) it was selected an area of study located in the coordinates 36°56'N to 37°11'N and 7°47'W to 8°17'W.

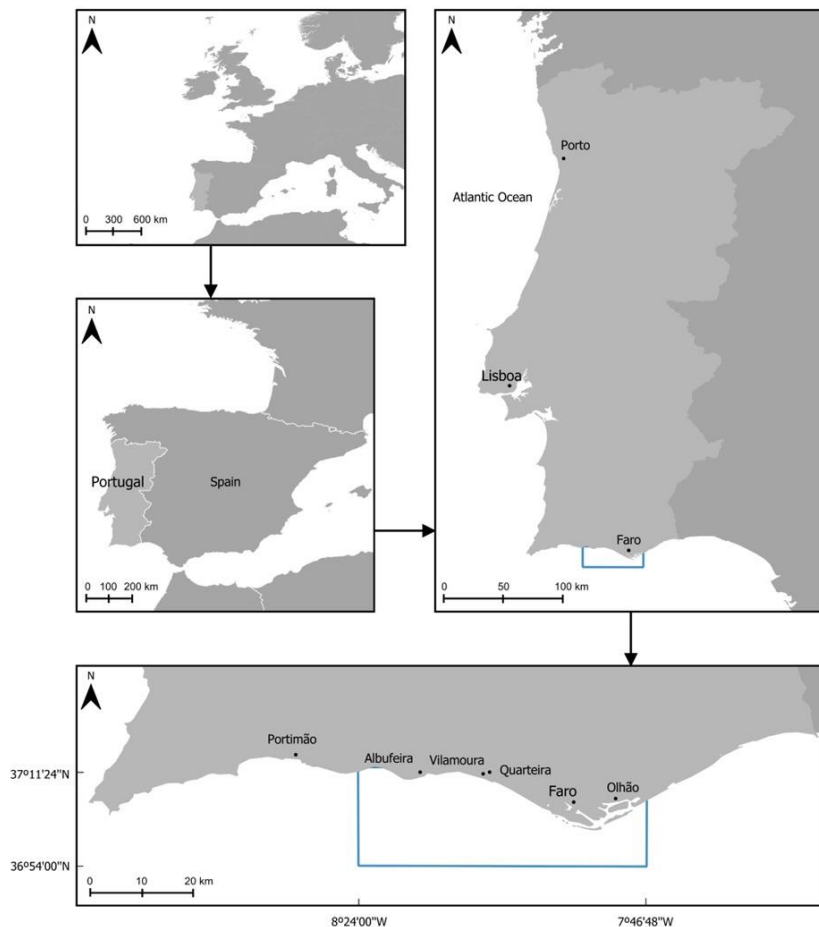


Figure 2. Location area of study. Source: Adapted from Eurostat (n.d.). The software used to create the map was QGIS version 3.36.1 Maidenhead, 2023 (<http://qgis.org>).

2.2 Data selection and classification

- i. Using the location of vessels emitted by the Automatic Identification System (AIS), it was selected hourly data from January, February, March, July, August and September 2022 and January, February and March 2023. This dataset was acquired within the scope of the FCT project SEARM-FIT (2022.01783.PTDC).
- ii. The data was classified using the Maritime Mobile Service Identity (MMSI) number and the European Union Fleet Register (European Commission, n.d.), to classify the vessels according to their activity (fishing or recreational) and according to fishing gear (seiner, multi-gear or trawler).
- iii. The data obtained was cleaned considering the types of vessels that provide information according to their eligibility of artificial reef use. The aspects taken into account to clean the data were:
 - a. Bearing in mind that the artificial reefs are located within 2 to 5 nautical miles off the coast, trawlers were excluded due to the Portuguese regulation prohibiting trawling activities within six nautical miles from the coastline (Regulatory Decree 43/87, of July 17th 1987).
 - b. Vessels traveling at speeds greater than 5 knots were excluded, based on the assumption that vessels moving at low speeds were having drifting behavior, while those exceeding 5 knots were navigating. This implies that vessels traveling at lower speeds might be spending time in the area rather than being in transit (Ramos et al., 2024).
 - c. There were selected only vessels related to recreational activities (sailing, charter and passenger) and fishing vessels. Were excluded tankers, cargo vessels, tugs and special crafts, and unspecified ships. This considering its unlikely that these types of vessels are involved in interactions related to ecosystem services as well as artificial reefs usage.

2.3 Data processing

The data was processed using Geographic Information System (GIS) to obtain density values per unit area based on vessel typology (recreational, seiner, and multi-gear) and the types of habitats (artificial reefs, sandy bottoms and rocky areas), using Kernel Density estimation. Kernel Density estimation is a nonparametric technique that allows to obtain the probability of density and patterns of data (Chen, 2017). This creates a probability density function based on individual sample data that allows to represent the probability of density of continuous variables (Węglarczyk, 2018). Additionally, distance values from each recorded vessel location to the coast, artificial reefs, and rocky areas were also extracted (Figure 3) using a tool called Distance to the nearest hub (QGIS, 2023).

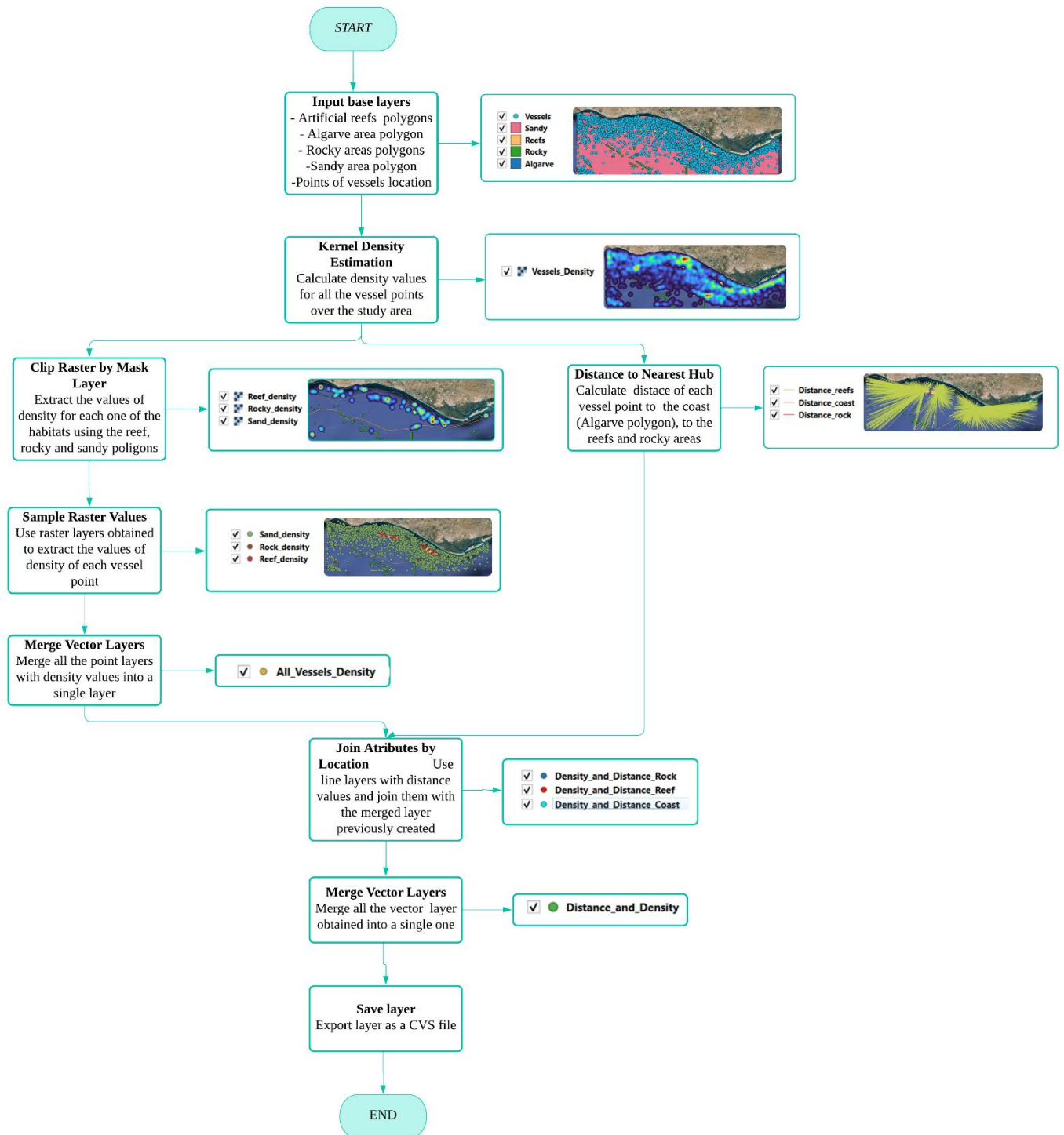


Figure 3. GIS data processing and extraction workflow

2.4 Statistical analysis

In SPSS a general linear model of Analysis of Variance (ANOVA) test was performed to identify and analyse statistical differences between the density means of the different type of vessel, as well as the effect of distance to the coast and different habitats (artificial reef, sandy bottoms and rocky areas). The statistical analyses were done considering a significance level for $p < 0.005$, AIC and

R^2 values to evaluate how the different model proposed fit the data used. ANOVA test allows to compare more than two independent means, as well as to analyze the influence of multiple factors and interactions between them, while considering categorical and continuous variables based on a single dependent variable (Field, 2013).

In this study, it was chosen an ANOVA test as it was aimed to compare vessel density with multiple independent categorical variables, which in this case were vessel type (seiner, multi-gear and recreational) and habitat type (sandy bottoms, rocky areas, and artificial reefs) and how they affect a dependent variable which is vessel density. This test allows to identify effect of each independent variable but also the possible interaction between all the variables analyzed.

There were use different models to analyze how the different combinations of factors (e.g. vessel type, habitat type, distance to coast, reefs and rocky areas) can influence vessel density. This allows to explore the interactions effect between variables and how the dependent variable might be affected in relation to the other variables.

Six different hypotheses were considered, from which a model was created to evaluate whether these assumptions were true or not. This approach allowed to test the main effects, interactions, and potential impact of covariables in vessel density.

Hypothesis 1

H_0 : There is no significant effect of habitat type in vessel density

H_1 : There is a significant effect of habitat type in vessel density

Hypothesis 2

H_0 : There is no significant effect of habitat type and distance to coast in vessel density

H_1 : There is a significant effect of habitat type and distance to coast in vessel density

Hypothesis 3

H₀: There is no significant effect of habitat type and distance to artificial reefs in vessel density

H₁: There is a significant effect of habitat type and distance to artificial reefs in vessel density

Hypothesis 4

H₀: There is no significant effect of habitat type and distance to rocky areas in vessel density

H₁: There is a significant effect of habitat type and distance to rocky areas in vessel density

Hypothesis 5

H₀: There is no significant effect of vessel type and distance to coast in vessel density

H₁: There is a significant effect of vessel type and distance to coast in vessel density

Hypothesis 6

H₀: There is no significant effect of vessel and habitat type and distance to coast in vessel density

H₁: There is a significant effect of vessel and habitat type and distance to coast in vessel density

3 RESULTS

3.1 Records on vessel typology and their distance from the coast

A sample of 2353 AIS records was used for this study. The sample consisted of recreational and professional fishing vessels (seiner and multi-gear). The most abundant were recreational vessels, with a total of 1204 vessels, followed by 685 seiner and 464 multi-gear (Figure 4).

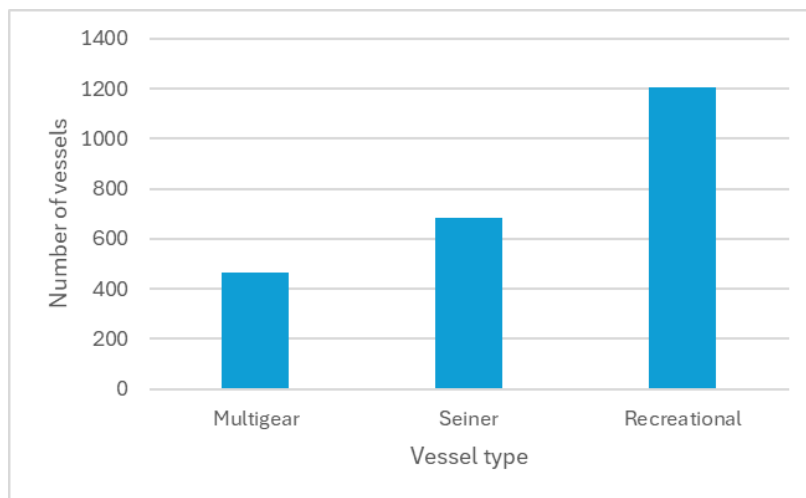


Figure 4. Total number of vessels by typology classification

Considering the distance from the coast, there is no specific pattern related to the seiner and multi-gear vessels (Figures 5 and 6). However, it is evidenced how the number of recreational vessels decreases further from the coast (Figure 7).

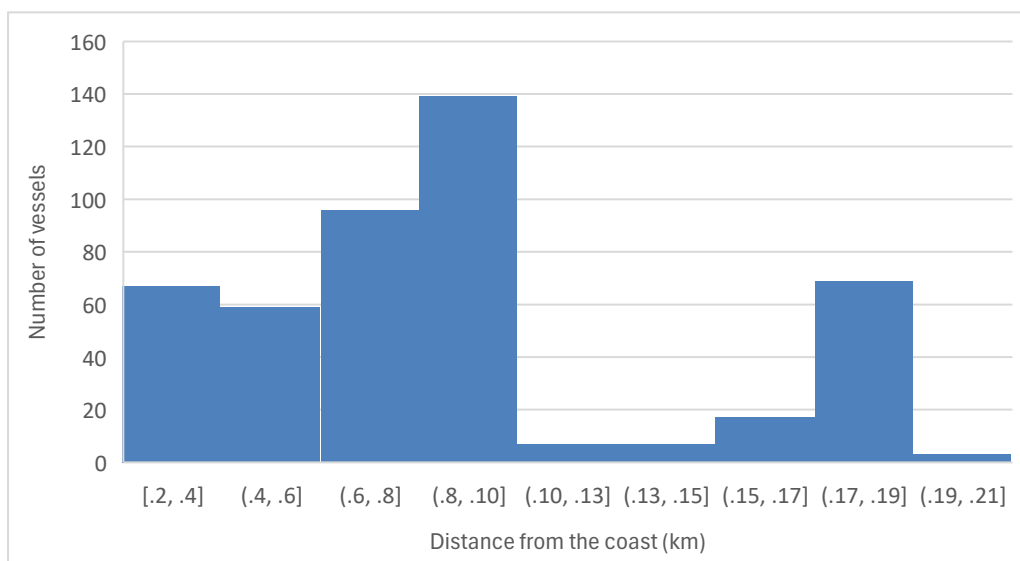


Figure 5. Multi-gear fishing vessels distribution from the coast

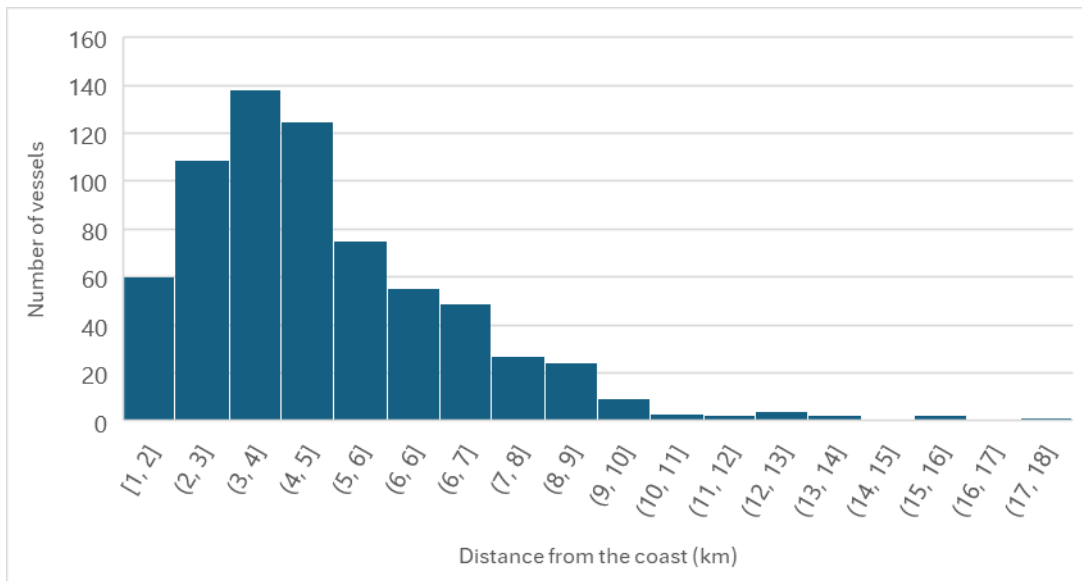


Figure 6. *Seiner fishing vessels distribution from the coast*

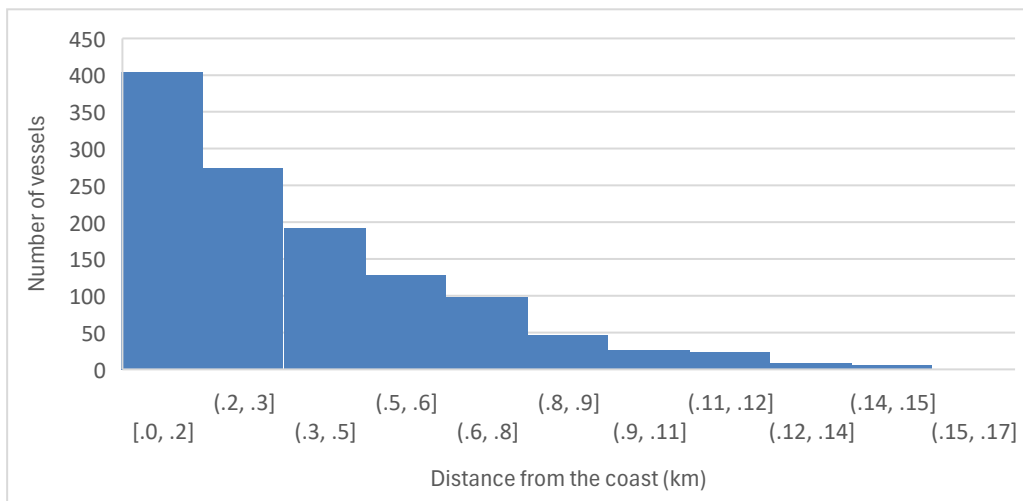


Figure 7. *Recreational vessels distribution from the coast*

3.2 Vessel density by habitat type according to métier

Regarding the density of vessels in the different type of habitats obtained from the Kernel density estimation using GIS, there is a higher density of vessels per unit of area in sandy bottoms with a total of 7.39, followed by 4.23 in artificial reefs and 2.56 in rocky areas.

Following are presented 6 different models tested to assess influence of distance to coast, distance to artificial reef and distance to rocky areas, habitat type (sandy bottoms, artificial reefs and rocky areas), and type of vessels (recreational, seiner and multi-gear), on vessels density.

Table 2. *General linear model results to analyse the difference in vessel density between the different habitat types; sandy bottoms, rocky areas and artificial reefs (Hypothesis 1)*

Variable	Df	F	Sig
Habitat	2	62.991	<0.001
R2		0.050	
AIC		13686,037	

Note. Complete results are provided in Annex A

When evaluating the possible effect of habitat type and distance to coast on vessel density, it was found that there is a significant effect of both of them (Table 3).

Table 3. *General linear model results to analyse the effect of distance to coast and habitat on vessels density (Hypothesis 2)*

Variable	Df	F	Sig
Habitat	2	78.548	<0.001
Distance to coast	1	242.357	<0.001
R2		0.139	
AIC		13686,037	

Note. Complete results are provided in Annex B

The third and fourth hypotheses aimed to identify the effect of distance to artificial reefs which was found to be false as no significant effect was found (Tables 4).

Table 4. *General linear model results to analyse the effect of distance to reefs and habitat in vessels density (Hypothesis 3)*

Variable	Df	F	Sig
Habitat	2	62.987	<0.001
Distance to artificial reef	1	0.259	0.611
R2		0.050	
AIC		13697,037	

Note. Complete results are provided in Annex C.

Hypothesis 4 proved to be false as there was not found any significant effect of distance to rocky areas in relation to vessel density (Table 5).

Table 5. *General linear model results to analyse the effect of distance to rocky areas and habitat*

on vessels density (Hypothesis 4)

Variable	Df	F	Sig
Habitat	2	62.016	<0.001
Distance to rocky areas	1	0.126	0.723
R2		0.050	
AIC		13697,037	

Note. Complete results are provided in Annex D

Model number 5 proved the significant effect of distance to coast and vessel type in vessel density, both with p-values below 0.05 (Table 6).

Table 6. *General linear model results to analyse the effect of vessel type and distance to coast on vessel density (Hypothesis 5)*

Variable	Df	F	Sig
Vessel type	2	60.59	<0.001
Distance to coast	1	327.721	<0.001
R2		0.126	
AIC		13514.898	

Note. Complete results are provided in Annex E

The last hypothesis, which stated there is an effect of habitat type, vessel type, and distance to coast on vessel density, proved to be true as the model showed a significant effect of all the variables considered (Table 7).

Table 7. *General linear model results to analyse the effect of habitat, vessel type and distance to coast in vessel density (Hypothesis 6)*

Variable	Df	F	Sig
Habitat (Fixed factor)	2	61.157	<0.001
Distance to coast (Covariable)	1	371.566	<0.001
Vessel type (Fixed factor)	2	7.961	<0.001
Habitat * Vessel type	4	0.858	0.488

R2	0.182
AIC	13514.898

Note. Complete results are provided in Annex F

Considering model 6 gave an R2 equal to 0.182 and the lowest AIC (13514.898), it was chosen to be the best model as it is the one with the highest value. This model shows a significant effect of habitat, distance to coast and vessel type on vessel density.

As it is evidenced in table 8, vessel type significantly affects vessel density but the interaction between vessel type and habitat doesn't. This indicates that both vessel type and habitat independently have a significant effect in vessels density. However, the lack of effect between the intersection of these variables indicates that the effect of vessel type on density doesn't depend on the habitat type.

Table 8. Relationships between variables of model 6 (*H = Habitat, AR= Artificial reef, R=Rocky areas, S= Sandy bottoms, T= vessel type, M=multi-gear, Se=Seiner, Re=Recreational*).

Parameter	B	Est. Dev	t	Sig
H = AR	-3.418	0.688	-4.966	<0.001
H = R	-5.184	0.620	-8.364	<0.001
H = S	0 ^a			
T = M	2.953	0.271	10.891	<0.001
T = Se	1.112	0.206	5.401	<0.001
T = Re	0 ^a			negat
[H=AR]*[T=M]	-2.156	1.718	-1.255	0.210
[H=AR]*[T=Se]	-0.139	0.979	-0.12	0.887
[H=AR]*[T=Re]	0 ^a			
[H=R]*[T=M]	1.532	1.248	1.228	0.220
[H=R]*[T=Se]	-0.163	1.163	-0.140	0.888
[H=R]*[T= Re]	0 ^a			
[H=S]*[T=M]	0 ^a			
[H=S]*[T=Se]	0 ^a			
[H=S]*[T= Re]	0 ^a			

Note. a Parameter set to zero because it is redundant

When comparing vessel densities at a specific location, the coefficient B shows that for every recreational vessel, there are 2.953 more multi-gear vessels and 1.112 more seiner vessels (Table 8). This suggests that multi-gear and seiner vessels have the highest densities among the types analyzed, the first one being the predominant one.

Considering habitat type alone, there is a significant effect in vessel density, highlighting the relevance of this variable and how it can influence fishing activities. This variation shows how specific environments can be more attractive or favorable for the fishing community. This relationship is illustrated in Table 8, where it demonstrates how each habitat can affect fishing intensity, being sandy bottoms preferred.

There were found no significant changes or patterns in habitat density when comparing winter and summer periods (Figure 8).

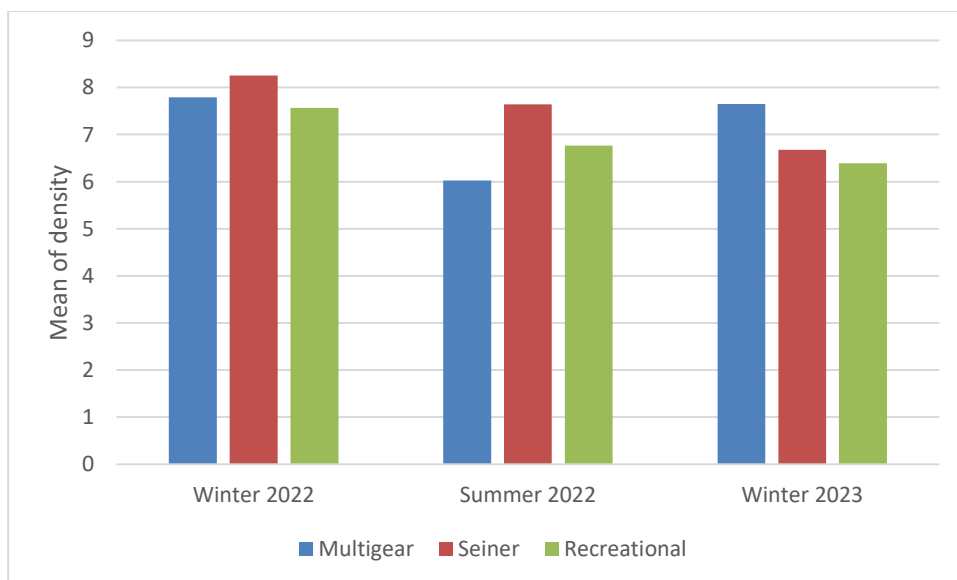


Figure 8. Means of vessels density in summer and winter periods

4 DISCUSSION

Regarding the artificial reef area, the negative values suggest a decrease in vessel density in the artificial reefs and rocky areas in comparison to the sandy bottoms. However, multi-gear show higher intensity in rocky areas which could be attribute to the ability of these vessels to use different fishing techniques and a diversity of gears, that are better suited to adapt to different types of habits, depts and others (Duarte et al., 2009; Moura et al., 2016).

No specific pattern was found regarding seiner and recreational vessels regarding season, but there is an increase in the presence of multi-gear vessels in both winter periods (Figure 8). This might be related to the increase of spawning during this season which has been found to be related to an increase of landings of pelagic fish (Bueno-Pardo et al., 2020). However, the study presented by Szyuka et al. (2022) suggest otherwise, as it showed evidence that multi-gear vessels in the Algarve don't change their operations based in seasonal variability and land target species through the entire year.

The density value obtained for the recreational vessels do not suggest a use of artificial reefs more than other habitats, while there is a preference for sandy bottoms. However, is important to consider the factor of distance to the coast. This pattern can be related to the influence of the scenic value in the coastal area, as the main recreational activities in the Algarve are related to sightseeing along the coast, dolphin watching and others (Correia & Crouch, 2004; Serra et al., 2013; Doldur, 2018). Studies show that tourist perceive the landscapes as one of the main attractions to visit coastal areas (Morgan, 1999; Onofri and Nunes, 2013). The higher values of density closer to the coast, might be related to this preference, where visits to the caves and coastal tours are predominant services offered by tourism companies (Valle et al., 2011; Guerreiro et al., 2016). Additionally, the presence of recreational vessels in some areas might be attributed to scuba diving activities. For instance, the B24 Liberator, a wreck accidently sunken in 1943, was found to be a popular diving site and frequented by recreational vessels (Rangel et al., 2014).

Additionally, it is important to take into consideration the principle of proximity which indicates a

tendency of different type of vessels to operate in specific areas according to their features and areas of interest (Hamel et al., 2018). This, in relation to recreational activities, it has been evidence that aspects such as travel time can influence where the activities are done, as well as the characteristics of a specific area (Paudel, et al, 2011). This would explain the significant effect of distance to coast in vessel density, where could be assumed that recreational vessels tend to stay closer to the coast due to aspects such as travel time, and the recreational activities previously referred.

Other study from Ramos et al. (2006a) showed evidence of recreational vessels interacting with artificial reef modules. All the records collected showed predominant activity of recreational fishing, although this type of reefs were found to be the least preferred ones for diving activities and no record was found related to this activity. The study sampled vessels smaller than 9 m long, which are smaller than the ones required to have the AIS tracking system. Is important to take into consideration that the SOLAS Regulation V/19-1, which requires ships to be equipped with AIS, was only made mandatory in Portugal from 2008 (DGRM, 2013) and this research was done previous this time. However, this provides insight of potential behaviour of fishing vessels that operate without AIS in the present.

Taking into consideration the influence of proximity in fishing vessels, these had been found to operate in areas with high concentration of target species and fish availability (Saul and Die., 2016). The results didn't show any specific pattern related to distance from the coast for multi-gear fishing vessels, but the highest concentration seiner vessels was found between 2 to 6 kilometers (Figure 4). This suggests the significant role of economic factors, as fishing closer to the coast implicates less travel time and fuel expenses, thereby reducing overall costs (Dunn et al., 2012).

There is evidence of provisioning ecosystem services, as the vessels density indicates the presence of fishing vessels in the artificial reef area. This aligns with other studies, where fishermen reported perceiving provisioning ecosystem service in the Oura artificial reef (Ramos et al., 2019).

The patterns found suggest that the type of habitat is significantly important for fishermen to choose where they'll fish. The result show a preference of choosing sandy habitats, followed by artificial reefs and rocky areas. This suggests that sandy bottoms can offer important ecosystem services and

do not always require intervention to improve habitat conditions, as other studies have proposed (Falcão et al., 2009; Bombace et al., 1994). The results show that in the area of study selected, sandy bottoms are the most intensively used type of habitat for fishing and recreational activities.

Sandy bottoms had been perceived as plain habitats that do not significantly promote diversity or fish abundance, when it is compared to other type of habitats such as artificial reefs (Fujita et al., 1996). However, sandy bottoms in shallow marine areas contain multiple organisms that harbour sea life (Watling, 2005) and 70% of benthic fauna is mostly found in the first 8 cm of these sediments surface (Kotwicki et al., 2005; Giere, 2008;). Previous considerations reflect the importance of sandy bottoms for numerous fish species.

In relation to the predominant density of multi-gear vessels in the area of study, it can be related to the type of gear used and target species. In the south coast of Portugal, multi-gear vessels predominantly use traps and pots, the most common gear type, to catch species like cuttlefish and octopus (Erzini et al., 2008).

Another factor to take into consideration to explain why sandy bottoms are the areas with the highest density of fishing vessels, could be attributed to the accessibility of these type of habitats that allow fisherman to reach productive areas easier. In relation to target species, these areas might be better to avoid bycatch species that could be more present in areas closer to the artificial reefs or rocky areas (Werner et al., 2006).

Ecosystem services have proven to provide significant benefits to human beings, as it has been described through this piece of research. However, cultural services such as recreational activities have been found to eventually cause negative impacts in the ecosystems, by attracting more people to these visited areas and increase some pressure over the environment and affecting the quality of the ecosystem services supplied (Aktürk and Güneroğlu, 2021; Pellaton et al., 2022).

Regarding recreational fishing, which has been found to be one of the main marine recreational activities done in Portugal (Hyder et al., 2018), it had been found that most of the species caught, particularly European seabass, were caught below the legal minimum landing size, with most of the fish as small as 15 cm, despite the legal limit being 36 cm (Guerreiro et al., 2011). This has

significant negative effects on ecosystems, as catching fish before they can grow to a reproductive age can lead to a future decline in fish stock (Najmudeen and Sathiadhas, 2008; Kamei et al., 2013). Also related to provisioning services, the increase of fishing activity in a specific area can lead to an alteration of the services offered as they can lead to unsustainable fishing (Braat et al., 2010; Polovina, 1989).

The increase of recreational activities in the coastal areas and the lack of environmental awareness among tourist, can cause negative impacts on this type of environments. For this reason, despite the perceived cultural ecosystem services, they can also contribute to a decrease in the environment quality (Guerreiro et al., 2016).

5. CONCLUSION AND FURTHER WORK

In comparison, between the 3 types of habitats studied, sandy bottoms were found to be the ones with the highest intensity of use for recreational and fishing activities. This reflects the importance of preserving these natural habitats and the significant contribution to the local communities by providing ecosystem services.

Distance to coast was found to significantly influence the presence of recreational and seiner vessels, which mainly operate in areas closer to the shore. These findings highlight the importance of considering factors such as travel time and cost for the fishing and marine recreational industry, as these might influence the activities. Additionally, in relation to recreational vessels, their proximity to the coast can be related to the scenic value of the Algarve's coastal landscapes.

The distance to the different habitats did not show a significant effect in the vessels' activity. This reflects that the other factors considered, such as habitat type, have a more critical role for the fishing vessels to choose an area to operate.

There was found no significant use of the ecosystem services provided by the artificial reefs, either by fishing or recreational vessels. However, this does not imply that artificial reefs do not provide these services, as numerous studies have shown how they contribute positively to fishing

communities (Bohnsack and Sutherland, 1985; Johnson et al., 1994; Ramos et al., 2006a; Watanuki and Gonzales, 2006; Santos et al. 2011). The lack of use evidenced from the fishing vessels might be affected by the vessels size, as the data use only includes vessels of 300 gross tonnage and upwards, which are the ones required by the European Parliament and Council (2002) to have mandatory AIS tracking system (Directive 2002/59/EC of 27 June 2002). This implies, that there is missing information of smaller fishing vessels, which are likely within the artificial reef area (Cardenas, 2011; Tessier et al., 2014).

Considering the missing information, its necessary to continue with further studies using alternative methodologies that allow collect information of vessels without AIS systems. Additionally, the hourly location records present limitations to identify and understand vessels patterns and activities. For this reason, it's necessary to continue doing studies with more frequent data collection that allow to obtain more accurate results regarding the vessels interactions with the different habitats.

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6. ANNEXES

Annex A – Results ANOVA test model 1

Factores inter-sujetos

		N
Habitat	Reef	81
	Rocky	79
	Sand	2193

Estadísticos descriptivos

Variable dependiente: Density

Habitat	Media	Desv. estándar	N
Reef	4,2314521250	2,1851563268	81
Rocky	2,5617001441	1,2173228278	79
Sand	7,3940228725	4,5709838638	2193
Total	7,1229129167	4,5540477213	2353

Pruebas de efectos inter-sujetos

Variable dependiente: Density

Origen	Tipo III de suma de cuadrados	gl	Media cuadrática	F	Sig.
Modelo corregido	2481,959 ^a	2	1240,980	62,991	<,001
Intersección	7905,605	1	7905,605	401,282	<,001
Habitat	2481,959	2	1240,980	62,991	<,001
Error	46296,993	2350	19,701		
Total	168160,498	2353			
Total corregido	48778,953	2352			

a. R al cuadrado = ,051 (R al cuadrado ajustada = ,050)

Estimaciones de parámetro

Variable dependiente: Density

Parámetro	B	Desv. Error	t	Sig.	Intervalo de confianza al 95%	
					Límite inferior	Límite superior
Intersección	7,394	,095	78,011	<,001	7,208	7,580
[Habitat=Reef]	-3,163	,502	-6,297	<,001	-4,147	-2,178
[Habitat=Rocky]	-4,832	,508	-9,507	<,001	-5,829	-3,836
[Habitat=Sand]	0 ^a	.	.	.	.	.

a. Este parámetro está establecido en cero porque es redundante.

Annex B – Results ANOVA test model 2

Factores inter-sujetos

		N
Habitat	Reef	81
	Rocky	79
	Sand	2193

Estadísticos descriptivos

Variable dependiente: Density

Habitat	Media	Desv. estándar	N
Reef	4,2314521250	2,1851563268	81
Rocky	2,5617001441	1,2173228278	79
Sand	7,3940228725	4,5709838638	2193
Total	7,1229129167	4,5540477213	2353

Pruebas de efectos inter-sujetos

Variable dependiente: Density

Origen	Tipo III de suma de cuadrados	gl	Media cuadrática	F	Sig.
Modelo corregido	6811,885 ^a	3	2270,628	127,093	<,001
Intersección	11678,741	1	11678,741	653,688	<,001
Dis_coastkm	4329,925	1	4329,925	242,357	<,001
Habitat	2806,677	2	1403,339	78,548	<,001
Error	41967,068	2349	17,866		
Total	168160,498	2353			
Total corregido	48778,953	2352			

a. R al cuadrado = ,140 (R al cuadrado ajustada = ,139)

Estimaciones de parámetro

Variable dependiente: Density

Parámetro	B	Desv. Error	t	Sig.	Intervalo de confianza al 95%	
					Límite inferior	Límite superior
Intersección	9,165	,145	63,117	<,001	8,880	9,449
Dis_coastkm	-,352	,023	-15,568	<,001	-,396	-,308
[Habitat=Reef]	-3,620	,479	-7,555	<,001	-4,560	-2,681
[Habitat=Rocky]	-4,971	,484	-10,268	<,001	-5,920	-4,022
[Habitat=Sand]	0 ^a	.	.	.	.	.

a. Este parámetro está establecido en cero porque es redundante.

Annex C – Results ANOVA test model 3

Factores inter-sujetos

		N
Habitat	Reef	81
	Rocky	79
	Sand	2193

Estadísticos descriptivos

Variable dependiente: Density

Habitat	Media	Desv. estándar	N
Reef	4,2314521250	2,1851563268	81
Rocky	2,5617001441	1,2173228278	79
Sand	7,3940228725	4,5709838638	2193
Total	7,1229129167	4,5540477213	2353

Pruebas de efectos inter-sujetos

Variable dependiente: Density

Origen	Tipo III de suma de cuadrados	gl	Media cuadrática	F	Sig.
Modelo corregido	2487,055 ^a	3	829,018	42,067	<,001
Intersección	5786,240	1	5786,240	293,612	<,001
Distance_Reefkm	5,096	1	5,096	,259	,611
Habitat	2482,584	2	1241,292	62,987	<,001
Error	46291,898	2349	19,707		
Total	168160,498	2353			
Total corregido	48778,953	2352			

a. R al cuadrado = ,051 (R al cuadrado ajustada = ,050)

Estimaciones de parámetro

Variable dependiente: Density

Parámetro	B	Desv. Error	t	Sig.	Intervalo de confianza al 95%	
					Límite inferior	Límite superior
Intersección	7,325	,165	44,441	<,001	7,002	7,649
Distance_Reefkm	,008	,016	,509	,611	-,024	,040
[Habitat=Reef]	-3,161	,502	-6,292	<,001	-4,146	-2,176
[Habitat=Rocky]	-4,834	,508	-9,509	<,001	-5,831	-3,838
[Habitat=Sand]	0 ^a	.	.	.	.	.

a. Este parámetro está establecido en cero porque es redundante.

Annex D – Results ANOVA test model 4

Factores inter-sujetos

		N
Habitat	Reef	81
	Rocky	79
	Sand	2193

Estadísticos descriptivos

Variable dependiente: Density

Habitat	Media	Desv. estándar	N
Reef	4,2314521250	2,1851563268	81
Rocky	2,5617001441	1,2173228278	79
Sand	7,3940228725	4,5709838638	2193
Total	7,1229129167	4,5540477213	2353

Pruebas de efectos inter-sujetos

Variable dependiente: Density

Origen	Tipo III de suma de cuadrados	gl	Media cuadrática	F	Sig.
Modelo corregido	2484,434 ^a	3	828,145	42,020	<,001
Intersección	5985,626	1	5985,626	303,713	<,001
Dis_rock	2,474	1	2,474	,126	,723
Habitat	2444,462	2	1222,231	62,016	<,001
Error	46294,519	2349	19,708		
Total	168160,498	2353			
Total corregido	48778,953	2352			

a. R al cuadrado = ,051 (R al cuadrado ajustada = ,050)

Estimaciones de parámetro

Variable dependiente: Density

Parámetro	B	Desv. Error	t	Sig.	Intervalo de confianza al 95%	
					Límite inferior	Límite superior
Intersección	7,340	,179	40,916	<,001	6,988	7,692
Dis_rock	,022	,061	,354	,723	-,099	,142
[Habitat=Reef]	-3,149	,504	-6,253	<,001	-4,137	-2,162
[Habitat=Rocky]	-4,820	,510	-9,459	<,001	-5,819	-3,821
[Habitat=Sand]	0 ^a	.	.	.	.	.

a. Este parámetro está establecido en cero porque es redundante.

Annex E – Results ANOVA test model 5

Between-Subjects Factors

		N
Typology	Multigear	464
	Seiner	685
	Tourism	1204

Descriptive Statistics

Dependent Variable: Density

Typology	Mean	Std. Deviation	N
Multigear	7,1690954137	4,7154600343	464
Seiner	7,5835561991	4,1435593917	685
Tourism	6,8430380604	4,6933906408	1204
Total	7,1229129167	4,5540477213	2353

Pruebas de efectos inter-sujetos

Variable dependiente: Density

Origen	Tipo III de suma de cuadrados	gl	Media cuadrática	F	Sig.
Modelo corregido	6183,378 ^a	3	2061,126	113,664	<,001
Intersección	55172,095	1	55172,095	3042,552	<,001
Dis_coastkm	5942,728	1	5942,728	327,721	<,001
Typology	2178,171	2	1089,085	60,059	<,001
Error	42595,575	2349	18,133		
Total	168160,498	2353			
Total corregido	48778,953	2352			

a. R al cuadrado = ,127 (R al cuadrado ajustada = ,126)

Estimaciones de parámetro

Variable dependiente: Density

Parámetro	B	Desv. Error	t	Sig.	Intervalo de confianza al 95%	
					Límite inferior	Límite superior
Intersección	8,652	,158	54,667	<,001	8,342	8,963
Dis_coastkm	-,488	,027	-18,103	<,001	-,541	-,435
[Typology=Multigear]	2,961	,274	10,789	<,001	2,423	3,499
[Typology=Seiner]	1,071	,205	5,234	<,001	,670	1,472
[Typology=Tourism]	0 ^a	.	.	.	.	.

a. Este parámetro está establecido en cero porque es redundante.

Annex F – Results ANOVA test model 6

Between-Subjects Factors

		N
Habitat	Reef	81
	Rocky	79
	Sand	2193
Typology	Multigear	464
	Seiner	685
	Tourism	1204

Estadísticos descriptivos

Variable dependiente: Density

Habitat	Typology	Media	Desv. estándar	N
Reef	Multigear	4,2628507271	2,7938977855	7
	Seiner	4,7436427425	2,4280049479	37
	Tourism	3,7133212315	1,6938083095	37
	Total	4,2314521250	2,1851563268	81
Rocky	Multigear	2,9296492099	1,0494988133	15
	Seiner	2,8858421611	1,2118564135	18
	Tourism	2,3148785725	1,2335626466	46
	Total	2,5617001441	1,2173228278	79
Sand	Multigear	7,3589945220	4,7351998186	442
	Seiner	7,8845651682	4,1347985762	630
	Tourism	7,1321503343	4,7177958687	1121
	Total	7,3940228725	4,5709838638	2193
Total	Multigear	7,1690954137	4,7154600343	464
	Seiner	7,5835561991	4,1435593917	685
	Tourism	6,8430380604	4,6933906408	1204
	Total	7,1229129167	4,5540477213	2353

Pruebas de efectos inter-sujetos

Variable dependiente: Density

Origen	Tipo III de suma de cuadrados	gl	Media cuadrática	F	Sig.
Modelo corregido	9039,453 ^a	9	1004,384	59,217	<,001
Intersección	10264,839	1	10264,839	605,204	<,001
→ Dis_coastkm	6302,108	1	6302,108	371,566	<,001
Habitat	2074,568	2	1037,284	61,157	<,001
Typology	270,040	2	135,020	7,961	<,001
Habitat * Typology	58,236	4	14,559	,858	,488
Error	39739,500	2343	16,961		
Total	168160,498	2353			
Total corregido	48778,953	2352			

a. R al cuadrado = ,185 (R al cuadrado ajustada = ,182)

Estimaciones de parámetro

Variable dependiente: Density

Parámetro	B	Desv. Error	t	Sig.	Intervalo de confianza al 95%	
					Límite inferior	Límite superior
Intersección	9,019	,157	57,372	<,001	8,711	9,327
Dis_coastkm	-,505	,026	-19,276	<,001	-,556	-,454
[Habitat=Reef]	-3,418	,688	-4,966	<,001	-4,767	-2,068
[Habitat=Rocky]	-5,184	,620	-8,364	<,001	-6,400	-3,969
[Habitat=Sand]	0 ^a	.	.	.	.	.
[Typology=Multigear]	2,953	,271	10,891	<,001	2,421	3,484
[Typology=Seiner]	1,112	,206	5,401	<,001	,708	1,516
[Typology=Tourism]	0 ^a	.	.	.	.	.
[Habitat=Reef] * [Typology=Multigear]	-2,156	1,718	-1,255	,210	-5,524	1,213
[Habitat=Reef] * [Typology=Seiner]	-,139	,979	-,142	,887	-2,060	1,782
[Habitat=Reef] * [Typology=Tourism]	0 ^a	.	.	.	.	.
[Habitat=Rocky] * [Typology=Multigear]	1,532	1,248	1,228	,220	-,915	3,978
[Habitat=Rocky] * [Typology=Seiner]	-,163	1,163	-,140	,888	-2,444	2,118
[Habitat=Rocky] * [Typology=Tourism]	0 ^a	.	.	.	.	.
[Habitat=Sand] * [Typology=Multigear]	0 ^a	.	.	.	.	.
[Habitat=Sand] * [Typology=Seiner]	0 ^a	.	.	.	.	.
[Habitat=Sand] * [Typology=Tourism]	0 ^a	.	.	.	.	.

a. Este parámetro está establecido en cero porque es redundante.

