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Environmental and Social Perceptions of the new Anchorage Area of Culatra Island (Ria Formosa, Portugal)

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Master of Marine and Coastal Systems (MaCS)

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Declaração de autoria de trabahlo/ Declaration of authorship of work

Environmental and social perceptions of the new anchorage area of Culatra Island (Ria Formosa, Portugal).

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

I declare to be the author of this work, which is original and unpublished. Authors and works consulted are duly cited in the text and are included in the list of references.

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Resumo

O plano de gestão do Parque Natural da Ria Formosa estabelece áreas de ancoragem distribuídas por todo o sistema lagunar. A Associação de Moradores da Ilha da Culatra é a primeira a candidatar-se à construção e exploração de uma área de ancoradouro na Ria Formosa. As percepções ambientais e sociais relativas à nova área de ancoradouro da Culatra foram analisadas através de um processo participativo baseado em questionários estruturados. Especificamente, os inquiridos foram divididos em quatro grupos denominados academia, utilizadores de embarcações, ilhéus e administração pública. Todos preencheram o mesmo questionário que abrangia questões ambientais, socioeconómicas e técnicas relativas ao local de ancoragem que está planeado construir utilizando amarrações ecológicas e recifes artificiais como poitas. Os dados foram analisados através de análise estatística, com uma Análise da Componentes Principais para visualizar as relações entre as respostas e os grupos. Posteriormente, as perguntas foram analisadas uma a uma para compreender as perceções dos inquiridos sobre o projecto. Os resultados destacaram o conhecimento comum em torno dos recursos naturais presentes na Ria Formosa. No entanto, observou-se uma falta de informação sobre a sua importância e necessidade de os proteger. A área de ancoragem é vista como uma útil na transição verde da ilha, principalmente pelo grupo de ilhéus. A academia, a administração pública e o grupo de utilizadores de barcos mostraram opiniões mistas sobre a utilidade do projecto para a transição verde. É necessário um apoio mais amplo para que o local de ancoradouro seja aceite e útil, e as acções de co-gestão precisam de implementar uma abordagem holística que envolva todas as partes interessadas.

Abstract

The Ria Formosa Natural Park management plan establishes anchorage areas distributed all over the lagoon system. The Culatra Island Residence Association is the first to apply for building and exploitation of an anchorage area in the Ria Formosa. Environmental and social perceptions of the new anchorage area for Culatra were explored through a participatory process based on structured questionnaires. Specifically, respondents were divided in four groups named academia, boat user, islander, and public administration. All completed the same questionnaire that covered environmental, socio-economic, and technical questions regarding the anchorage site that is planned to be constructed with eco-moorings and artificial reefs as weight blocks. Data was analysed through statistical analysis, with a Principal Component Analysis to visualise the relationships between answers and groups. Afterwards, questions were analysed one by one to

understand what respondents perceive about the project. Results highlighted the common knowledge around the natural resources present in Ria Formosa. However, a lack of information regarding their importance and necessity to protect them has emerged. The anchorage area is perceived as a useful tool to help the green transition of the island, mainly by the islander group. The academia, public administration, and boat user group showed mixed opinions on the usefulness of the project towards the green transition. A wider support is needed for the anchorage site to be accepted and useful, and the co-management actions need to implement a holistic approach that involves all stakeholders.

Keywords: eco-mooring, green energy transition, stakeholders, co-management, participatory process, questionnaires

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1. Introduction

With the increase of blue economy and blue tourism, and the consequential creation of favourable development for communities (Sidman & Fik, 2005), the necessity of proper ocean management has been recognised to guarantee economic and social advancement of coastal areas (Jasmi & Fernando, 2018).

At present, Culatra community are aiming to a more sustainable development, in particular energy efficiency and self-sufficiency, reduce energy poverty, solve water scarcity, reduce waste, and improve pollution management (Pacheco et al., 2022). In this context, Culatra Island was selected as one of the six pilot European islands by Clean Energy for EU Islands Programme, which challenges insular communities to acquire stronger control over their traditional activities, following a strategic Clean Energy Transition Agenda (CETA) to achieve the goals previously stated.

Since 70% of all anthropogenic activities happen in coastal areas, environmental and socio-economic changes take place at a local level (Vaz et al., 2013). A project to build eco-moorings has been put forward for Culatra Island, located in the Algarve, South Portugal. Culatra is one of the five islands that are a part of Ria Formosa (Natural Park), one of the most important wetland and barrier system in South Portugal due to its ecological and socio-economic importance (Kombiadou, 2019). Culatra is a small island that overcame many challenges since fisherman settle in the area 150 years ago, such as environmental issues related to the location inside the natural park, uncertain legal status, and socio-economic challenges (Pacheco et al., 2022). Fishing, aquaculture, and tourism are the main sources of income for the island and during summer Culatra experiences the triplication of the resident population, especially between June and August (CETA Culatra, 2019). Since the site is visited by sailors all over the world and by nautical touristic companies, the Residents Association - Associação de Moradores da Ilha da Culatra (AMIC) - has underlined the necessity of a more organised anchorage system. At present the boats anchor around the channel and on top of the seagrasses meadows without any rules, causing habitat depletion and water pollution. Moorings also affect the Ria Formosa populations of long-snouted seahorse (*Hippocampus guttulatus*) and short-snouted seahorse (*Hippocampus hippocampus*), which are classified in the International Union for Conservation of Nature (IUCN) red list as 'near threatened' (Correia, 2021).

The new anchorage plans the installation of 57 moorings (48 for boats up to 12 metres and the remaining 9 for boats up to 18 metres) for a total of 16.8 ha in front of the island, which requires an ecological assessment to evaluate the viability of the project. In addition, because of Culatra's

history as a fishing community, a socioeconomic assessment is also necessary to fully report the advantages and disadvantages around the mooring site for the islanders. The concession documents were signed between AMIC and Docapesca Portos e Lotas, SA on February the 13th, 2020. A preliminary study of the area was conducted by a specialised company to assess the feasibility of the project.

The aims of the present study were the following: (1) evaluate environmental and social perceptions regarding the anchorage system at Culatra; (2) give possible solutions and improvements to the project and (3) create a guideline for responsible utilisation of the area, based on the analysis of the answers received. Results were based on a participatory process, with the involvement of four different groups (academia, boat user, islander, and public administration) to assess the perceptions around environmental, technical, and social aspects of the anchorage area (hereafter designated as CLTR1).

2. Literature Review

The ever-increasing blue tourism and yachting generates economic development for local communities, but the increasing number of boats has strong impacts on the maritime environment (Sidman & Fik, 2005), particularly on the quality of the ecosystem, since anchorage can cause stresses on the seabed and destroy important habitats with various deleterious consequences (Pioch & Leocadie, 2017). A mooring system comprises an anchor, a rode (rope or chain), a buoy and a pennant. The impacts of a conventional mooring system (Figure 1) are generally due to the rode dragging on the substrate and destroying the environment or the improper design and placement in the water (Musson et al., 2015).

For an anchorage system to be sustainable and environmentally friendly, careful planning is essential and many factors must be considered. In fact, environmental, physical, and operational aspects of the area where the planning is happening will influence the location, size and layout of the anchorage system. Another factor that needs to be included are the behavioural and social responses to the new anchorage site as often they can be seen as useless and with impairments to the panorama (Urban Harbors Institute, 2013).

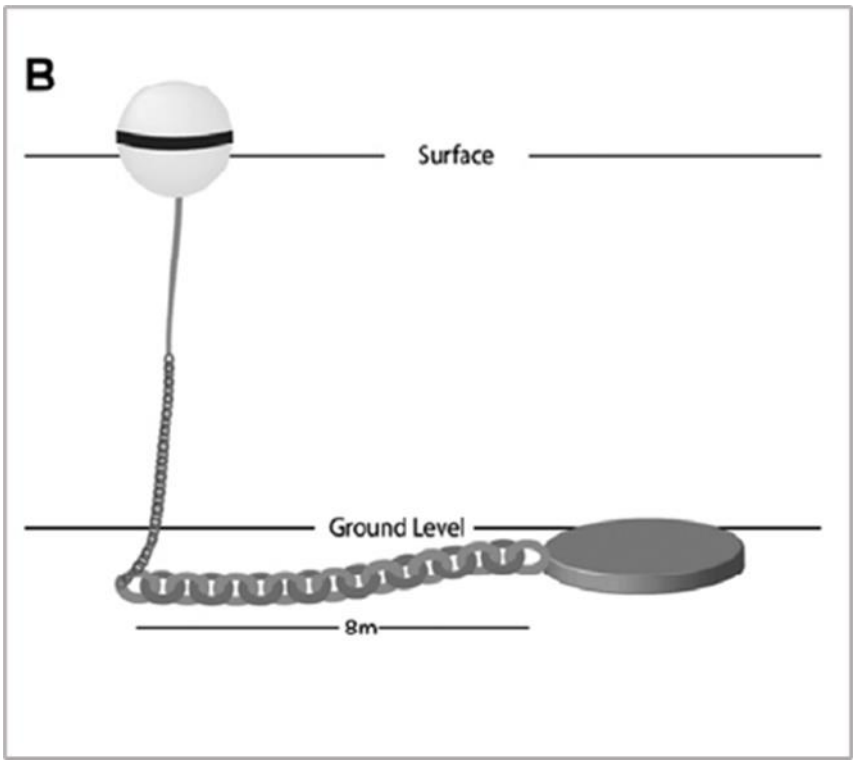

Figure 1. Schematic representation of a traditional mooring, with the anchor chain dragging on the seabed (adapted from Demers et al., 2013).

Seagrass meadows are key ecological providers for sediment stabilization and natural coastal defence, carbon sequestration, nutrient cycling, nursery grounds and they enhance biodiversity (Orth et al., 2006). A study by Jackson et al. (2015) estimated that seagrasses associated species contributed 30-40% to the value of commercial fisheries landings, highlighting its economic value. Unsworth et al. (2019) affirmed that challenges in seagrasses conservation lie in informing on their status and condition, as data is scarce and scattered, with different metrics in many regions (de los Santos et al., 2019). In Europe, seagrass loss peaked in the 1970s, and losses were attributed to wasting disease, water quality degradation, coastal development, and disturbances (de los Santos et al., 2019). Anchors can remove seagrasses during anchoring and during retrieval, whereas the rode can remove them during all the operation time. The anchoring activities usually affect the rhizomes and bury seeds of seagrasses, inhibiting germination (Luff et al., 2019). For example, in a study by Demers et al. (2013) it was observed that around traditional swing moorings there was virtually no seagrass for at least 9 m within the structure. During the 1900s and 2000s there was a gain in seagrass coverage with expansions of *Zostera noltii* and *Zostera marina*. These two elements, the slowing down and expansion, led to reversal of the negative decadal rate of net change during the 2000s and the recovery was attributed to natural improvements, but also to management actions (Dolch et al., 2013 & de los Santos et al., 2019).

In the Ria Formosa, the aquatic plants are often subject to intense boat mooring and anchoring, together with bivalve hand trawling and channel dredging and inlets openings (Cunha et al., 2011). Their decline can cause biodiversity loss, coastal fisheries impoverishment, decrease in water quality, increase in turbidity, and increase in coastal erosion (Cunha et al., 2011). The three species of seagrasses found in Ria Formosa are *Cymodocea nodosa, Zostera marina* and *Zostera noltii*, making the Portuguese coast unique in terms of seagrasses biodiversity as Portugal forms a biogeographic admixture zone where Atlantic species at their southernmost distributional limits encounter Mediterranean and African species that extend northwards (Cunha et al., 2011). The most widely distributed in Ria Formosa is *Zostera noltii* (15.74 km2), occupying 45% of the intertidal areas (Cunha et al., 2011).

Some major impacts on the species are caused by propeller scarring and anchoring, which are widespread activities on the mudflats of the lagoon. *Zostera marina* is the most endangered, and its largest population has been found in the Culatra channel, with five meadows along the margins of the channels and two more in the mudflats and shallow channels. In the lagoon, *Cymodocea nodosa* extends through the main and secondary channels, to a maximum of 2 m depth (Cunha et al., 2009). Shallow and sheltered bays provide ideal conditions for seagrasses growth, but these sites are also attractive sites for boaters, and it is often problematic to balance maritime activities and conservation activities (Casado & Bentz, 2013).

Another potential issue related to anchoring and high boating activities is the introduction of non-native species which have the potential to threat the biological diversity of the ecosystem in which they are inserted (Houngnandan et al., 2022). Invasive alien species are estimated to be the fourth major driver of biodiversity loss (Borges & Gabriel 2019). Anchor's lockers often enhance fragment survivorship and become vectors for dispersal of different species in new/pristine habitats (West et al., 2007). For example, in the Mediterranean Sea anchoring creates favourable conditions for the settlement of *Caulerpa* species and for its dispersal when the anchor is released (Lowe et al., 2000). In the Ria Formosa the invasive green algae *Caulerpa prolifera* has been identified as rapidly expanding and taking over soft bottoms and competing with meadows in shallower areas (Parreira et al., 2021). Another example of alien species introduced in Ria Formosa through maritime activities is the Atlantic blue crab (*Callinectes sapidus*), which has been identified only recently (2016) by fishermen in the lagoon (Morais et al., 2019). Ballast waters have been recognised as one of the possible vectors of introduction, since the species is endemic to the western Atlantic (Nehring, 2011). According to Mancinelli et al. (2013) the Atlantic blue crab can impact benthic communities

at multiple trophic levels. Its establishment in the lagoon has been made easier by the various habitat present, e.g., sandy and muddy bottom, submerged vegetation, minimal changes in salinity (Morais et al., 2019).

Bio colonisation is also a problem in mooring systems as it is defined as aggregation of marine organisms (mussels, seaweed, sponges, barnacles, tubeworms, etc.) on underwater structures (Decoyer et al., 2020). These accumulations vary in space and time along the line of the marker buoy, but they have impacts on line's weight, line's buoyancy, and tension (Wright et al., 2016). Hence, the risk of failure of the line is possible and mostly correlated to fatigue and corrosion of the line. This problem must be tackled during management of the mooring system (Decurey et al., 2020).

Favoured places for leisure boating activities are shallow and sheltered areas (Parry-Wilson et al., 2019), which are often sensitive habitats, e.g., seagrasses meadows, spawning and nursery grounds, macroalgal beds, reefs, and shellfish beds (Morrisey et al., 2018). In particular, seagrasses are key for fisheries, carbon sequestration and coastal protection (Duarte, 2002). When disturbed and fragmented, the integrity of these sensitive systems can decline (Wilcox & Murphy, 1985). One of the solutions to minimise the fragmentation and disturbance is the use of eco-moorings, which have been found to benefit the environment when compared to traditional moorings (Urban Harbor Institute, 2013; Musson et al., 2015; Pioch & Leocadie, 2017; Parry-Wilson et al., 2019; Tevi, 2020). They are usually designed with rigid or buoyant parts that reduce seabed abrasion and avoid habitat fragmentation, while keeping the boat secured in place (Luff et al., 2019).

The main difference between the conventional moorings and the eco-moorings is the anchor line as in eco-moorings it will not be laying on floor like in conventional moorings. In fact, eco-moorings have a mid-water float that helps lifting the line/chain from the bottom (Figure 2), avoiding damage to the bed (Musson et al., 2015).

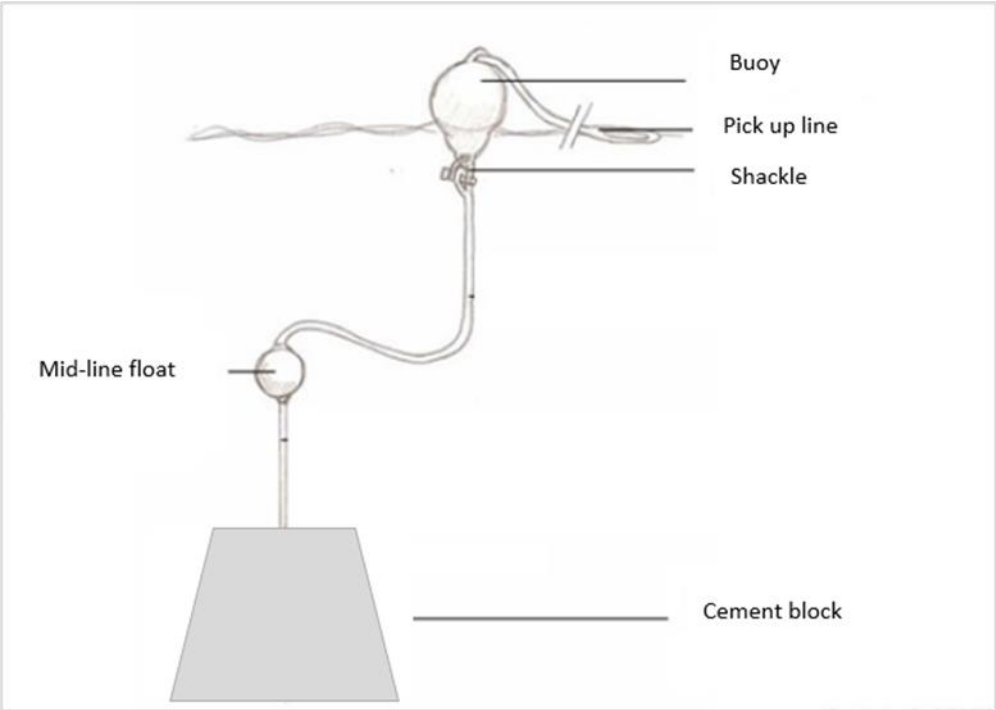

Figure 2. Representation of a first-generation eco-mooring with a mid-water float to avoid chain scarring (adapted from Pioch & Leocadie, 2017).

Pioch & Leocadie (2017) have delineated three generations of eco-moorings. The first one includes a pre tensed anchor line, which is characterised by a simple concrete block on the floor topped with a pre tensed anchor line. Usually, there is a mid-line buoy to lift the chain from the seafloor (Figure 2). The second generation is a screw that fixes the anchor line directly to the seabed. It has minimum impact as there is little surface in contact with the seafloor. It can have various shapes of screws, depending on substrate (Figure 3a and 3b).

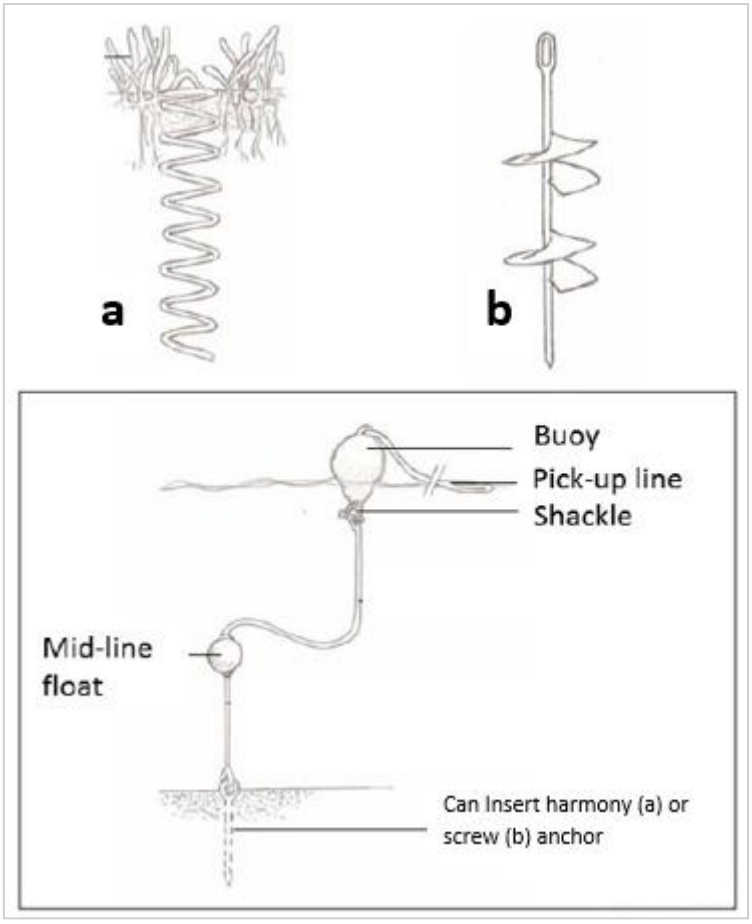

Figure 3. Representation of second-generation moorings (adapted from Pioch & Leocadie, 2017), where two types of screws (a and b) are represented.

The third generation is a mooring block designed with ecological considerations (Figure 4). The idea is to integrate effective mooring concrete blocks with biomimicry of local habitats and accelerate restoration (damages caused by past unorganised anchorage) and provide new habitats for local marine organisms (Musson et al., 2015).

Eco-moorings cultivate 5 to 10 times more species diversity in comparison to a classical concrete block (Pioc & Leocadie, 2017). For example, in New South Wales, between 2009 and 2013 seagrass recolonization was recorded around eco-moorings installations, where bare patches were due to high wave and sediment actions (Morrisey et al., 2018). In the UK, in an attempt to preserve seagrasses, a modification of traditional swing mooring, by adding a mid-float to lift the chain, showed that the seagrass density surrounding the modified swing was twice as high as that of the standard moorings (Luff et al., 2019). A study on benthic biota in Tasman Bay, reported that horse mussels could recolonise the affected areas within a year or two. Their presence has also been associated with acceleration in the development of associated biological assemblages in the area (Morrisey et al., 2018).

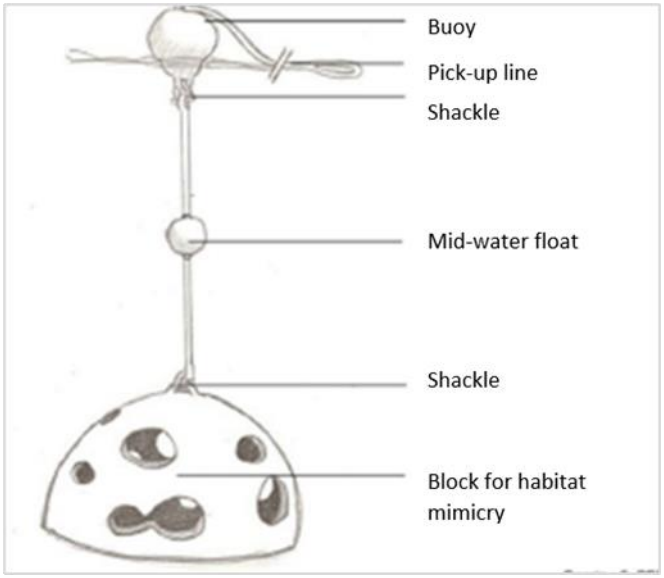

Figure 4. Eco-mooring with an artificial reef implemented in the anchor block (adapted from Pioch & Leocadie, 2017).

Each eco-mooring design is created for a specific context, considering hydrodynamics, yacht size (block weight), local biodiversity, and bottom conditions (Musson et al., 2015; Pioch & Leocadie, 2017). Those designs are not only environmentally friendly, but also durably fitted. This can be seen in the instalment in Deshaies (Guadalupe, French Caribbean Sea) or Mamoudzou (Mayotte, French Indian Ocean), where after hurricane Irma in 2017, all the eco-moorings installed were still operational and safe to use (Pioch & Leocadie, 2017). During rough weather (e.g., storm surges, swells), water level can rise rapidly and with a traditional mooring, the boat is usually pulled back towards the anchor. This would cause vertical pull, compromising holding capabilities (Urban Harbors Institute, 2013). Eco-moorings are designed with higher stretch, generating more horizontal holding force while the boat moves. In Vineyard Haven (MA), a pulled test showed that a helix anchor (second generation, Figure 3) provided the greatest holding power, followed by concrete blocks (first generation, Figure 2) (Urban Harbors Institute, 2013). Hence, eco-moorings are primary designed to minimise chain abrasion on the seabed, while ensuring safe moorings for vessels in different sea conditions (Luff et al., 2019). However, to date, there are few reported trials of eco moorings usage, characteristics, and importance, underlying the novelty of the design (Pioch & Leocadie, 2017). Salaun et al. (2020) reported that in the South of France eco-moorings were used as artificial reefs to restore ecological functions of the seabed as spawning and nursery ground at the same time that they were useful tools for maritime activities. The project described by Salaun *et al*. (2020) involved effective coastal management and public investments. Parry-Wilson et al. (2019) found that the placement of eco-moorings in shallow bays in the UK alleviated the pressure caused on seagrasses by anchoring activities. However, despite the positive results towards seagrass

recovery, there was a lack of social acceptance and understanding of the necessity of the eco-mooring systems. As such, management actions related to anchorage and moorings should involve careful planning with real integration of coastal plans in political decisions, more awareness for fisherman and boaters to minimise scarring by boat propellers and by anchoring. Major involvement of society, scientists, politicians, and resource managers is needed to invert the losses of marine biodiversity. A targeted educational program for regulators and the public would encourage the use of eco-friendly moorings, highlighting their safety and their importance (Parry-Wilson et al., 2019). Moreover, the costs for moorings installation, equipment and maintenance can affect the decision-making process (Musson et al., 2015). In fact, some insurance companies might not want to cover higher fees if eco-mooring projects are considered 'new technologies'. If they would fall under the definition of swing moorings, the policies would be the same as for conventional moorings and so with lower prices (Luff et al., 2017).

3. Case study

3.1. Study Area

The Ria Formosa barrier island system extends for 55 km and includes two peninsulas (Ancão and Cacela), five islands (Barreta, Culatra, Armona, Tavira and Cabanas), six tidal inlets, salt marshes, sand flats and tidal channels (Andrade, 1990) (Figure 5). Tides in the area are semi-diurnal, with ranges between 2.8 and 1.3 m for spring and neap tides, but during spring tides, 3.5 m ranges can be reached (Ferreira et al., 2016). Wave energy is moderate, but its action is affected by the cuspate shape of the system. The West coast is more energetic since it is exposed to the dominant wave conditions (W-SW), whereas the East coast is directly exposed only to E-SE waves (Ferreira et al., 2016). Wind is averagely moderate (3 m/s) and mainly from the West (Pacheco et al., 2018). Its regime depends on the pressure centres that affect the climate in the region (Northern Hemisphere sub-tropical anticyclone – Azores high) (Pacheco et al., 2021). West winds and those from Northwest and Southwest are predominant in eastern Algarve and usually more intense. Wind speed is weak, with maximum values for North and West directions. As a rule, during the year, the wind from the Southwest (summer) and North (winter) directions are dominant. Levante wind can disrupt this regime for a few days and can reach high speeds (Andrade, 1985).

The Ria Formosa system is generally very dynamic, and morphological and hydrodynamic changes are often related to tidal inlet evolution. These changes have influenced sediment transport, tidal flats and salt marshes, farming, and navigation and accessibility of the whole system (Ferreira et al., 2016). The embayment presents large salt marshes, sand flats and natural and dredged channels

(Salles et al., 2005). Salt marshes are found on silt-clay sediments and the most abundant species are *Spartina maritima*, *Salicornia nitens*, *Arthrocnemum perenne*, *Suaeda maritima* and *Atriplex portucaloides* (Carrasco et al., 2021). Tidal flats connect the salt marshes and the tidal channels and are characterised by silt-clay or muddy-sand bottoms (Falcão et al., 2003). Mud and muddy-sand sediments prevail in the inner parts of the lagoon and intertidal areas, whereas near the inlets and main channels sandy sediments are prevalent (Granja, 1984; Monteiro, 1989). Overall, in the Ria Formosa channels, sediments vary from fine to coarse sand and the presence of Zostera marina contributes to sedimentation of suspended particles (Falcão et al., 2003). Generally, sediments are sand dominated with bioclastic elements (Andrade, 1990).

Culatra Island is around 7 kilometres in length and 1.2 kilometres in width (Figure 5). It can be divided in three areas according to the morphodynamical characteristics: the east end is unoccupied and characterised by curvy sand spits; the west end is partially artificial because of the Faro-Olhão Inlet jetties and seawall system and the central part is characterised by dune ridges, tidal channels, and washovers (Garcia et al., 2002). The island has three villages: Culatra, Hangares and Farol. It can be accessed by boat, and is part of the Municipality of Faro, Union of Parishes of Sé and São Pedro. The island is part of the Ria Formosa Natural Park (PNRF). The PNRF partially overlaps the Special Protection Area (SPA) of Ria Formosa and the Site of Community Importance (SIC) Ria Formosa/Castro Marim. In addition, it is a RAMSAR site, a wetland of international ecological importance as reported by the Instituto da Conservação da Natureza e das Florestas (ICNF).

Figure 5. Location of the study area within the Ria Formosa barrier system and coastal lagoon (red square), located in South Portugal. Represented in the white square is Culatra Island (map made with QGIS, image from Google Earth).

Culatra Island is permanently inhabited by 1000 people, who mainly live from fishing, shellfish activities and tourism. The population has been present in the area for the last 150 years and family activities are generally passed on to the younger generation. The housing settlement dates to the 16th century when people seasonally worked in the sardine fishing communities. Some families decided to settle in the area because of the richness of the waters of Ria Formosa. There was a progressive increase in housing, but the location and social isolation were still an issue, so to meet their basic needs, the community started collective actions to sustain themselves. In 1987, the AMIC was founded, and social and economic improvements have taken place since then. The work done by AMIC, and that is currently underway, has as primary focus defending the continuity, sustainability, and identity preservation of the Culatra Fishing Community. Recently, the community has been recognised by the National Government, granting legal status to occupy the Public Maritime Domain. This implies the concession for land use for the next 30 years and this can be renewed if the families provide proof of continued link with the fishing activities (CETA Culatra, 2019).

Ria Formosa has great ecological and socio-economic value, with diverse habitats (Kombiadou et al., 2019). While tidal flats are important areas for clam cultivation, the Ria Formosa is an important nursery and feeding ground for shellfish and fish species and these characteristics are important income sources for the Culatra Fishing community, since the population is linked to artisanal fishing and shellfish activities (CETA Culatra, 2019). Clam and oyster production at Ria Formosa represent, respectively 90% and 26% of the national production. Oyster production is getting more popular with the younger generation of the community (Pacheco et al., 2021).

3.2. Context for a New Anchorage Area

The initiative "Culatra 2030 – Sustainable Energy Community" is a demonstration project covering multiple aspects of green transition, with attention to the specific needs of the island. The project was established in 2019 under the scope of the EU initiative 'Clean Energy for EU Islands'. The success and decision making of the initiative relies on a community participatory process based on the cooperation between citizens, authorities, companies, and researchers, which are brought together to evaluate different potential technology pathways. It aims to address and tackle the challenges faced by the islanders, while creating a pilot green socio-economic model case (CETA Culatra, 2019). As part of Culatra2030 Agenda, a new environmentally friendly anchorage project has been proposed, aiming to sustainably use the space in front of the island. Recreational boating is very popular all around the lagoon, and adjacent to Culatra Island there can be more than 200 anchored vessels during the summer (Figure 6). Hence, the necessity for a mooring area to preserve the marine environment. Generally, locals have their slot in the local harbour for their boats, so the anchorage site is mainly for temporary boaters.

Figure 6. Aerial view of anchored boats in front of Culatra fishing harbour in July 2019, highlighting the uncontrolled anchoring of many vessels (image taken from Google Earth, 2022).

As of now, there is no strategic impact assessment of the area. However, AMIC must deliver to Docapesca (the entity that owns the area concession) a management plan, regulations, and an execution plan of all the works regarding the new mooring system. Afterwards, the documentation will be sent by Docapesca to the Portuguese Environmental Agency (Agência Portuguesa do Ambiente, APA), Ria Formosa Natural Park (Parque Natural da Ria Formosa, PNRF) and the Maritime Authorities (Capitania de Olhão), so that they can decide if the works can proceed or if they need to alter the planning. Up until now, both APA and PNRF have released a positive approval for the project, which was conditioned to the presentation of a more complete execution plan, including an environmental monitoring plan.

3.3. The Proposed Coastal Intervention

The anchorage area (CLTR1) was defined on the PNRF Ordinance, and it covers 16.8 ha, accommodating 57 eco-moorings, 48 of them for boats up to 12 m, and the remaining 9 for boats up to 18 m (Figure 7). Boats longer than 18 m will not be allowed to dock, because of space and mobility issues. The layout was defined accordingly with the specific conditions of local hydrodynamics, boats weights and local biodiversity. The eco-mooring will be gravity weights (simple design but reliable), with artificial reefs to enhance growth and to conserve the flora and

fauna in the channel. The blocks will be attached to a tension anchor line, with a buoy at mid water to avoid the dragging on the chain on the seabed.

The mooring weights will be built with circular economy materials so that waste materials can be reduced i.e., the concrete blocks will be built with the aim of using all the resources from fishing activities; gravel will be replaced by oyster shell ash, as they are composed of calcium carbonate ($CaCO_3$) which is one of the components found in cement. The shells will be crushed using a machine acquired by AMIC and the sand will be taken from the leftover dredged volume for the installation of the Fishing harbour. This will reduce the impact on the environment by removal actions. The construction will take place on the island, in an infrastructure that supports the Fishing harbour. Because of the material and resources acquired by AMIC, the only materials that will need to be transported to the island are cement bags, metal chains and buoys.

Overall, the mooring lines consists of a buoy floating at the surface, connected to a riser chain through a shackle and 4D links. Mid water, another buoy will be attached to the chain. The underwater chain will be attached to the cement block resting on the seabed, to avoid chain dragging.

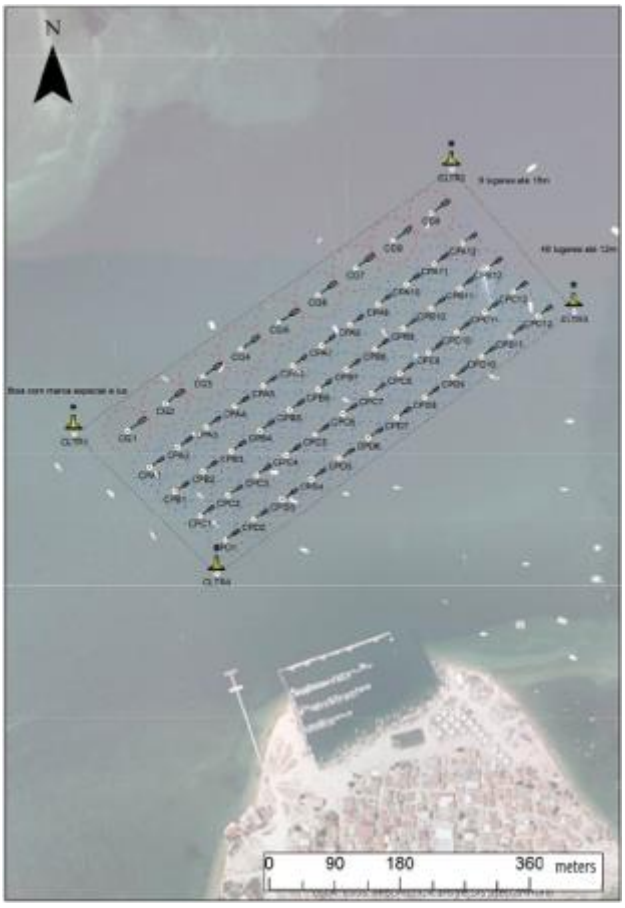

Figure 7. Area designated for the mooring complex CLTR1 in front of Culatra Island (adapted from Pacheco et al., 2021). All the marker buoys have been assigned a name and the northernmost row is designated for bigger boats (up to 18 m).

The distance between each mooring will create navigation corridors, with safety distances for each vessel, aided by maritime signalling buoys. The buoys chosen to delineate the area are Buoys Balizamar A 800 with a float ø0.80 m. They are equipped with LED lights at the top, with a range of two nautical miles, solar panels and sealed batteries, on-off controls, electronic eclipser, programmable lights, and omnidirectional light beams. The buoys will have a metallic chain and 4D links, connected to concrete blocks and they will be painted using epoxy.

4. Methodology

It is a complex matter to unify marine conservation, social needs, and economic advancements (Salaun *et al*., 2020). Interviews and questionnaire have been used in previous studies (Costas et al., 2015; Parry-Wilson et al., 2019; Martinez et al., 2020; Domingues et al., 2021) as powerful tools to assess environmental and social responses in communities. Moreover, community participation is a bottom-up approach, considered crucial to solve local issues and generate revenue (Rahman et al., 2021).

4.1. Questionnaires

To achieve the thesis goals, the necessity for the anchorage area was evaluated, taking into consideration its location (e.g., regulations in place), flora, fauna, and economic and leisure activities. The participatory strategy was based on questionnaires made to collect quantitative and qualitative information about the perception of the area and the project.

Before asking for the completion of the questionnaires, target respondents were divided into four groups: the public administration with jurisdiction over Culatra, the academia, boat users and the community of the island. The questions were all multiple choice but closed- answer. The questionnaire was divided into sections: the first one aimed to collect demographic data (age, gender, education level and occupation). The second one had a total of 10 questions about the environmental sensitivity. Then followed a short section of five questions about the carrying capacity of the system. Afterwards, questions were more technical and strictly related to the anchorage area, with four questions directed only to those that use and/or own a boat. This section included diagrams of the location, size, and accommodation space of CLTR1, a simplified version of an eco-mooring and artificial reef that could be built in the mooring block. The last part comprised six questions about social and economic aspects of the project, related to the island's necessities and its transition to clean energy. The types of possible answers were a mix of yes/no type and 3-point Likert scale with (1= not confident, 2= neutral, 3= confident). Before each group of questions

few lines were written as introduction to the topic. Questionnaires were distributed online (both English and Portuguese versions) to those specific groups of people chosen previously and a copy of the questions can be found in Appendix A.

4.2. Questionnaires Analysis

Before the analysis, numerical values were assigned to answers so that a quantitative analysis could have been done. The statistical analysis was short as the most valuable part of the results is the question-by-question analysis. RStudio and Microsoft Excel were used for data exploration and analysis.

4.2.1. Demographic Data Analysis

Data regarding age, gender, occupation, educational level, and group was firstly analysed by percentages distribution, firstly by age and targeted group and then by gender and targeted group. Age divisions and the four targeted groups were then plotted into a stacked bar chart divided also by gender to visualise the counts numbers. Chi-squared contributions with Pearson's Chi-Square values were reported for age and group and gender and group.

4.2.2. Principal Component Analysis

A Principal Component Analysis was run to show groupings and relationships between and within groups and their answers. Eight key questions (1.8, 1.9, 1.10, 2.5, 3.7, 3.8, 4.5, and 4.6, see Annex A) were selected, and the remaining ones were plotted as supplementary on top of the main ones, avoiding issues with the use of excess variables. Individuals and variables plots were created and analysed. Variance proportions were also reported.

4.2.3. Question Specific Analysis

Answers were then analysed separately by topic (environment, carrying capacity, technical elements, and socioeconomics) and by groups (academia, boat users, islanders, and public administration). Results were plotted into stacked bar charts and pie charts for better visualisation. Moreover, counts for each answer were added to the graphs. The aim was to understand were agreements and differences of opinions regarding the anchorage area were.

5. Results

The questionnaires received a total of 37 answers. The analysis showed that answers were dissimilar for most of the questions, especially those specific to anchoring and boating activities from the "Carrying Capacity" section and the "Technical Specificities of The Anchorage Site" section in the questionnaire. Relatively similar answers were found in the "Social Aspects and Contribution to the

Island's Sustainability" section of the questionnaire. Questions from the "Environment Sensitivity" section such as *Do you know that Ria Formosa is a protected natural area?* (Q1.1), *Do you know that Ria Formosa is under high pressures of natural and anthropogenic nature?* (Q1.2), *Do you know how wetlands are important for the system balance and functioning?* (Q1.3), *Do you know the importance of seagrasses beds?* (Q1.4), *Do you know the importance of nursery grounds?* (Q1.5) had 100% agreement between respondents. The same results were recorded for *Do you know what habitat pressure means?* (Q2.1) and *Do you think that the natural park should have rules regarding the nautical activities in the lagoon?* (Q2.2). Most respondents agreed in the questions that asked: *Are you aware that there are many meadows and nursery grounds in the channels?* (Q1.6), and *Do you know that anchoring outside designated areas can have detrimental impacts on these sensitive habitats?* (Q1.7) with 36 yes and 1 no in both.

The following sections are a breakdown of the results, starting from demographic data, followed by a principal component analysis and then a question specific analysis, to see where agreements and divergences lie.

5.1. Demographic Data

There is a total of 12 respondents belonging to the "Academia" group (32%), 10 "Boat User" (27%), 9 from the "Public Administration" (24%), and 6 from the "Islander" group (16%). Most respondents were between the age of 45-54 (35%), with highest participation from the "Academia" group. The age group 55-64 represented 24% of the participants, with equal respondents (8%) from the "Academia" and "Public Administration". The next groups were 35-44 (19%) with most answers coming from the "Boat User" group. The age group of 65-74 represented 11% of the answers with low participation from all groups. The lowest number of respondents belonged in the age groups of 18-24 (5%) and 25-34 (5%). For the former answers only came from the "Islander" group, whereas the latter had a mix from "Islander" and "Public Administration" groups (Table 1).

The sampled group is largely male dominated (76%), with only 24% of the answers coming from females. Noticeable is the absence of female respondents from the "Islander" group (Table 1 & Figure 8).

Table 1. Percentages (%) distributions of demographic data, divided into age groups (upper section), gender (lower section) and sorted by targeted group (academia, boat user, islander, and public administration).

Age	Academia	Boat User	Islander	Public administration	Total
18-24	0.0	0.0	5.4	0.0	5.4
25-34	0.0	0.0	2.7	2.7	5.4
35-44	5.4	10.8	0.0	2.7	18.9
45-54	16.2	10.8	0.0	8.1	35.1
55-64	8.1	2.7	5.4	8.1	24.3
65-74	2.7	2.7	2.7	2.7	10.8
Total	32.4	27.0	16.2	24.3	100.0

Gender	Academia	Boat User	Islander	Public administration	Total
f	13.5	5.4	0.0	5.4	24.3
m	18.9	21.6	16.2	18.9	75.7
Total	32.4	27.0	16.2	24.3	100.0

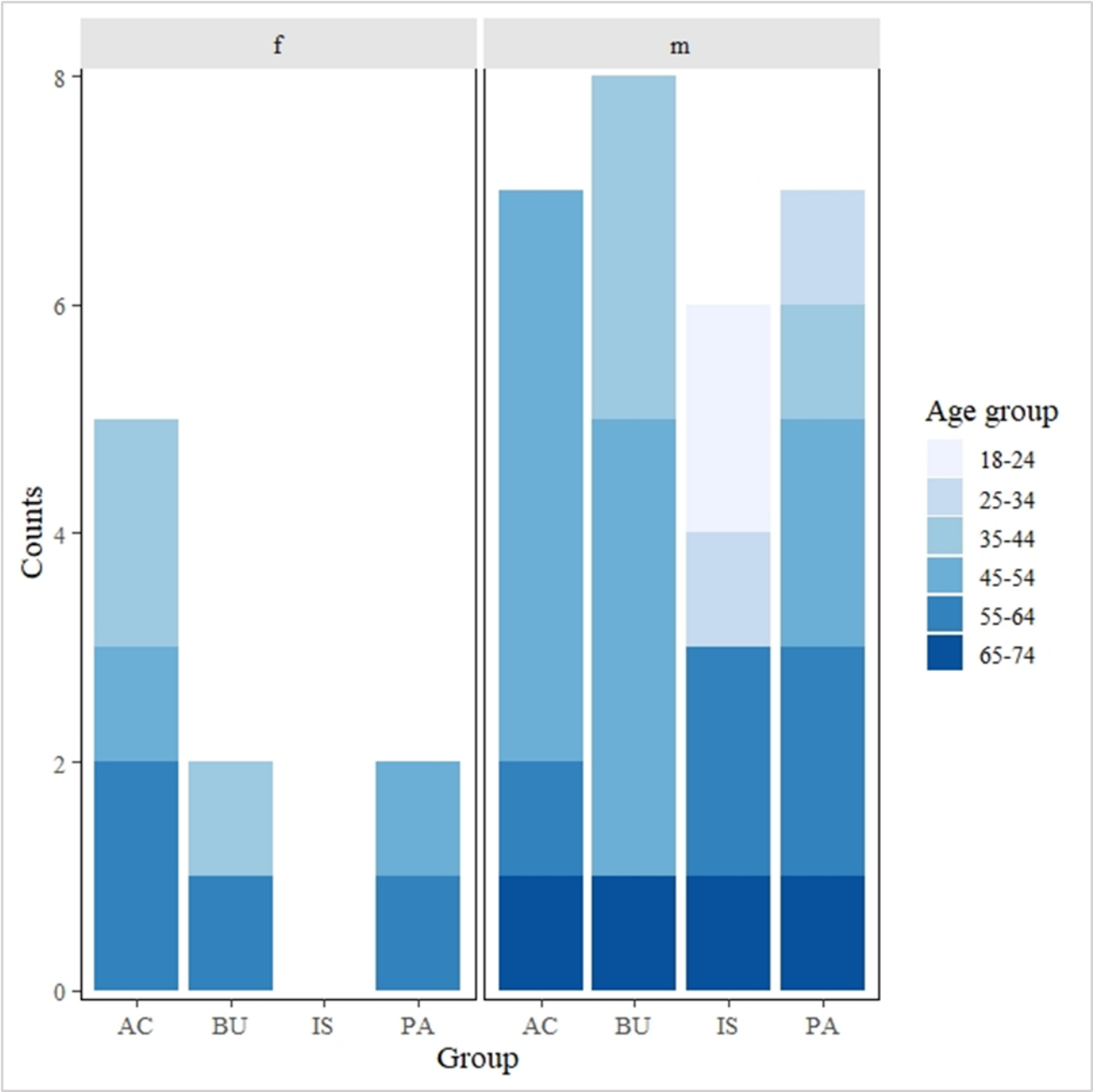

Figure 8. Bar chart grouping together demographic data from the respondents. The x axis represents the four targeted groups: academia (AC), boat user (BU), islander (IS), and public administration (PA). Different colours represent the different age categories. The data is also divided by gender (f- female; m- male).

For an independent analysis by group, gender and age, Pearson's Chi-square contributions were calculated. They showed that the age by group data was independent (21.829, df= 15, p-value= 0.1124), as well as the gender by group one (4.012, df= 3, p-value= 0.2601) (Table 2), without rejecting the null hypothesis stating the groups were independent.

Table 2. Chi-square contributions for age by group data (upper section) and for gender by group data (lower section).

Age	Academia	Boat User	Islander	Public administration	Total
18-24	0.649	0.541	8.658	0.486	10.334
25-34	0.649	0.541	1.408	0.542	3.14
35-44	0.032	2.349	1.135	0.290	3.806
45-54	0.755	0.067	2.108	0.008	2.938
55-64	0.002	0.844	0.200	0.300	1.346
65-74	0.068	0.006	0.19	0.001	0.265
Total	2.155	4.348	13.699	1.627	21.829

Gender	Academia	Boat User	Islander	Public administration	Total
f	1.484	0.077	1.459	0.016	3.036
m	0.477	0.025	0.469	0.005	0.976
Total	1.961	0.102	1.928	0.021	4.012

5.2. Principal Component Analysis

Questions were initially analysed through a Principal Component Analysis (PCA), to visualise on score plots clusters of answers based on their similarities between and within groups. The two dimensions with the highest proportion of variance were Dim. 1 (30.78) and Dim.2 (19.13), despite only explaining 50% of the variability together. The rest of the variance is explained by the other six dimensions. (Table 3).

Table3. Principal Component Analysis results with variance, proportion of variance and cumulative proportion of each dimension.

Principal Component Analysis

	Dim.1	Dim.2	Dim.3	Dim.4	Dim.5	Dim.6	Dim.7	Dim.8
Variance	2.464	1.530	1.113	0.98800	0.730	0.625	0.323	0.227
Proportion of Variance	**30.795**	**19.131**	13.914	12.348	9.125	7.816	4.037	2.835
Cumulative Proportion	30.795	49.926	63.840	76.187	85.312	93.128	97.165	100.000

The variables correlation plot showed the general direction of the questions and whether groupings based on similarities could have been made. Most of the questions have similar patterns, with some exceptions such as Q1.9 (If you knew about the presence of a seagrass bed, would you anchor anyway?) (Figure 9). Generally, blue question variables are clustered together, showing the least variance among them.

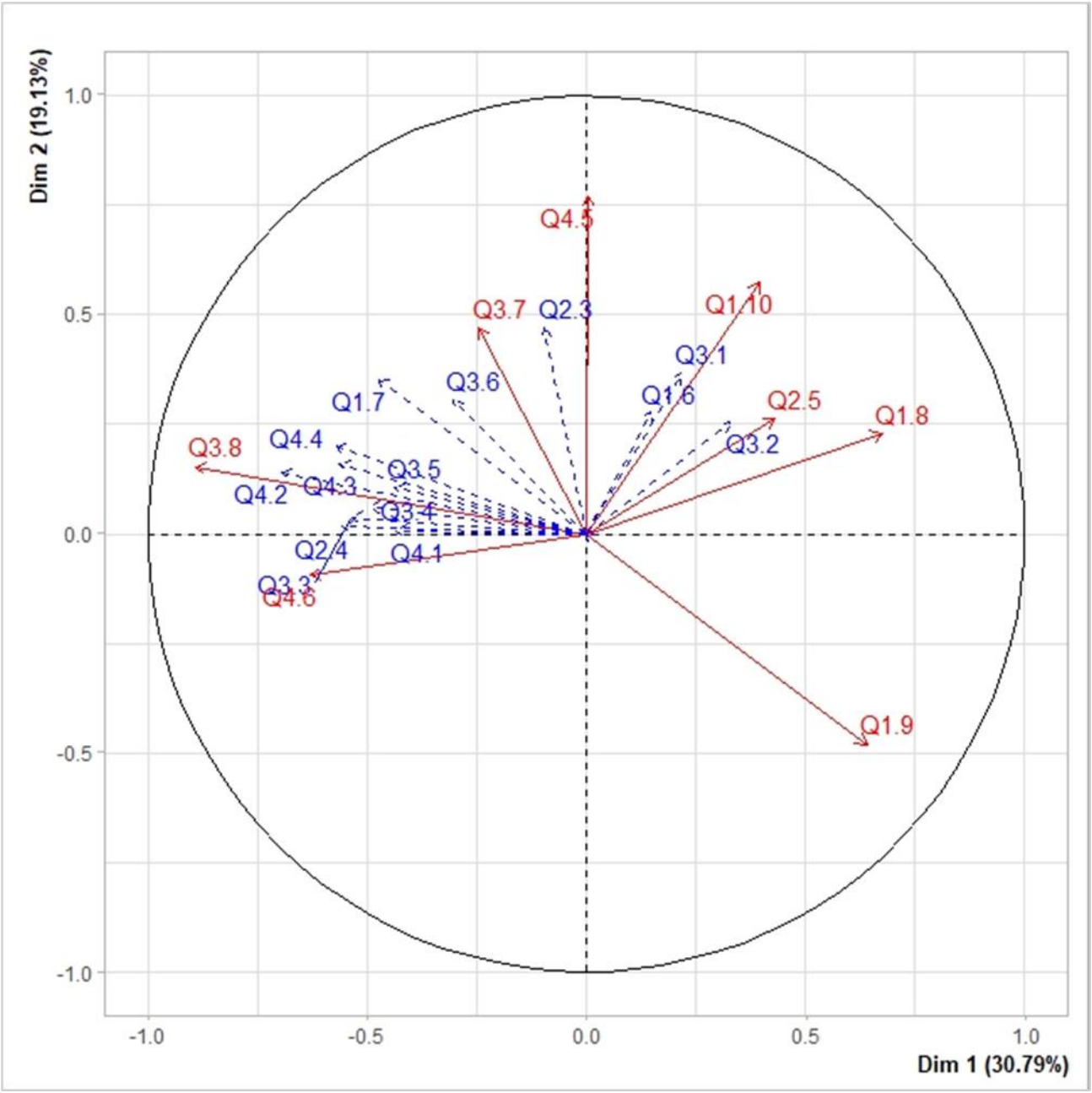

Figure 9. Variable correlation plot showing questions similarities and differences. Positively correlated variables are grouped together, whereas negatively correlated ones are opposite sides of the plot. Red variables are the main questions plotted, whereas blue ones are supplementary.

From the individuals and groups plot, the answers are not so different for among respondents, but the boat user group (BU, red) is the one with the highest amount of different answers. The other three appear more similar (Figure 10). Moreover, it is possible to see how the individuals (dot + number) are grouped. The boat user group has divergent answers from others (e.g., red points 26, 35, and 34), with some similarities to individuals from the academia (AC, black point 30) and islanders (IS, green point 9) (Figure 10).

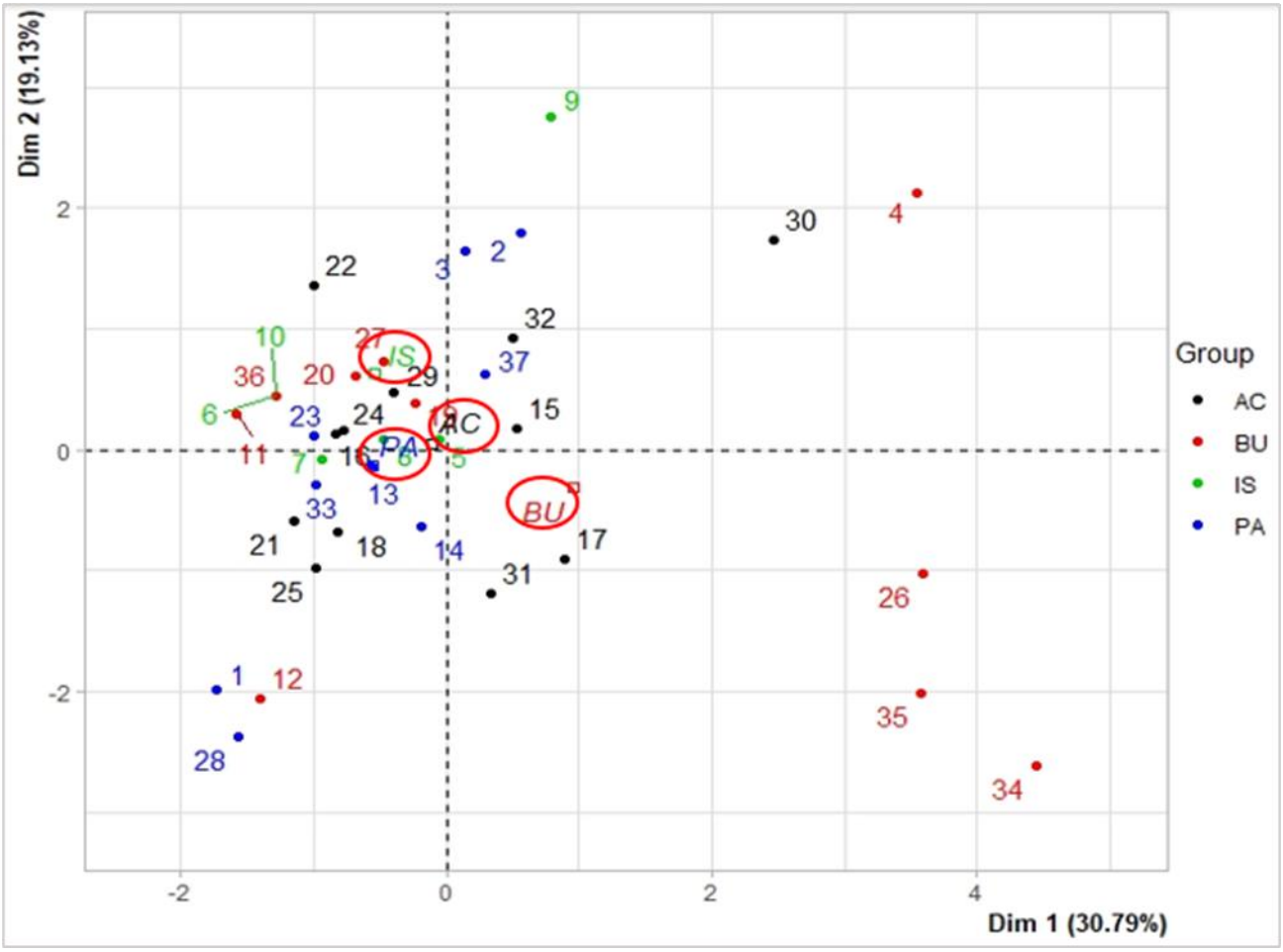

Figure 10. Individuals plot showing how similar or not the answers given by the participants were. Every number corresponds to one individual. Circled in red are shown the four targeted groups: AC= academia (black), BU= boat user (red), IS= islander (green), and PA= public administration (blue).

5.3. Question Specific Analysis

For this section, single questions were analysed individually. The answers were divided into the four topics of the questionnaires: environment, carrying capacity of the system, technical questions regarding the anchorage system and socio-economic questions.

5.3.1. Environmental questions

The possible answers to the questions present in these sections were “yes”, “no”, and “don’t know”. Questions 1.1 to 1.5 (*Do you know that Ria Formosa is a protected natural area? Do you know that Ria Formosa is under high pressures of natural and anthropogenic nature? Do you know how wetlands are important for the system balance and functioning? Do you know the importance of seagrasses beds? Do you know the importance of nursery grounds?)* were all positively answered, whereas for question 1.6 and 1.7 (*Are you aware that there are many meadows and nursery grounds in the channels? Do you know that anchoring outside designated areas can have detrimental impacts on these sensitive habitats)* only one “no”/ “don’t know” per question was recorded, against all other “yes”. These questions were related to the status of Ria Formosa, in terms of pressures, key

elements of the natural park and how anchoring can affect important elements of the lagoon. Most varied answers were found in questions 1.8 to 1.10 (*Do you know if you ever have anchored on a seagrass bed? If you know about the presence of a seagrass bed would you anchor anyway? Do you think Ria Formosa is well managed?)* and they are shown in Figure 11. Question 1.8 asked: *Do you know if you ever have anchored on a seagrass bed?* Answers were divided in 11 "yes", 13 "no" and 11 "don't know". Two respondents skipped the question. Boat users had no difficulty on stating yes or no, and this might be an indication that they are aware of their surroundings when anchoring.

Question 1.9 asked *If you knew about the presence of a seagrass bed, would you anchor anyway?* The majority answered "no" across the groups, with 4 exceptions that answered "yes" in the boat user and academia clusters. Only one respondent skipped the question.

Question 1.10 addressed the management of Ria Formosa in terms of provided information to the public about its species, environmental status and possible activities that can be done. 19/37 answered "no", and within the different groups "no" was the most chosen answer also.

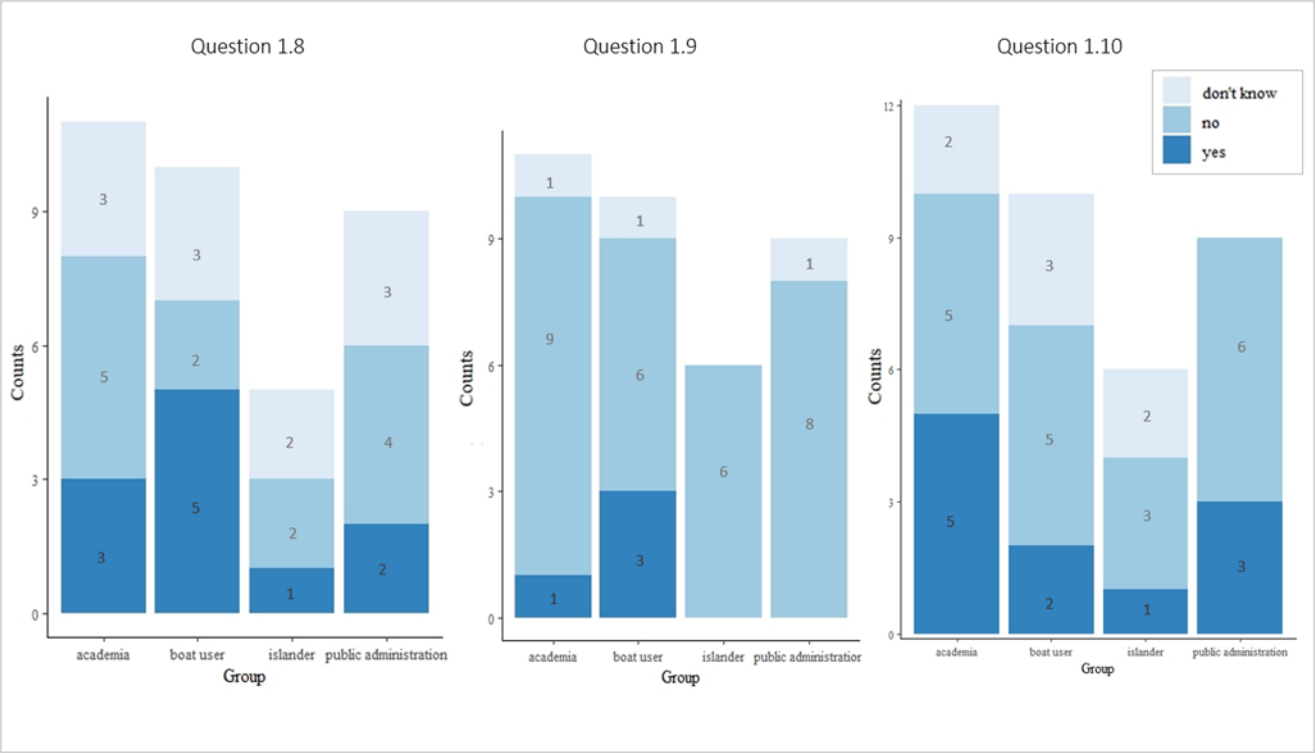

Figure 11. Answers per group for questions 1.8 (Do you know if you ever have anchored on a seagrass bed?), 1.9 (If you knew about the presence of a seagrass bed, would you anchor anyway?) and 1.10 (Do you think Ria Formosa is well managed?), regarding environmental issues. Counts of answers per group are represented in the columns and on the y axis. The colours represent the three options for answering those questions (yes, no, don't know).

5.3.2. Carrying Capacity Questions

For this section possible answers were either "yes" or "no".

For questions 2.1 (*Do you know what habitat pressure means?*) and 2.2 (*Do you think that the natural park should have rules regarding the nautical activities in the lagoon?*) all respondents chose

“yes”. Question 2.3 asked whether mooring systems can help the control of boating traffic. Most of the answers were positive (31/37), however six argue that it will not help. When asked if respondents would use a predesigned anchoring site, only seven out of 37 responded “no”. The highest count of “no” is found in the boat user group (5/10). In the islander group, two answers from respondents out of six were recorded as “no”. It must be considered that islanders might already have their spot at the local harbour. The final question (2.5) asked whether participants would feel more comfortable using their own anchor in a designated site, rather than a provided one. Twelve (12) out of 36 said they would feel more comfortable with their own anchor, whereas 24 out of 36 would use a provided one if given the option (Figure 12). The boat user group, which would be the more involved regarding this question, had four respondents answering that they would rather use their own anchor in a designated site.

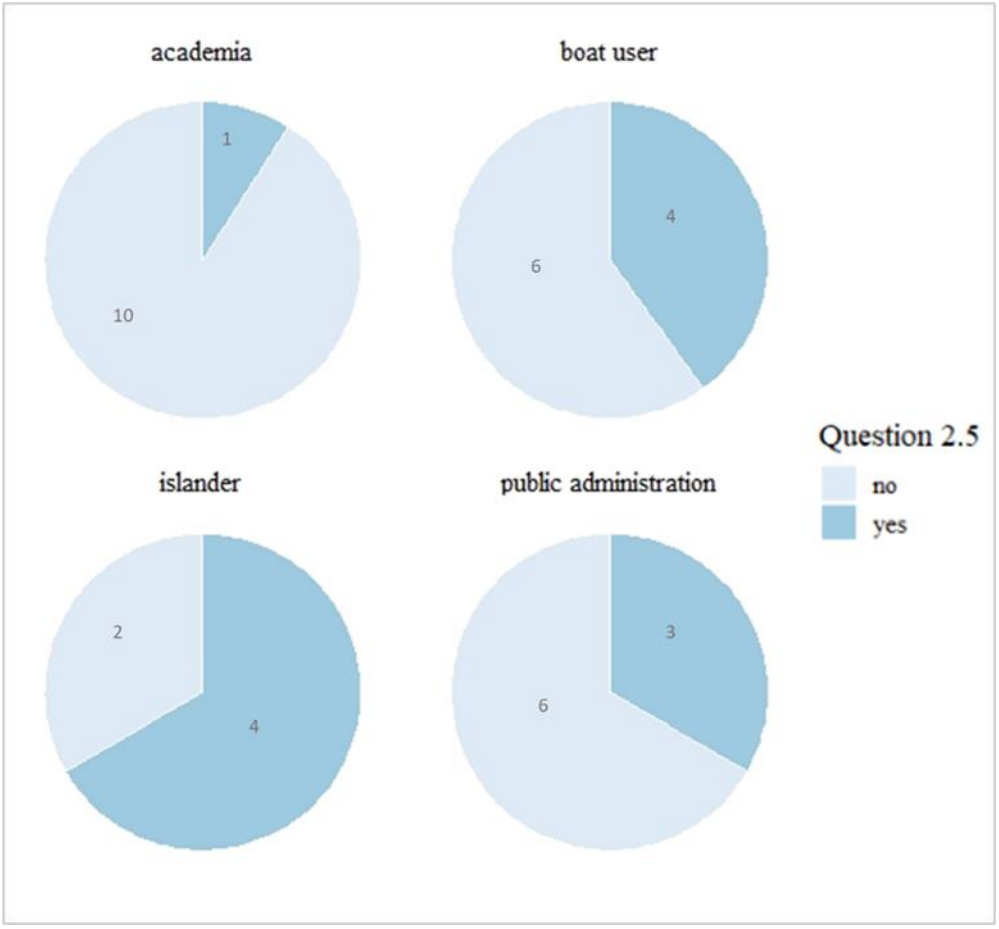

Figure 12. Answers per group regarding question 2.5 (Would you feel more comfortable using your own anchor in a designated site, rather than a provided one?). Each pie represents a group and with the counts for either yes or no.

5.3.3. Technical aspects of CLTR1 questions

Possible answers for questions 3.1 to 3.4 were “yes”, “no”, “maybe”, and “don’t know”. Here, images of the project and moorings were also shown to help answer the questions. Most respondents across the four

groups answered positively when asked if they knew what an eco-mooring was (Q3.1). Moreover, they appeared to be aware that eco-mooring can serve as habitat structures for marine species (Q3.2). In the public administration group, four answers were recorded as “no”, which is the same amount found in the academia group. When asked *would you use a provided eco-mooring knowing it will benefit the environment* (Q3.3) 31 respondents chose “yes”, three chose “maybe” and one selected “don’t know”. Two respondents who belonged to the boat user group selected “no” saying they would not use a provided eco-mooring.

Question 3.5 and 3.6 asked about levels of confidence or doubts about the security related to eco-moorings. The possible answers were “confident”, “neutral”, and “not confident”. For the question *how confident would you feel in mooring your boat with an eco-mooring?* (Q3.5*)* most participants were confident in using an eco-mooring. In the boat user group three answers were recorded as “neutral” and one as “not confident” (out of ten from that group). Regarding the security of eco-moorings (question 3.6) the groups academia and public administration agreed on its positive usage. Doubts were recorded among the respondents’ boat user and islander. Nevertheless, for both groups (7/10 and 4/6 respectively) the majority regarded the eco-mooring as safe to use. Question 3.7 (*Considering the dimensions and number of boats that moored there, do you think that 57 moorings will be enough for the area?*) had as possible answers also “confident”, “neutral”, and “not confident”. According to most answers, the anchorage site appears to not have enough space to accommodate the number of boats coming to Ria Formosa. The islander group, differently from the other three showed confidence in the fact that 57 moorings will be enough for the area (Figure 13). In addition, this question was skipped by 14 respondents.

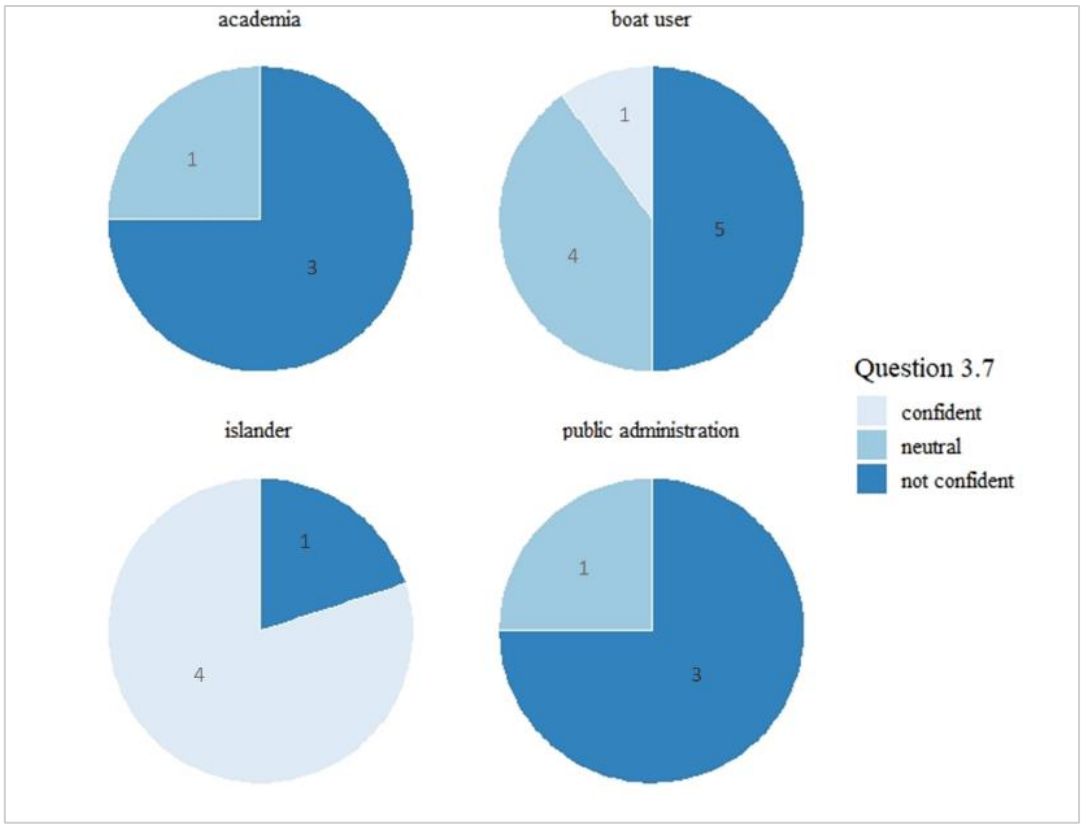

Figure 13. Answers per group for question 3.7 (Considering the dimensions and number of boats that moor there, do you think 57 moorings will be enough for the area?). Each pie represents a target group, and the counts of each possible answers is represented in the slices.

In question 3.8 preferences between mooring freely in the area available for the anchorage or use provided moorings were asked. This question was only for those respondents that owed and/or use a boat. Respondents expressed a general preference for fixed mooring, with some preferences towards free mooring in the boat user and academia groups (Figure 14). The “do not moor” answer was written for those that do not own or use a boat, which are mainly for the academia and public administration. Nine out of 37 respondents skipped the question.

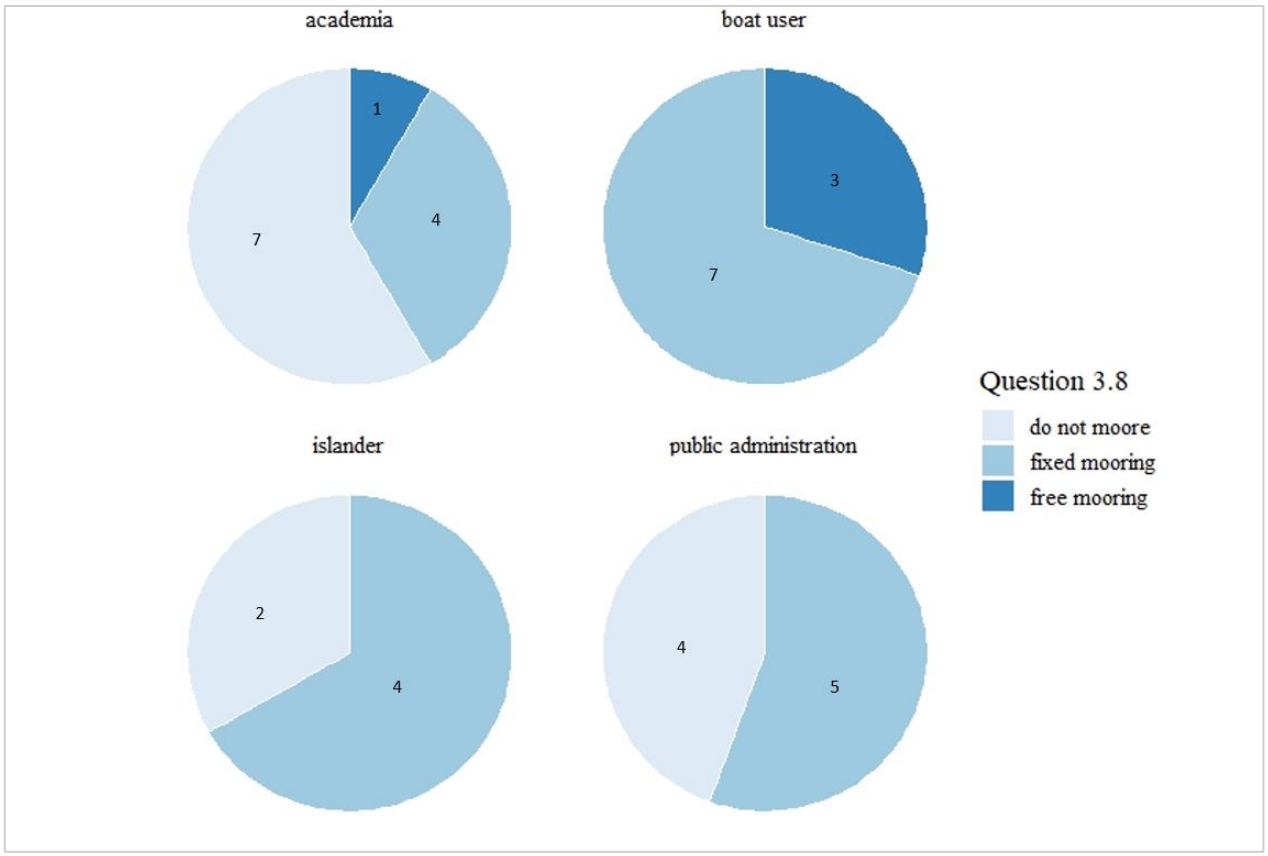

Figure 14. Answers per group for question 3.8 that asked: The anchorage area is limited (16.8 ha). Would you prefer to use the moorings created by experts for the space or would you rather moor freely in the same space? Each pie represents a targeted group and counts of answers are represented in the slices.

5.3.4. Socio-economic questions

Possible answers to choose in this section were “yes”, “no”, “maybe” and “don’t know”. When asked if the anchorage system could be a useful sustainability tool to have, the vast majority replied positively, whereas one boat user answered “no”. At the question *would you pay for a must use eco-mooring?* answers were again mostly positive, with two “no” on the boat user group. Moreover, some “don’t know” were recorded in the academia group.

Respondents agreed that they would use the mooring site knowing it can help the island’s energy transition (question 4.3). However, some negative answers and “don’t know” can be found in the academia and boat user group. In addition, to the following question (4.4) *Do you think Culatra, and the community would benefit from the construction of the mooring site?* two “no” were found in the “boat user” group, and two *maybes* among the public administration answers. Moreover, there were four total “don’t know” divided between academia (2/12), boat user (1/10) and public administration (1/9) groups.

Question 4.5 asked whether the anchoring site can help with the summer boating traffic and here answers were mixed (Figure 15, question 4.5). Most answers are still positive, but there is a level of

uncertainty among all groups, expressed by the “maybe” and “don’t know” counts, 13/37 and 4/37 respectively.

Regarding the answer to the question 4.6 *Do you think the anchorage system will be able to provide more employment and benefits for Culatra and for its visitors?* The replies were generally positive (20/37 replied “yes”) with uncertainties among the groups (e.g., two “no” and two “don’t know” were recorded in the boat user group and three “maybe” in the public administration group), except for the “islander” group which all five answers were yes, and one skipped the question (Figure 15, question 4.6).

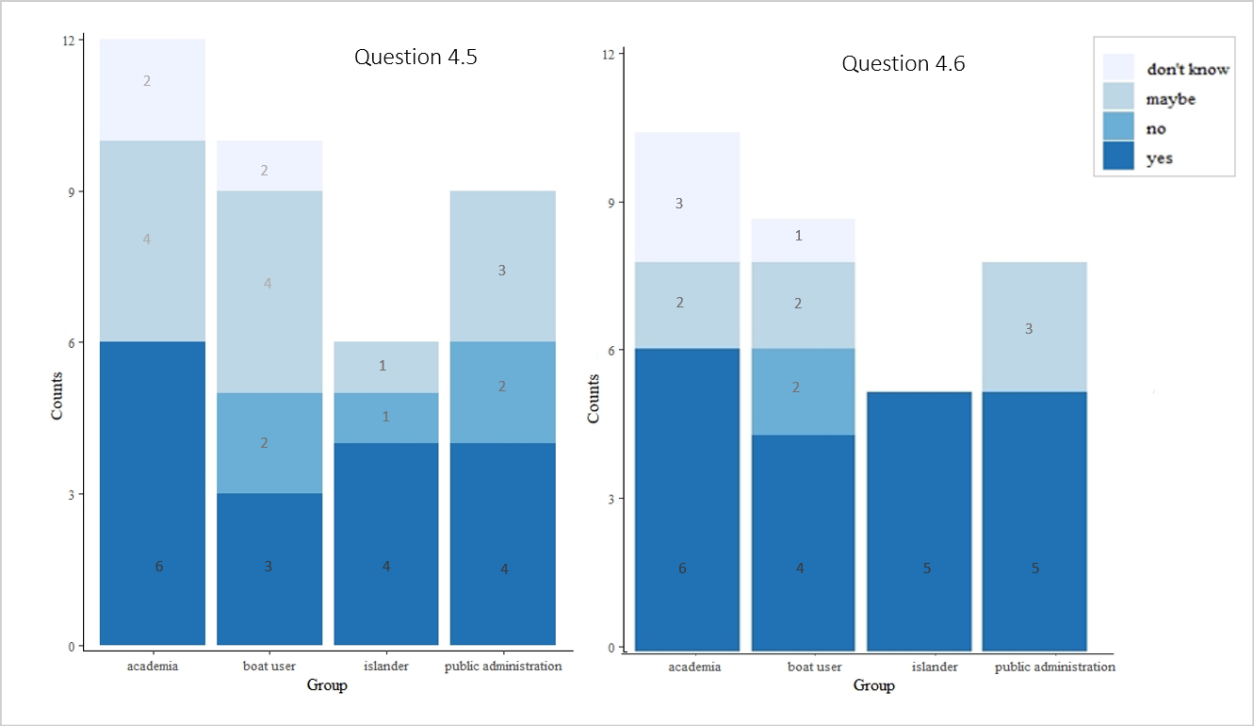

Figure 15. Answers per group for question 4.5 (Do you think the anchoring will help controlling the number of boats and tourists coming during summer?) on the left and 4.6 (Do you think the anchorage system will be able to provide more employment and benefits for Culatra and for it visitors?) on the right. Counts of the answers given are represented on the y axis and reported in each section of each column.

6. Discussion

The present work aimed at understanding the social perceptions of the impacts that the new anchorage area for Culatra Island could have environmentally and socioeconomically and, based on the answers given, propose possible solutions and improvements to the project.

6.1. Environmental and Social Perceptions

Demographically, respondents were mostly older males. This can be attributed to either the willingness to participate in the questionnaires, the nature of the topic studied, or the way the

questionnaires were distributed. However, some respondents from Culatra were younger, between the age of 18 and 25. This could be seen as a positive indication that despite the difficulties of living on the island, the younger population seems keen in being involved in the progression of the island and its socioeconomic status. It is not uncommon for the younger population to continue working on the family's legacies dedicating themselves to fishing and marine farming activities (CETA, 2019). Yet, the participation from the islander group was lower compared to those of academia, boat users, and public administration groups. This could be due to the higher difficulty in reaching participants from Culatra as questionnaires had to be filled out by hand rather than online.

Nevertheless, participants from all groups seemed to have a good understanding of the natural habitat and resources present in the Ria Formosa lagoon area. Answers from the environment section suggested that there was awareness about the environmental status of the natural park, the importance of seagrasses, and of nursery grounds and their presence in the area. This can be attributed to local knowledge and experience working in the area. UNESCO defines ecological knowledge as the understanding and skills developed by having long histories with the natural surroundings (Bastari et al, 2017), which is the case for fisherman living in Culatra. Moreover, UK studies have found that seagrass is an easily recognised plant by local communities even without knowing much about it (Jefferson et al., 2014). This can be seen in the replies to the environmental questions, where respondents were aware of seagrasses and nursery grounds in Ria Formosa. Moreover, answers to the question *Do you know if you have ever anchored on a seagrass bed?* showed that respondents that answered yes were aware of the underlying natural environment, but some participants answered that they did not know whether seagrass was present or not. Their answers may be related to the notion that Ria Formosa requires better management and an improved communication regarding its natural resources and species to the general public. An example to improve this communication would be to include relevant information online, such as protected species and importance of the lagoon system, as it is provided at the website from the Guanacaste Conservation Area. It contains a wide array of wide array of information, including basic information on key species and habitats as well as a database with scientific and technical studies conducted in the area (Maestro et al., 2022).

A study by Parry-Wilson et al. (2019) investigating the connection between boating behaviour and seagrass awareness, showed that a high number of respondents were aware of the presence of seagrass but did not adjust their boating behaviour accordingly. Despite noticeboards and information on local websites about the seagrass species, anchoring activities were recorded

anyway. This poses important questions regarding the threats to seagrass habitats and potential implications for dependent biological communities. Thus, further investigations into boating behaviour and its connection to existing knowledge of the marine environment are required to answer these questions. Similarly, to the question *If you knew the presence of seagrass, would you anchor anyway?* some respondents from the boat user group affirmed that they would anchor anyway suggesting either a lack of knowledge on the importance of these habitats or they believe that their boat and freedom are more relevant, even knowing seagrasses importance and so choosing to prioritise lifestyle over environmental considerations. It has been advised that having highly visible solutions like eco-moorings accompanied by messages that encourage their usage, could help enhancing pro environmental behaviour (Easman et al., 2018), together with education and cultural behaviour changes.

Results indicated a consensus about the need to have more regulation around nautical activities in the natural park. Furthermore, there was a general agreement that a mooring site might help to control traffic. Nevertheless, mixed opinions on the use of a predesignated site for mooring could be interpreted as a mistrust in unfamiliar equipment that users have never seen before. Nonetheless, an unwillingness to park in places not chosen by visitors cannot be excluded as a possible explanation to the answers given regarding the predesignated mooring site. These answers suggest that issues could stem from cultural ideas whereby changing from free anchoring to fixed place and under fee is not accepted, regardless of the environmental and social benefits.

Regarding the anchorage site CLTR1, answers suggested that 57 mooring spaces were not an adequate amount as required by users of the area. The installation of eco-moorings implicitly fixes the numbers of spots available in the location. As a result, boaters may choose to moor at an alternative location if all available slots are occupied during high peak (Hirst et al., 2017). Maritime Safety Queensland (2019) stated that anchorage areas should be restricted to a certain limit size to better preserve the seabed and to avoid fragmentation and larger impacts on the seabed. From the answers, the islander group seemed to agree that the moorings will be enough for the vessels passing by, however, this could be due to the lower number of respondents or the fact that they already have a place for the boat in the harbour in front of the island. Nevertheless, their local experience and knowledge should be taken into consideration when taking management decision as this group will be likely affected.

Since the first consideration when choosing any anchorage site is ‘shelter’, as advised by the Royal Yachting Association (Evans, 2011), it could be possible that vessel safety is the main consideration

when choosing a mooring spot, which in turn could have created a natural bias within questionnaire replies. Connected to this observation, answers from the Culatra questionnaire showed that eco-moorings were regarded as safe by most users. However, in other studies respondents affirmed that their main worry was the chain or rope would float up and get tangled in the propellers of the boats (Parry-Wilson et al., 2019). In addition, it could be proposed that respondents are cautious about using eco-moorings as they may have never used them before or have only seen them on schematics. It is also worth noting that the groups of academia and public administration seemed confident in the safety of the eco-moorings, whereas boat users and islanders had less confidence about their safety. Although it cannot be directly inferred, these differences could suggest that respondents who are in closer contact with marine facilities and use them every day are wearier of unknown tools and could be more comfortable using their own anchors and lines (traditional tools). It should be considered that previous studies have reported that the main issues with eco-moorings malfunctioning were related to a lack of maintenance, faulty equipment, and biofouling (Hirst et al., 2017). Thus, the paramount for the effective usage of eco-moorings is a good maintenance schedule and rigorous quality controls. Answers to question 3.8 (*The anchorage area is limited (16.8 ha). Would you prefer to use the moorings created by experts for the space or would you rather moor freely in the same space?),* suggested that most of the respondents were content with using fixed and provided moorings, whereas in the boat user group some were opposed to their use and preferred a more independent mooring/anchoring decision. Contrary to these answers, in the UK, 82% of online respondents preferred to moor over anchoring (Parry-Wilson et al., 2019). Unwillingness to switch to fixed moorings could be linked again to the idea of not wanting to change behaviour in favour of lifestyle and/or lack of information regarding the importance of the marine environment of Ria Formosa. Moreover, stakeholders often do not agree with management decisions out of fear of losing social, recreational, or economic livelihoods a behaviour often observed in connection with the establishment of marine protected areas (MPAs) (Gray et al., 2010). Nevertheless, it has been observed and reported that damages to the seabed are higher when anchoring outside defined areas, impairing sustainable development of marine economy of coastal cities (La Manna et al., 2015).

In case the usage of eco-moorings would become a standard practice, awareness of their purpose and the willingness of boaters to use them might increase and could lead to behavioural changes in the boating community (Ariely et al., 2009; Gneezy et al., 2011). In this context, it is crucial to consider the opinions of recreational boaters as their opposition has potential to affect the

successful implementation of projects, as seen in the in the past where the lack of support by boaters effectively stalled the implementation of an Italian MPA (Salmanoa & Verardi, 2001).

The opposition of boaters in the present study could be due to the monetary fee that would have to be paid to use the moorings and lack of freedom to choose their preferred spot. However, the money generated by the new anchorage area would support the Culatra community and their transition to green energy. Hirst et al. (2017) stated that recreational boaters are more inclined in paying a fee when it is the best and cheapest solution, and equally imposed on all users, including locals or visitors. In addition, if the eco-mooring slots mostly remain unused, it may reduce the perceived need to pay and make boat users choose another location to anchor (Hirst et al., 2017).

As costs are related to Culatra's green energy transition, respondents were asked whether they thought the community would benefit from the construction of the mooring site or not. Answers suggested that the usefulness of this construction is not certain. This could stem from the fact that similar projects in the vicinity are not in place which could make it difficult for respondents to envision the potential outcome. Nevertheless, eco-tourism has proven to help the accessibility to resources by local communities, to protect and preserve social and cultural heritage, and improve overall living standards and creating more economic possibilities (Rahman et al, 2021). For instance, in previous studies (Kovačić & Favro, 2014; Parry-Wilson *et al.,* 2019) it was reported that more benefits would come from eco-moorings usage in terms of finances, employment, and marine conservation. A study assessment reported that there was an increase in income of 2.9% together with employment rates after the installation of a mooring site in Croatia (Kovačić & Favro, 2014). As such, the local government should help disseminating information about benefits and improvements that a mooring site can offer to locals and visitors through local harbours, mooring providers, vessels retailer, and through local businesses such as cafes, restaurants, and public buildings (Parry-Wilson et al., 2019). Furthermore, targeted educational campaigns could increase community driven conservation management and foster a sense of marine citizenship (McKinley & Fletcher, 2010). Replies from the questionnaire already suggested that islanders believe the anchorage site can help the community and, hence, participation of the local community appears vital to promote ecotourism and management of the area, as seen in the creation and management of MPAs (Rahman et al., 2021).

6.2. Guidelines for the responsible utilisation of the area

The anchorage site can be seen as a small protected area since the mooring blocks will serve as artificial reefs. To succeed, the area will need an effective coordination and cooperation by management and users. In Aoterroa (New Zealand), the planning of a MPA evolved from a conflictual to more collaborative process after an increasingly inclusive and holistic management approach was adopted (Maestro et al., 2022). A committee of stakeholders could be a good solution to help the implementation of rules and for decision making regarding CLTR1. Co-management legitimises community involvement, respects the community's need for socio-economic development and supports the use of their historical rights (Kelleher, 1999), while at the same time ensures the functioning and proper usage of the new anchorage area. After an initial trial of the area, management decisions should be adaptive and transparent, incorporating scientific and local knowledge and take into consideration users experiences. It is important to consider changes that include environmental and socio-economics aspects, while maintaining the safety of CLTR1. If rigorous and sustainable management is followed, it will be likely that the mooring site will be more accepted and similar projects will be created elsewhere in the lagoon, while enhancing traditional, cultural, and historic interest in the area (Kovačić & Favro, 2014).

Generally, rules should cover all aspects of mooring activities, from before the boat arrival to the end of the stay. A document with rules and specific details should be made available (online and/or at the harbour). For instance, a mooring spot should be booked and paid before arrival and coordinated with the harbour master. For CLTR1, the PNRF ordinance stats that moorings should have temporary daily rates. Those that use the mooring should be able to access details regarding the area and it regulation beforehand. The regulations handbook should contain specifications on how to approach the area and the maximum speed allowed. Moreover, it could state rules regarding the slots assigned (e.g., do not change spot with other vessels once it has been assigned for safety reasons). Garbage disposals and directions on how to store waste material should also be clearly delineated for the users. Waste bins should be made available on Culatra to correctly dispose of vessels' garbage. The responsible management of an anchorage site in Zadar County allowed for a reduction of impacts on the marine environment and protection from invasive species such as *Caulerpa taxifolia* and *Caulerpa racemosa*, when great emphasis was put into the collection of garbage from boaters and having appropriate disposal tools (Kovačić & Dundović, 2012).

Inspections of the eco-mooring and all the components should be carried out regularly (every 2-3 years) to verify stability and safety of all the components. When moored, users should regularly check that the vessel is safely moored, to avoid accidents with neighbouring boats.

To avoid boaters anchoring outside CLTR1, marine police should regularly be present in the surrounding area to oversight boats coming to Ria Formosa and enforce rules of no anchoring unless with specific work permits. In addition, mooring sites are more popular for cruisers and sailing boats, which usually carry a smaller inflatable boat to move to shore. Unless there will be a service to transport visitors to Culatra, the necessity of self-transport to the island should be stated together with CLTR1 rules and regulations.

6.3. Methodological limitations

The methods used for this research were insightful and useful for such project. Nevertheless, improvements and changes can be made.

The number of participants in the questionnaires was limited implying that results may have some degree of uncertainty. To improve the representability for each group and a stronger statistical basis, more participants are needed. To improve this, an alternative method of questionnaire diffusion should be considered to reach more people.

Closed answers questions do not allow detailed responses from the participants, and sometimes it can be difficult to infer what a respondent really thinks or believes. Therefore, in person interviews should be considered as a tool to overcome this limitation and collect more in-depth answers. Focus groups could be tested as well to see how opinions diverge.

Biased answers must be considered in the methodological process too. In fact, background, culture, and lifestyle have likely influenced the answers given by the participants. For instance, the boat user group is biased because they will have to change part of their lifestyle, hence their answers appear more towards free anchoring and no fees. On the other hand, islanders will benefit from the project for example in terms of navigation in the channels, so they are seeming more supportive of the mooring site. These biases cannot be eliminated but need to be counted for in these types of studies.

It would be of value to recreate a questionnaire after one year from the operativity of CLTR1, to verify if opinions have changed and users have concerns and comments after using one of the eco-mooring slots.

7. Conclusions

The present study provided first insights on the perception of the Culatra community, boaters, academia, and public administration on the new anchorage site proposed for Culatra Island in the context of Clean Energy for EU islands. The adjacent idea to the new mooring site is to help in controlling the anchorage actions happening in Ria Formosa and so help the protection and conservation of important meadows and nursery grounds present in the channels. A questionnaire was developed to access the perceptions of the above-mentioned communities to the new eco-mooring site.

Respondents showed understanding of the marine environment of Ria Formosa and its channels. However, boat users demonstrated a lack of interest in changing their anchoring activities over environmental concerns. This behaviour has been thought to be related to an unwillingness to change lifestyle but also to a possible lack of information regarding the importance of species and ecosystems of the area.

Some participants showed concern over the limited number of slots that will be available for mooring. It is suggested that any change to the carrying capacity of CLTR1 should be carried out after the installation and use of the site, as to make changes only if necessary. The eco-moorings were considered safe by most, and doubts were thought to be linked to a lack of use of eco-moorings and their novelty in the area. Moreover, those against the use of CLTR1 might not be against the eco-moorings but against the change that they imply, from free anchoring to a paid slot. Nevertheless, answers suggest that the project is seen as beneficial for Culatra and its community by the islanders, with some doubts from the other three groups. Here, a need for educational campaigns, information dissemination and transparency about the management of the area has been highlighted. Regarding the opinions of boaters, it has been suggested to consider their opinions and implement solution and changes, when necessary, as their support is paramount for the functioning of CLTR1. All stakeholders should be involved for an effective co-management of the area, and a holistic approach should be implemented for a proper use and maintenance of the area.

The methods used were useful and insightful, however for further insights other strategies should be considered, such as open questions and focus groups as well as more participants answering the questionnaires to have a more robust and representative sample.

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Annex

Annex A: Questionnaire copy

ECOLOGICAL AND SOCIO-(ECONOMIC) ASSESSMENT OF THE PROPOSED NEW ANCHORAGE AREA OF CULATRA ISLAND

QUESTIONNAIRE - ENGLISH VERSION

Thank you for taking part in this questionnaire related to the new anchorage area for Culatra Island. The questionnaires' answers will be used to complete a master thesis at the University of Algarve. There are 4 sections, there is no right or wrong answer, what we are interested in is your opinions. The questionnaire is anonymous.
The questionnaire will take *10 minutes maximum*.

Thank you very much for your collaboration!

For any inquiry please email: Azzurra Tommasi – azzurratommasi@outlook.com

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Before starting, please indicate

Age:
Gender: M F other
Educational level:
Occupation:

1: ENVIRONMENT SENSITIVITY

The protection and responsible usage of Ria Formosa is paramount seen the growing urban pressure, touristic pressure, and the usage of the land around the lagoon for socioeconomic activities (e.g., oyster and clam farming, salt farming etc.).

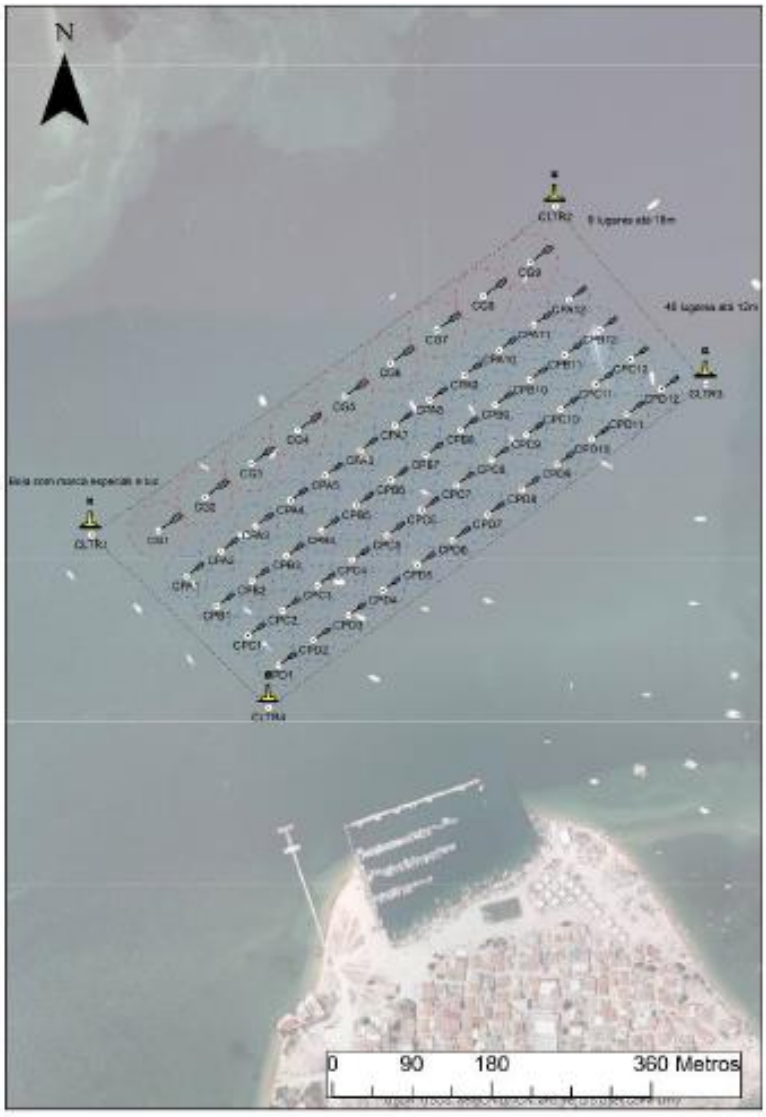
ENVIRONMENT SENSITIVITY			
Do you know that the Ria Formosa is a protected natural area?	yes	no	I am not sure
Do you know that Ria Formosa is under high pressures of natural and anthropogenic nature?	yes	no	I am not sure
Do you know how wetlands are important for the system balance and functioning?	yes	no	I am not sure
Do you know the importance of seagrasses beds?	yes	no	I am not sure
Do you know the importance of nursery grounds?	yes	no	I am not sure
Are you aware that there are many meadows and nursery grounds in the channels?	yes	no	I am not sure
Do you know that anchoring outside designated areas can have detrimental impacts on these sensitive habitats?	yes	no	I am not sure
Do you know if you ever have anchored on a seagrass bed?	yes	no	I am not sure
If you knew about the presence of a seagrass bed, would you anchor anyway?	yes	no	I am not sure
Do you think Ria Formosa is well managed? (e.g., information about species present, habitat sensitivity, activities that can be done)	yes	no	I am not sure

2: CARRYING CAPACITY/CHARGE CAPACITY

Carrying capacity refers to the amount of socioeconomic activities Ria Formosa can sustain and that will not negatively affect the ecosystem as whole permanently. When managing Ria Formosa is very important to consider this parameter as it will affect the actions that need to be implemented to protect the area. E.g., how many nautical activities can be carried out without increasing pollution or disturbing the ecosystem?

CARRYING CAPACITY OF RIA FORMOSA		
Do you know what habitat pressure means?	yes	no
Do you think that the natural park should have rules regarding the nautical activities in the lagoon?	yes	no
Do you think a mooring system can help with the control of boating traffic in the channels?	yes	no
Would you use the designated anchoring site?	yes	no
Would you feel more comfortable using your own anchor in a designated site, rather than a provided one?	yes	no

3: TECHNICAL SPECIFICITIES OF THE ANCHORAGE SITE (CTRL1)



57 eco-moorings (48 for boats up to 12 m and 9 for boats up to 18 m).

- Gravity weights determined considering vessel weights and safety factors in extreme weather conditions
- Regular maintenance plans to ensure proper working and reparation works when necessary

Figure 1. Location of anchorage area

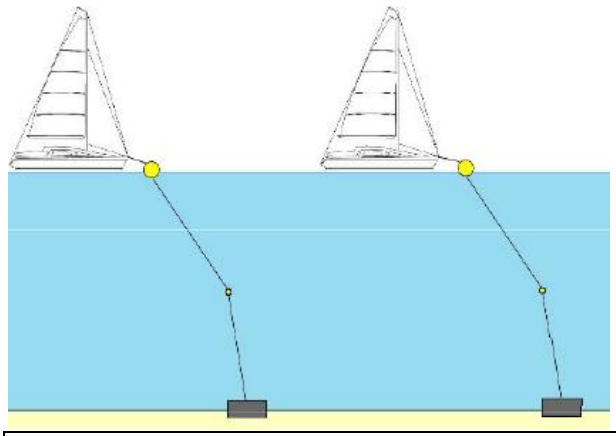


Figure 2. Example of eco-mooring with boats. Mid water buoy to avoid chain drag

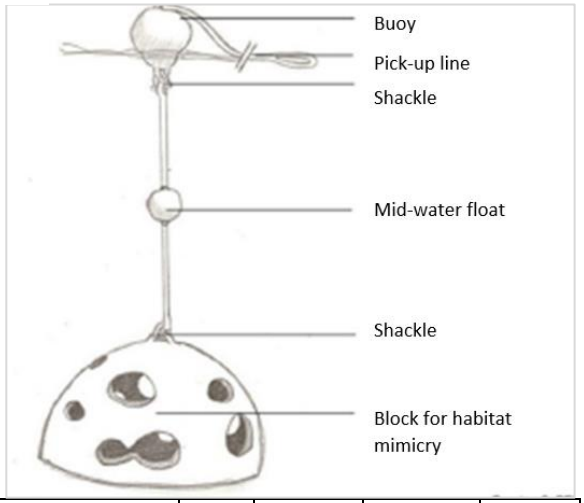


Figure 3. Eco-mooring example with an artificial reef to enhance habitat colonization

CTRL1				

Did you know what an eco-mooring is before seeing the images above?	yes	no	maybe	don't know
Do you know an eco-mooring can be used as a habitat for marine species?	yes	no	maybe	don't know
Would you use a provided eco-mooring knowing it will benefit the environment?	yes	no	maybe	don't know
Would you moore at an eco-mooring, knowing that it has been designed to resist extreme weather conditions?	yes	no	maybe	don't know

Answer the next parts only if you own/use a boat:

CTRL1	**Not confident**	**Neutral**	**Confident**
How confident would you feel in mooring your boat with an eco-mooring?	1	2	3
How confident are you about the security of the eco-mooring?	1	2	3
Considering the dimensions and number of boats that moore there, do you think that 57 moorings will be enough for the area?	1	2	3

The anchorage area is limited (16.8 ha). Would you prefer to use the moorings created by experts for the space or would you rather moore freely in the same space?	fixed mooring	free mooring	do not moore there

4: SOCIAL ASPECTS OF THE USERS TO CONTRIBUTE TO THE ISLAND'S SUSTAINABILITY

The anchorage area is a pilot project of the initiative Culatra2030, Sustainable Energy Community, an energy transition and sustainable agenda managed by the Culatra Island Resident Association (AMIC).

The anchorage area will sustainably use the space in front of the island. The project has no commercial interest. There will be several services associated with the anchorage area e.g. laundry, transfer to shore, waste collection, etc. All the money made from the mooring fees will be direct to the Culatra Sustainable and Environmental Fund, a financial tool to support the community on fighting energy poverty, promote social cohesion and preserve the island identity, safeguarding the environment.

SOCIAL ASPECTS				
Do you think the anchorage system is a useful sustainability tool to have in the area?	yes	no	maybe	Don't know
Would you pay for a must use eco-mooring?	yes	no	maybe	Don't know
Would you use the mooring site knowing its profit will be used for the island's energy transition and for the conservation of Ria Formosa?	yes	no	maybe	Don't know

Do you think Culatra and the community would benefit from the construction of the mooring site?	yes	no	maybe	Don't know
Do you think the anchoring will help controlling the number of boats and tourists coming during summer?	yes	no	maybe	Don't know
Do you think the anchorage system will be able to provide more employment and benefits for Culatra and for it visitors?	yes	no	maybe	Don't know