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# Boating Tourism and Fishing Interactions: A Social Network Analysis Using AIS Data

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**Abstract:** Boating tourism in coastal–maritime areas often overlaps spatially and temporally with other economic activities, such as fishing, leading to complex interactions. These interactions can create opportunities for positive cooperation or generate conflicts that pressure natural resources and stakeholders. The aim of this study is to show whether or not there is evidence of interactions between fishing ($n_f$ = 43) and tourism/recreation ($n_t$ = 65) vessels. This study focuses on the interaction between maritime tourism activities and fishing in southern Portugal, using a social network analysis (SNA) approach based on automatic identification system (AIS) data to evaluate spatial and temporal patterns. The findings reveal that tourism activities dominate zones closer to the coast, with intermediate areas serving as shared spaces where interactions between vessel activities are more likely to occur. There was evidence of occasional interactions between a few recreational and fishing vessels (two passengers and three seiners), but the inferences from the results are insufficient to demonstrate how beneficial they are for both activities.

**Keywords:** automatic identification system (AIS); common pool resources (CPRs); maritime tourism; social network analysis (SNA)

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## 1. Introduction

Marine and coastal tourism is one of the sectors with well-established activities in the blue economy scope. Furthermore, in recent decades, there has been a growth in tourism in general, and maritime and coastal tourism activities have accompanied this development [1,2]. Fisheries is also one of the sectors with well-established activities in the blue economy [3].

On a local scale, these two sectors of the blue economy interact in a certain way [4,5]. On the one hand, marine and coastal tourism focuses on leisure activities and provides entertainment experiences to its clientele in essentially non-extractive activities, but some are also extractive, e.g., angling [6,7]. On the other hand, professional fishing, focused on catching wild fish (extractive activity), supplies local or larger-scale markets, which in turn also sustain part of the tourist activity (i.e., in gastronomy and hospitality).

The interaction between economic activities that take advantage of the resources (i.e., goods and services) in coastal zones can be modelled, and their relationships of involvement can be analysed through network approaches. Under this lens, some studies related to social network analysis can be found [8–11].

As presented in the previous paragraphs, although there are some studies in the literature that focus on the different activities carried out by boat and that explore the coastal zone, little is still known about the interaction between the different activities. The reasons for this lack of studies could be diverse, including the complexity of collecting and analysing data assertively.

This study aims to contribute to the analysis of the complex network of interaction between maritime tourism and fishing activities through AIS data via a social network analysis. Additional tools such as the Sankey diagram and the dendrogram are also used to strengthen the SNA and to facilitate the understanding of trends in the analysed data.

## 2. Literature Review

### 2.1. Common Pool Resources (CPRs)

Marine spaces provide us with diverse resources, and people benefit by consuming many of them without taking them away from the environment [12]. There are other resources that are subtracted, such as fishing resources [13].

Marine spaces, however, are used by several stakeholders, and they may eventually be conserved or over-exploited, which can generate some conflicts. This rationale leads us to the theory of common pool resources pioneered by Elinor Ostrom and continued by other authors [14,15]. This theory explores the governance systems, norms, and rules that regulate the exploitation of resources and allow them to be managed in a sustainable way [16].

Sharing information about the abundance and availability of natural resources is, however, a tacit way of managing them in a more sustainable way [17]. The CPRs theory allows for highlighting the pressure exerted on the exploitation of resources, their overlap, and engendering management solutions through collective governance or management recommendations [18].

### 2.2. Automatic Identification System (AIS)

Vessel tracking performed by AIS has several advantages [19,20]. AIS records contain spatial-temporal information on passenger boats (regardless of their size), fishing boats (e.g., in the EU if they are at least 15 m long or 300 GT), and other types of boats [21]. These records are provided on a voluntary basis from a transponder, which is equipment mounted on the vessels themselves [22].

AIS pings are a way to collect a large volume of data in a trusted and non-intrusive way [23]. In addition, AIS records allow for visualising the simultaneous occurrence of vessels in a given area, which in turn facilitates the recognition of the interactions that may exist between coastal area users [24].

The spatial and temporal interception of activities such as maritime tourism and fishing have aroused some research interest due to their relevance in the busiest coastal zones [25]. An analysis of AIS data allows for verifying where there are the highest densities of spatial use by the stakeholders and where there are overlapping areas [26]. A proper understanding of these phenomena allows for improvement in management processes and can be effectively used for maritime spatial planning [27].

### 2.3. Social Network Analysis (SNA)

In the maritime–coastal space, understanding the interactions between groups of actors and exploited resources is important [28]. However, these interactions make the system complex, and there is no shared consensus for its approach [29]. Systems are complex because they usually include a large number of components that interact with other complementary forms [30]. To facilitate this understanding, networks (e.g., SNA or social-ecological) are very useful tools to facilitate the visualisation and analysis of complex systems [31,32]. An approach using SNA from AIS data allows the researcher to meet the design principles of CPR theory, namely because it is possible to establish well-defined boundaries, monitor and verify interactions between activities, and improve the understanding of the (in)existence of collective choice arrangements.

The tourist destination is a key factor in tourism management research. Economic activities carried out in coastal areas aimed at exploiting existing resources, whether in a non-extractive or extractive way, are key to establishing contact and arousing the interest of customers [33–35]. Boat trips to observe the natural beauty of the coastal areas, as well as to enjoy marine resources through underwater or fishing/angling activities, are important generators of economic benefits, where tourists are willing to pay for memorable moments of entertainment and leisure time [36].

The resources obtained by professional fishing are also generators of economic wealth by entering the food market—through intermediaries and distribution networks—which is consumed not only by locals but also by visitors and tourists [37]. There is a more recent phenomenon that consists of the incorporation of fishing into tourism activities, where it sometimes becomes more profitable to take tourists fishing than to practice fishing as the main economic activity [38]. This activity is called fishing-tourism and has been generalised by several countries [39–43].

## 3. Methodology

### *3.1. Research Question*

In systems of exploitation of living resources where there are several groups of actors/stakeholders—in light of the CPRs theory—it is of crucial importance to know how these resources are exploited by different groups and what interaction exists between them [44]. With this focus as a premise, the present study used AIS pings as primary data, and from these, a research question (RQ) was built:

RQ: What are the identifiable patterns of the tourism and fishing vessels that use the resources identified in the study area under analysis and their interaction?

### *3.2. Conceptual Approach*

It is ascertained whether there is any type of communication or cooperation between the social entities (i.e., the different vessels and the firms that operate them) with regard to the sharing of common resources (Figure 1). To this end, the terrestrial and satellite AIS records of the different vessels operating in the area under analysis are used to categorise the type of vessels according to the distance from the coast and the type of resources sought after.

From the collection of these AIS data, it will be possible to explore ways of analysing them so that information can be obtained that may be useful for decision-makers to improve coastal management of maritime traffic in the areas under analysis [19–21,27]. Thus, in the present study, it was defined that it would be possible to explore AIS data in three complementary ways, as described below. In short, namely, trying to understand the interaction between vessels of different activities (i.e., with the help of an SNA), understanding whether there are seasonal differences in terms of resource exploration and number of vessels (i.e., through Sankey diagrams), and summarising the hierarchy of the type of activities found in AIS pings according to resource exploration (i.e., through a dendrogram).

Social network analysis (SNA): from the categorisation of these data, in order to better understand the complex interdependencies—similar to what has been conducted in other research contexts [10,17,45]—a social network was built, where the social network was composed of the categories/types of vessels, i.e., recreational and fishing, and the different activities that can be related. Social interaction (between these vessels) included the total number of AIS records and the pattern of proximity of other vessels.

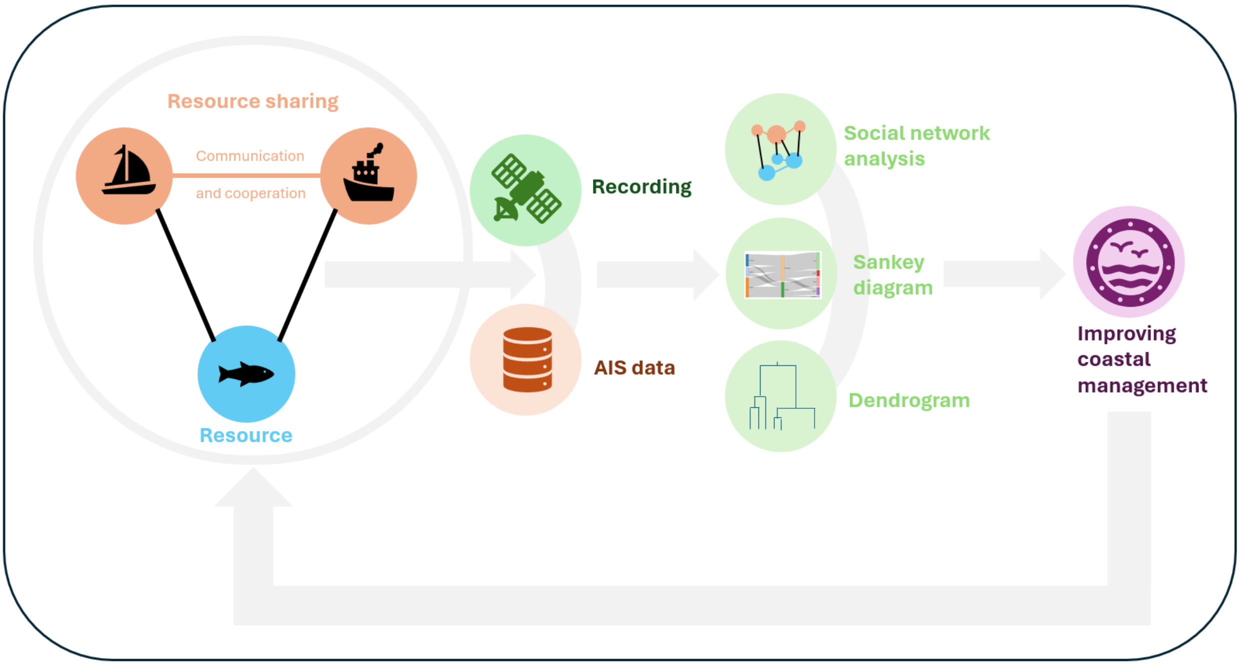


**Figure 1.** Conceptual approach: Within the circle are the probable interactions between the recreational and fishing vessel activities. AIS data collected by satellite or terrestrial make it possible to gather useful information on vessel activity over time. By using an SNA approach with ancillary methods, it is possible to suggest information that can inform coastal managers and decision-makers.

Sankey Diagram: To obtain another perspective of visualising the analysed SNA data, including the features, following the suggestions given by Chong et al. [46], a Sankey diagram was plotted. The Sankey diagram was constructed from the different proportions of the variables under analysis, i.e., anchoring port/marina, number of AIS pings relating to vessels according to their type (fishing or recreational), and the type of resource exploited. In this comparative analysis it is important to distinguish between the 3 months with a propensity for worse sea conditions and the other 3 months with more pleasant sea conditions, so the Sankey diagram was divided into two parts (the coldest period defined here for simplicity as January to March, corresponding approximately to winter, and the warmest period from July to September, adjusting to summer).

Dendrogram: In addition to the above, in order to better understand the interaction of maritime vessel activities, a dendrogram—from the suggested approaches by Galili [47]—that uses a top-down hierarchical categorisation that incorporates the characteristics of all the vessels involved and groups them by clusters is defined. The similarities between the different activities are analysed. This type of analysis also gives clues about cooperative aspects or friction between different activities.

### *3.3. Data Sources*

The raw data to be selected for further analysis should report a well-defined time scale (e.g., months, seasons, complete years) and timing for receiving the signal from the AIS records (i.e., number of pings/time interval). The contribution to the construction of networks should be supported by other methods of collecting primary or secondary data, such as visits to marinas and fishing ports and cross-referencing information with, for example, the European Fleet Register (https://webgate.ec.europa.eu/fleet-europa/, this site was accessed several times between 2 and 27 September 2024). Table 1 shows the information needed for data collection.

**Table 1.** Data collection from AIS pings crosschecked with other sources to be used in the SNA.

| Variable | Description |
|---|---|
| Vessel ID | The identification of the vessel (e.g., MMSI, name). |
| No. Pings | Identified number of AIS data records, cleansing, and selection of the useful ones. |
| Activity type | By crosschecking data, an economic/leisure activity for the vessel is attributed either as fishing or recreational. |
| Area used | From the number of pings and its characterisation, it is possible to identify the area used by that vessel. |
| Resource(s) | Associated with the different areas are some resources that stimulate economic or leisure activities. |
| Interaction | The degree of systematic occurrence of some vessels in a given area in similar time periods. |

## 4. Findings

### *4.1. Study Area*

The case study area chosen was the central area of the Algarve (Portugal) because it is a place where many interactions between maritime and coastal activities occur (Figure 2).

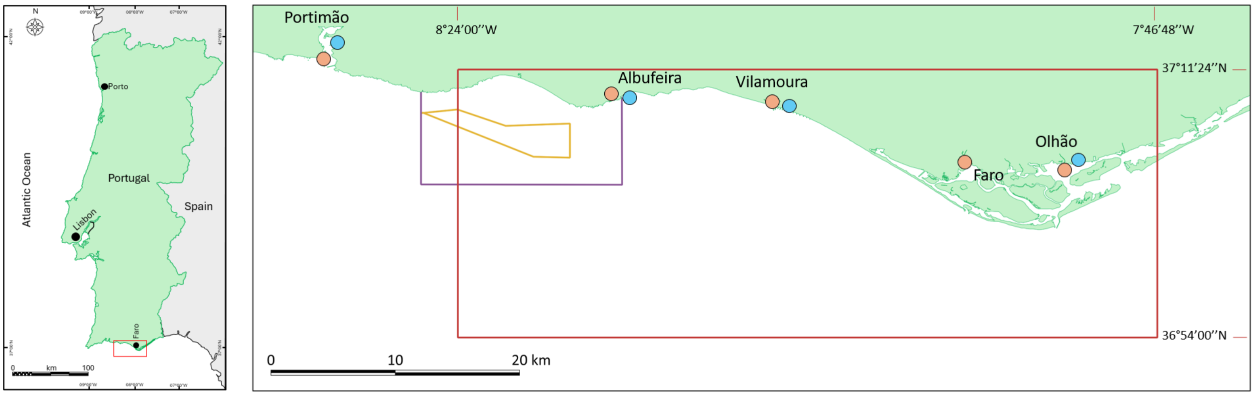


**Figure 2.** Map showing the case study location off south Portugal and the main areas where maritime–coastal activities can be found. Orangish circles represent marinas where recreational boats are berthed, and bluish ones represent ports for fishing vessels. The red rectangle is the AIS study area for the years 2022/3, whereas the pinkish area is a recently created MPA (access restrictions in the central polygon since 2024) [48].

### *4.2. Data Analysis*

The data under analysis reports the full years of 2022 and 2023 with AIS data collection on an hourly basis (Table 2). To show some interaction, it was defined—after empirical analysis—that the number of users (social nodes of the network) that demonstrated some regularity in the use of resources should be equal to or greater than 22 records/pings per boat and must have at least one vessel nearby (i.e., up to 1 nautical mile) in at least five of these records.

A total of 108 vessels were found. Of these, 65 were recreational (4758 pings) and 43 were fishing (30,896 pings). Of the recreational boats, only three met the previous premises (all passenger boats), while of the fishing boats, only one was left out of the social network analysis due to no known interaction with other fishing/recreational activities (the longliner).

It is worth noting that hourly AIS data have some limitations as they may not cover short-term interactions between vessels. AIS data also does not cover vessels that lack this type of equipment (transponder). For the reasons stated above, it is reiterated that the analysis in the present study only allows for a partial representation of interactions between vessels.

**Table 2.** Data distribution and classification by vessel category.

| Activity | AIS Classification | Vessel Typology | No. of Vessels | No. of Pings | Observed Interaction |
|---|---|---|---|---|---|
| Recreational | | | | | |
| | Passenger | Passenger | 3 | 2666 | High (inter) |
| | Pleasure Craft | Pleasure Craft | 41 | 1411 | Low |
| | Sailing | Sailing | 21 | 681 | Low |
| | **Total** | | **65** | **4758** | |
| Fisheries | | | | | |
| | Fishing | Trawler | 22 | 15,910 | High (intra) |
| | Fishing | Seiner | 16 | 12,519 | High (inter) |
| | Fishing | Multi-gear | 4 | 2383 | High (intra) |
| | Fishing | Longliner | 1 | 84 | Not known |
| | **Total** | | **43** | **30,896** | |

**Note:** Pings consist of the summation of hourly records for a period of two consecutive years (2022/3).

### *4.3. SNA Relationships with Vessels*

From the data collected (Table 2), regarding fishing vessels with high interaction, whether intra their typology or with other typology of vessels (inter), an SNA can be constructed to infer the interaction that occurs between vessels and consequently between economic activities (i.e., fisheries and tourism/recreation).

Recreational nodes: From the data analysis, it can be seen that three passenger vessels are responsible for over 56% of the AIS pings related to recreational vessels. On average, this typology of vessels also has the overall highest average number of pings per vessel (889 pings/vessel).

Fisheries nodes: About 87% of all sets of AIS pings come from the fishing fleet. Within this fleet, seiners and trawlers are the ones with the most records. The seiners have the highest average of the AIS pings, closely followed by trawlers (782 pings/vessel and 723 pings/vessel, respectively).

The vessels (nodes) with the most pings also have the most edges. In fishing boats, the domain is divided between three types of boats, while in the recreational, there is a clear dominance for passenger boats.

From (Figure 3) it can be seen that there are three distinct communities: the first is composed of 22 vessels in outer waters as recurrent trawlers (pinkish and bluish); the second has 16 seiners (greenish) and three passenger boats (orangish) closer to the coast; the third is composed of only four fishing vessels (multi-gear for multipurpose fisheries). Most of the interaction takes place with vessels of the same category, with sporadic cases of vessels of other categories occurring in nearby locations in the same time frame. Table 3 shows the main metrics calculated.

**Table 3.** Main network metrics used in the SNA.

| | |
|---|---|
| Nodes: | 45 |
| Edges: | 175 |
| Average degree: | 3.889 |
| Average weighted degree: | 3.889 |
| Network diameter: | 6 |
| Graph density: | 0.088 |
| Connected components: | 3 |
| Modularity: | 0.292 |
| Statistical inference: | 315.321 |
| Average clustering coefficient: | 0.508 |
| Average path length: | 2.182 |

Source: Own elaboration. Note: Only the data from the vessels that showed high interaction were used.

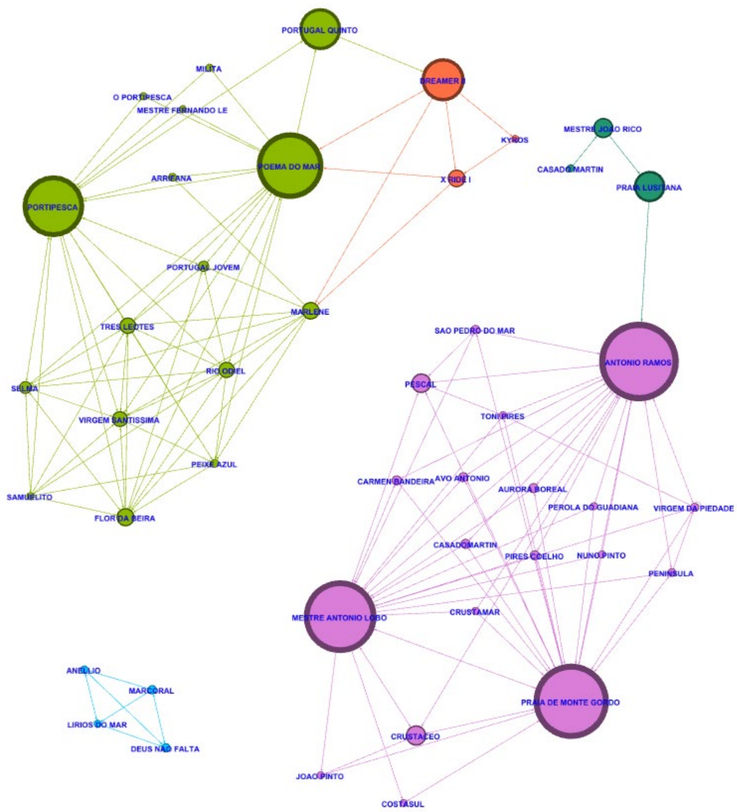


**Figure 3.** SNA model showing the interaction between recreational and fishing vessels (Algarve, Portugal). For the analysis, the Gephi software (version 0.10.1) was used, which is available from https://gephi.org/.

### 4.4. Sankey Diagram

The Sankey diagram shows that the importance of places is linked with the time of year (Figure 4). In winter, it is the fishing ports that prevail in terms of contribution to maritime traffic, while in summer, it is usually the marinas that generate the most pings. Although fishing boats are active all year round, they are usually subject to harsher weather conditions during the winter, and consequently, there are sometimes days when fishing is not practiced.

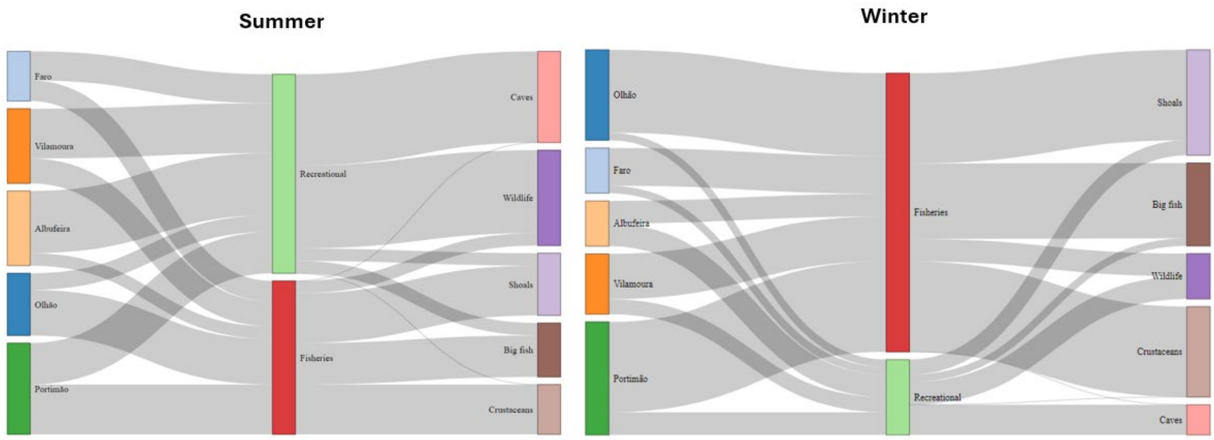


**Figure 4.** Sankey diagrams showing contrasting seasons (summer and winter). The left side nodes refer to ports and marinas, whereas the right side is related to the type of resources sought after. R Development Core Team (2024) [49].

In the summer, there is a prevalence of places with recreational boats, where a large part of the activities are not resource extractive. In winter, ports with fishing vessels in more important locations have more activity than marinas. Non-extractive resources also have a decrease in demand in the low season. Generally speaking, the number of recreational boats decreases considerably in winter. Fishing vessels, while not decreasing, have limited activity to fewer days at sea.

### *4.5. Dendrogram*

There is a clear distinction between recreational maritime activities and fisheries at the first level (Figure 5). In recreational boats, most of them have multiple functions, some of them with non-specific activities and others with emphasis on biological or geological resources. The remaining vessels focused on biological resources; some have prevalence only by non-extractive activities such as observation (of the resources), and the rest focus on extracting activities (e.g., angling). In the professional fishing part, there is a clear distinction between passive gear vessels and active gear vessels.

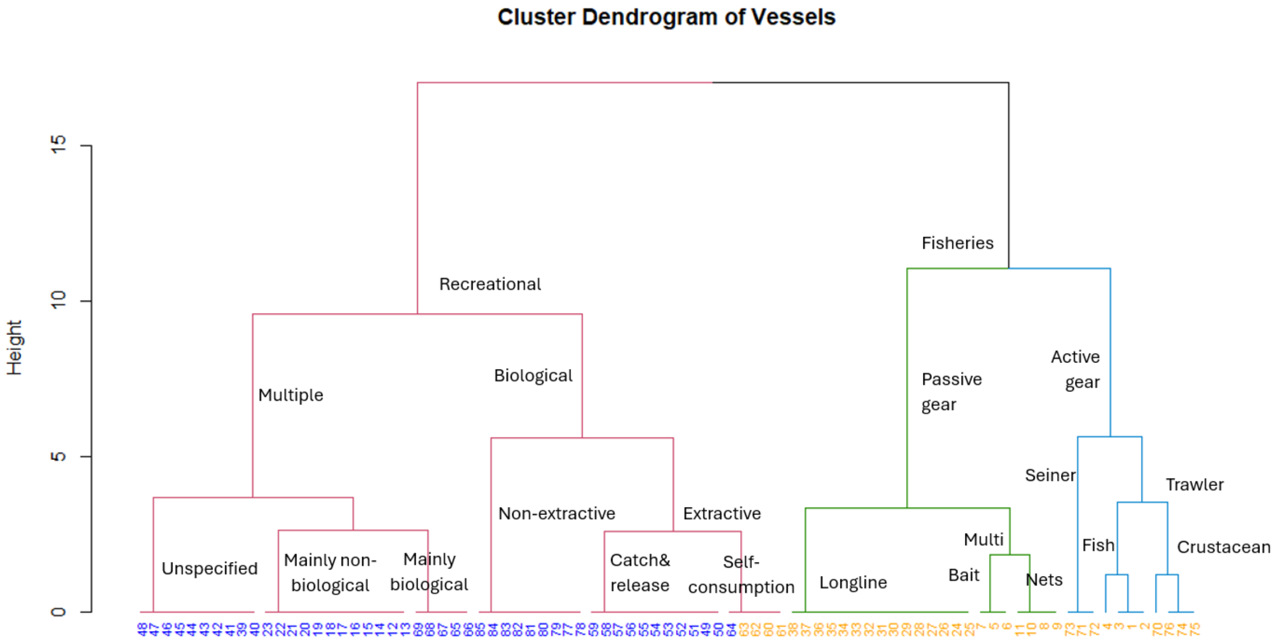


**Figure 5.** Cluster dendrogram. To construct the dendrogram, the AIS pings from Table 2 were used, but 23 boats were left out because they had few records (17 sailing and 6 fishing). The lower level shows vessels codified by a number (bluish recreational and orangish fishing). R Development Core Team (2024) [49].

## 5. Discussion

### *5.1. Resource Dependency*

Both tourist activities and those related to fishing depend on the good availability of resources. Many of these resources are shared by various activities. Maritime tourism is very dependent on the existence of biodiversity, namely marine wildlife [50]. Because professional fishing is aware that the sustainability of resources is very important, an abundance of commercial-size stocks should exist for the activity to be viable [51].

At the time this study was carried out, the area under analysis, defined by the red rectangle in Figure 2, was determined. Within this area, there are many resources used by different vessels (primary stakeholders), as described by [52]. Several boating activities have been identified for this area (Table 2). For example, passenger vessels that take tourists on boat trips use areas very close to the rocky coast to show the cliffs that have caves through which the sea enters [53]. For instance, the Benagil cave is now subject to daily limitations due to pressure on carrying capacity since August 2024. In this same area, there are several sites with natural and artificial reefs that are in some way exploited, either by fishing [54] or recreational activities [55], as demonstrated by some of the literature consulted.

### 5.2. Interaction Areas

The analysis of the data allows us to verify that several areas of interaction occur. Cooperation is easier in situations where vessels target different types of resources [56]. Tourist activities in search of wildlife may sometimes take place near areas where passive fishing gear is anchored. In these situations, the entanglement of wildlife in nets can occur, causing inadvertent harm to wildlife observation or damaging fishing gear [57].

There will be no other situations to report since the trawlers operate at a distance quite off the coast, where there are no major tourist activities. As far as seiners are concerned, they are gears that essentially operate from dusk until dawn, and at those times, there are usually no boating tourist activities. From Figure 3 (SNA), it can be seen that it is only in the intermediate water areas where there is some interaction between passenger boats and some (few) of the purse seine boats. All other activities do not interact with each other at the area level.

Authors such as Natale et al. [58] have determined fishing efforts through AIS and cross-referencing data. Although AIS records do not give us direct information about the type of activity that each vessel carries out, by cross-referencing this data with other type of information sources, it can be deduced what the main types of activity of the vessels are and from where they come from (Figure 4). This type of information is very important for prioritising the type of activity and understanding what type of resources are used depending on the areas used/visited. We were thus able to infer that the typology of vessels was more focused on the extraction of marine resources (fishing) or non-extraction (passenger vessels) (Figure 5).

### 5.3. Temporal Patterns

The AIS data show that the patterns of recreational tourist activities occur during the day. There is greater incidence in the warmer seasons or when the holiday periods (e.g., Christmas and Easter) receive a greater abundance of visitors who are predisposed to participate in these types of activities.

In the case of fishing, although there are fewer records in the winter months, the activity, regardless of the type of fishing gear, extends throughout the year. The limitations of the activity are limited to storm days when the inlets are closed or when certain fishing quotas have already been reached (essentially purse-seine vessels). There are still limitations if boats go to the shipyard for annual maintenance or repairs [59]. This type of break usually occurs in the months of December and January. Several records that corresponded to this type of situation were found. For this purpose, it was considered that the boats were in dry dock.

In winter, there is apparently no potential conflict due to the lower activity of recreational boats. As can be seen from the Sankey diagrams (Figure 4), there is a slight prevalence of more records of recreational boats in the summer, but this is reversed for the winter season, where records related to fishing activities prevail. In the summer, the potential conflict increases slightly, and it may only be in the intermediate coastal areas where there may be some overlap in the areas of interest to exploit resources.

All other activities are related to vessels that do not interact with each other if it is considered the same time period. However, it is important to note that AIS data have limitations and that it is not possible to infer what actually happens, but only what can be discerned from the processed data [60].

### 5.4. Implications of the Interactions

From the analysis of the data, it was found that there is some spatial overlap between the vessels, but at a temporal level, this occurrence is not evident. In terms of ecological impacts, fishing extracts natural resources (fish), but apparently at a sustainable rate [61]. This evidence comes from the existence of species subject to annual quotas, which are established within the European Union's common fisheries policy (CFP). Additionally, there are records of landings in fishing statistics that show some constancy in the quantities and diversity of species [62]. In the analysis of the data, it can be seen that the fishing that is carried out the furthest from the coast is trawling, which shows evidence that this fishing method causes some damage to the habitats where it is cast [63]. However, the interaction of the vessels that use this fishing method with nautical tourism activities is minimal and is only related to the movement of the vessels when they go to or come from fishing.

Purse seine is a fishing method that interacts most with boat tourism activities, and as it aims to capture pelagic fish, there is a strong relationship with the marine mammals that feed on these species and which are sought after by leisure passenger boats [64]. All these vessel activities cause some pollution, not only in terms of carbon footprint [65] but also in terms of noise that causes some harm to marine species, which is why mitigating measures are being sought for this problem [66].

Sometimes, interactions between economic activities can also expand a little; that is, some small fishing boats, many of them without AIS, tend to provide leisure services to tourists in the summer seasons in the sense of fishing linked to tourism (as shown in Figure 5 for the case of 'extractive for self-consumption'). In these cases, fishermen take tourists fishing, earning more from the leisure service provided than from the economic income obtained from fishing catches. This evidence can be corroborated by some literature in other geographies, such as Spain [67,68], Italy [69,70], and elsewhere [38–43].

There is no evidence of negative interactions between recreational boating activities and fisheries. In other words, professional fishing apparently does not suffer harm, namely damaged fishing gear, caused by the dynamics of recreational activities, despite the literature mentioning cases in which damage does occur [71]. Therefore, it seems that there are more opportunities for cooperation than for conflicts to occur [72].

At a social level, there is an important arrangement to regulate economic activities related to both fishing and tourism and leisure, which is why a recent marine protected area (MPA) was created (Figure 2) [73]. These types of action demonstrate that there is a capacity to bring together stakeholders for the mutual enjoyment of the common good (CPRs). The presence of an MPA and its recent implementation could contribute to the CPR principles defined by Ostrom, particularly because clear limitations have been established, and there is apparently greater ease of monitoring the area.

Recently, steps have also been taken to regulate visits to areas close to the coast due to the high pressure that was evident on the carrying capacity along the rocky sandstone coast [53]. There is also the case of the existence of artificial reefs in the central zone of the area under analysis, which have had the function of "creating/attracting" and protecting marine resources and also, in a certain way, distributing the allocation of fishing effort [74,75].

## 6. Conclusions

This article presents a simple methodology using a social network analysis and its application to the interaction between tourism and fisheries through the use of non-intrusive data from AIS. These results are a valuable aid to the governance of activities carried out within a framework of CPRs.

The results achieved are, however, restricted due to the very limitation of AIS data, which is not comprehensive of the entire fleet of vessels that use and exploit the resources coming from a given area, and consequently, its applicability is less than what happens in reality. However, as competition for space in the marine environment continues to intensify, this methodology allows inferences about the development of the aforementioned activities and their interaction and can be replicable in other geographies. Addressing the limitations of AIS data, thorough improvements or regulation could enable this type of social network analysis to be further developed as a policy tool to manage stresses and exploitation of the marine environment.

The approach in this study has some innovative aspects. However, these aspects need to be more consistent. Thus, as recommendations for future studies, there are two important aspects to consider.

First, the study would become more comprehensive if there was access to the dynamics of smaller boats without AIS—regardless of whether they are fishing or tourism/leisure—in order to better infer the interactions between the different activities. In the present study, it can be easily concluded that interactions between different vessel activities do indeed exist but that they are underestimated due to the lack of data—i.e., AIS or equivalent—for smaller vessels. Therefore, for future research, it is recommended that data be obtained from all types of vessels that interact in the maritime–coastal zone in order to have greater coverage of interactions between vessels.

Second, the vessel interaction criteria addressed in this study are somewhat questionable. Additionally, these interaction criteria also require some further development in order to make the entire analysis more consistent and comprehensive. In this regard, it is recommended that future research not only build upon the approach used in this study but also explore the interaction between vessels using more objective criteria (e.g., not just the distance between vessels and the number of times they are detected in the same space-time context).

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