Conservation of *Posidonia oceanica* in the Mediterranean Sea

A case study analysis of barriers to the conservation of Posidonia and the role of contextual factors from a social-ecological perspective

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Abstract

Because of the valuable ecological functions and ecosystem services *Posidonia oceanica* meadows provide to nature and humans, the critical consequences associated with their deterioration and the irreversibility of losses, it is crucial to protect and conserve the Posidonia meadows that exist today. The continuous regression of Posidonia, despite extensive policies at the EU level, and the disagreement about its conservation indicate context dependency and the presence of barriers situated at the local level. This research therefore aims to get a better understanding of these barriers to the conservation of Posidonia and the role of contextual factors from a social-ecological perspective. Because there are prima facie reasons to suppose that island and mainland sites will present different challenges to Posidonia conservation, the research project explores this hypothesis through a comparative case study approach, while applying the DPSIR framework. The main research questions addressed are: "Do island and mainland coasts face different barriers in the conservation of *Posidonia oceanica* and, if so, what are the contextual factors determining these barriers?" and "What measures can be taken to overcome barriers to the conservation of Posidonia?" The research revealed barriers relating to lack of awareness, policy constraints, and knowledge uncertainty that were not be linked to the specific island or mainland contexts. Recommendations to overcome these barriers involve awareness raising, boundary work, and communication and consensus building.

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List of abbreviations

CEAB	Centre d'Estudis Avançats de Blanes
CFP	Common Fisheries Policy
CICES	Common International Classification of Ecosystem Services
CNR	Consiglio Nazionale delle Ricerche (National Research Council)
DPSIR	Driver-Pressure-State-Impact-Response
EEA	European Environment Agency
ES	Ecosystem service(s)
EU	European Union
ICZM	Integrated Coastal Zone Management
InVEST	Integrated Valuation of Ecosystem Services and Trade-offs
IMC	International Marine Centre
IMEDEA	Institut Mediterrani d'Estudis Avançats
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
ISPRA	Istituto Superiore per la Protezione e la Ricerca Ambientale (Italian National Institute for Environmental Protection and Research)
IUCN	International Union for Conservation of Nature and Natural Resources
MAP	Mediterranean Action Plan
MLG	Multilevel governance
MPA	Marine Protected Area
MSP	Marine Spatial Planning
PES	Payment for Ecosystem Services
SES	Social-ecological system(s)
UNEP	United Nations Environment Programme
UoB	University of Barcelona

1. Introduction

Seagrass meadows are among the most important and valuable ecosystems globally, because of the core ecological functions they fulfil and because of the essential contributions they provide to human society (Boudouresque, Bernard, Pergent, Shili, & Verlaque, 2009; Cullen-Unsworth et al., 2014; Telesca et al., 2015). Nevertheless, they are threatened by anthropogenic pressures globally, causing a worldwide decline and degradation of seagrass ecosystems. Estimates of the loss of seagrass meadows vary between 7 and 19% during the past two decades, meaning they are not only among the most valuable ecosystems, but also among the most threatened and vulnerable ecosystems on earth (Boudouresque et al., 2009; Griffiths, Connolly, & Brown, 2020; Unsworth et al., 2018). Changes in seagrass distribution or widespread losses inevitably lead to changes in the environment and the loss of the vital ecosystem services (ES) they provide (Orth et al., 2006). Seagrass ecosystems are part of what are called coupled social-ecological systems in which nature and society are strongly interconnected. Seagrass meadows support (local) societies in both direct and indirect ways through their ES. This close connection between seagrass ecosystems and society will likely affect their respective resilience (Cullen-Unsworth et al., 2014).

This study concerns the conservation of *Posidonia oceanica*, a seagrass species endemic to the Mediterranean Sea. From a European perspective Posidonia is of particular importance as the main seagrass species in the Mediterranean, constituting a key component in Mediterranean coastal ecosystems and because of its particular capacity to sequester carbon (Marbà, Díaz-Almela, & Duarte, 2014; Telesca et al., 2015). Observations of the general trend of regression of Posidonia have increased awareness of the vulnerability of this key ecosystem, which has led to efforts to monitor and assess its conservation status. The international and particularly the European level have contributed substantially to the protection of *Posidonia oceanica* so far by adopting policies and stimulating conservation actions. However, while the overall regression of Posidonia is quite well established, the origin and scope of threats, their contribution to this regression and the scale at which management actions should be taken are more uncertain and disputed (J. M. González-Correa, Sempéré, Sánchez-Jérez, & Valle, 2007; Guillén et al., 2013; Telesca et al., 2015). Despite comprehensive policies at the international and European level, conservation efforts have shown mixed successes. This suggests that spatial variability exists in the nature and impact of stressors, the vulnerability of meadows, the effectiveness of conservation measures or barriers to conservation. In this case, it is essential to understand what broader contextual factors play a role in seagrass conservation.

This study examines barriers to Posidonia conservation from a social-ecological perspective through a comparative case study analysis to gain understanding of the influence of contextual factors on *Posidonia oceanica* conservation. It applies the Driver-Pressure-State-Impact-Response (DPSIR) framework to evaluate and compare Posidonia conservation efforts at different sites. The DPSIR framework contributes to understanding complex environmental matters/social-ecological systems by breaking down the different components from human and natural systems and setting out the way these components are connected. It, therefore, contributes to understanding the relations between the different cross-sectoral pressures, their drivers and their cumulative impact in order to take more efficient conservation measures. There are prima facie reasons to suppose that island and mainland sites will present different challenges to Posidonia conservation. The research project therefore makes a comparison of island and mainland case studies. The main research questions addressed are: "Do island and mainland coasts face different barriers in the conservation of *Posidonia oceanica* and, if so, what are the contextual factors determining these barriers?" and "What measures can be taken to overcome barriers to the conservation of Posidonia?"

2. Background: seagrass conservation

2.1. Ecosystem services and other concepts

Seagrass meadows are among the most important and valuable ecosystems globally and they are key components within coastal systems. They constitute crucial natural capital because of the core ecological functions they fulfil and because of the wide range of ES they provide (Boudouresque et al., 2009; Costanza et al., 1997; Cullen-Unsworth et al., 2014; Ruiz-Frau, Gelcich, Hendriks, Duarte, & Marbà, 2017).

2.1.1. Natural capital, ecosystem functions and ecosystem services

Ecological or ecosystem functions are the habitat, biological or system properties or processes that shape the structure and function of an ecosystem. ES are the benefits people derive, directly or indirectly, from ecosystem functions (Costanza et al., 1997; Henderson et al., 2019). However, because the ecosystem functions and services concepts are so strongly interwoven the distinction between them is not always clear. Additionally, natural capital is a term used to describe the 'stock of materials or information' comprised in ecosystems that generates flows of materials, energy, and information, autonomously or in conjunction with services from other capital stocks, that compose these ES (Costanza et al., 1997).

Changes to the natural capital and its ecosystem functions affect the ecosystem productivity and resilience and can disturb the provision of ES ("What is natural capital?," n.d.). The ES concept allows to connect natural systems to society and has emerged over the past two decades as a major framework for discussing social-economic-ecological interactions used in both research and policy (Cullen-Unsworth et al., 2014; Ruiz-Frau et al., 2017). It provides a way of looking at the relationship between natural and social systems in economic terms by valuing these ES and accounting the effects of their disturbance on human well-being (Costanza et al., 1997; Cullen-Unsworth et al., 2014; Ruiz-Frau et al., 2017). From this perspective, environmental policy decisions and nature conservation actions pursue the preservation of natural capital to sustain ES based on their instrumental value.

2.1.2. Seagrass ecological functions and ecosystem services

Seagrasses are considered important biological indicators of marine water quality and coastal system health, because of their ecological functions and their sensitivity to environmental alterations. Changes in seagrass distribution or widespread seagrass losses entail the loss of these crucial ecosystem functions and inevitably leads to changes in the environment and in the provision of ES (Campagne,

Salles, Boissery, & Deter, 2015; Orth et al., 2006). The Common International Classification of Ecosystem Services (CICES) specifies three categories of ES: provisioning, regulation and maintenance, and cultural ES. The mapping, modelling and valuation of coastal ES is still lagging behind that of terrestrial ecosystems due to the absence of detailed spatial information on habitat distribution and the difficulty of quantifying functions and processes in the strongly interconnected marine environment (Ruiz-Frau et al., 2017).

First and foremost, seagrass meadows supply important regulation and maintenance ES. They form nursery, habitat and feeding grounds for many marine organisms, among which are several commercially important fish species, contributing to maintaining fisheries as well as to biodiversity in general. Furthermore, by reducing wave energy seagrasses contribute to coastal protection and the prevention of coastal erosion. Protection against coastal erosion is additionally provided by the accumulation of seagrass residues on the beaches. Reducing wave energy and slowing down the water, in addition, allows sediment stabilisation within the seagrass root systems, which increases water clarity. As seagrasses filter the water, they further increase water clarity and quality by removing harmful nutrients (Campagne et al., 2015; McKenzie, 2008; Pergent et al., 2018). Finally, seagrass meadows are an important store of ocean carbon. Despite occupying only 0.2% of the seafloor, seagrass meadows account for 10% of the annual ocean carbon storage and, as a result of the millennia over which seagrass meadows have sequestered and stored carbon within their sediments, they constitute a vast long-term carbon stock (Pergent et al., 2014; Unsworth et al., 2018; Zimmatore, 2019).

In addition to regulation and maintenance services, seagrasses also derive numerous cultural ES from these regulating and maintenance services. Because of their contribution to water clarity and quality seagrasses create a beautiful environment for recreational activities that support tourism. Furthermore seagrasses are the subject of different research and education activities and they can constitute part of people's cultural heritage and identity (Campagne et al., 2015; Cullen-Unsworth et al., 2014). Despite their many recreational, research and educational opportunities, cultural services of seagrasses have been studied less than other seagrass ES (Ruiz-Frau et al., 2017). Finally, in a number of cases, seagrasses also offer certain provisioning services as material or for medicinal purposes (Campagne et al., 2015; Cullen-Unsworth et al., 2014).

2.1.3. Valuation of natural capital and ecosystem services

The valuation of ES provides a way of integrating nature conservation into decision-making. Economic valuation through monetary approaches is most commonly used in policy, as it allows monetary estimates to be made of the benefits provided by ecosystems and the impact of changes to these benefits and to analyse trade-offs between policy alternatives (Bourguignon, 2015; Lau, 2013; Robertson, 2011). Different valuation methods exist for attributing economic value to ES. One resource management tool that has emerged integrating valuation of ES is the Payment for Ecosystem Services (PES) scheme. PES constitutes a market-based tool that uses the valuation of ES to provide an economic incentive to restore or conserve ecosystems and their services. It is entails transactions – often on voluntary basis – for additional provision of ES that would not have been produced without the arrangement. PES encompasses different tools, such as direct public or private payments, tax incentives, cap-and-trade markets, certification programmes and voluntary markets (Kuhfuss, Rivington, & Roberts, 2018; "Payments for Ecosystem Services," n.d.).

Carbon credit markets are a type of PES scheme linked to offsetting. Carbon credits are tradable permits or certificates that allow the holder to emit one ton of carbon dioxide or an equivalent of another greenhouse gas. They were created to reduce the effects of global warming by compensating for the emission of carbon dioxide and other greenhouse gasses from industrial activities ("What is a Carbon Credit?," n.d.). Most carbon credits come from offsetting schemes involving conservation and restoration projects that sequester and store carbon ("Carbon Offsets Explained," n.d.; Kuhfuss et al., 2018). Coastal ecosystems and oceans play an important role in storing and redistributing carbon dioxide. Mangroves, salt marshes and sea grasses, for example, can all capture and store carbon. These ecosystems can play an important role in climate change mitigation and thus blue carbon credit systems are being established as part of management strategies for their conservation (Lau, 2013; Xie He, 2016).

2.1.4. Nature's Contribution to People and relational value

While the ES concept is able to connect natural and social systems while referring to a broad range of sociocultural, ecological and economic dimensions and in relation to different units, monetary approaches have been predominant and the concept of ES and their instrumental valuation have been criticised for commodifying nature and capturing the broad range of worldviews, knowledge systems, and stakeholders too narrowly (Chan et al., 2016; Kadykalo et al., 2019; Ruiz-Frau et al., 2017). As a consequence, a number of new concepts have emerged in the debate about motivation to protect

nature, such as Nature's Contribution to People and the relational value. However, both concepts have not yet appeared in seagrass research and literature.

2.2. Systems analysis

2.2.1. Social-ecological systems

Systems are sets of things that are interconnected in such a way that they display their own behavioural pattern over time. Systems thinking is a way of understanding such systems by looking at the relations and interactions of the constituent elements. It is based on the belief that a system is more than the sum of its parts and that its components will act differently when isolated from the rest of the system. By getting an understanding of how the system works, one can learn where to intervene in a system to support constructive change (Learning for Sustainability, n.d.; Meadows, 2008).

Seagrass meadows and the coastal ecosystems they are part of form wider social-ecological systems (SES), in which nature and society are strongly interconnected. In these SES, ecological and social processes are interdependent and reciprocal feedback loops exist between them (Heslinga, Groote, & Vanclay, 2017; Unsworth et al., 2018). Different pressures across sectoral, institutional and jurisdictional boundaries and the combined effect of pressures through complex relations and feedback loops can create cumulative impacts (Griffiths et al., 2020). In order to understand the evolutions seagrass meadows undergo and balance the ecological and human aspects of the system, it is necessary to look at the multitude and complexity of pressures faced by seagrass meadows and the relations and interactions of these pressures with other elements across multiple sectors within the larger SES. Hence, it is crucial to gain an understanding of seagrass systems as SES and to find frameworks that can help in exploring the relationships between the natural and human elements of these systems. The ecological dimensions of seagrass system have been relatively well studied. Its social aspects and the interaction between society and nature remain underexplored. (Campagne et al., 2015; Ruiz-Frau, Krause, & Marbà, 2019).

2.2.2. The DPSIR framework

The Driver-Pressure-State-Impact-Response (DPSIR) framework provides a recognised and well-established conceptual framework for studying complex SES. It was developed by the EEA. It helps describe and structure complex environmental matters in an integrated way through a system-based approach by identifying cause–effect relationships between human and natural systems and across spatial and temporal scales. Connections between environmental, social and economic domains can therefore be described in a meaningful way for policy by breaking down the different components of

environmental problems and setting out the way these components are connected. Simultaneously, it allows the effectiveness of possible responses to be estimated based on the described cause-effect relations (Atkins, Burdon, Elliott, & Gregory, 2011; Balzan et al., 2019; Lewison et al., 2016; Mateus & Campuzano, 2008; Maxim, Spangenberg, & O'Connor, 2009).

The DPSIR framework has been used in the context of coastal issues to understand how an integrated upland-coastal management can address stressors from both upland and marine origins and to understand how humans both benefit from and impact coastal environments, how the challenges are perceived by decision-makers and how they design communication and integrated management strategies (Lewison et al., 2016). This also goes for the contemporary issue of the regression of seagrass, more specifically *Posidonia oceanica*. This regression cannot be ascribed to a single cause, but is caused by a complex set of direct and indirect pressures (Boudouresque et al., 2016). Therefore, the DPSIR framework could contribute to understanding the relations between the different cross-sectoral pressures, their drivers and their (cumulative) impact in order to take more efficient conservation measures.

The DPSIR framework presents environmental matters as a repeating (iterative) chain of causal links starting with drivers, which exert pressure on the natural environment. This causes the physical, chemical and biological conditions – the overall state of the environment – to change. The impact of these changes on society may bring about responses by society or policy-makers (Kristensen, 2004; Mateus & Campuzano, 2008; Oesterwind, Rau, & Zaiko, 2016).

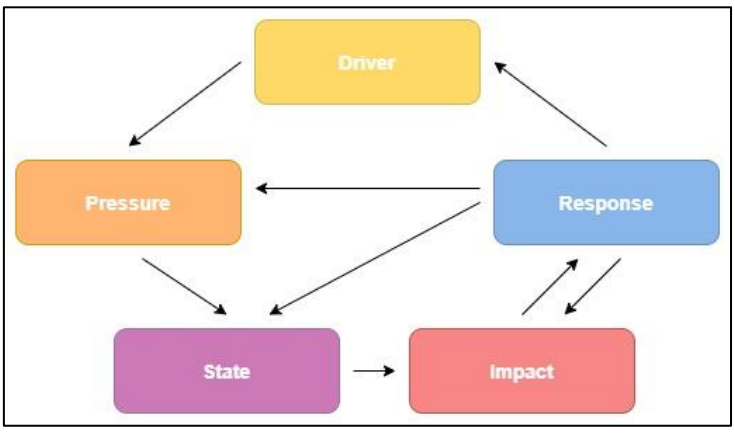

Figure 1. DPSIR diagram. Adapted from the European Environmental Agency.

Like any methodological framework, the DPSIR framework has both strengths and weaknesses. Its main strength lies in its ability to simplify complex (natural) systems and to capture and clarify relations between elements in society and the environment. However, in this ability to simplify lies an inevitable lack of comprehensiveness and a risk of oversimplifying the issue. Only a sub-set of the complex interrelations between different components can be described. Addressing this is a matter of finding a balance between simplifying and clarifying the issue sufficiently, while still including all fundamental elements of the system. In that case, the DPSIR framework can provide an inclusive tool that allows for effective communication between different stakeholder groups (Mateus & Campuzano, 2008; Patrício, Elliott, Mazik, Papadopoulou, & Smith, 2016).

A shortcoming of the DPSIR framework is that there are no standardised definitions for the different DPSIR concepts (Lewison et al., 2016; Patrício et al., 2016). While this can create confusion and complicate the application of the DPSIR framework, it has the advantage of allowing the applied definitions to be adapted to better fit the specific case at hand. Finally, Lewison et al. (2016) states that responses included in the DPSIR framework are often limited and focused on traditional governance and legislative responses. In addition, a wide range of responses with the potential of nudging behaviour, directing investment or even altering the preferences and values that lie at the basis of decisions underlying drivers and pressures, should be considered.

2.3. Mediterranean case: *Posidonia oceanica*

From a European perspective *Posidonia oceanica* is a seagrass species of particular importance. It is the most widespread seagrass species in the Mediterranean Sea and it constitutes a key component in Mediterranean ecosystems (Marbà et al., 2014). This is also the reason for its relevance from a policy perspective, as it is not only awarded a special protection status, but also serves as an indicator in different environmental policies. This section explains the role of Posidonia in Mediterranean ecosystems, its conservation status, threats and how its conservation is addressed at the international level.

2.3.1. Description and distribution

Posidonia oceanica (Linneaus) Delile is a seagrass species endemic to the Mediterranean Sea. It is the most wide-spread seagrass species in the Mediterranean and has been estimated to cover 25,000 to 50,000 km² along the coastlines of most Mediterranean countries (see Figure 2 and Appendix A), where it grows on both sand and rock substrate up to depths of 40 to 45 meters if the water is sufficiently

transparent. Its occurrence in estuaries is less common due to the high input of fresh water and fine sediments. (Boudouresque et al., 2016; Duarte, 2001; Pergent et al., 2018)

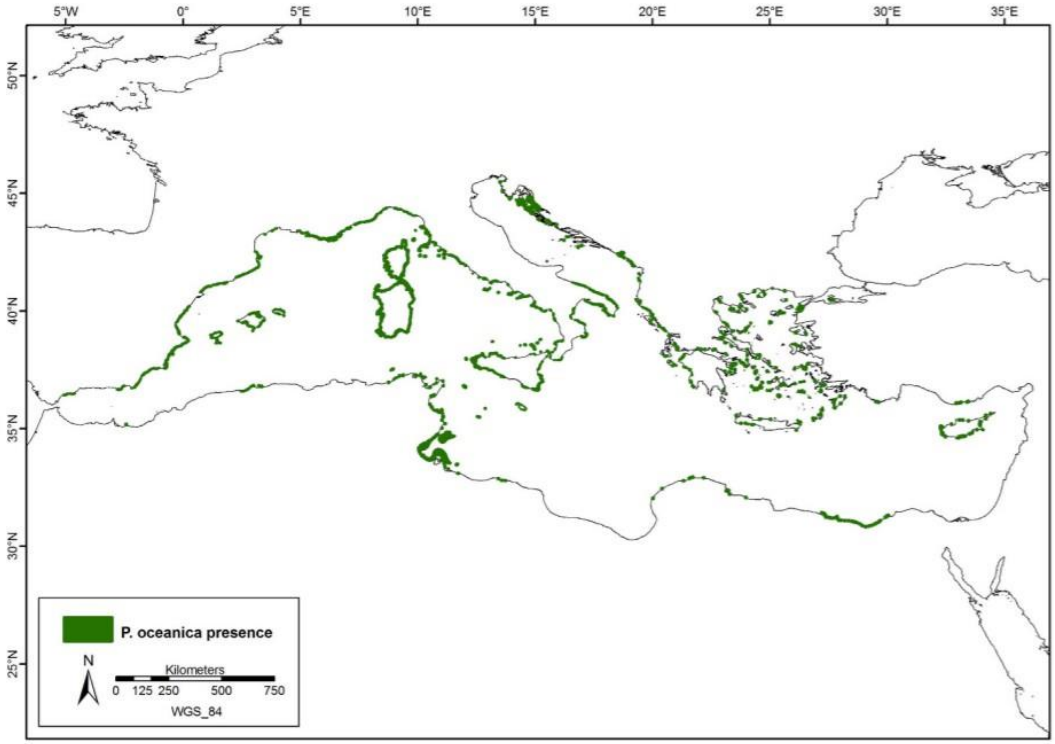

Figure 2. Distribution *Posidonia oceanica* in 2015. Source: Telesca et al., 2015.

Posidonia oceanica is a large, slow-growing seagrass with a long life span, and, like all seagrasses, it is a clonal, rhizomatous plant which undertakes photosynthesis. Posidonia meadows form 'mattes', consisting of interlaced remnants of roots, rhizomes and entangled sediment, that help trap sediment and mediate the motion of waves. Inside these mattes, massive amounts of carbon are stored for thousands of years. Posidonia is considered to be the most effective seagrass species in carbon storage (Monnier et al., 2019). When Posidonia leaves and rhizomes die off and wash up on the beach they accumulate and form 'banquettes', which provide coastal protection (Borum, Duarte, Krause-Jensen, & Greve, 2004; Díaz-Almela & Duarte, 2008; McKenzie, 2008; Vacchi et al., 2017). Posidonia tolerates relatively large water temperature variations, from approximately 10°C to 28°C. It thrives in transparent and oxygenated waters. It is sensitive, therefore, to nutrient pollution and overloading. It is also sensitive to salinity fluctuations, turbidity and the increase of sedimentation rate (Díaz-Almela & Duarte, 2008; Marbà & Duarte, 2010; Pergent et al., 2018; Sureda, Box, & Tejada, 2015).

2.3.2. Threats and overall trends

Posidonia like many other seagrasses, is subject to anthropogenic pressures. Human activities, such as coastal development for residential and commercial purposes, fishing, aquaculture, industry,

agriculture, energy production, transport and recreation as well as climate change and invasive species can put pressure on Posidonia meadows (Borja et al., 2006; Boudouresque et al., 2009; Pergent et al., 2018). This is because they can alter the environmental conditions within the meadow ecosystem, for example by changing sunlight and nutrient levels, sea level, turbidity, salinity, temperature, current and wave action (McKenzie, 2008; G. Pergent et al., 2012). Anthropogenic pressures on the Mediterranean coastal zone have increased rapidly during the second half of 20th century due to population growth and increase in tourism. Furthermore, the ongoing trend is one of continuously increasing human pressure (Boudouresque et al., 2009; Marbà et al., 2014).

Due to the slow growth and low genetic diversity as a clonal organism, Posidonia meadows are fragile and vulnerable ecosystems. As a consequence of their slow growth, losses of Posidonia meadows can be considered virtually irreversible as recovery of meadows exceeds human timescales related to the continuing provision of ecosystem services by Posidonia meadows (Boudouresque et al., 2009; J. M. González-Correa et al., 2007; Guillén et al., 2013; Marbà et al., 2014; Telesca et al., 2015).

The overall trend of Posidonia meadows is one of a general regression – especially during the second half of the 20th century – in accordance with worldwide trends of seagrass decline (Nordlund et al., 2018; Orth et al., 2006; Telesca et al., 2015). While a recent halt and potential reversal of this trend have been reported (De los Santos et al., 2019; Guillén et al., 2013)., declines and degradation of Posidonia meadows are still being recorded (see Figure 3) (Telesca et al., 2015). However, disagreement exists about the origin and scope of threats, their contribution to this decline and the scale at which management actions should be taken. While some state that these declines are to be ascribed to mainly local stressors that can be sufficiently addressed through local management actions (J. M. González-Correa et al., 2007; Guillén et al., 2013), others emphasise the importance of taking into account regional and global elements in conservation actions (Marbà et al., 2014; Mari, Melià, Fraschetti, Gatto, & Casagrandi, 2020). This disagreement suggests that Posidonia conservation faces spatial variability in the nature and impact of stressors, vulnerability of meadows, effectiveness of conservation measures and/or barriers to conservation.

Because of the ecological functions and ES Posidonia meadows provide to nature and humans, the critical ecological and economic consequences associated with their deterioration and the irreversibility of losses (Marbà et al., 2014; Pergent et al., 2014; Telesca et al., 2015) it is crucial to protect and conserve the Posidonia meadows that exist today. Disagreement regarding Posidonia conservation suggests spatial variability in conservation challenges and indicates the importance of

understanding what contextual factors potentially play a role in seagrass conservation and how these interact.

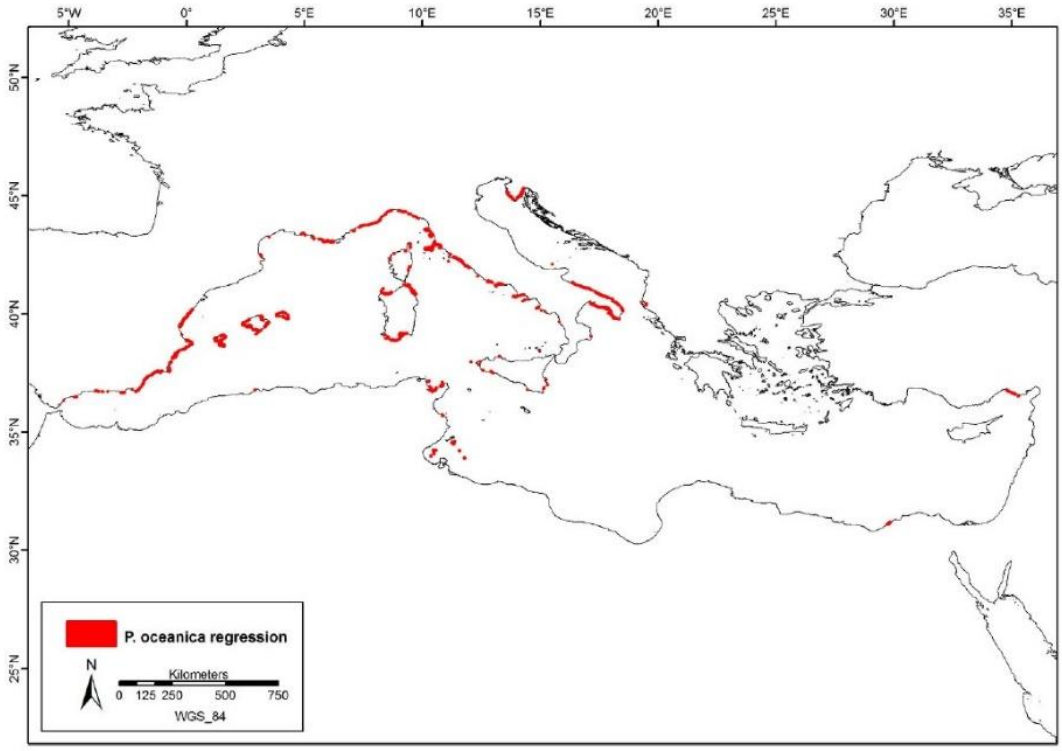

Figure 3. Regression of *Posidonia oceanica*. Source: Telesca et al., 2015.

2.3.3. International and EU regulations

Observations of the general trend of regression of Posidonia have increased awareness of the vulnerability of this key ecosystem and have led to efforts to monitor and assess its conservation status. Furthermore, seagrass has become the subject of several international policies and regulations aimed at improving the marine ecological environment (Marbà et al., 2014; Marbà et al., 2013) as well as of national and local policies (see 4.1.2 and 4.2.2). What follows offers a brief overview of the most important international and EU policies and regulations for the conservation of Posidonia in the Mediterranean Sea. For a more detailed overview of the different policies and regulations, see Appendix B.

In first instance, there are a number of regulations that assign a special conservation status to Posidonia. The Bern Convention, the Barcelona Convention and the Habitats Directive are aimed at nature conservation specifically and each offer special protection to Posidonia as a species or as a habitat. The MAP (including the Barcelona Convention), the EU WFD and the MSFD furthermore support the conservation of Posidonia through environmental protection in a more indirect manner. The enhanced environmental management, the adoption of ICZM, the reduction of pollution levels

and the water quality improvement associated with these regulations all eliminate pressures to Posidonia. The WFD and MSFD, moreover, use Posidonia or seagrasses in general as indicators for environmental status. Finally, the Council regulation concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea that is part of the CFP directly addresses trawling pressures (among others) on Posidonia by prohibiting these activities above 50m – i.e. within the range where Posidonia grows – as well as on seagrass beds specifically.

2.3.4. Multilevel governance in the EU

The different international and EU regulations that improve the marine environment are important to the conservation of Posidonia. However, they still require conversion by national, regional or even local actors through implementation efforts. The EU policy-making and implementation context involves different actors, interests and processes across different levels of government and governance. The complexity and interplay that characterise EU policy-making processes are reflected in the concept of multi-level governance (MLG) (Knill & Duncan, 2007). MLG refers to the constant process of steering in decision-making shaped by various actors from private and public sectors representing supranational, national, regional and local levels (Ganeshalingam, 2011; Suškevičs, 2012). The different tiers that participate in the EU policy-making process are often characterized by overlap and interdependence (Ganeshalingam, 2011). Competencies and responsibilities are shared between multiple levels and different departments of government. EU policy is the result of a complex process of constant coordination across and within these levels and departments. This is also the case for EU environmental policy specifically (Benz & Papadopoulos, 2006; *Charter for Multilevel governance in Europe*, 2014; Ganeshalingam, 2011; Knill & Duncan, 2007).

To understand the issue of the conservation of Posidonia, it is important to be aware of the influences associated with MLG processes. Seagrass meadows and coastal ecosystems compose SES (Heslinga et al., 2017; Unsworth et al., 2018) and their management and conservation involve multiple levels and departments, different stakeholders and diverging interests, affected by formal, informal and unlawful actions and multiple sectors and activities. The development and implementation of policies does not only occur at the international or EU level. Furthermore, the continuous regression of Posidonia, despite extensive policies at the international and EU level, indicates that these barriers likely arise in the transposition of policies from the international to the local level continue to obstruct successful conservation. The aims and effectiveness of international policies are thus affected by their transposition from the international to the local level, which can result in variability between sites.

2.4. Aim, objectives and research questions

This research aims to study the interaction between people, their activities and the conservation status of Posidonia meadows, especially as mediated through conservation efforts. The **overarching aim** of the research is to get a better understanding of barriers to the conservation of *Posidonia oceanica* and the role of contextual factors from a social-ecological perspective. The existing disagreements about the origin and scope of threats, their contribution to the current regression of Posidonia and the scale at which management actions should be taken suggests that Posidonia conservation faces spatial variability and is context dependent. The continuous regression of Posidonia, despite extensive policies at the EU level, furthermore indicates that there are still barriers obstructing successful conservation and that these are likely to be situated at the transposition of policies from the international to the local level.

A screening study of cases allowed to identify different research angles that embodied the context dependency hypothesis while representing different contextual factors that might play roles in the effectiveness of Posidonia conservation efforts. A **specific research angle** was eventually selected, based on considerations of feasibility and scientific interest (see 3.1.2.2). A first research angle entailed a comparison of Posidonia conservation in different geopolitical contexts, for example European and African countries or EU and non-EU countries. A second option was to compare the conservation of Posidonia meadows in shared seas (i.e. seas bounded by many countries) with those influenced only by one country; for example the east coast of Italy versus the west coast of Italy. A third research angle considered was to compare the conservation of Posidonia around islands, where the origin of threats is potentially limited to geographically clearly-delineated sites, to conservation of Posidonia off mainland coasts. A variation of this research angle would constitute a comparison of Mediterranean islands among themselves. A fourth and final research angle would entail a comparison of the conservation of Posidonia meadows along the coast to that of *Posidonia* meadows located near estuaries, hence having a strong inland connection.

Eventually, the specific angle chosen to test the hypothesis of context dependency is the comparison of island and mainland coasts, which differ in contextual factors, such as geophysical and potentially policy characteristics. The geographically clearly-delineated space of island sites could facilitate the implementation of more local measures that would benefit the conservation of Posidonia. The boundaries of the SES are more clearly defined and the origin of elements influencing the system is equally limited to this delineated space. Furthermore, a degree of political independence from the

mainland could influence the conservation of Posidonia. All of these are factors that could affect conservation effectiveness of off-island and off-mainland Posidonia meadows.

An analysis of the SES in different case studies will therefore aim at investigating whether there are differences between island and mainland sites in the challenges and barriers facing conservation efforts as well as what contextual factors these differences depend on. This is done with the intention of formulating recommendations for policy, practice and research on how conservation efforts can be improved in the respective island and mainland contexts. If no considerable differences can be found, the aim is to identify common challenges and recommendations.

To achieve its aim, this research has the following **objectives**:

(1) to identify the main pressures affecting *Posidonia* meadows and the drivers and impacts of these different pressures and their interactions;
(2) to analyse whether there are any differences between the drivers, pressures and impacts faced by islands and those faced by the mainland;
(3) to analyse how these different pressures and their drivers and/or impacts are addressed in conservation projects;
(4) to identify barriers to the conservation of *Posidonia* and explore whether there are any differences between the barriers that occur at island sites and those occurring at mainland sites and what factors determine or influence these;
(5) to formulate recommendations for policy, practice and/or on how the barriers faced by island and mainland sites might be overcome.

The **research questions** formulated to guide the research, therefore, are as follows: “Do island and mainland coasts face different barriers in the conservation of *Posidonia oceanica* and, if so, what are the contextual factors determining these barriers?” and “What measures can be taken to overcome barriers to the conservation of Posidonia?”
In respect to each of the selected case studies, the research will ask:

1. What pressures affect Posidonia meadows? What are the drivers of these pressures? What are the impacts of these pressures?
2. Are there differences between the drivers, pressures, and/or impacts at the different sites?
3. What drivers or pressures are addressed by the conservation project and how are they addressed? What measures are taken by the conservation project? What stakeholders are involved? Are all pressures addressed?

4. What barriers do conservation projects face? Are there differences between barriers to conservation at island sites and barriers to conservation at mainland sites? What factors influence or determine these? What contextual factors play a role in the conservation of *Posidonia oceanica*?
5. How can the barriers to Posidonia conservation be overcome? Can currently implemented or proposed responses help in overcoming the barriers? What additional measures should be taken by policy, practice and/or research?

3. Methods

3.1. Research design

The research applies the DPSIR framework and determinant analysis to explore the design and effectiveness of Posidonia conservation efforts at different case study sites. It compares findings from contrasting (off-island and off-mainland) sites to explore the role of contextual factors.

3.1.1. The DPSIR framework

The DPSIR framework provides the main structure for this research. The definitions of the elements used in the research were based on the key literature about the DPSIR framework and its applications: Atkins et al. (2011); Elliott et al. (2017); Gabrielsen and Bosch (2003); Gregory, Atkins, Burdon, and Elliott (2013); Kristensen (2004); Lewison et al. (2016); Mateus and Campuzano (2008); Newton and Weichselgartner (2014); Petrosillo, Aretano, and Zurlini (2015). Common elements of different definitions were identified while taking into account the specific context of this research (see Appendix B).

In this process, a decision was made to split the driver component into a motivation and an action component, as suggested by Elliott et al. (2017). Drivers are thus composed by both human wants and needs and social and economic developments in society reflecting those wants and needs – the motivation – as well as the human activities that take place as a consequence of those needs, wants and developments – the action. Consequent changes to the natural system caused by the human activities are referred to as pressures. Based on Borja et al. (2006) four categories of pressures were distinguished: (1) pollution; (2) alteration of the hydrological regime; (3) changes in the morphology and physical disturbances; and (4) pressures on biology and its uses. These pressures cause changes to the physical, chemical and biological conditions that define the state of the environment at a specific moment in time. Impacts are the direct and indirect positive and negative consequences for society as a result of changes in the natural system. Because of the similarity of this impact definition and the ES, impacts can be considered changes in ES. Even though some debate exists about inserting the ES concept in the DPSIR framework (Lewison et al., 2016), it provides a widely recognised way of connecting natural systems to society. Finally, the societal and policy reactions to impacts in order to reduce, mitigate, compensate or reinforce them, are called *responses*. These responses can link back to any part of the chain from driving forces to impacts.

By applying a wide definition that refers to both societal and policy responses a wide range of responses is expected to be identified, rather than only traditional governance and legislative

responses, hence addressing another shortcoming of the DPSIR approach. Oversimplification of the issue was mitigated by both applying qualitative research methods and drafting a DPSIR diagram for each of the case studies. Visualising the issue in a DPSIR diagram can reveal possible gaps making it possible to highlight and address these. In addition, because qualitative research methods offer insights on interpretation, context, and meaning of events (Patten & Newhart, 2018) they better support judgement of what constitutes a good balance between simplifying and clarifying the system, while still including all relevant elements.

In addition to the DPSIR components, stakeholders and barriers relevant to the conservation issue were identified and examined for each of the case studies. While these elements are not strictly part of the DPSIR approach, they contributed relevant information that was necessary to answer research questions adequately. Stakeholders were defined as persons, social entities or organizations that have an interest or stake in the conservation of Posidonia and related conservation efforts and/or that are able to act or exert influence on Posidonia conservation policies and measures or on the project itself, meaning those actors who are affected by or can affect relevant decisions (Enserink et al., 2010; Reed, 2008). This definition is broader that simply actors that are involved in the project, in order to allow identifying all actors that are potentially relevant to the case. Any actions, events, circumstances or elements that complicate the conservation of Posidonia were considered barriers relevant for the purpose of this research.

3.1.2. Case study analysis

3.1.2.1. Comparative exploratory case study approach

To analyse barriers to the conservation of Posidonia and the role of contextual factors this study used a comparative exploratory case study approach. The study presents and compares three cases of Posidonia conservation. One of the case studies is situated in Catalonia on the Spanish mainland, one on the Balearic Islands and one is located in Italy both on the mainland in Campania and on Sardinia (see Figure 4). An online research and subsequent structuring and linking of alternatives as well as exploratory first contacts with conservation projects and researchers provided the foundation for the selection of case studies (see 3.1.2.2). The chosen case studies do not constitute a representative sample for the whole of the Mediterranean Sea. Instead, purposive sampling was used with the aim of identifying case studies offering scope to test the hypothesis that seagrass conservation efforts and/or related barriers are context dependent.

Figure 4. Map case studies.

This study performed case studies with the aim of both theory development and theory testing. The theory to be tested concerned the context dependency of Posidonia conservation. Further theory development based on a pre-screening of potential case studies, data collection and interpretation would include what factors play a role in the conservation of Posidonia.

3.1.2.2. Case study selection

In a first instance an overview was made of projects and efforts active in the conservation of Posidonia, as well as researchers and institutes active in the field. This was based on an **online search**. Conservation projects were identified through a google search of different combinations of search terms including '*Posidonia oceanica*', 'seagrass', 'conservation', 'Mediterranean Sea' and variations of these terms. The webpages of renowned international organisations, such as the EU, UNEP and the IUCN were reviewed. Projects located in the Northern, Southern, Eastern and Western Mediterranean were found. However, a larger proportion of the projects were located in the North and the West as opposed to the South and the East. All projects were taken into consideration equally, regardless of their location. The overview of conservation projects resulting from this search was organised according to country and continent, type of geographical location (mainland or island) and timeframe of the project. In order to reflect the current situation as much as possible projects were deemed relevant if they were ongoing or had ended no longer than 5 years ago. The search for conservation projects and efforts was ended when no additional projects could be found based on the above criteria. Researchers and research institutes were identified based on a list of recent papers covering Posidonia

and its conservation. The researchers and institutes found were structured on a country basis. Additional structuring was done by country region where the researchers and institutes were located. Researchers and institutes from countries all over the Mediterranean were represented in this selection.

Based on the online search, a number of **characteristics** that were thought could influence Posidonia conservation were used to characterise each project: continent, country, EU membership, type of geographical location (off-mainland or off-island) and location near a significant estuary, i.e. near the mouth or delta of an international river system. The different projects were also checked against the four research angles to identify which hypotheses and angles they could be used to address (see 2.4).

With these potential research angles in mind, a selection of projects and researchers all over the Mediterranean were **contacted to explore** their willingness and availability to participate in this research. This was to enable practical aspects, such as the possibility of securing interviews from supportive and knowledgeable parties, to be factored into the case study selection process. Most positive responses came from projects situated in Spain and Italy and from researchers and institutes located in Spain, France and Greece. Based on the positive responses of projects and researchers, the **possible research angles were re-evaluated**.

This resulted in four re-evaluated options. A first option would be to compare the conservation of Posidonia on different Mediterranean islands (the Balearic Islands, Corsica, Sardinia and the Greek islands) in order to identify common, potentially island-specific aspects. Another possibility was comparing the conservation issues of Posidonia meadows subject to the influences of rivers crossing multiple countries. For this, French and Greek projects could provide eligible case studies. Furthermore, a comparison of barriers to the conservation of Posidonia located near estuaries to those away from estuaries was still deemed a workable research angle. A last potential research angle consisted of comparing conservation off-island with off-mainland sites. For this research angle case studies in Spain and Italy were available.

The strongest cases, with both confirmed projects and researchers, appeared to be the comparison of Mediterranean islands or the comparison of island to the mainland coast. Both cases had a number of considerations for and against their selection. Based on an exchange of ideas with researchers, after looking into willing projects more extensively and after making the necessary additional contacts a **final decision** was made for the island versus mainland case because this encompassed a balanced trade-off between what was scientifically interesting and what was practically feasible.

For this research angle five conservation projects and organisations were eligible and willing to provide information supporting the case studies. Due to unresponsiveness at later stages, this resulted in three case studies. In these three case studies the different contexts of both mainland and island are represented for both Spain and Italy. An overview of the different case studies is given in chapter 4.

3.2. Research methods

3.2.1. Data collection

Qualitative research methods were used for the collection of data. These methods constituted a literature review, document analysis and semi-structured interviews. The aim was to obtain a data set representing a number of diverse cases to explore variation of contextual factors in Posidonia conservation; i.e. the ambition was to carry out an exploratory study that might pave the way for more detailed future research. There was no requirement for the cases to be representative or for data collection to be exhaustive. The main concern is to explore whether the research hypotheses from a reasonable basis for further research.

At a first stage of the research, a literature study of peer-reviewed articles provided background and contextualising information for this research and its conceptual, theoretical and methodological framework. Literature was retrieved from scientific databases ScienceDirect, JSTOR and Google Scholar through an online search as well as the bibliography from relevant literature. In addition, documents from international organisations complemented the information acquired through the literature study. The documents that were analysed contained information regarding the CICES as well as policies and regulations.

At a second stage semi-structured interviews were conducted with the conservation projects and organisations and researchers. An overview of the interviews that were conducted can be found in Appendix D. The interviews were conducted via Skype. Interviews were preferred as this would allow clarifying questions to be asked instantly. With the permission of respondents, interviews were recorded. They were subsequently transcribed for analysis using Otter.ia. All interviews were conducted in English. In one case, the informant preferred to correspond through written answers to questions. While this was not the preferred way to collect data, this was more comfortable for the informant and it did deliver rich information.

The interviews with the conservation projects and organisations were organised in two rounds. The first set of interviews focussed on getting an overall image of the drivers, pressures, state and impacts

experienced by the projects or conservation efforts. For these interviews, a common outline of questions was created (see Appendix E). The outline was aligned with the DPSIR framework. Initial questions asked about the past and current state of the Posidonia meadows at the project site. Subsequently drivers and pressures and how they altered the state were discussed as well as what impact this had. Finally, some preliminary questions were asked about past responses adopted at the project sites as well as particular barriers to the conservation of Posidonia faced by the project.

For the second round of interviews individual lists of questions were drafted for the different projects to build on and deepen the data collected at the first interview (see Appendix F). This included clarifications about the state, pressures, impacts and past responses. In addition, the second interview covered previously-implemented responses at the project sites as well as planned or desired responses. Attention was paid to the motivation behind and logic of responses and to the roles of policy-makers, society, and economic actors in their implementation.

The following informants, put forward by the conservation project or efforts, have been interviewed:

- Seaforest LIFE: Matteo Ruocco, a scientist in charge of technical support and coordination of LIFE projects at D.R.E.Am. Italia;
- Projecte Alguer de Mataró: Xavier Seglar, a scientist affiliated with the Escola del Mar de Badalona, who helps in the coordination of the project operation and protocols as well as communication about the project.

In addition to the interviews with conservation projects and organisations, interviews with researchers with expertise in the field of Posidonia were conducted. The purpose of these was to get a more general overview of the situation in the project region and to place the information from the projects in a broader context. The interviews followed the same general outline as the first interviews with the conservation projects. Some (sub)questions that were site specific were left out. Additional questions about what responses or measures should be taken according to them were added. For Spain, Teresa Alcoverro of the Centre d'Estudis Avançats de Blanes (CEAB) and a researcher of the University of Barcelona (UoB) (hereafter referred to as researcher UoB) provided information about the situation in Catalonia. Núria Marbà and another researcher (hereafter referred to as the IMEDEA researcher), both affiliated to the Institut Mediterrani d'Estudis Avançats (IMEDEA), provided information about the Balearic Islands. Italian researchers that contributed to the research are Ivan Guala from the International Marine Centre (IMC), regarding the circumstances on Sardinia, and Michele Scardi from the University of Rome 'Tor Vergata', who provided information about the Italian mainland situation.

Upon analysing the data from the interviews, a second literature review and document analysis were conducted with the purpose of complementing or further clarifying the information received in the interviews as well as supporting findings and recommendations. For the recommendations, a literature search centred around the key issues of awareness raising, boundary work and uncertainty.

3.2.2. Data analysis

The data collected in the interviews was analysed through an iterative process of coding, inspired by DeCuir-Gunby, Marshall, and McCulloch (2011). The mode of analysis included content analysis, determinant analysis and systems analysis using the DPSIR framework to identify key relationships. A **codebook** was drafted based on a prior literature study. This codebook consisted of eight general categories: Drivers, Pressures, State, Impacts, Stakeholders, Barriers, Responses and Project objectives. Each of these categories was divided into a number of specifying categories that were further specified into a second and even third level where useful. For example, the category Pressures was divided into four specifying categories: Pollution, Hydrology, Morphology and Biology. Pollution in its turn consisted of two sub-categories: Chemicals and nutrients – which in their turn covered further specifying categories, such as Sewage, Nutrient runoff and Other discharges – and Heat. The codebook was reviewed after each of the interviews in the context of the data from the interviews. The general Objectives category was dropped as it did not add value. Revisions of the codebook mainly led to changes in the specifying categories. Sub-categories were added, merged or split up. The result of this process is the final codebook that can be found in Appendix G.

The process of **coding** of the interviews likewise involved multiple stages. In a first round of coding the general categories of Driver, Pressures, State, Impacts, Stakeholders, Barriers and Responses were applied to (parts of) a sentence or multiple sentences describing the same idea or concept. In a second round the applicable specifying categories were allocated. Eventually the specifying categories allocated in round two were updated where necessary after revisions of the codebook. For the first round of coding the programme Atlas.ti was used. Afterwards tables were created to facilitate the application of the specifying coding categories. These tables can be found in Appendix H. Because generally, the 'state' element was not particularly specified by the interviewees, no table for further specification was deemed necessary. The output from coding was entered into **DPSIR diagrams** per case study. These DPSIR diagrams contain the most important drivers and pressures, effects on the state, the most important impacts and responses and the relations between these elements. In terms of responses, both past responses and desired responses or project responses were included. Past responses and implemented project responses are connected to other DPSIR components with solid

lines. Desired or provided responses that have not yet been completed yet are connected with dotted lines, to show on what DPSIR components the potential responses could have an influence. This allowed identification of correlations between codes. Furthermore, frequency of codes was examined to identify trends across case studies.

3.2.3. Role of Covid-19

Because of the presence and impact of Covid-19 a reflection regarding the influences of Covid-19 on the execution of the research is in order. Data collection was relatively unaffected by Covid-19 restrictions. Interviews were conducted via skype and the necessary information from literature and documents could be found on online databases. Due to Covid-19 restrictions travel to the different project sites was not allowed for a large part of the time. It would have been valuable to get a first-hand impression of the local situation and to obtain first-hand information from other stakeholder groups, such as locals or tourists. However, this constitutes a minor limitation and the research as a whole could be carried out relatively undisturbed.

4. Case study overview

Before discussing the results, a brief overview of the conservation projects and policy contexts that compose the case studies, is useful. Three case studies have been selected, of which one on both the Italian mainland and coast of Sardinia and two Spanish case studies on the mainland coast and on the Balearic Islands, respectively.

4.1. Italy

4.1.1. Conservation project: Seaforest LIFE

The Seaforest LIFE project, situated in Italy on both the mainland coast and the coast of Sardinia, provided the information for the Italian case study. The project involves three national parks that comprise multiple MPAs and protected Natura2000 sites: Asinara National Park and the National Park of La Maddalena Archipelago in Sardinia and Cilento and Vallo di Diano National Park in Campania. The project is coordinated by D.R.E.Am. Italia (a research organisation) and involves other research organisations, universities and consulting companies (Seaforest LIFE, n.d.-c, n.d.-d).

The main objective of the project is to restore the habitats of the Posidonia meadows present in these national parks through conservation actions in order to increase the capacity of the carbon reservoirs of the Posidonia oceanica meadows. The project mainly aims to address pressures created by anchoring and Posidonia unfriendly mooring. Actions the project undertakes to achieve this objective relate to a quantification of the carbon deposits in the Posidonia meadows and the setting up of a carbon credit market, the implementation of a mooring management plan, the sustainable management of Posidonia banquettes on the beach and exploring revegetation of stranded Posidonia seeds and sprouts (Seaforest LIFE, n.d.-d). Further information about the Seaforest LIFE project can be found on its website: https://www.seaforestlife.eu/en/

4.1.2. Policy context

The different international regulations mentioned above are implemented into or are applicable at the national level in Italy. There seems to be no further specific protection of Posidonia at the national level nor are there many conservation actions at the local level (M. Ruocco, personal communication, July 31, 2020). However, the establishment of national parks constitute a relevant factor to the conservation of Posidonia meadows in the Seaforest LIFE case. Italy has set out its protected area and national park policy in its framework law on protected areas (no. 394/91), which outlines the fundamental principles for the institution and management of protected areas regarding their mission,

classification and governance ("Frequently Asked Questions about Italian Protected Areas," n.d.). The park authority of the different national parks also adopt park regulations (art. 11), which governs the exercise of the activities permitted within the territory of the park, and a park plan (art. 12), which regulates the general organisation, restrictions and guidelines for nature conservation.

4.2. Spain

4.2.1. Conservation projects

4.2.1.1. Projecte Alguer de Mataró

The Spanish mainland case study was supported by the Project Alguer de Mataró. This project initially started out as part of a broader monitoring programme of the Catalan government called the "Catalan seagrass meadows watching net" that took place along the entire Catalan coast. When a change of protocol and methods occurred, the Escola del Mar de Badalona, which is closely linked to the Badalona town council, decided to continue the local Mataró project on its own, with funding of the Mataró town council, following the former methods, in order to be able to carry on with the data gathered so far.

The main objective of the Mataró project is to monitor the Posidonia meadows of Mataró and their evolution in order to get a better understanding of the effect of both human activities and natural events. Hence, the project is not a conservation project in the strict sense. Furthermore, the Escola del Mar de Badalona does not have any coastal management competencies. However, the project does take some action related to conserving the Posidonia meadows by informing the local authorities of Mataró about the (potential) consequences of their actions and by trying to raise awareness among the public.

More information about the Projecte Alguer de Mataró can be found on its website: http://posidonia.mataro.org/

4.2.1.2. The Balearic Islands

Posidonia ecosystems are of great importance to the Balearic Islands. The meadows cover almost 56,000 hectares and the largest Mediterranean Posidonia meadow can be found in between Ibiza and Formentera ("Balearic Islands: Posidonia," n.d.; "The Posidonia," n.d.). Posidonia is the target of many conservation actions by Balearic authorities and many project have been set up for this purpose, such as for example the Posidonia LIFE project ("Project LIFE Posidonia website," n.d.), the Save Posidonia project founded by the insular council of Formentera ("About the project," n.d.) or the Posidonia protection project of IbizaPreservation ("Posidonia protection," n.d.).

The Balearic Islands case study does not analyse a conservation project. Originally, a marine conservation organisation based on the Balearic Islands was contacted and confirmed its participation for this case study. However, due to unresponsiveness on behalf of the organisation the interviews that were conducted with Núria Marbà and another researcher at the IMEDEA provided the information for this case study instead.

4.2.2. Policy context

Unlike Italy, Spain does have additional protection of Posidonia on top of international regulations. Posidonia meadows are protected at the national level, where it is protected by the Law (42/2007) on Natural Heritage and Biodiversity, and at the regional level. In Catalonia Posidonia has been protected as a species, like all seagrass species are, since 1991. In the Balearic Islands trawling and aquaculture on seagrass meadows have been prohibited since 1993, long before the Common Fisheries Policy was adopted (Díaz-Almela & Duarte, 2008). Furthermore, a 'Posidonia decree' was adopted recently in 2018. This decree endorses the conservation of *Posidonia oceanica* and the biological communities of which it is a part by regulating those uses and activities that may affect the species and its habitat and by promoting actions that contribute to actively to the maintenance and achievement of a favourable conservation status (see 5.3.3.5).

5. Results

5.1. Seaforest LIFE

5.1.1. Stakeholders

The Seaforest LIFE case comprises actors from governmental, scientific, societal and economic sectors that also constitute stakeholders. This diversity is reflected in the project partners and collaborators to the project.

The project is coordinated by the research organisation D.R.E.Am. Italia. It manages the partnership and project planning and is responsible for developing an app connected to the mooring plan (M. Ruocco, personal communication, June 16, 2020). Other research organisations involved in the project are ISPRA, CNR, Water Right Foundation, the Universities of Palermo and Tuscia and the consulting companies Carbonsink and Paragon Europe. These different research organisations provide technical advice in their respective fields of expertise for monitoring activities and for the development and implementation of conservation actions. The list of project partners is completed by three national parks. These national parks have their own managing bodies but fall under the supervision of the national Ministry of the Environment. They contribute knowledge about the local situation relevant to the development and implementation of conservation actions (M. Ruocco, personal communications, June 16, 2020 and July 31, 2020).

Besides the project partners a number of other actors are involved in executing project actions. Matteo Ruocco explains that the local Carabinieri diving unit provides technical and logistical support for the monitoring activities in Cilento national park. Furthermore, tourists and local people constitute stakeholders that can be involved in collecting seeds and sprouts for transplantation. The implementation of a carbon credit system aims at involving large and small economic actors (mainly those operating in the touristic sector). Local tourist operators will also be involved in dissemination actions for raising awareness about the importance of Posidonia and the issues related to its conservation. Finally, a company that develops sustainable building materials will take part in the ‘sustainable management of beached Posidonia residues’ (Seaforest LIFE, n.d.-a).

The Ministry of the Environment is indirectly involved in the Seaforest LIFE project through the national parks, its responsibilities include protection of biodiversity, ecosystems and marine-coastal heritage, land and water protection, policies to combat climate change and global warming. It can thereby also influence Posidonia conservation through policy-making at the national level. The Ministry also supervises the activities of ISPRA ("Competenze," 2018). While local authorities can also take measures

in support of the conservation of Posidonia, local authorities are not yet actively involved in the project there and no additional conservation measures are taken by the local authorities of the different project areas. However, there is an intention to engage local policy-makers in the promotion of the carbon credits model and the implementation of mooring plan (see 5.1.1.3).

5.1.2. The Seaforest LIFE project (current status) in a DPSIR perspective

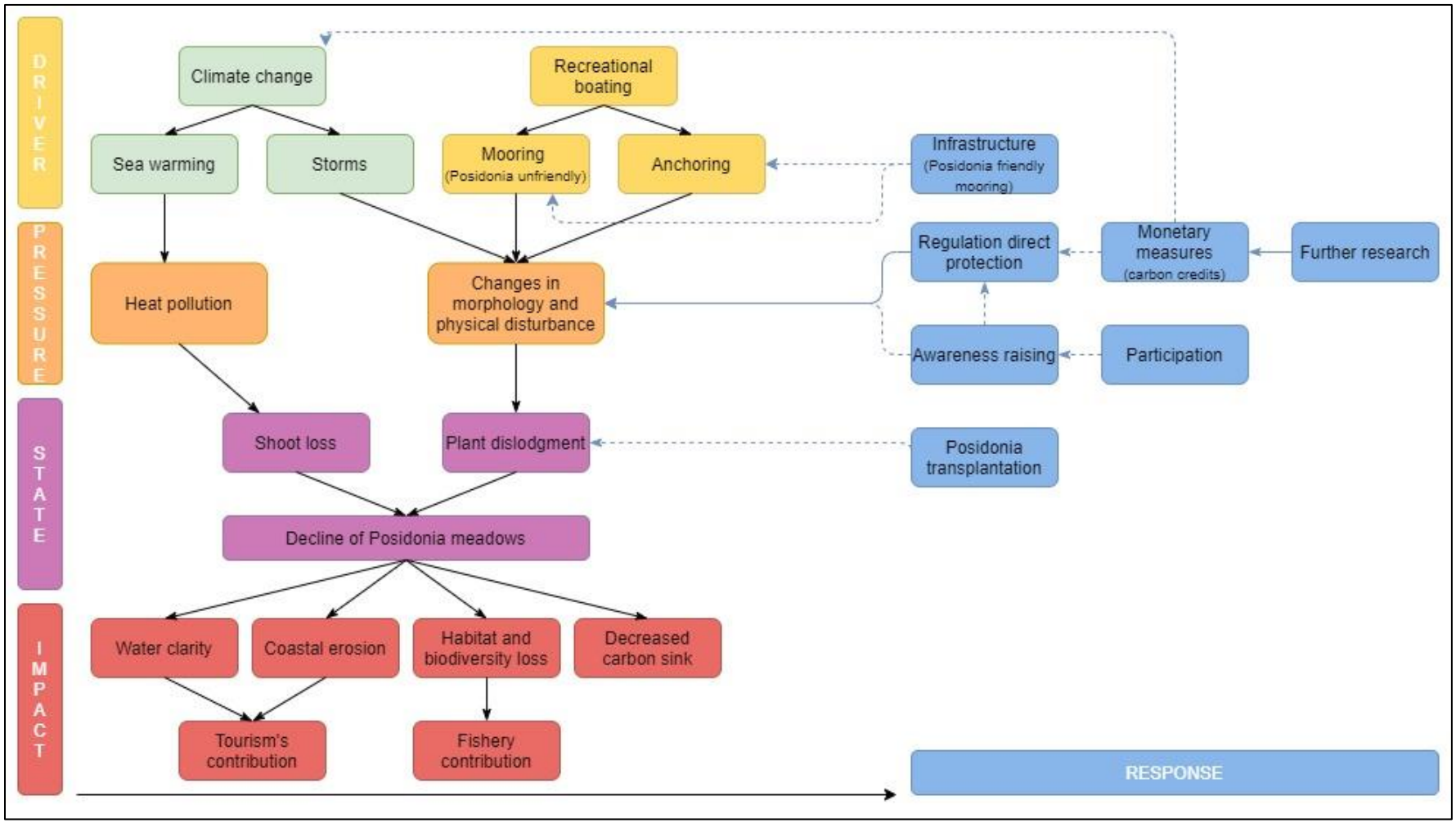

Figure 5. DPSIR diagram Seaforest LIFE project[1].

[1] Climate change was added in green because of the distinct nature of this driver compared to the other more local and more explicitly anthropogenic drivers.

5.1.3. Past evolutions

Past evolutions regarding the conservation of Posidonia at the Seaforest LIFE project areas have been influenced primarily by policies and actions at the European and national level and not so much at the local level. This inaction is attributed by Ruocco to local authorities giving priority to other interests over environmental protection. It can also be linked to a lack of awareness about the issue at the local policy level. Furthermore, activities in the national parks have been mainly directed at monitoring the status of the Posidonia meadows. But no specific conservation actions have taken place in the past (M. Ruocco, personal communication, July 31, 2020). However, some observations can be made regarding the reported absence of pollution (M. Ruocco, personal communication, June 16, 2020) and coastal development (I. Guala, personal communication, July 7, 2020), which link back to policies at the European level and to the establishment of national parks.

5.1.3.1. European policies

The Common Fisheries Policy, more specifically the regulation concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea, is particularly relevant because of its direct application within EU member states (EU Publications Office, 2015). It introduced a prohibition of trawling that benefits Posidonia. Furthermore, a number of other European directives, namely the Habitats directive and the WFD, have brought Posidonia to the attention of environmental managers at the national level (De los Santos et al., 2019). Especially the Habitats directive and the establishment of Natura2000 sites can be presumed to have benefitted the conservation of Posidonia in the Seaforest LIFE case, since all three national parks comprise Natura2000 site.

5.1.3.2. National park regulations

Around the same time the Habitats directive was introduced the three national parks where the project is located, were established. The establishment of national parks entails the adoption of park regulations and a park plan. They govern the exercise of the activities permitted within the territory of the park and the general organisation, restrictions and guidelines for nature conservation in the park. This provides an explanation for the absence of drivers like pollution and coastal development. Guala and Scardi both indicate urban pressures such as pollution and coastal development as common threats to Posidonia in Sardinia and Campania, respectively. However, they do not occur (significantly) in the project areas. Ruocco directly connects the absence of significant pollution as a threat to the fact that the project areas constitute national parks where stricter regulations apply. While he does not say so explicitly, the absence of coastal development as a threat in the Seaforest Life project areas can also be explained by these stricter regulations. Furthermore, all of the parks have included a

prohibition of anchoring on Posidonia meadows or 'valuable bottoms' in their park regulations (Brambilla, Simeone, Antognarelli, & Miozzo, 2019).

5.1.4. Current situation

Both Italian researchers, Guala and Scardi, confirmed that the overall health of the Posidonia meadows in Campania and Sardinia is quite good, with significant regressions only occurring in areas of high local pressure. Guala states that drivers of these pressures around Sardinia usually consist of trawling – due to a lack of enforcement – and coastal development and urbanisation, which entail the building of infrastructure, sewage discharge and industrial pollution. Scardi equally mentions coastal development and urbanisation for the Campanian coast– however not recently – as well as the artificialisation of rivers.

Current regressions at the Seaforest LIFE project areas are caused by the anchoring and mooring related to recreational boating (M. Ruocco, personal communication, June 16, 2020). However, Guala notes that an assessment of the meadows in Asinara national park he participated in – independent of the Seaforest LIFE project – revealed a lower quality of the meadows than expected. Despite the absence of direct urban pressures, the state of the meadows was not as good as expected, indicating the influence of some persisting or more distant pressures. Ruocco indicates that the increase in population during the peak tourist season can increase pollution pressures. However, anchoring and mooring still constitute the main threats in the project areas.

5.1.4.1. Anchoring and mooring

Both anchoring and mooring are linked to recreational boating by tourists and the local population. The persistence of anchoring as a threat is remarkable considering the anchoring prohibitions in the different national parks. This is attributed to a lack of awareness among mainly tourists and the local population, but also among local policy-makers, about the existence and the importance of Posidonia and about the impact of anchoring on Posidonia and a lack of enforcement of the anchoring prohibition on the Posidonia meadows by the coast guard (see 5.1.1.4) (M. Ruocco, personal communication, June 16, 2020).

Anchoring causes a physical disturbance resulting in uprooting of shoots or dislodgement of plant rhizomes or leaves, which leaves a scar along the trail of the anchor (Boudouresque et al., 2009; Francour, Ganteaume, & Poulain, 1999; Milazzo, Badalamenti, Ceccherelli, & Chemello, 2004). Hydrodynamic currents can prevent the gaps from being covered again and can even enlarge them

(Díaz-Almela & Duarte, 2008). However, the pressure created by anchoring is not wholly undisputed. Based on his personal observations, Scardi states that under certain conditions Posidonia meadows might be able to sustain a persistent pressure from anchoring, depending on physical and geomorphological factors (water depth, absence of currents, weather conditions, size of the anchor). Literature confirms that the damage from anchoring mainly depends on the frequency and density of anchoring. Posidonia meadows can support anchoring if they are able to produce more new shoots every year than those uprooted or damaged by anchoring. Furthermore the size of the boat and the size and type of anchor also influence the extent of the damage as well as certain characteristics of the meadow, like weak matte compactness and high rhizome baring (Boudouresque et al., 2009; Díaz-Almela & Duarte, 2008; Francour et al., 1999; Milazzo et al., 2004).

In the project areas deadweight moorings (see Box 1) also create pressure on Posidonia meadows. Although no explicit connection is made by the interviewees, this is presumably to be blamed on lack of awareness of decisionmakers. In the view of Ruocco, dead-weight mooring and anchoring form the main threats to Posidonia meadows. Both cause a physical disturbance. The current dead-weight mooring crushes Posidonia. In combination with the dragging of the mooring chain, this leaves a gap in the Posidonia meadow. As is the case for anchoring, these gaps are unlikely to cover again when removing the moorings and can become enlarged due to currents (Díaz-Almela & Duarte, 2008).

5.1.1.1. Climate change

Another threat to Posidonia that Ruocco mentions (briefly) is climate change. Global warming and storms related to climate change put pressure on the environment of Posidonia in the form of heat and turbidity. Heat events increase both shoot mortality rates and shoot recruitment, where shoot mortality exceeds recruitment, causing a regression of the meadow (Marbà & Duarte, 2010). Not much information is available about the effects of storms on Posidonia meadows, besides the studies from Gera et al. (2014) and Oprandi et al. (2020). According to these studies storms cause damage to Posidonia meadows by uprooting or burying plants. They furthermore indicate that meadows might be able to recover from storm events in absence of other natural and anthropogenic stressors. However, the presence of these stressors and the increased frequency and intensity of storms can prevent recovery of meadows from the effects of storms. Finally, the cumulative impacts of local pressures can cause Posidonia meadows and other marine ecosystems to be less resistant to climate change events overall (Marbà & Duarte, 2010).

Box 1. Mooring systems

Mooring systems comprise an anchor on the sea bottom, a floating structure to which boats can be attached, and a mooring line that links these and holds the floating structure in place. ("How it works. How do mooring systems work?," n.d.). Different types of mooring anchors exist. The conventional mushroom and pyramid type mooring is shaped like an inverted mushroom or pyramid, allowing it to dig into the surface of soft sea bottoms easily. It develops holding power by digging in and creating suction (Burden, 2020; "What are Mooring Anchors?," 2019). Screw-in or helix anchors are shafts with wide blades spiralling around it that are screwed into the seabed (Burden, 2020; "Mooring Your Boat on the Lake- About Moorings," 2012). Another type of mooring anchor is the grouted anchor system, where a plate or a single anchor ring with one or many threaded rods or ringbolts secured into a boulder underwater (P. Francour, Magréau, Mannoni, Cottalorda, & Gratiot, 2006). Finally, deadweight moorings consist of a dead weight – a large concrete block – that is lowered onto the seabed resisting movement with its sheer weight (Díaz-Almela & Duarte, 2008; "Mooring Your Boat on the Lake- About Moorings," 2012).

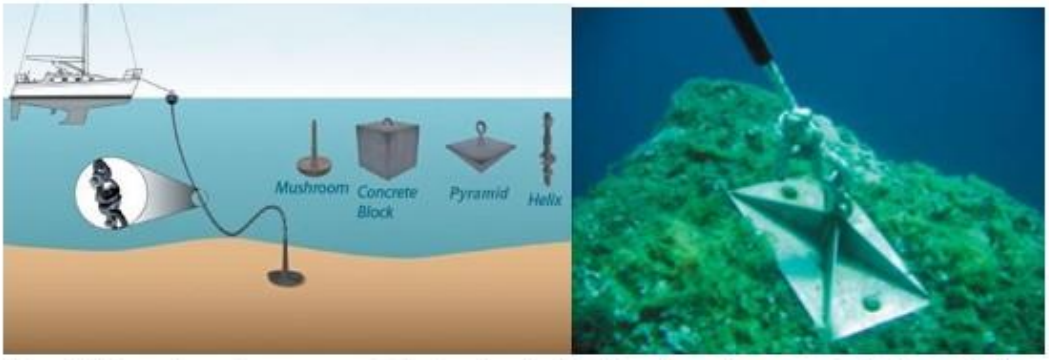

Figure 6. Types of mooring systems. (a) Retrieved and edited from https://www.practical-sailor.com/sails-rigging-deckgear/screw-types-prove-their-mettle-in-load-testing; (b) Source: Francour et al., 2006.

5.1.1.2. Impacts

Four impacts of Posidonia degradation and decline are mentioned in the interviews with the Seaforest LIFE project respondent: a change in water colour linked to water clarity; reduced protection against coastal erosion; reduced biodiversity due to the disappearance of habitat (feeding and nursery grounds) for fish and other species as well as reduced production of oxygen; and disturbance to carbon sequestration and storage, including the release of carbon deposits accumulated over millennia in the matte. These are consistent with impacts described in the literature (e.g., Marbà et al., 2014).

Especially, this last impact is particularly pertinent to the Seaforest LIFE project, since its overall objective is to *increase* the capacity of the carbon reservoirs of Posidonia meadows and to realise financial value in this this through carbon credits (Seaforest LIFE, n.d.-d). Studies indicate that the loss of Posidonia meadows could potentially lead to the release of stored carbon deposits (Marbà et al., 2014; Mateo, Romero, Pérez, Littler, & Littler, 1997). Reversing the loss of Posidonia meadows thus not only preserves the carbon sequestration and storage function of Posidonia, but also prevents the re-release of stored carbon.

The importance of water clarity is immediately connected to Sardinia's tourism by Ruocco, since water clarity and colour constitute an important part of the image tourists have of Sardinia in particular. The ES of water filtration and coastal protection are connected to tourism more broadly by Campagne et al. (2015). Similarly, Posidonia conservation contributes to the productivity fisheries. All of these are related to provisioning services. The Seaforest LIFE project itself does not pay particular attention to these impacts and is not quantifying them.

5.1.1.3. Project responses

Ruocco explains that the project evolves around five lines of action, described on the project website, which are aimed at improving the conservation of Posidonia at the project areas. Actions are addressed to the main causes of pressure: anchoring/mooring (tackled by direct actions) and climate change (reflected in the projects carbon credit system).

A first action consisted in performing further research quantifying the deposits of carbon and estimating the rate of change due to the degradation of meadows caused by anchoring and mooring. This research serves as a foundation for introducing a system of carbon credits (see 2.1.3), which constitutes a second action. The value of the ES derived from the carbon storage of the meadows, is estimated using the InVEST model[2]. Credits are based estimating the value of the avoided loss of carbon storage through conservation of Posidonia. The carbon credits can potentially attract investment to fund conservation actions through associated carbon offsetting arrangements; for example, the project intends to approach both bigger and smaller companies that operate in the local tourist sector (e.g. the Sardinian ferry companies and local hotel and holiday companies) about offsetting their carbon emissions through carbon credits issued against Posidonia conservation. Additional potential benefits of this carbon credit scheme raised by Ruocco are the scope for awareness raising among the participating economic actors and their client base. By informing

[2] Website: https://naturalcapitalproject.stanford.edu/software/invest

customers and clients about their participation, the economic actors create a positive image for themselves, and simultaneously inform the general public about the importance of Posidonia.

The project is also taking concrete conservation measures through the development and implementation of a mooring management plan, which involves installing eco-compatible or 'Posidonia-friendly' mooring infrastructure (see Box 2). The removal of the dead-weight moorings will leave gaps in the Posidonia meadows. The Seaforest LIFE project will aim to fill these by transplanting cultivated Posidonia shoots from seeds and sprouts collected from the beach. A final action entails using Posidonia that is cleaned from the beaches in construction materials. This action does not contribute to the conservation of Posidonia but is intended to make productive use of a material that, otherwise, would go to waste.

Box 2. Posidonia-friendly mooring

Posidonia-friendly mooring refers to mooring systems and set-ups that do not cause damage to the state of Posidonia meadows both during their installation and when they are in use. An extensive description of Posidonia-friendly (and other ecological) moorings can be found in P. Francour, Magréau, Mannoni, Cottalorda, and Gratiot (2006) *Management guide for Marine Protected Areas of the Mediterranean sea, Permanent Ecological Moorings*.

Mooring infrastructure is preferably installed on meadow clearings. The screw-in or helix anchor type (see Box 1) is suitable for sandy substrate. Grouted anchors (see Box 1) on the other hand, are most suited for patches with boulders and bedrock. For Posidonia meadows without clearings, but with a well-developed matte, a special ecological anchor type exist: the steel coil anchor, Harmony type P. (Díaz-Almela & Duarte, 2008). It makes its way through the dense network of entangled rhizomes and plant roots without cutting, crushing or destroying elements of the matte. The anchor furthermore does not affect the leaves or plant rhizomes and it does not cover any surface area of the seabed – as opposed to dead-weight mooring Once installed the matte additionally provides pullout resistance to the mooring (P. Francour et al., 2006). An immersed floating element is attached to the mooring line preventing damage from the mooring line to the seabed because of scouring across the meadow (Díaz-Almela & Duarte, 2008; P. Francour et al., 2006).

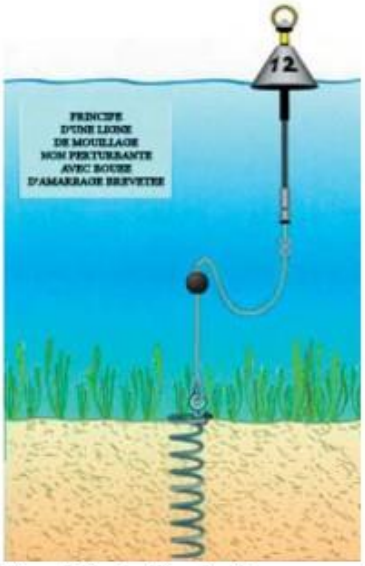

Figure 7. Steel coil anchor Harmony type P. Source: Francour et al. (2006).

In the realisation of these actions raising awareness through participation and dissemination play an important role. The project's dissemination campaign focusses on educating both the local population and tourists about the importance of preserving Posidonia and the effects of anchoring. This will be done through the distribution of informative leaflets with the help of local economic actors (M. Ruocco, personal communication, June 16, 2020) and the use of bulletin boards placed in the project areas to inform visitors (local operators, users, tourists, owners, farms etc.) about the project, its aims and its interventions (Seaforest LIFE, n.d.-b). The decision to involve locals and tourists in collecting seeds for transplanting into the meadows, also aims to raise awareness (M. Ruocco, personal communication, July 31, 2020). The project aims to reach all levels of the local population through general information campaigns involving leaflets/brochures, online webinars, etc., and by introducing Posidonia conservation and the project into the school curriculum through activities and video lessons (M. Ruocco, personal communication, July 31, 2020).

5.1.1.4. Barriers

The main challenges for the conservation of Posidonia according to the sources interviewed in respect to the Seaforest LIFE case study are a lack of awareness among tourists and the local population and local policy-makers about the existence and the importance of Posidonia and a lack of enforcement of the prohibition to anchor on the Posidonia meadows.

Lack of awareness has multiple effects that complicate efforts to conserve Posidonia. Firstly, lack of awareness on the part of local policy-makers, in combination with them having other priorities, is claimed as the main reason they have failed to address to enforce the anchoring prohibition and continue to use deadweight mooring systems. The lack of awareness of boat users (tourists and locals) of the existence and importance of Posidonia, the impact of anchoring and the reasons for anchoring restrictions is claimed by respondents to contribute to the continuing anchoring/mooring pressures on the Posidonia meadows in the project areas. Ignorance leads to boat users (involuntarily) creating pressure by anchoring on Posidonia meadows. Ruocco confirms that by making them aware of these pressures the project hopes to reduce pressure by encouraging compliance with regulations and to build a support base for additional policy measures and actions at the local level aimed at protecting the meadows.

The lack of enforcement of the coast guard is, according to the interviewees, to be attributed to limited resources for the enforcing the anchoring prohibition. This is due to the coast guard having to fulfil

other responsibilities and the inability to check the compliance of every single boat in the whole area they are responsible for (M. Ruocco, personal communication, June 16, 2020; M. Scardi, personal communication, July 7, 2020). Furthermore, Guala states that the coast guard and other (policy or military) authorities responsible for the enforcement of regulation in protected areas, do not have an interest in environmental issues or possess the right ecological knowledge to enforce the application of anchoring prohibitions, for example, they lack knowledge about the location of Posidonia meadows. The following anecdote illustrates this issue:

> "I was with my boat in an MPA and the coast guard told me to move to another place. I [had] put the anchor in the sand and the place that they indicated to me was on Posidonia. I said sorry this is a protected area I cannot do that. 'No, you cannot stay there'." (I. Guala, personal communication, July 7, 2020)

5.1.1.5. Contextual factors

In terms of the contextual factors that influence the occurrence of drivers, pressures, impacts or barriers, no distinction is made between different island and mainland project areas. When asked about potential differences, Ruocco states that differences cannot necessarily be attributed to factors that are specific to islands or the mainland, but to characteristics that are specific to the individual project areas.

Concerning anchoring pressures, Ruocco indicates that the mainland coast of Campania has less space to anchor, because it has a relatively short plateau with a sudden drop into the deep, but allows the boats to spread out better compared to the islands. He estimates that these geophysical differences in combination with the historical and natural characteristics of the islands influence the pressures from anchoring in the different project areas.

Regarding the awareness of the local population Ruocco suggests that having a background or cultural heritage connected to the sea influences people's awareness. Around the Sardinian islands of La Maddalena and Asinara people have a stronger connected to the sea than along the Campanian coast. The Campanian coast does not have much of a past of fishing for example and thus a cultural connection to the sea is less present there. People along the Sardinian islands on the other hand did engage more in seaside activities and could therefore probably still have a stronger cultural connection today.

In relation to the awareness and attitude of tourists Scardi particularly links awareness of tourists to the type of tourism. While tourists in Spain or France also seek activities such as walking and swimming that have some nature aspect to them, Italian tourists mostly want to sun-bathe and have little interest in nature. Guala furthermore indicates that both the strong advertisement of Mediterranean beaches with a 'Caribbean-like' white-sand beach image and the level of education of tourists– in combination with information and dissemination campaigns –affects their awareness of and accepting attitude and attitudes, including (non)acceptance of Posidonia on the beaches, which is often the only time Posidonia is visible to them.

5.2. Projecte Alguer de Mataró

5.2.1. Stakeholders

In the Mataró case study, there are many actors and stakeholders that, directly or indirectly, influence or can be affected by decisions related to Posidonia conservation. These represent scientific, policy, economic and societal fields. The principal actors running the project are the Escola del Mar de Badalona, which is closely linked to the Badalona town council, and the SPAS diving club. While the Escola del Mar de Badalona supervises the project and makes decisions about scientific aspects, the SPAS diving club makes decisions about non-scientific aspects and provides volunteer divers, who play an essential role in data collection. The project is supported and funded by the Mataró town council. Additionally, the Mataró port authority occasionally helps with logistic matters. In the initial stages of the project local fishermen's associations were involved in the demarcation of the Posidonia meadow of Mataró. With the University of Barcelona, which was part of the original project but stepped out in 1992, there is still occasional contact. During meetings project progress is discussed and ideas and opinions about Posidonia conservation and the project are exchanged (X. Seglar, personal communication, June 23, 2020). A final actor involved in the project, identified based on the project website, is the Natural Sciences Section of the Mataró Museum, which has contributed to dissemination and awareness raising about Posidonia meadows and conservation ("Let's act," n.d.).

Besides the actors involved in the project, Seglar identifies a number of other stakeholders to the Posidonia conservation issue in Mataró more generally. These include Environmental Department of the Catalan government, which set up the original project. There are also a number of national and the regional (Catalan) government departments that have different responsibilities and competencies in environmental policy and in other related or relevant policy fields, like infrastructure and transport, tourism and leisure, and water. There are also other marine research centres in the wider area, such as the Institut de Ciències del Mar in Barcelona and the CEAB, that have roles or interests in the

research, conservation and management of Posidonia. Researchers Alcoverro and UoB estimate that the presence and work of these institutes is relevant for gathering scientific knowledge and raising general awareness about the issue in the area. Local economic actors from the tourism industry (other than the diving centres) and the local population are stakeholders because they influence the conservation of Posidonia by pushing other priorities with the local authorities. Diving centres form a separate stakeholder group, because they have contrasting interests and differing stance regarding the conservation of Posidonia due to the importance of Posidonia meadows for their activities and due to direct consequences their disappearance could have for the coastal ecosystem and consequently for their business. Diving centres have engaged with local authorities and have started different initiatives focused on protecting Posidonia, such as reviewing their own practices[3], actively incorporating environmentally conscious behaviour in their activities to raise awareness[4] and informing their customers about Posidonia[5]. Finally, Seglar indicates that some NGOs could be considered as stakeholders. However, they do not carry out structured action nor do they have clear goals related to the conservation of Posidonia.

[3] https://mediterraneandive.es/filosofia/
[4] https://posidoniadive.com/cursos/compromiso-conservacion-entorno-marino/
[5] https://mediterraneandive.es/filosofia/, https://blaumar.cat/alguer-de-mataro/

5.2.2. Projecte Alguer de Mataró (current status) in a DPSIR perspective

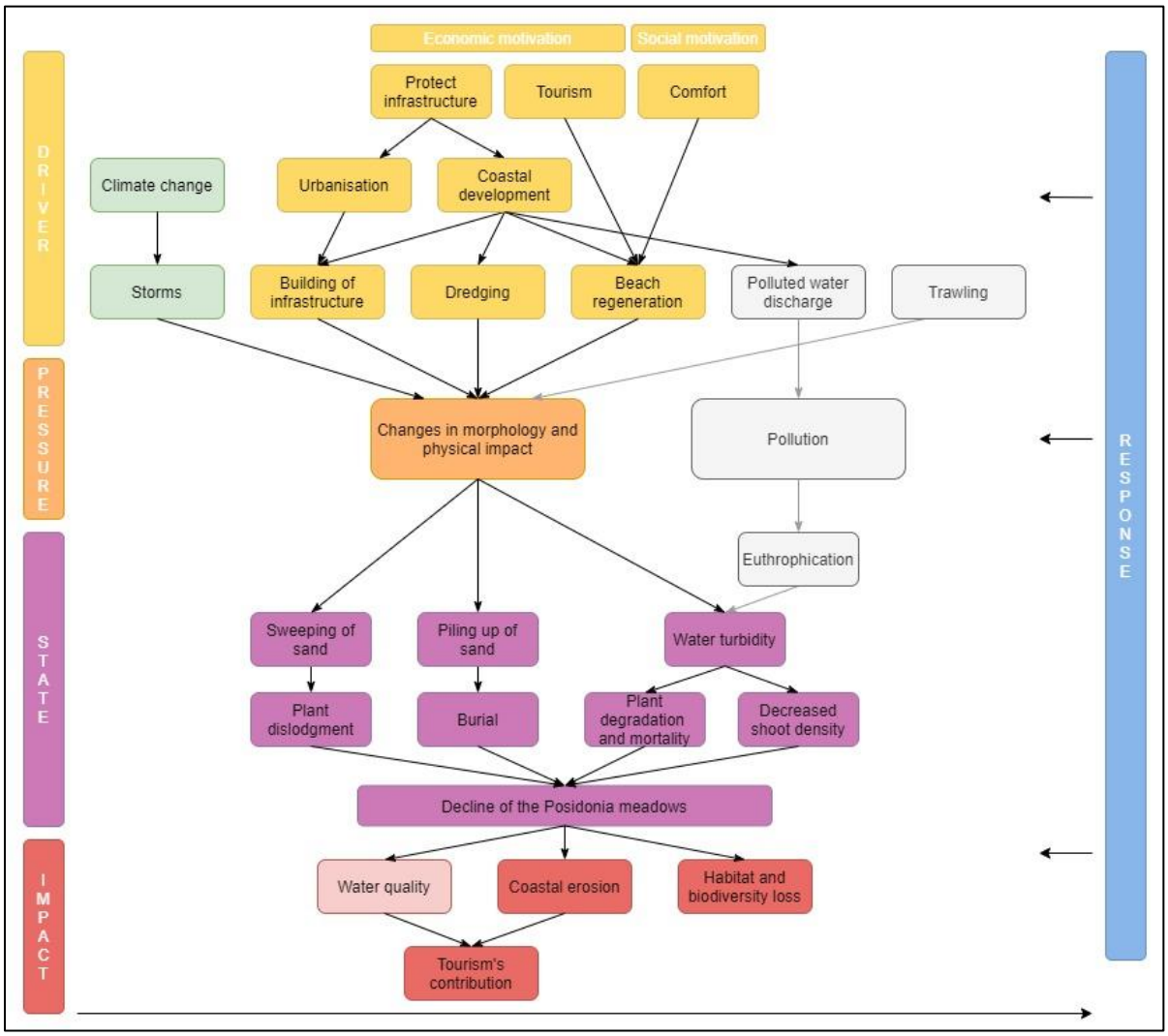

Figure 6. DPSIR diagram Projecte Alguer de Mataró[6].

A diagram with elaborated past and desired responses can be found in ***Fout! Verwijzingsbron niet gevonden.***. ***Fout! Verwijzingsbron niet gevonden.***.

5.2.3. Past evolutions

Two pressures that used to affect the Posidonia meadows of Mataró are the physical impacts from trawling and water pollution from sewage discharge. Both of these pressures have been addressed through policy responses. In addition, coastal development has had and continues to have an effect on the coastal environment of Mataró, including its Posidonia meadows.

[6] Climate change was added in green because of the distinct nature of this driver compared to the other more local and more explicitly anthropogenic drivers.

5.2.3.1. Trawling

Trawling can physically disturb the meadows by breaking leaves and rhizomes or by uprooting shoots (Boudouresque et al., 2009; J. González-Correa et al., 2005). Trawling additionally affects sediment composition and dynamics, causing resuspension and mixing of layers of sediment (J. González-Correa et al., 2005). However, trawling no longer affects the Posidonia meadows of Mataró. Seglar indicates three reasons for this: firstly, the European prohibition on trawling above 50m and on Posidonia meadows provided the necessary legislative framework to address this threat; secondly, (illegal) trawl fishing was inhibited by the installation of artificial anti-trawling reefs (see Box 3) around the meadows; and finally, increasing awareness among fishermen of the value of Posidonia (partly achieved by inviting local fishermen to participate in the project) has helped in phasing out trawling.

Box 3. Artificial reefs

Artificial reefs are submerged structures "placed on the seabed to mimic some functions of a natural reef, such as protecting, regenerating, concentrating and/or enhancing populations of living marine resources. This includes the protection and regeneration of habitats. Reefs serve as habitat that functions as part of the natural ecosystem while doing 'no harm' " (Fabi et al., 2015, p. 2). They are used in coastal waters worldwide for many different purposes, including the protection of sensitive habitats of ecological interest, such as Posidonia meadows, from fishing activities. This type of artificial reefs is referred to as protection artificial reefs (Fabi et al., 2015).

Different types of artificial reef units are made of different materials. Since they have to be able to withstand the power of fishing vessels, protection artificial reefs aimed at deterring fishing usually consist of concrete block with deterrent arms – long iron beams (Fabi et al., 2015). This type of reef is commonly used in Spain. It is also referred to by Seglar from the Mataró project.

Figure 9. Module design for an artificial reef (with deterrent arms) for the protection of habitat. Retrieved from "London Convention and Protocol/UNEP: Guidelines for the Placement of Artificial Reefs" (2009).

5.2.3.2. Sewage discharge

When asked about other pressures that have been addressed successfully Seglar states that the tightening of laws, rules and regulations regarding the water quality and discharges of substances to water also helped to reduce turbidity and made the water column more transparent. Researchers Alcoverro and UoB indicate that the water quality in Catalonia has improved significantly, thanks to an

increasing number of water treatment plants. This can be linked to the regional implementation of the European WFD (see 2.3.3 and Appendix B), which they mention was very successful in Spain overall and in Catalonia specifically. In some cases, however, storms can still cause an overload of the sewage system (see 5.2.4.2).

5.2.3.3. Coastal development and urbanisation

As Seglar puts it, "the last decades there have been tens, if not hundreds, of actions along the Catalan coastline that have altered the coastal dynamics and the longshore drift." These are related to coastal development and urbanisation. Coastal development activities included beach regeneration, dredging at ports and the construction of (tourist) infrastructure, such as breakwaters, dykes, ports for recreational navigation, hotels and apartment buildings, streets and promenades. The construction of roads and buildings can also be linked to more general trends of urbanisation. The alteration (artificialisation) of rivers, another driving force Seglar points out, has also been a component of urbanisation trends. Apart from direct pressures these activities generated, they have also created considerable, long lasting indirect impacts on the coastal ecosystem of Mataró.

The construction of (tourist) infrastructure, such as hotels and apartments and streets and promenades, creates direct pressures in the form of physical disturbance to meadows and turbidity because of the sediment suspension. There are also indirect morphological pressures, such as changes in the sediment composition and disturbance of the sediment dynamics. Coastal development activities are capable of upsetting the natural balance of both the emerged and the submerged area of the beach-dune system (Roig Munar et al., 2012). The same goes for constructions like breakwaters, dykes and ports (in Mataró for recreational navigation) built in the water or at the water border. These constructions equally create a direct physical disturbance to the meadows. They increase the level of suspended material in the seawater and cause morphological pressure by altering sediment dynamics, changing the way sediment is distributed along the coast. In the long term, development and urbanisation activities related to coastal infrastructure construction can also entail continuing turbidity and pollution pressures (Boudouresque et al., 2009).

The artificialisation of rivers is another element claimed by Seglar to have had a considerable effect on the Posidonia meadows of Mataró. This affects sediment transport along the waterway and composition and dynamics, reinforcing the coastal erosion issue and threatening the Posidonia meadows. On the other hand, Alcoverro and Researcher UoB note that, while artificialisation of riverbeds might affect the sediment transport along the waterway, uncontrolled waterways can

equally lead to problems with water quality due to pollution entering the waterways, for example in heavy rainfall situations. A balance should thus be found between in the degree to which rivers are altered.

Urbanisation and coastal development trends are associated with growth in population, employment economic activities and living standards (Bhatta, 2010). These social and economic motivations act as strong drivers for the activities that continue to put pressure on Posidonia meadows. Particularly the importance of tourism in the region constitutes an important element that contributes to stimulating processes of urbanisation and coastal development. Different interviewees indicate that, while generally pushed by local authorities, the national government is an important stakeholder when it comes to (coastal) infrastructure decisions.

As a result of project efforts to inform and warn the local authorities, pressures from specific coastal development actions have been reduced. When specific development plans are announced, the members of the Mataró project provide advice and warnings. However, the local authorities decide whether they accept and apply these and, overall, Seglar says there is little feedback between the local authorities and the project. The content, scope and success of these advices and warnings as well as rules and procedures applicable to coastal development projects were not further elaborated by the respondent.

5.2.4. Current situation

5.2.4.1. Coastal development and urbanisation

Coastal development activities constitute an important focus of the Mataró project. While coastal development is a continuing threat, it has been successfully managed to the point where, even if the pressure has not been entirely eliminated, direct threats from coastal development activities have reduced and are considered more manageable. Whereas local authorities usually push national authorities, Seglar indicates that the local authorities and economic actors in Mataró are not demanding further coastal development and that, simultaneously, they are easier to approach and sensitise to the effects of specific actions. However, certain coastal development activities continue to exert pressure on the Mataró meadows and are even pushed by local actors.

The importance of ‘sun and beach’ tourism to the local economy and expectations from tourists and residents for clean, sandy beaches lead to local economic actors and authorities amplifying these demands and pushing for beach regenerations to compensate the effects of coastal erosion. Seglar

furthermore mentions regular dredging of the port inlet to counter the effects from coastal erosion. Both activities entail the movement of large amounts of sediment and are associated with the (re)suspension and (re)deposition of sediment, affecting water clarity and sediment dynamics. Beach regenerations, in addition, can cause the burial or smothering of Posidonia meadows (Aragonés, García-Barba, García-Bleda, López, & Serra, 2015; Carlo, Benedetti-Cecchi, & Badalamenti, 2011). Finally, the reinforcement, protection or restoration of existing infrastructure also puts pressure on coastal ecosystems. The Maresme region coastal railway, for instance, requires regular infrastructural works in respect to potential and actual wave and storm damages. The railway itself, and protective infrastructure around it create considerable physical and sedimentary impacts on the Posidonia meadows.

All of these urbanisation and coastal development activities have an influence on the overall balance of the sediment dynamics and their effects are still felt. They aggravate coastal erosion, the effects of storms and the decline of the Posidonia meadows. However, as Seglar notes, the exact cause-effect relation of these activities and the pressures they have created, are hard to prove, as many indirect and multivariate relations exist between them and the level of synergy between them is not easy to determine. The presence of river influx seems to add complexity in the Mataró case. This complexity, in combination with a lack of resources for research, contributes to knowledge uncertainty in the Mataró case (see 5.2.4.5).

5.2.4.2. Storms

However, in the current situation, Seglar considers the biggest threat to the Mataró Posidonia meadows is from storms. Storms can cause sweeping, resuspension of sediment and piling up of sediment. Sweeping leads to the dislodgment of Posidonia shoots. The (re)suspension of sand causes water turbidity which can cause additional degradation of the meadows. However, this does not seem to be the case in Mataró since the meadows are in a healthy state. Sediment piling causes the burial of plants (X. Seglar, personal communication, June 23 and July 14, 2020). Seglar reports the sweeping of sand by storms constitutes the biggest threat to the Mataró meadows. Furthermore, storms with heavy rainfall can cause an overload of the sewage system. Because the sewage system cannot collect all the water, (unfiltered) water to overflows in pipes that run directly into the sea which can lead to nutrient pollution. However, Seglar claims these effects to be very local and less significant. Finally, an indirect consequence of storms is brought up by researchers Alcoverro and UoB. They note that infrastructure along the coast are often storms, requiring maintenance and restoration works to be carried out, which creates additional pressures on the meadows linked to coastal development.

Storms have increased in frequency and intensity as a consequence of climate change. Furthermore, it is suspected that changes in dynamics and composition of the sediment reinforce the effects of storms, compromising the chances of the meadow to recovery from storm events. However, the exact cause-effect relationship and interactions are hard to unravel, due to the many indirect and multivariate relations.

5.2.4.3. Impacts

Mataró is highly impacted by coastal erosion. Other impacts play a much less important role according to Seglar. Coastal erosion is particularly problematic because of the importance of 'sun and beach' tourism in the Maresme region for the local economy and the importance of sand beaches for this type of tourism. However, because of significant changes in sediment dynamics along the Mataró coast, Seglar reports that the importance of the role the Posidonia meadows still play in reducing coastal erosion is unsure. This statement contrasts with the considerable role of seagrasses in stabilizing sediments (Gacia & Duarte, 2001) and attenuating waves (Koch et al., 2006) described in the literature.

While water quality and especially clarity constitute other ES that Posidonia contributes to tourism, this is not mentioned by the interviewee. Besides coastal erosion, the only other impact of the regression of Posidonia meadows he mentions is a loss of habitat and biodiversity. In contrast to coastal erosion, the local economic impact of biodiversity loss is not as direct since there is no significant fishing industry and diving activities revolve around the rock bar ecosystems instead. However, a relation exists between these ecosystems and Posidonia meadow ecosystems. This link with the activities of diving centres explains why diving centres are engaging with local authorities and have started different initiatives focused on protecting Posidonia. Finally, other impacts like the effect on carbon sequestration and storage and filtration of the water were mentioned by experts, but not by the project respondent.

5.2.4.4. Possible responses

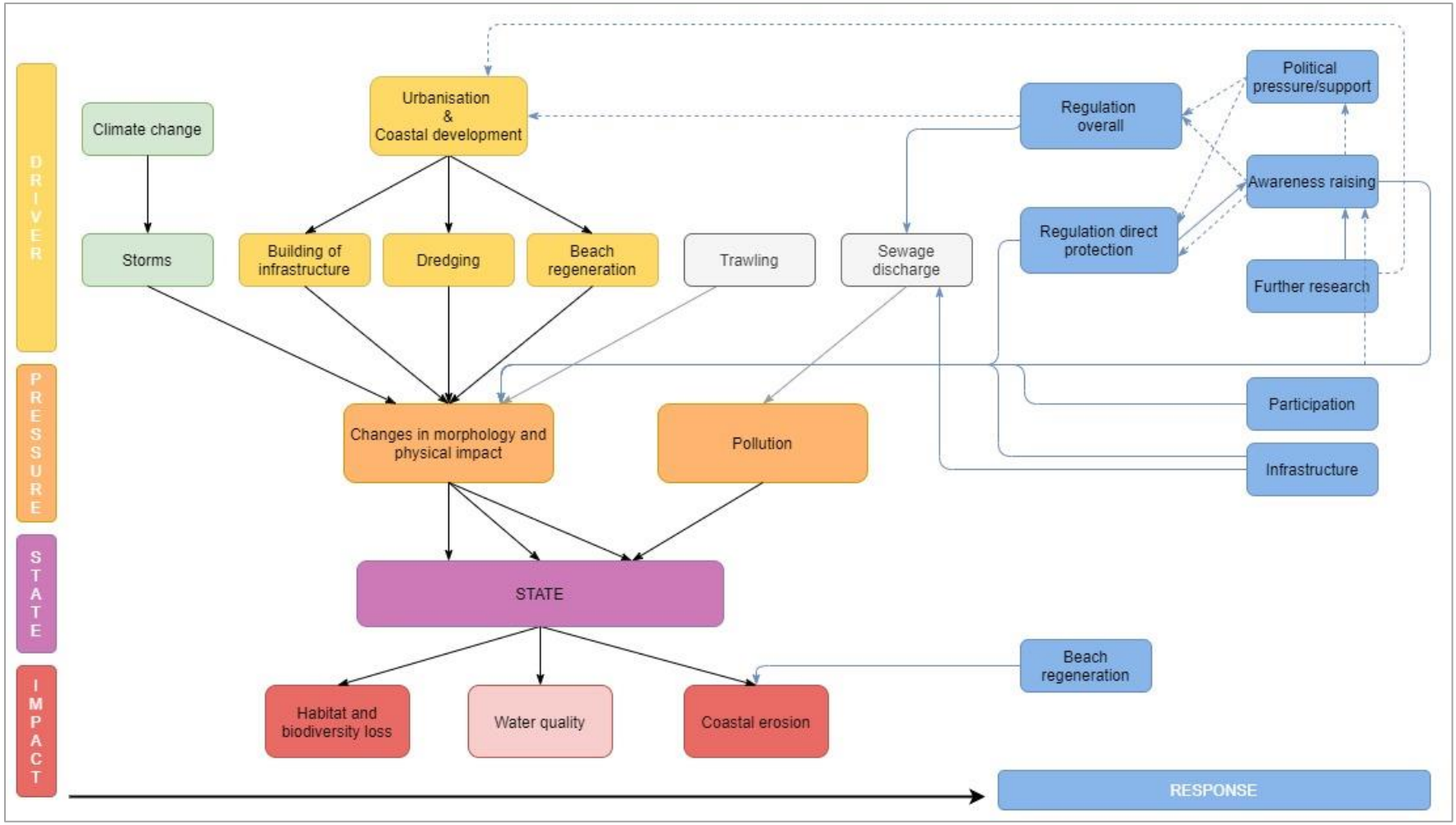

Figure 10. DPSIR diagram Projecte Alguer de Mataró incl. responses[7].

[7] Climate change was added in green because of the distinct nature of this driver compared to the other more local and more explicitly anthropogenic drivers.

From the perspective of the Mataró project, further action is needed in Mataró and in the broader region to protect the Posidonia meadows. Improving the direct regulatory protection of Posidonia as well as creating an integrated framework of overall regulations for coastal development is deemed most important by Seglar. This concerns actions relating to coastal constructions, river courses, sewage systems, beach regenerations and recreational activities around the meadows such as diving or underwater fishing, if proven that these affect the meadows. This also includes providing corrective measures to avoid impacts on the sediment transport of actions considered indispensable. However, eventually alternative solutions to beach regeneration are still to be studied and implemented. Further research is needed to better understand the particularities of threats and damages along the whole Catalonian coast. This requires the support of a new research project along the whole Catalonian coast that simultaneously creates a network with existing research programmes. Seglar also suggests an evaluation of the water quality in order to adapt the current rules in Catalonia.

Finally, awareness-raising among the general population is needed concerning the importance of Posidonia and the impacts its disappearance could have. Seglar confirms that, while this will not directly affect the drivers and pressures threatening the Posidonia meadows, it can generate pressure on local policy-makers for improving policy responses. Some dissemination actions have taken place, for example an exhibition about 'The forests at the bottom of the Sea' at the Mataró museum. However, the project itself does not undertake structural dissemination actions. Rather, the Escola del Mar de Badalona works on raising awareness through its educational activities.

5.2.4.5. Barriers

Based on Seglar's answers, three barriers to conservation of Posidonia meadows at Mataró faces can be identified: knowledge uncertainty, a lack of awareness and policy constraints. These barriers are the consequence of the complexity of the issue, resource constraints, conflicting policy priorities and administrative complexity (institutional compartmentalisation) In essence, Posidonia conservation at Mataró lacks an integrated regulatory framework that can provide for coherent coastal management and development.

In terms of cause-effect relations the Mataró case constitutes the most complicated of the three case studies. Conservation is clouded by uncertainty rooted in the complexity. Even if the project had access to more research resources the effects of individual activities on Posidonia as well as the level of synergy that exists between them are hard to establish. The uncertainty eventually leads to a lack of

response from local policy-makers as uncertainty increases the scope for contestation and denial and makes it easier to promote short-term economic interests over environmental conservation.

Concerning the national government, the interviewed researchers indicate physical distance from the coast, limits a proper understanding of issues relating to coastal management. While Seglar feels local government has become more aware, pressures to prioritise other issues are exerted on local political decision makers by local businesses and people, potentially because they are unaware of the severity of the issue. Regarding the awareness of the general public, Seglar states that while they are often familiar with what Posidonia is, they do not understand sufficiently the importance of its preservation, the intensity of the pressures certain activities the Posidonia meadows, and the severity of the issue. According to Seglar, people are becoming more aware about Posidonia and some of the issues surrounding it thanks to an increase in scientific research and attention for this from mainstream and online media. However, as Alcoverro and Researcher UoB explain, awareness raising and dissemination in Catalonia has not been organised or supported on a systematic basis or top-down. Dissemination is based on individual initiatives from research institutes and projects.

Finally, a number of political and institutional issues contribute to the lack of response from policy-makers, including the fragmentation of authority across different levels and departments, different policy priorities and the short-term focus of politics due to periodic elections. Institutional fragmentation complicate the handling of coastal matters due to shared or overlapping responsibilities and competencies between central and regional governments ("Spain," n.d.; Suárez de Vivero, 2002). Within their respective governments, different departments and agencies are responsible for issues in artificially separated and delineated domains. There is no single authority for coastal management. Rather this responsibility is shared between regional governments and the municipalities within them (Suárez de Vivero, 2002) with many other departments and agencies responsible for policy domains that affect coastal management, such as urban and spatial planning, biodiversity, water quality and tourism ("Spain," n.d.). On top of that, administrations often prioritise social or economic issues over environmental issues. At the local level, this is the case for beach regenerations. Local authorities continue beach regenerations despite repeated advice to stop these from the Mataró project because of their damaging impact to the Posidonia meadows. The advice is overridden by pressures from local businesses and people.

5.2.4.6. Contextual factors

In relation to the Mataró case, contextual factors were mostly mentioned when talking about stressors and not so much when talking about drivers. A morphological factor that recurred to explain the absence of anchoring or aquaculture was the 'open coast' of Mataró. The straight coastline and open sea are simply not 'fit' for anchoring or aquaculture. Pressures from trawling have been addressed by past policy responses both at the EU level, because of a prohibition in the Common Fisheries Policy (see 2.3.3 and Appendix B), and at the local level, through the installation of anti-trawling reefs. The same applies to pressures from water pollution, which were addressed because of the EU WFD (see 2.3.3 and Appendix B) and the installation of water treatment plants.

One geophysical contextual factor can be identified in relation to conservation challenges in the Mataró case: the presence of rivers. This creates an inland connection that complicates the set of drivers in this case and thus adds to complexity. Furthermore, tourism is a complicating factor that sometimes exacerbates other challenges. Seglar highlights the importance of different types of tourism. Certain types of tourist activities include elements of culture, sport or nature as well as sunbathing –The incidence of these is greater closer to Barcelona. Other tourists are only interested in passing time on the beach. So-called 'sun and beach' tourism is more common in the north of the Maresme region. The first type of tourism provides a stronger foundation for environmental action than the second type. The second type tends to widen the gap between economic and environmental interests.

5.3. The Balearic Islands

5.3.1. Stakeholders

While the Balearic Island case study does not cover a specific conservation project stakeholders with a general interest in the conservation of Posidonia and/or that are able to exert influence on Posidonia conservation policies and measures can be identified based on the interviews with Núria Marbà and researcher IMEDEA. These stakeholders are likewise distributed across policy, research, societal and economic sectors.

As policy competencies in Spain are shared between different levels and different departments of government and coastal management is the responsibility of both regional governments and the municipalities within them (Suárez de Vivero, 2002), the conservation of the Balearic Posidonia meadows involves governmental departments from national, regional and local levels. Researcher IMEDEA indicates that the advice from expert committees composed of scientists connected to

research institutes such as their own is consulted at the local level when policy decisions related to the conservation of Posidonia are taken or when conservation laws are drafted. It is not fully clear how much influence expert committees have on the final decision, however. Other actors and stakeholders in Balearic Island Posidonia conservation in (see 5.3.3 and 5.3.4) are port authorities, yachting associations, local tourist operators and other economic actors. The many tourists that travel to the Balearic Islands every year also directly and indirectly affect the Posidonia meadows and they can therefore likewise be considered as stakeholders. Finally, the local population evidently constitutes a stakeholder group as well.

5.3.2. The Balearic Islands (current status) in a DPSIR perspective

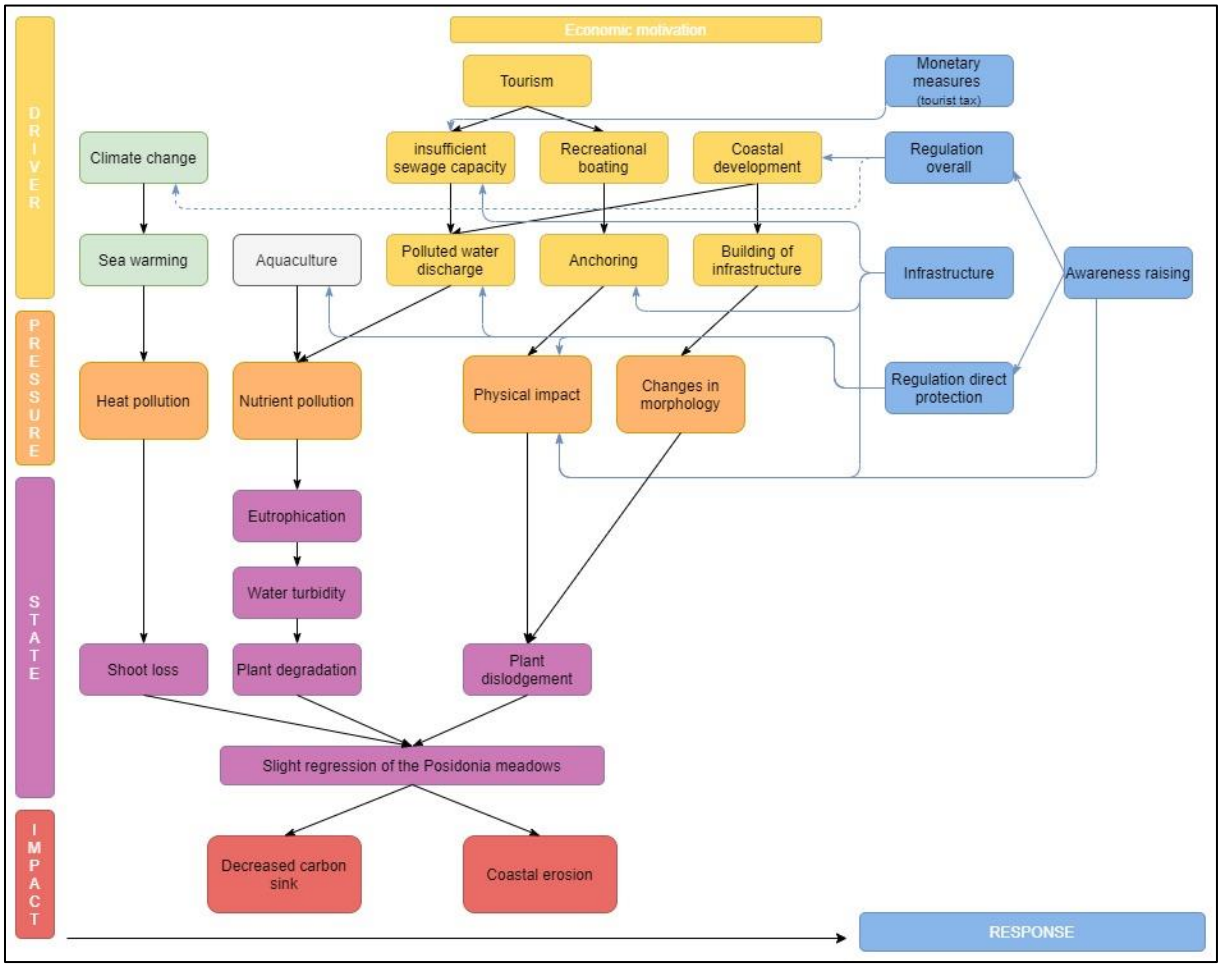

Figure 11. DPSIR diagram Balearic Islands[8].

[8] Climate change was added in green because of the distinct nature of this driver compared to the other more local and more explicitly anthropogenic drivers.

5.3.3. Past evolutions

5.3.3.1. Sewage discharge

A first issue that the Balearic Islands have been dealing with and that Marbà highlights is the discharge of sewage water into the sea due to an overload of the Balearic sewage system, especially during the peak tourist season. The overload is due to the limited capacity of the storm and wastewater treatment plants on the Balearic Islands, which are tailored to the size of the local population. The outflow into the sea of untreated organic matter and nutrients causes eutrophication, which increases the water turbidity. These conditions damage and limit the growth of Posidonia plants (Ralph, Tomasko, Moore, Seddon, & Macinnis-Ng, 2006)

The Balearic government has made efforts to improve water quality. However, increasing the capacity and effectiveness of water treatment requires costly investment in infrastructure. The relevant competencies for water, infrastructure, finance and conservation are split across different levels and departments of government, which complicates the decision-making and implementation processes, as has been illustrated by the history of inaction at the Palma facility. Financial resource limitations have also prevented the needed expansion and improvement of infrastructure. Interaction between such factors can add to inertia: if different agencies cannot agree, for example, this also makes it more difficult to assemble necessary funds.

An additional and complicating element that is brought up by Researcher IMEDEA is that federal policy involves the redistribution of regional tax revenues within Spain. Tax revenues of all the different Spanish regions are assembled centrally and redistributed back to the different regions by the national government. Recently, a Sustainable Tourism Tax (see 5.3.3.4) has been introduced by the regional government of the Balearic Islands that could partially address this issue, as this local tax is exempted from the redistribution regime. The resources gathered through this tax are to be invested in protecting environmental and cultural heritage that benefits tourists who visit the islands and could, in principle, be used to improve infrastructure that serves these purposes.

5.3.3.2. Recreational boating

Besides pollution pressures, Marbà explains that the Balearic Posidonia meadows also face physical disturbances from anchoring, causing the uprooting of shoots or the dislodgement of plant rhizomes or leaves, leaving scars in the meadows (Boudouresque et al., 2009; Francour et al., 1999; Milazzo et al., 2004), as explained in section 5.1.4.1. Several measures have already been taken to address this pressure. Marbà specifies that monitoring and dissemination actions have been adopted in the Balearic

islands and the government-led Posidonia LIFE project has installed infrastructure, Posidonia-friendly mooring spots (see Box 2), that can be reserved via an online booking platform providing an alternative for anchoring ("Action C1. Installation of anchoring points and definition of areas where yachts may anchor.," n.d.). Furthermore, the recent Posidonia decree (see 5.3.3.5) includes an explicit prohibition to anchor on Posidonia, thus offering an additional legal protection.

5.3.3.3. Coastal development

Another pressure to the Posidonia meadows at the Balearic Islands is the construction of infrastructure. Marbà indicates that regulations are much more restrictive and much more strictly applied than in some coastal mainland regions, so potential direct impacts from development activities are less likely. However, past development has disturbed the balance of the beach-dune systems and changed the sediment dynamics in the Balearic Islands. This interferes with the natural movement of sediments from the land to the water and vice versa, as well as along the coast, enhancing the risk of erosion and holding potential to affect the Posidonia meadows.

5.3.3.4. Sustainable Tourism Tax

The Sustainable Tourism Tax was brought up by Researcher IMEDEA in relation to the urgent need to improve water treatment plants. The tax was introduced in 2016 to support investments in the development and protection of the environment and sustainable tourism as a user-charge to compensate for the impacts of tourism on the environmental and cultural capital of the Balearic Islands and distortion of the local economy; e.g. the housing market ("What is the ITS?," n.d.). The funds gathered through the Sustainable Tourism Tax are re-invested in sustainable tourism projects “which have the objective of environmental development and protection, the promotion of sustainable tourism, the recovery of historical heritage, scientific research, the promotion of training and employment, and the acquisition and rehabilitation of housing for social renting” ("Purpose ITS," n.d.).

The broad definition of the objectives of the Sustainable Tourism Tax allows a wide variety of projects, including those related to the conservation of Posidonia, to fit within their remit. Projects monitoring and mapping the meadows, the improvement of a water treatment plant, and a project focussing on addressing pressures from recreational boating are funded by this tax already[9]. Extending and expanding such projects can help to further supporting Posidonia conservation and relieving pressures and impacts.

[9] Information about the funded projects can be found on the Sustainable Balearic Islands website: http://www.illessostenibles.travel/en/financed-projects/search

5.3.3.5. The Posidonia decree

The Balearic Posidonia decree ('El decreto Posidonia') was adopted in 2018 after a process of public information, during which contributions from stakeholders from different sectors were received (*El decreto de posidonia, pendiente de los dictámenes del CES y el Consejo Consultivo*, 2018). By legally enshrining a number of conservation actions and measures such as the mapping of the Balearic Posidonia meadows (article 3), their general protection (article 4), the management of dead Posidonia residues on the beaches (article 6), a prohibition of anchoring on the meadows (article 7), the establishment of a Posidonia committee (article 9) and dissemination and awareness raising (article 11), it constitutes a pioneering regulation in Europe (*El Consell de Govern aprueba un decreto pionero para conservar las praderas de posidonia*, 2018).

The decree has been criticised and challenged in court by nautical interests for targeting this sector too much, while insufficiently addressing 'the real problem' of sewage discharges caused by wastewater treatment plants and outfalls, which are a government responsibility (Colmenero, 2019). This finger pointing from the nautical sector to the government and vice versa was likewise brought up by Marbà. She stated that while everyone agrees that Posidonia must be preserved, both sides claim that it is the other side that is responsible for the decline of Posidonia.

5.3.3.6. Awareness raising

Awareness raising and dissemination campaigns are indicated by Marbà as an important strategy for Posidonia conservation at the Balearic Islands. The level of awareness of the Balearic people is estimated as above average by respondents also including those from other case studies. When asked about the reasons for this, Marbà referred to the role of media and government. The media has taken an interest in research related to Posidonia and has started communicating research results, which has led to the general public becoming more aware. Furthermore, she indicates that government initiatives, like the Posidonia LIFE project, have played a role in awareness-raising. These initiatives entail dissemination campaigns from government towards different groups. Firstly, teaching about Posidonia is included in the curriculum from a primary level onwards and schools participate in workshops organised by research institutes (Núria Marbà, personal communication, July 8, 2020). A different example of dissemination is a comic book developed by the Posidonia LIFE project to teach children about Posidonia ("Action E1. Development of material for the education of the general public," n.d.). Secondly, the Posidonia LIFE project aims to enhance the understanding of the general public about "the role of Posidonia oceanica and its importance in terms of habitat, conservation of

the population of various commercial species, and its role in the process of sand production" by distributing different kinds of media, such as posters, brochures and videos ("Action E1. Development of material for the education of the general public," n.d.).

The effects of the wider dissemination campaigns and education of the public were not specifically discussed. However, it was implied that increased awareness incites pro-environmental behaviour, eliminating certain pressures, and creating support for (stricter) conservation measures addressed to other pressures. The potential effect of awareness-raising on eliminating pressures by changing individual behaviour is clear. In relation to anchoring pressures, Marbà additionally refers to the active informing of boat users by guards and volunteers about anchoring restrictions in the nature reserves and availability of alternative anchoring locations. At the individual level, this has an immediate effect on the pressures to the Posidonia meadows.

5.3.4. Current situation

The current state of the Posidonia meadows surrounding the Balearic Islands is quite good. However, despite the many conservation actions adopted at the Balearic Island sites a slight decline of the meadows can be observed generally with bigger declines occurring at sites with high pressures. Drivers that continue to put pressures on the Balearic Posidonia meadows are the polluted sewage discharge caused by an overloaded sewage system and water treatment infrastructure as well as anchoring from recreational boating on the meadows. Likewise, the effects of coastal development can still be observed. Researcher IMEDEA stated that these drivers are strongly linked to Balearic Islands tourism, which is very important to the local economy. Finally, Marbà was also asked about invasive species as a potential stressor to Posidonia meadows. According to her, the pressure from invasive species is not as important as other pressures. It constitutes a more significant issue in the Eastern Mediterranean Sea than it does in the Western Mediterranean.

5.3.4.1. Sewage discharge

The persistence of pressure caused by polluted sewage discharge is mainly due to political and institutional factors, including compartmentalisation of responsibilities and the regime for redistributing financial resources within Spain, which has contributed to a net outflow of investment funds from the Balearic Isles to the rest of Spain. With the case of a water treatment plant in Palma, where the improvement of the water treatment plant has been dragging on for over two decades, Marbà illustrates that action is delayed due to the different levels and departments of government not being able to reach an agreement, as well as a general short term focus of politics. The high capital

cost of wastewater treatment facilities and the need for political decisions over planning capacities and financing of these wastewater treatment facilities complicate decision-making on this matter. It is conceivable – this was not discussed with the interviewees – that issues such as how much installed capacity is needed and who should pay for the extra capacity needed to meet peak loadings constitute points of contention between the different parties.

This issue is exacerbated by the tax revenue redistribution policy in Spain, which is brought up by Researcher IMEDEA. Despite the Balearic Islands being the region of Spain that generates the most revenues, thanks to tourism, authorities are not fully empowered to allocate locally-raised revenues to wastewater treatment because of the redistribution policy in Spain. The Sustainable Tourism Tax that was introduced in 2016 could address this issue. However, it is too early yet to observe the effects of the projects funded by the tax.

5.3.4.2. Recreational boating

According to Marbà, pressures generated by anchoring from recreational boating continue because tourists lack awareness and are difficult to reach. Actions in nature reserves by guards and volunteers to inform local boat users works well, but Marbà feels this is less effective as a way to inform the many tourists that visit the Balearic Islands. Additionally, Marbà states that controlling every single anchoring activity around the Balearic Islands is impossible, due to the limited resources available to monitor compliance relative to the number of boats. It is not yet apparent what the impact will be of the anchoring prohibition and awareness raising measures adopted through the Posidonia decree in relation to this pressure.

5.3.4.3. Climate change

Finally, climate change is raised by Marbà as an increasingly important driver affecting Posidonia. She mainly highlights the effects of heat events. A rise in temperatures and in frequency of heat waves due to global warming creates additional heat pressure on Posidonia meadows. The increased shoot recruitment that is observed after hot summers cannot make up for increased shoot mortality caused by heat events, meaning there is a net loss of shoots (Marbà & Duarte, 2010).

5.3.4.4. Impacts

Two impacts were mentioned linked to the degradation of Posidonia meadows: coastal erosion and the decrease of the carbon sink. Currently, coastal erosion is mostly a consequence of disturbance of

the beach-dune system, but there is interaction of dune systems and Posidonia meadows. Regressions of Posidonia meadows and associated reduction or loss of their sediment stabilising characteristics could amplify the coastal erosion process. Yet it is the role of the Posidonia meadows as a carbon sink that is of particular importance to the Balearic Islands, because of the extent of its Posidonia meadows. Marbà states that the meadows sequester an equal or even greater amount of carbon compared to the Balearic Island forests. Regressions of Posidonia meadows not only reduces their capacity to sequester carbon, but could also potentially lead to the release of carbon that has been stored in the matte for millennia (Marbà et al., 2014; Mateo et al., 1997). Other possible impacts that could be relevant to the Balearic Islands, such as a loss of ES of water filtration that supports tourism or a loss of biodiversity, were not mentioned or stressed by the respondents.

5.3.4.5. Possible and planned responses

However, more measures to improve the conservation of the Posidonia meadows can and should be taken according to the respondents. In terms of regulations, enforcement of the conservation measures enshrined in the Posidonia decree is to be improved and if necessary reinforced, especially in those areas where pressures from both anchoring and nutrient pollution are high. The capacity of water treatment plants is to be increased to improve the water quality. In addition, an integrated coastal zone management for activities both on land and in the water is proposed. This could reduce pressures from pollution and changes in morphology. A suggestion that made by Marbà to support the overall conservation of Posidonia is the integration of Posidonia in climate mitigation policies, considering its importance as a carbon sink. This could benefit both the mitigation of climate change and Posidonia itself, which is sensitive to warming. Finally, campaigns to raise awareness among tourists and to educate the local population are deemed necessary by the respondents. This would facilitate enforcement of the Posidonia decree and support further future action.

5.3.4.6. Barriers

Conservation actions around the Balearic Islands face a number of barriers currently. While the local population and policy-makers are generally aware of the importance of Posidonia and its conservation, tourists lack awareness about its presence, importance and the restrictions put in place to protect Posidonia. This contributes to persisting anchoring pressures. A search of online boating forums indicates displeasure and opposition of boat users regarding the mooring infrastructure and the price

of mooring.[10] The attitudes expressed could constitute an additional barrier, however, the extent and degree of embeddedness of unsupportive attitudes was not examined in this research.

In relation to both anchoring and nutrient discharge the respondents brought up the denial of responsibility by certain actors. Because certain actors and stakeholders deny the contribution of these drivers threatening Posidonia meadows they omit to take responsibility, despite acknowledging the importance of Posidonia. Marbà explains that port authorities and yacht associations minimise the importance of anchoring and blame Posidonia meadow regression on poor water quality. Governments in their turn point to pressures created by anchoring. This results in opposition to anchoring restrictions by the nautical industry and it complicates solving sewage discharge issues on top of the barriers explained in section 5.3.4.1. Furthermore, both issues face barriers imposed by resource limitations. Resource limitations make controlling every single anchoring activity around the islands impossible. A lack of financial resources has also delayed progress on water treatment. However, the Sustainable Tourism Tax might help alleviate this issue.

Other elements that complicate the conservation of Balearic Island Posidonia are related to the organisation of political institutions, political priorities and policy conflicts, as discussed before. ("Spain," n.d.; Suárez de Vivero, 2002). The short-term focus of politics due to regular elections complicates the adoption of an integrated, long term coastal management approach. The balancing of the conservation of Posidonia, with other policy priorities can prevent or complicate the implementation of environmental measures. Given how important tourism is to the local economy it tends to take priority. If measures are believed to affect touristic activities and if actors from the tourist industry oppose environmental conservation measures, their economic interests tend to be prioritised by local politicians.

5.3.4.7. Contextual factors

In relation to the drivers and pressure, no specific natural contextual factors were raised by respondents. Only the influence of past policy responses at the higher and particularly at the lower regional level was mentioned by interviewees. This means that the main reason for stressors not having been addressed is likely to be the presence of barriers. When discussing the lack of awareness as a barrier, both respondents firmly confirmed that they believe socio-cultural heritage and a connection to the sea influences awareness. Overall, the awareness of the local population of the

[10] See for example the following forum discussions: https://www.noonsite.com/report/balearic-islands-be-aware-of-the-posidonia-life-project-if-wanting-to-anchor/ and https://forums.ybw.com/index.php?threads/new-balearic-islands-law-effective-from-today.504634/

Balearic Islands is estimated to be quite good. Islanders are surrounded by sea and have always had a close connection to the marine environment. The main barriers to conservation of Balearic Island Posidonia meadows are related to political institutions and processes, where the context is partly locally determined but is also linked to the Spanish policy context and the local tax redistribution regime.

6. Case study comparison and discussion

6.1. Case comparison

6.1.1. Stakeholders

The conservation of Posidonia concerns actors from a variety of sectors: science, policy, business and society and it engages the activities of many people in different capacities. A number of stakeholder groups appear in all three case-studies: policy-makers across all policy levels (local, regional, national and international), scientific research institutes, the local tourist industry and other economic actors, the local population and tourists.

Generally, most local economic actors and tourist operators primarily have economic interests and their concern is that their activities could be affected negatively and directly by Posidonia conservation. Restrictions on boating, for example, could discourage people from renting boats or visiting certain harbours. Operators of beach bars and restaurants are worried that leaving Posidonia residues on the beaches could drive tourists to 'more attractive' alternative beaches or to other resorts and tourist destinations altogether. In consequence, these actors tend to stress their own (private and immediate-term) economic interests over (common and longer-term) environmental interests. The diving centres form an exception to this because their business interests and broader values are economically aligned with the conservation of Posidonia meadows, which help maintain the marine ecosystems and biodiversity that divers appreciate.

6.1.2. Drivers and pressures

Climate change is a unique driver that recurs in all three case studies. It is distinct from the other, more local drivers, however, because of its global scale and extremely complex nature. This is also a reason why this driver remains largely unaddressed, although some attention is paid in relation to the carbon sequestration and storage capacities of Posidonia and the potential role of Posidonia in climate mitigation policies. In all case studies, some reference was made to the cumulative impacts of local pressures causing Posidonia meadows and other marine ecosystems to be less resistant to climate change events overall, which is confirmed by Marbà and Duarte (2010).

Besides climate change, a common element in all three case studies is tourism. Tourism generates pressure on Posidonia meadows in different ways, through different activities. In a first instance, the influx of people due to tourism directly increases urban pressures such as sewage discharge. Recreational boating in the Mediterranean Sea is also strongly associated with tourism, though not

exclusively, and leads to anchoring pressures. Finally, a more indirect consequence of tourism is coastal development. In Mataró pressure to regenerate beaches is exerted by local tourist operators and related economic actors, such as hoteliers, to attract tourists. The construction of coastal infrastructure is partly linked to tourism, for example in the Balearic Islands, although this was not explicitly highlighted by the interviewees.

In first instance, it is not surprising that all case studies are faced by solely anthropogenic drivers, since this is known to be the main threat to Posidonia meadows. A number of drivers occur in more than one case study. Urbanisation and coastal development constitute a prominent issue in the field of Posidonia conservation, entailing both the construction of infrastructure and discharge of polluted water. Several researchers stated that the consequences of coastal development are much more severe compared to those of other drivers. The absence of this driver in the Seaforest LIFE case can likely be attributed to the fact that project sites are located within the boundaries of protected areas. The interviews with Guala and Scardi suggest that urbanisation and coastal development do create pressures on other places along the coasts of Sardinia and Campania. However, the construction of infrastructure is said to not have been a particularly important issue along the Campanian coast in recent years.

Anchoring occurs as a driver in both the Seaforest LIFE and the Balearic Islands case studies. The effects of anchoring are disputed. Differences of opinion are usually based on arguments that variance in physical and geomorphological characteristics, such as currents, sediment conditions, weather conditions or shape of the coast (straight coastline, bays, coves), influences the effects of anchoring on Posidonia meadows. The absence of anchoring in the Mataró case is attributed to morphological characteristics, namely the fact that Mataró has an open, straight coast.

Overload of the sewage system occurs only in the Balearic Islands case study. It is due to the current wastewater treatment capacity being insufficient to handle variation in wastewater volumes during the touristic season. In this specific case study, this seems to be the consequence of the high capital cost of wastewater treatment facilities and the planning and financing of capacity requiring political decisions. Reaching agreement is complicated by severe fragmentation of roles and authority in Spain, with different levels and many different agencies of government holding competencies in relation to this issue. This is exacerbated by the tax revenue redistribution regime in Spain. Politicians within the Balearic Islands are not able to allocate the necessary resources to wastewater treatment, despite the Balearic Islands generating high revenues, thanks to tourism.

The same issue does not occur in the Mataró case study, located on the Spanish mainland. This is likely to be because the significance of tourism in much higher in the Balearics, where the ratio of tourist visitors to local residents is extraordinarily high and very variable across the year , thus demanding a proportionally bigger investment in water treatment. Another element that could have played a role is that the Catalan government made investment in water quality a priority much earlier than the Balearic Islands as part of implementing the WFD, which was necessary given its position on the mainland.

Finally, the complexity of drivers and their interactions is particularly emphasised by the respondent from the Mataró project. Marine conservation generally faces challenges of complexity, because of the spatial interconnectivity of ecosystem processes. However, Seglar's emphasis stands out compared to the other case studies where this natural complexity is not raised as an issue. One explanation for this is the relevance of rivers in the Mataró case, which is lacking in both other case studies. This creates a stronger influence from inland activities, creating a more complex set of drivers.

The definitions for the DPSIR components that were applied for this research were based on literature about the application of the DPSIR approach in marine environments. Four categories of pressures were identified: pollution, changes in hydrology, changes in morphology and physical disturbances, and pressures on biology and its uses. However, of these four pressures, only two appear in the case studies. Whereas hydrological events and pressures on biology and its uses can affect Posidonia, these are mostly subsidiary to pollution pressures and changes in morphology and physical disturbances.

6.1.3. Impacts

Whereas Posidonia can provide many ES, only prevention of coastal erosion was mentioned for all three case studies. All other impacts (reduction of water clarity, decrease of the carbon sequestration and storage and habitat and biodiversity loss) were mentioned for two of the three case studies.

When analysing the interviews, impacts were not discussed as elaborately as other elements of the DPSIR framework. Whereas drivers and pressures are discussed very extensively, this seems much less the case for impacts. The 'impacts' code was applied only 32 times across all interviews. The 'driver' and 'response' codes on the other hand were applied 125 and 155 times, respectively. Remarkably, 22 of the 32 'impact' codes stem from the 5 interviews with the Seaforest LIFE and the Mataró projects.[11]

[11] The interviews with Marbà and Researcher IMEDEA for the Balearic Islands case study were not taken into account because they were originally interviewed as researchers, without intention of using the interviews foundation for case study analysis.

In the interviews with the Mataró project the number of impacts was also significantly lower than the 'driver' and 'response' codes. However, in the interviews with Seaforest LIFE the 'impact' code is applied as often as the 'driver' code. This indicates a slightly different discourse from the Seaforest LIFE project (moreover the only actual conservation project) compared to that of researchers.

An element mentioned by several interviewees (Scardi, Ruocco and Alcoverro and Researcher UoB) is the invisibility of the Posidonia ecosystem and the indirect effect of impacts. Some allusions are made that seem to suggest that impacts on society are only perceived to be relevant if the general public can observe them, mostly because they affect people's livelihoods. Looking at impacts mentioned in the case studies, this seems to be confirmed. All but one of the impacts are visible to society. Coastal erosion and water clarity can be observed (in time) by recurring visitors of the beach and play an important role in tourism, which constitutes an important economic sector in all three case studies. Habitat and biodiversity loss can be observed by and affect the activities of two specific stakeholders: divers and fishermen. A decrease of carbon sequestration and storage on the other hand is not visible to society, but it constitutes an important ES because of the extraordinary carbon sequestration capacities of Posidonia. Attention for this ES in a context of global attention for climate change mitigation is thus not completely unexpected.

6.1.4. Responses

While many common drivers and pressures occur around the coasts of EU member states, each case study has a unique set of past and current drivers and is at a different stage of addressing them, which results in different past, ongoing and desired/planned future responses. Firstly, regulations mainly from the EU or national level granting Posidonia a special status and/or addressing certain threats directly, such as anchoring or trawling, were adopted in the past in all case studies. Secondly, there was unanimous agreement about the importance of (further) awareness-raising as a response. Actions to raise awareness include the dissemination of information in oral and written form as well as participation to conservation activities. Awareness-raising occurs often at the initiative of researchers and conservation projects. Of the studied cases, the only one where awareness-raising is done top down by the regional government, is the Balearic Islands. The main purpose of increasing awareness is to generate a response. It can lead to the actor changing their behaviour, thus taking away that driver or pressure. This is, for example, the motivation for raising awareness among recreational boaters about the impacts of anchoring. Alternatively, respondents indicate that increasing awareness could generate a policy response in two manners. In a first instance, it can result in policy-makers recognising the need to take measures. Secondly, respondents believe that societal awareness can create a

support base for policy action, in some cases even in the form of voter support in elections, and can put pressure on politicians to take measures.

6.1.5. Barrier

A policy factor that complicates the conservation of Posidonia is the balancing between environmental and economic interests, where economic interests are usually prioritised. These economic interests are mostly linked to tourism, which constitutes a fundamental part of the (local) economies of the case studies. Environmental conservation measures are unpopular with economic actors because they often involve constraining tourists or reducing immediate amenity values. Measures are opposed by the tourist sector for fear of losing income. Leaving Posidonia residues on the beaches to protect the beaches from erosion is one such measure unpopular among tourist industry interests. Tourist interests pressure local politicians to prioritise their economic interests over environmental considerations. Interestingly enough, a disconnect has been found between tourists' perceptions and local tourist industry actors' perceptions of Posidonia, suggesting that there are cases where the latter feel more negatively about Posidonia residues on the beach than the tourists themselves. (Mossone, Guala, & Simeone, 2019). If this is the case for other conservation measures, this would mean more weight could be allocated to environmental interests than is allocated now. This is something to be investigated for different conservation measures.

For the Spanish case studies additional barriers constitute the fragmentation and compartmentalisation of decision-making competencies in coastal management. Multiple levels of government as well as different government agencies have exclusive or shared competences in a wide range of policy fields that affect coastal management. This causes overlap between the competencies of different administrations, but also gaps in responsibilities ("Spain," n.d.). The issue of administrative complexity did not come up in the Seaforest LIFE case. However, since Italy also constitutes a regionalised country with overlapping competences between the central and regional governments, this seems to be an issue that could come up in other Italian cases ("Italy," n.d.). Reasons why administrative complexity did not affect conservation in the Seaforest LIFE case seem to be the success of policy responses at the higher level (see 5.1.3.2) and the seemingly uncontroversial nature of the projects' responses to address pressures from anchoring and mooring. In addition to the administrative complexity, there is an inherent short-term focus of politics due to regular elections. The conservation of Posidonia demands a long term, integrated approach. This requires agreement to be reached between many different government actors and agencies as well as thinking past the next elections.

Another barrier is a lack of awareness of Posidonia and issues surrounding its status among local policy-makers, residents and tourists. Several interviewees mention that this is due to Posidonia ecosystems being invisible because they are submerged and the impacts of their decline on society are also not immediately visible. Knowingly and unknowingly people fail to obey restrictions and add to pressures on Posidonia meadows because they lack awareness. Lack of awareness among policy makers also contributes to lack of policy response or to the poor enforcement of measures that is observable in the case studies. Several interviewees stated a belief that awareness-raising would benefit acceptance of conservation measures.

In the Mataró case study, a third kind of barrier appears: knowledge uncertainty. The complexity of interactions (involving indirect, multivariate and cumulative effects) combined with limits on financial and scientific resources made available for research, make it difficult to acquire knowledge and evidence to reduce uncertainty. Contradictions among experts raises concern that this might not be limited purely to the Mataró case and that this might be a barrier that arises in other cases, though not to the extent of the Mataró case. The extent of complexity and associated uncertainty in the Mataró case could be related to the stronger inland connection due to the presence of rivers. A similar issue occurs – to a lesser extent – In In the Balearic Islands case, where the presence of multiple interacting pressures and cumulative effects was used by some stakeholders to deny their contribution to the regression of Posidonia and to blame other stakeholders. Uncertainty – or lack of definitive evidence – offers opportunity to deny responsibility. This is an aspect of complex systems that – from a perspective sustainability– raises a “burden of proof” issue and calls for applying a precautionary approach.

All of the above barriers contribute, directly or indirectly, to a delay or a lack of response from policy-makers. This leads to the persistence of drivers or pressures, especially those requiring a more difficult or integrated response. Only a limited number of barriers also complicate Posidonia conservation by reinforcing drivers or pressures. An overview of how these different barriers interact among each other and with the DPSIR components can be found in Appendix I.

6.1.6. Contextual factors

In order to examine context dependency of Posidonia conservation, it is necessary to consider what contextual factors distinguish or unite the different case studies. In first instance, different interviewees mention a number of geo-physical factors when describing and distinguishing different

sites and explaining drivers and pressures on Posidonia, especially the morphology of the coast in relation to the occurrence of anchoring pressures. An open sea with a straight coastline is less suitable for anchoring than a coastline or archipelago with many coves and bays. Whether the coastal plateau is extended or drops quickly also influences the amount of space available for anchoring. Where more space is available conditions are considered more favourable for anchoring. Furthermore, the presence of a river seems to be a natural factor that adds to the range of drivers and pressures affecting the Posidonia ecosystem and its conservation. In general, however, past policy responses that have successfully addressed some drivers and pressures are the reason certain drivers are pressures are less relevant now than previously. This is as expected, considering the DPSIR framework describes an iterative process. However, the three case studies show that not all drivers and pressures have been successfully addressed in all locations.

Remaining barriers are mostly those linked to political structures and processes and socio-cultural factors. The decentralised character of the power structure, comes forward particularly in the Spanish case studies. Furthermore, it appears that the management of Posidonia is affected by socio-cultural heritage and the type of tourism that is dominant. Firstly, the awareness of the local population about the role and importance of Posidonia is believed by most respondents to be higher when they have close socio-cultural or historical connections with the marine environment. Such close connection leads to people being more aware about the marine environment and valuing it. This helps compensate for the invisibility of the Posidonia ecosystem and causes people to be more aware of direct and indirect impacts. This factor highlights the relevance of the NPC and relational value concepts in conservation (see 2.1.4). Similarly, different types of tourist can be more or less receptive of stricter conservation measures. Several respondents state that conservation measures are more accepted when tourism does not focus only on sun and beach tourism.

6.2. Findings

The **overarching aim** of this research is to get a better understanding of barriers to the conservation of *Posidonia oceanica* and the role of contextual factors in this from a social-ecological perspective. The existing disagreement about the origin and scope of threats, about their contribution to the continuous regression of Posidonia and about the scale at which management actions should be taken suggests that Posidonia conservation faces spatial variability and so, is context dependent. The continuous regression of Posidonia despite extensive policies at the EU level, furthermore indicates there are still barriers to be overcome for successful conservation and that these are located at a more

local level in the implementation of higher level policies at the lower level. On the basis of the formulated research objectives and questions the following findings were obtained.

In terms of stressors a number of recurring drivers and pressures arise in the different case studies. However, every case study is confronted with a unique combination of drivers. This means there is some spatial variability in terms of stressors that is marked by some general trends. The similar drivers and pressures that occur are anchoring, coastal development, and sewage discharge – which is to some extent related to coastal development, but also to tourism. These drivers have a relatively local origin, scope and impact. The occurrence and scope of drivers and pressures is, apart from the influence of some natural factors, often linked to past policy responses. Tourism is an important common element that contributes to all of these drivers. It is also clearly put forward by respondents as the main motivation for sustaining activities and behaviour threatening the Posidonia meadows. Finally, all case studies experience pressures from climate change to which, moreover, the Posidonia meadows have become less resilient due to the cumulative impacts of local pressures

While Posidonia provides many ES, the same four impacts are mentioned by the respondents from the different case studies. Impacts of declines of Posidonia meadows are coastal erosion, reduction of water clarity, decrease of the carbon sequestration and release of carbon from the historical store, and habitat and biodiversity loss. Impacts were defined as any direct and indirect positive and negative consequences for society as a result of changes in the natural system. The limited number of impacts that were mentioned by the interviewees stands out, because of this broad impact definition and the many ES Posidonia provides. Reasons advanced by the respondents for this are the invisibility of the Posidonia ecosystem and the indirect effect of impacts. Some allusions are made that seem to suggest that impacts on society are only perceived to be relevant if the general public can observe them, mostly because they affect people's livelihoods.

Each case study has a unique set of past and current drivers and is characterised by different past, ongoing and desired responses. However, some common trends can be identified and two commonalities in the responses stand out. Firstly, regulations from the EU or national level providing direct protection to Posidonia and/or limiting activities that put pressure on Posidonia, have been fundamental to its conservation. Secondly, there was almost unanimous agreement among the interviewees about the importance of (further) awareness-raising as a response.

In addition, a few things can be said about how specific stressors are addressed in the different case studies. Introducing an anchoring prohibition has proven insufficient in both the Seaforest LIFE and the

Balearic Islands case study. The provision of an alternative anchoring infrastructure is insufficient and needs to be accompanied by active enforcement. Furthermore, awareness raising is crucial, because a lack of awareness is an important factor in the persistence of this pressure.

The researchers often indicate the need for an integrated coastal management to support the conservation of Posidonia. Particularly, addressing pressures from coastal development and sewage discharge requires such structural, integrated response involving all relevant parties. Particularly in the Mataró case pressures from coastal development continue to exist. Different barriers prevent an integrated response to this pressure from being adopted. Firstly, complexity of the issue, due to many indirect and multivariate relations of different coastal development activities, and knowledge uncertainty have led to local policy-makers denying responsibility. Additionally, coastal matters are not allocated to a single authority, but different levels and departments of government are responsible for coastal matters and relevant issues. This administrative complexity complicates decision-making in coastal matters. The same issue of administrative complexity is observed in the Balearic Islands case study in relation to sewage discharge issues, which require big infrastructural installations. On the other hand, limited resources prevent the Mataró project from (contributing to) overcoming these barriers. Therefore, the project focusses on talking to local authorities regarding beach regenerations and individual infrastructural projects. Furthermore, it works on awareness raising among the general public through education. In the other case studies researchers have also underlined the importance of (further) developing a more integrated approach for coastal management. Sewage discharge issues also require big infrastructural installations. In the Balearic Islands case study, a lack of resources as a consequence of administrative complexity, complicating reaching an agreement between different governments about political decisions over planning capacities and financing has prevented this issue from being fully addressed so far. Generating own revenues through a Sustainable Tourism Tax to invest in this kind of infrastructure could help address this issue.

The comparative case study analysis revealed that the barriers faced are not specific to an island or mainland context. Similar barriers were identified in the different case studies, namely those relating to political institutions and processes and a lack of awareness. The overarching issue to which these different barriers contribute is a lack of (adequate) response and – associated with that – a lack of an integrated coastal management. In a complicated case, like the Mataró case study, a high level of knowledge uncertainty adds an extra barrier, which complicates generating a response from policy-makers. Uncertainty is caused by the complexity and a lack of resources to provide needed knowledge.

In conclusion, the data of the three case studies only partially supports the hypothesis of spatial variability based on an island-mainland distinction. Drivers, pressures, responses and barriers differ between case studies. However, some general trends in terms of stressors, impacts and barriers can still be observed. The contextual factors that influence these differences could not be connected to specific island or mainland contexts.

6.3. Recommendations

Based on the above comparison and findings, a number of recommendations are formulated to address the lack of awareness, the policy barriers and the issue of knowledge uncertainty. In order to generate responses at the policy level these common barriers need to be addressed. This will result in aligning the different stakeholders and allow the adoption of both direct protection measures and a more integrated, long term approach.

6.3.1. Awareness raising

Increasing awareness by dissemination of information and participation to conservation activities is an evident response when dealing with barriers caused by a lack of awareness. The main purpose of increasing awareness, according to the respondents, is generating a response in the form of a change of behaviour. Additionally, increasing awareness could generate a stronger policy response. In the case studies, three groups are targeted by awareness raising efforts: the local population, (local) policy-makers and tourists.

Raising the awareness of the local population is effective when threats can be eliminated by a change of individual behaviour such as anchoring. In that case, awareness can incite an immediate behavioural change that reduces the pressure. However, turning awareness-raising into a policy response (see 6.1.4) can be expected to be a slow process. Especially in the Mataró case this can be expected to take time and would therefore on its own not be very effective as a response due to the complexity of the issue and other policy barriers.

Since socio-cultural heritage that involves a close connection with the marine environment benefits awareness of the public about the roles and importance of Posidonia, enhancing this heritage could benefit the conservation of Posidonia. This interplay between cultural and natural heritage and the need for greater cooperation between the two has increasingly been recognised within the EU (European Commission, 2018). The enhancement of this socio-cultural heritage connected to the marine environment can take many forms, such as inclusion in the educational curriculum, support for

or restoration of traditional marine activities – through which a connection with tourism could be made – or inclusion of a stronger social or cultural aspect in marine conservation projects. However, since socio-cultural heritage can be enhanced in many ways further research is needed on how to enhance socio-cultural heritage in a way that raises awareness about and supports the conservation of Posidonia.

The awareness of policy-makers at the local level is indicated as problematic in the Seaforest LIFE and Mataró case studies. Raising awareness among policy-makers could help change their priorities. However, most interviewees already engaged with these actors to some extent. This could indicate that awareness raising needs to reach further than current actions and aim to achieve a deeper learning. On the other hand, a number of other policy barriers need to be addressed in order to address the lack of policy response (see 6.3.2.).

Ultimately, awareness raising among tourists can change individual behaviour, eliminating pressures from anchoring. In addition, the perception and awareness of tourists plays a role in sustaining activities and behaviour threatening the Posidonia meadows and placing limitations on certain touristic activities is opposed by tourist operators for fear of losing income. Addressing this issue requires a more profound approach than simply awareness-raising through information campaigns. Because the level of awareness and the perception of tourists about Posidonia and the motivation is linked to the type of tourism that is common in a place, promoting a more eco-friendly type of tourism could benefit Posidonia conservation. This could also be connected to actions enhancing socio-cultural heritage. Unfortunately, the effects of eco-tourism on Posidonia conservation could not be further explored in this study and requires further research. Furthermore, a disconnect has been found between the perceptions of tourists and those of economic actors in the tourism sector (Mossone et al., 2019). While a change in the type of tourism could induce a change in tourists operators' perceptions, it remains questionable whether awareness-raising or a more eco-friendly tourism will suffice. A sufficiently strong connection needs to be created between local economic interests and the conservation of Posidonia.

The Seaforest LIFE project attempts to create such connection by setting up a carbon credit system (see 5.1.1.3). Additional benefits brought up by Ruocco is that the local touristic industry actors that are involved in the Posidonia carbon credits market can additionally play a role in raising awareness among tourists. By communicating about their participation in the Seaforest LIFE carbon credit scheme, the tourist industry actors create a positive image through environmental action and inform tourists about the existence and importance of Posidonia. However, since carbon credit systems are

very new in the field of seagrass conservation, their effectiveness is still to be demonstrated, which will take a considerable time. Considering the importance in influencing local administrations, different ways to create a connection between the economic interests of the touristic industry and environmental conservation interests should also be examined further. It can be concluded that awareness raising can create some response and can provide a foundation for policy responses. However other actions are needed to generate a policy response in situations where also a 'policy barrier' or knowledge uncertainty play a role.

6.3.2. Boundary work

Other actions are needed to address barriers related to administrative complexity and the balancing between environmental and other interests, where other interests usually get priority. Realising an integrated long-term approach is challenging in a context where many stakeholders from policy, science, business and society with diverging opinions and interests meet. The adoption of an integrated approach at a higher level could help overcome this barrier. However, while ICZM and MSP have already been adopted at the higher level[12], they have not yet reached lower levels. The reasons for this, however, do not fall within the scope of this research.

Overall, overcoming issues of administrative complexity and diverging opinions generating action at the local level requires boundary work. Boundary work consists of cooperating across sectoral boundaries, while continuing to demarcate clear boundaries between those sectors (Hoppe, 2010). In the different case studies, some interaction across different sectors exist, however, there does not seem to be any boundary arrangements. Boundary arrangements institutionally facilitate cross-sectoral interactions and knowledge or power structures in a given policy domain (Hoppe, 2010). They create the necessary participatory and opinion-shaping systems for coordination and cooperation (Suárez de Vivero, 2002; Suárez de Vivero & Rodríguez Mateos, 2005) for overcoming the barriers that occur in a context with many stakeholders that hold diverging opinions and interests. Through inclusive participation of stakeholders, mutual accountability, the creation of boundary objects, the co-production and sharing of knowledge and meta-governance and capacity building a more profound response can be generated at the policy level.

An example of such boundary arrangements is the Posidonia Committee that is to be established at the Balearic Islands by the Posidonia decree. The Posidonia decree states that a collegiate body "with

[12] The Barcelona Convention Protocol on Integrated Coastal Zone Management (ICZM) and the EU Directive (2014/89/EU) establishing a framework for maritime spatial planning (MSP) already provide in such integrated approach and apply to all case studies.

functions of deliberation, advice, proposal, monitoring and control in matters of Posidonia oceanica" is established. This committee is composed of stakeholders from regional governmental authorities and agencies, research institutes, fishermen, the recreational boating sector and NGOs. The effects of the establishment of this committee are still awaited, however, since it has only recently decided about the funding of its first ten projects.

The Mataró case would benefit from a boundary arrangement involving multiple stakeholders in order in relation to the coastal development issues. The boundary arrangement would serve as an environment where problem structuring can take place through joint problem formulation and the co-creation and sharing of knowledge (Vinke-De Kruijf, 2020) for policy-makers, scientists and tourist industry actors.

6.3.3. Addressing knowledge uncertainty

The complexity of the issue in the Mataró case creates a high level of knowledge uncertainty, which leads to policy-makers denying responsibility. This uncertainty is a characteristic of complex systems it shares with many cases of environmental decision-making (Ascough, Maier, Ravalico, & Strudley, 2008).

At the international and EU level, the precautionary principle is promoted as a central principle to guide decision-making and legitimise action in relation to the protection of the environment in situations characterised by risk and uncertainty (van Asselt & Vos, 2006). It entails that in case of threats of environmental damage where scientific certainty is missing states still have to take action and prevent environmental degradation (Kayikci, 2012). Furthermore, the precautionary principle can in some cases shift the burden of proof. In environmental law the burden of proof commonly lies with the opponents of potentially harmful activities. The increasing awareness of the unpredictability, severity and potential irreversibility of environmental effects of human activities has given rise to the precautionary principle, which shifts the burden of proof to those who intend to carry out potentially-damaging activities to demonstrate these will not harm the environment (Kayikci, 2012). However, this shift in the burden of proof is contested and does not universally apply.

Knowledge uncertainty additionally needs to be addressed through research and scientific consensus building to increase confidence and acceptance of findings . Busch, Brekke, Averyt, Jardine, and Welling (2013) have addressed this issue in the analogous arena of climate change. They identify several factors that contribute to improving acceptance and dialogue: a communication network; the translation of

science as well as a capacity for continuous assessment; coordination of efforts at different levels, eliminating duplication; improving access to data and information; and improving understanding of the impact of laws and regulations on adaptation policy and implementation (Busch et al., 2013). The suggestion made by respondent from the Mataró project for the establishment of a new research project along the Catalan coast that simultaneously creates a network with existing research programmes fulfils these elements. Such a network allows coordination, communication and sharing information and can help overcome this barrier to the adoption of conservation measures.

6.3.4. Further research

This research has revealed many issues and angles that are worth researching further. Firstly, a number of alternative research angles that are worth exploring were not pursued (see 3.1.2.2), mainly due to practical considerations. This included the comparison of Posidonia conservation in countries with different geopolitical contexts, for example European and African countries or EU and non-EU countries, the comparison of Posidonia meadows located in an international environment, meaning they could potentially experience influences from multiple countries, to meadows that meadows that would not experience such influences[13], the effects of the presence or absence of a river in different cases or the comparison of islands across the Western and Eastern Mediterranean. Any of these research angles could provide a basis for further research.

Secondly, a number of research issues further exploring the findings of the present research came up. Further research is needed on the best ways to enhance socio-cultural heritage in support of Posidonia conservation. The potential role of marketing tourism differently to attract different types of tourist also provides a subject for further research. Ways of creating a connection between the economic interests of the touristic industry and conservation interests should be examined further. Finally, research should explore the implementation of ICZM at the national level in Spain (and Italy) and its (potential) effect on Posidonia conservation with a view to examining local implementation.

6.4. Reflection and limits to inference

This study's limitations need to be taken into account when interpreting findings. In first instance, the selection of case studies was limited by feasibility considerations (resources and willingness and

[13] An interesting case would have been to study meadows located in the Adriatic sea on the east coast of Italy, with potential influences from Croatia, Bosnia, Montenegro and Albania, and meadows in the Tyrrhenian sea on Italy's West coast

availability of people to contribute) and thus a limited number of case studies was examined. This implies that the findings of this research are only valid for the three case studies that were examined. The number of interviewees was also limited, which entails the risk of reflecting few perspectives on the case. In addition, it would have been desirable to interview more actors and stakeholders for the different case studies as the interviewees were only able to provide a secondary account about the standpoints and opinions of these. In the end, the research included only one real conservation project. With regards to the Balearic Island case study it is to be noted that at the time of the interview, it was not considered as main information source for this case study, so certain aspects were not discussed in the depth ideally needed to serve as foundation for the case study analysis. Further expansion by the interviewer on certain answers did not always happen, due to the limited experience of the interviewer in conducting interviews.

Regarding the DPSIR framework it is to be noted that the original DPSIR elements would not have sufficed to explain the conservation issues in the case studies. The barriers component, which is not included in the DPSIR framework, has appeared crucial for explaining the SES, particularly when it comes to disconnects between responses and the other DPSIR components. Besides a few small improvements that could be made in the transcription and coding process, the overall methodological approach proved adequate for its intended purpose and could be applied easily.

7. Conclusion

An exploratory comparative case study analysis applying the DPSIR framework to perform systems' analyses revealed that the data of the three case studies only partially supports the hypothesis of spatial variability based on an island-mainland distinction. Drivers, pressures, responses and barriers differ between case studies however, some general trends in terms of stressors, impacts and barriers can still be observed. The contextual factors that influence these differences could not be connected to specific island or mainland contexts. The island-mainland hypothesis is therefore not supported by the data.

Similar barriers were even identified in the different case studies: barriers connected to policy structures and processes and to a lack of awareness. A policy barrier occurs due to the administrative complexity of a decentralized state and of the involvement of multiple stakeholders, policy-makers prioritizing other policy interests and the short-term focus of policy due to regular elections. These elements exacerbate the gap between policy and science, which advocates for an integrated, long-term approach. A lack of awareness exists among local policy-makers, the general public and/or tourists. is blamed partly on the invisibility of the Posidonia ecosystems and the indirect effect of potential impacts. Two socio-cultural elements play a role in the level of awareness of the local population and local policy-makers: the socio-cultural heritage and background of people can affect their strength of connection to the sea while the dominant type of tourism is relevant to understanding the interests and perceptions of tourists and their predisposition to be sensitive to conservation efforts and accepting of restrictions. In a complicated case, like the Mataró case study, a high level of knowledge uncertainty complicates generating a response from policy-makers. Uncertainty is caused by complexity and a lack of resources for acquiring needed knowledge.

The study was able to formulate recommendations to address these challenges. Increasing awareness by dissemination of information and participation to conservation activities is an evident response. Enhancing socio-cultural heritage, promoting a more eco-friendly tourism or creating connection between economic and conservation interests are other ways that can contribute to the awareness of stakeholders. While awareness-raising can provide a foundation for policy responses, additional action is needed in situations where also a 'policy barrier' plays a role. Overall, overcoming issues of administrative complexity and diverging opinions generating action at the local level requires boundary work. Boundary arrangements institutionally facilitate cross-sectoral interactions and knowledge or power structures in a given policy domain. They create the necessary participatory and opinion-shaping systems for coordination and cooperation of different stakeholders.

Finally, the complexity of the issue in the Mataró case creates a high level of knowledge uncertainty, which leads to policy-makers denying responsibility and thus creates a barrier to the adoption of conservation measures. This uncertainty is a characteristic of complex socio-ecological systems. In order to improve evidence and raise confidence in research findings dialogue must be improved. Relevant factors here include the development of a communication network; the translation of science; a capacity for continuous assessment; coordination of efforts at different levels; eliminating duplication; improving access to data and information; and, improving understanding of the impact of laws and regulations on adaptation policy and implementation.

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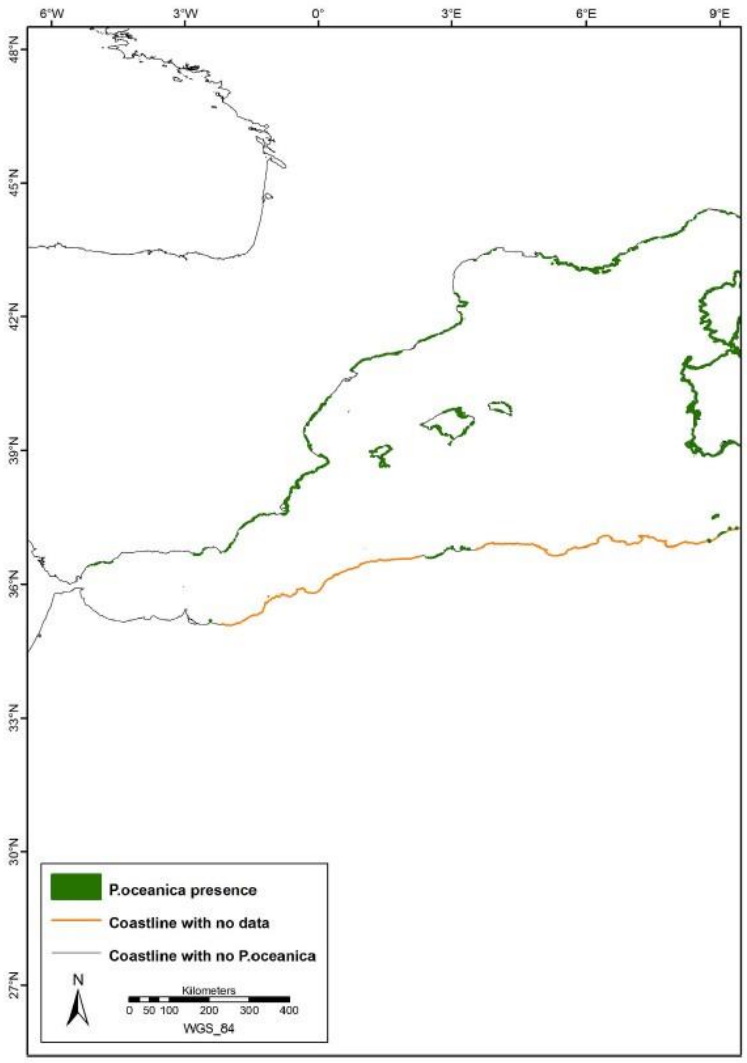
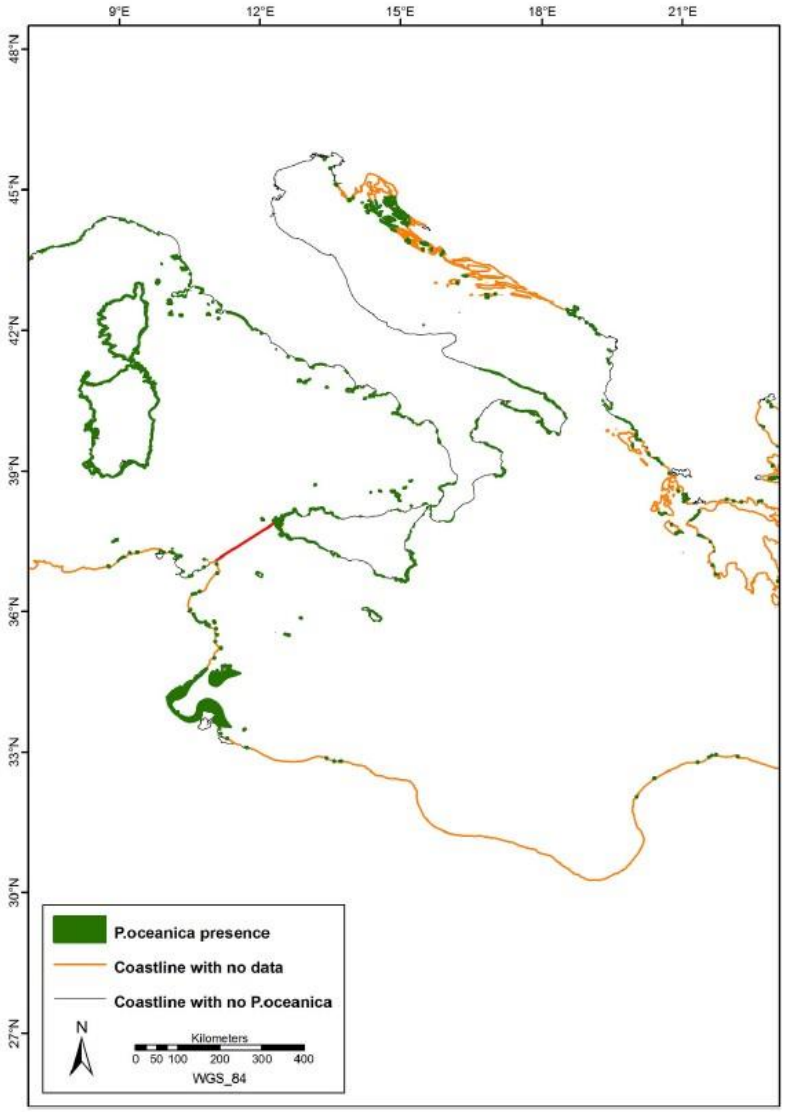
Appendices

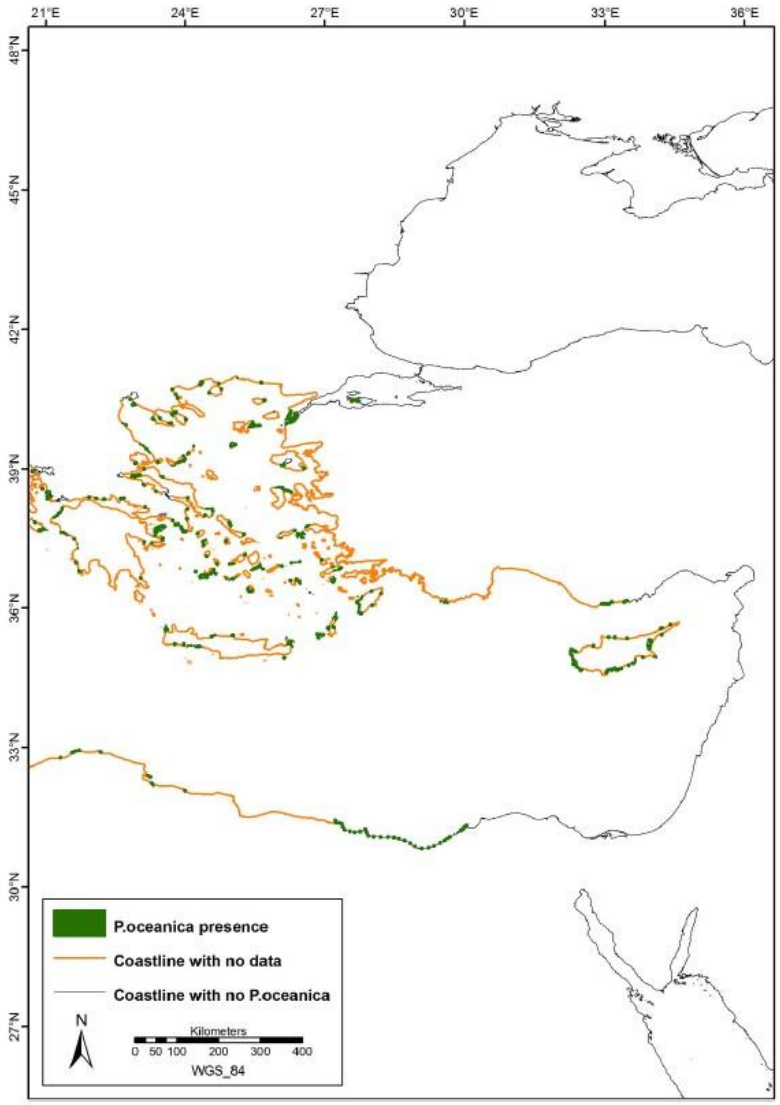
A. Distribution of *Posidonia oceanica* in the Mediterranean Sea



Distribution of *Posidonia oceanica* meadows in the Western Mediterranean Sea in 2015 (Telesca et al., 2015).



Distribution of *Posidonia oceanica* meadows in the Central Mediterranean Sea in 2015 (Telesca et al., 2015).



Distribution of *Posidonia oceanica* meadows in the Eastern Mediterranean Sea in 2015 (Telesca et al., 2015).

B. Overview international and EU policies and regulations

Regulation	Abbreviation	Year	Description/aims	Scope	Legal status	Posidonia protection
Convention on the Conservation of European Wildlife and Natural Habitats	Bern Convention	1979	Aims to conserve flora and fauna and their natural habitat, with particular attention for endangered and vulnerable species as well as to promote European in this field. It covers most the natural heritage of the European continent and has some extensions into Africa (Boudouresque et al., 2006; "Presentation of the Bern Convention," n.d.).	International (EU and non-EU)	Legally binding	Special conservation status for *Posidonia oceanica* as a species since 1996
Mediterranean Action Plan	MAP	1975	Established with the aim of providing an institutional framework for cooperation in addressing common barriers of environmental degradation in the Mediterranean Sea. The MAP's original objectives were to assist the Mediterranean governments in assessing and controlling marine pollution, in formulating national environmental policies and in building capacity to identify better development options and allocation of resources. Nowadays, the MAP concerns themes of land and sea-based pollution, biodiversity and ecosystems, land and sea interactions and processes, integrated coastal zone management, sustainable consumption and production, climate change adaptation and governance (European Commission, 2019a; "What we do," n.d.; "Who we are," n.d.).	Mediterranean region	Legally binding	General contribution through pollution management, biodiversity and ecosystem conservation and Integrated Coastal Zone Management (ICZM)
Convention for the Protection of the Marine Environment and	Barcelona Convention	1995	The main objectives of the Barcelona Convention are the assessment, control, prevention and reduction of pollution in the Mediterranean sea, the sustainable			- Dedicated Action Plan for Posidonia under the Protocol concerning

the Coastal Region of the Mediterranean			management of natural marine and coastal resources, the integration of the environment in social and economic development, the protection of natural and cultural heritage, strengthening solidarity among Mediterranean coastal States and contributing to improvement of the quality of life. The Convention has been supplemented with seven additional Protocols addressing specific aspects of Mediterranean environmental conservation. Together, the MAP and the Barcelona convention provide a comprehensive institutional, legal and implementing framework for protecting and enhancing the marine and coastal environment while promoting sustainable development in the Mediterranean region (European Commission, 2019a; "What we do," n.d.; "Who we are," n.d.).			Specially Protected Areas and Biological Diversity in the Mediterranean - Listing of magnoliophytes, among which *Posidonia oceanica*, as endangered or threatened species
European Council Directive (92/43/CEE) on the conservation of natural habitats and of wild fauna and flora	Habitats Directive	1992	Aims to promote the conservation of biodiversity by compiling a list containing a wide range of rare, threatened or endemic fauna and flora that are to be protected, while also taking into account economic, social, cultural requirements and regional and local characteristics. An EU wide Natura 2000 ecological network of protected areas is created through the Habitats Directive. These Natura 2000 sites are selected, based on a number of scientific criteria, to safeguard them against potentially damaging developments and ensure the long-term survival of Europe's most valuable and	EU	Implementation at the national level	- Listing of Posidonia meadows as a priority habitat for conservation - The Natura 2000 network greatly increased the number of protected seagrass sites across Europe (De los Santos et al., 2019), of which

			threatened species and habitats. (De los Santos et al., 2019; European Commission, 2019b, 2019d, 2020).			524[14] Posidonia beds
Directive (2000/60/EC) establishing a framework for Community action in the field of water policy	EU Water Framework Directive (EU WFD)	2000	Aims to coordinate the application of a number of measures that had been taken at EU level to tackle particular water pollution problems. In doing so, the EU pursued a number of objectives: expanding the scope of water protection to all waters, surface waters and groundwater; achieving "good status" for all waters; introduce a water management based on river basins; apply a "combined approach" of emission limit values and quality standards; getting the prices right; getting the citizen involved more closely; and streamlining legislation (European Commission, 2019c).	EU	Implementation at the national level	- Indication of seagrasses as key indicators of ecosystem health - Improving water quality
Directive (2008/56/EC) establishing a framework for community action in the field of marine environmental policy	Marine Strategy Framework Directive (MSFD)	2008	Created a framework that established an integrated approach to maritime activities and provides a long-term policy vision for Europe's marine environment. It obliges the EU member states to take the necessary measures to achieve or maintain "good environmental status (GES)" of the marine environment. (European Commission, 2011; Telesca et al., 2015)	EU	Implementation at the national level	Angiosperms have been listed as an indicator for GES and *Posidonia oceanica* as a representative species of the angiosperms, hence indirectly supporting Posidonia conservation.
Council regulation (No. 1967/2006) concerning	Common Fisheries Policy (CFP)	2006	The CFP manages European fishing fleets and for conserving fish stocks in order to ensure environmentally, economically and socially sustainable fishing and aquaculture, providing a	EU	Legally binding	protects Posidonia meadows both in a direct and an indirect way.

[14] Number based on a search by habitat type of Posidonia beds (Posidonion oceanicae) on the public Natura 2000 Network viewer (https://natura2000.eea.europa.eu/#) of the European Environmental Agency, which shows the status of the Natura 2000 network until 2019.

management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea			source of healthy food for EU citizens. It wants to achieve this by fostering a dynamic fishing industry and ensuring a fair standard of living for fishing communities (European Commission, n.d.). The Council regulation concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea was adopted in the context of the CFP (Council of the European Union, 2006).			- Prohibits the use of towed gears above 50 meters depth (entailing an indirect protection of Posidonia which grows up to 45m deep) - Specifically prohibits "fishing with trawl nets, dredges, purse seines, boat seines, shore seines or similar nets above seagrass beds of, in particular, *Posidonia oceanica*" (Council of the European Union, 2006)

C. Table DPSIR definitions

Paper	Definition
Driver/driving force	
Motivation Human needs and social and economic developments in society based on/as a consequence of human needs	
Action/activity The human activity that takes place as a consequence of the human need or social and economic development	
Gabrielsen, P., & Bosch, P. (2003). Environmental Indicators: Typology and Use in Reporting. (EEA)	describe the social, demographic and economic developments in societies and the corresponding changes in lifestyles, overall levels of consumption and production patterns
Mateus, M., & Campuzano, F. (2008). The DPSIR framework applied to the integrated management of coastal areas.	an established social need that represents a factor and social force that may induce changes in the state of the environment. This social need usually arises from the economical sphere, which means that drivers are frequently linked to the financial system. As such, drivers are usually considered to be economic and social goals of those involved in the industry, as well as economic and social policies of governments. In coastal areas, shipping, fisheries, tourism and aquaculture are among the most commonly mentioned drivers of DPSIR models.
Borja et al. (2006). The European Water Framework Directive and the DPSIR, a methodological approach to assess the risk of failing to achieve good ecological status.	the economic and social policies of governments, and economic and social goals of those involved in industry
Lewison et al. (2016). How the DPSIR framework can be used for structuring problems and facilitating empirical research in coastal systems.	Driving forces were almost exclusively anthropogenic factors such as population growth, demographic change (e.g., coastal urbanization), economic and industrial development, and climate change (although there were alternative perspectives on whether this should be considered an environmental driver given society's limited options to reverse its current trajectory). Coastal hazards and species invasions were also sometimes referred to as environmental drivers
Gregory, A. J., Atkins, J. P., Burdon, D., & Elliott, M. (2013). A problem structuring method for	In the context of the marine environment, the over-arching Drivers of social and economic development change refers to the need for food, recreation, space for living, and other basic human needs (Gray and Elliott, 2009; Atkins et al., 2011a) which are delivered through fisheries, recreational sites, bioremediation of waste, and so forth

ecosystem-based management: The DPSIR modelling process.	
Atkins, J. P., Burdon, D., Elliott, M., & Gregory, A. J. (2011). Management of the marine environment: Integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach.	need for food, recreation, space for living, and other basic human needs (Gray and Elliott, 2009) which are delivered through fisheries, recreational sites, bioremediation of waste, and so forth
Elliott et al. (2017). "And DPSIR begat DAPSI(W)R(M)!" - A unifying framework for marine environmental management.	Basic human needs
Newton, A., & Weichselgartner, J. (2014). Hotspots of coastal vulnerability: A DPSIR analysis to find societal pathways and responses.	Natural hazards and anthropogenic drivers Social and economic drivers. These include demography, health, education, governance, wealth, social needs, social networks, degradation of social-ecological systems, as well as development, urban, economic and technological.
Kristensen, P. (2004). The DPSIR Framework.	A 'driving force' is a need.

Pressure Means through which drivers (human activities) exert pressures on/cause changes to the natural system 4 categories (*this could change based on the narrative of the interviewees*) (i) pollution, comprising urban, industrial, agricultural and aquaculture discharges; (ii) alteration of the hydrological regime, including water abstraction, flow regulation and restoration activities; (iii) changes in the morphology, including land reclamation and infrastructures; and (iv) biology and its uses, including all kind of resource exploitation, changes in biodiversity and recreation	
Gabrielsen, P., & Bosch, P. (2003). Environmental Indicators: Typology and Use in Reporting. (EEA)	developments in release of substances (emissions), physical and biological agents, the use of resources and the use of land by human activities

Mateus, M., & Campuzano, F. (2008). The DPSIR framework applied to the integrated management of coastal areas.	means through which drivers are actually expressed, i.e., in the way they interfere and perturb the system. link between socioeconomic activities and the natural system. In a sense, all human activities end up by generating pressures on the environment, to a lesser or greater degree existing pressures on estuarine and coastal areas can be divided into four groups: […] (Borja et al., 2006) As such, pressures fall into three general categories that range from simple interference to inducing changes in the natural functioning of ecosystems: (a) fluxes into water bodies, (b) excessive usage of natural resources, and (c) changes in the food web
Borja et al. (2006). The European Water Framework Directive and the DPSIR, a methodological approach to assess the risk of failing to achieve good ecological status.	The ways that these drivers are actually expressed, and the specific ways that ecosystems and their components are perturbed, i.e. for the ecosystem effects of fishing, the central pressure would be fishing effort. Hence, the existing number of pressures were identified and divided into four groups: (i) pollution, including urban, industrial, agricultural and aquaculture discharges; (ii) alteration of the hydrological regime, including water abstraction, flow regulation and restoration activities; (iii) changes in the morphology, including land reclamation and infrastructures; and (iv) biology and its uses, including all kind of resource exploitation, changes in biodiversity and recreation.
Lewison et al. (2016). How the DPSIR framework can be used for structuring problems and facilitating empirical research in coastal systems.	pressures are changes in environmental parameters resulting from human activities (e.g., increasing levels of contaminants as a result of an increased volume of wastewater discharge as population grew).
Gregory, A. J., Atkins, J. P., Burdon, D., & Elliott, M. (2013). A problem structuring method for ecosystem-based management: The DPSIR modelling process.	Unless mitigation is employed, each of these Drivers has the potential to create Pressures on the system, such as the exploitation of fisheries, removal of the seabed, demands for the conservation of coastal amenity and marine biodiversity, and the discharge of contaminated waters.
Atkins, J. P., Burdon, D., Elliott, M., & Gregory, A. J. (2011). Management of the marine environment: Integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach.	recognition that there are natural pressures (based on ecology, climate, and other dynamic conditions) on the ecosystem which can lead to State Changes (natural variability & exogenic unmanaged pressures) pressures on the system can be locally/regionally/internationally endogenic managed pressures (such as power generation, and fisheries) or exogenic unmanaged pressures (such as climate change, and volcanic eruptions) Pressures on the system, such as the exploitation of fisheries, extraction of the seabed, demands for the conservation of coastal amenity and marine biodiversity, and the discharge of contaminated waters

	- endogenic managed pressures where the causes of potential adverse effects (e.g. power generation, fisheries, land claim) come from within a system and require local, regional, and/or international management - exogenic unmanaged pressures (Elliott, 2010). The latter are those pressures such as climate change, geomorphic isostatic activity and movement of alien species, for which our local management cannot address the causes of change but only address the consequences
Elliott et al. (2017). "And DPSIR begat DAPSI(W)R(M)!" - A unifying framework for marine environmental management.	the mechanisms of change and can result in changes to the natural system - Endogenic Managed Pressures - Exogenic Unmanaged Pressures
Kristensen, P. (2004). The DPSIR Framework.	Driving forces lead to human activities such as transportation or food production, i.e. result in meeting a need. These human activities exert 'pressures' on the environment, as a result of production or consumption processes, which can be divided into three main types: (i) excessive use of environmental resources, (ii) changes in land use, and (iii) emissions (of chemicals, waste, radiation, noise) to air, water and soil.

State Describes (a change of) the natural environment (as a consequence of pressures) In terms of physical, biological and chemical conditions	
Gabrielsen, P., & Bosch, P. (2003). Environmental Indicators: Typology and Use in Reporting. (EEA)	description of the quantity and quality of physical phenomena (such as temperature), biological phenomena (such as fish stocks) and chemical phenomena (such as atmospheric CO2-concentrations) in a certain area
Mateus, M., & Campuzano, F. (2008). The DPSIR framework applied to the integrated management of coastal areas.	The combination of physical, chemical and biological conditions defines the state of the environment in a given area
Borja et al. (2006). The European Water Framework Directive and the DPSIR, a methodological approach to assess the risk of failing to achieve good ecological status.	These pressures degrade the 'State' of the environment

Lewison et al. (2016). How the DPSIR framework can be used for structuring problems and facilitating empirical research in coastal systems.	pressures contribute to changes in the state of the environment, such as the abundance and health of fish or eutrophication of coastal waters.
Gregory, A. J., Atkins, J. P., Burdon, D., & Elliott, M. (2013). A problem structuring method for ecosystem-based management: The DPSIR modelling process.	As a result, the State of the system (e.g. the seabed structure or the water column) is changed
Atkins, J. P., Burdon, D., Elliott, M., & Gregory, A. J. (2011). Management of the marine environment: Integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach.	(e.g. the benthos or the water column)
Elliott et al. (2017). "And DPSIR begat DAPSI(W)R(M)!" - A unifying framework for marine environmental management.	changes in the natural environmental system as a result of a single or multiple Pressures, especially changes in physico-chemical variables (i.e. dissolved oxygen, organic matter, etc.) and changes to the health of all levels of biological organisation – the individuals, populations, communities and ecosystems State changes (positive or negative) should include those relating to the provision of intermediate and final ecosystem services as well as the underlying marine ecosystem components and processes
Kristensen, P. (2004). The DPSIR Framework.	As a result of pressures, the 'state' of the environment is affected; that is, the quality of the various environmental compartments (air, water, soil, etc.) in relation to the functions that these compartments fulfil. The 'state of the environment' is thus the combination of the physical, chemical and biological conditions.

Impact (Direct and indirect, positive and negative) consequences for society as a result of changes in the natural system ➔ Implies: consequences for society are linked to the deterioration/disappearance of ecosystem services	
Gabrielsen, P., & Bosch, P. (2003). Environmental Indicators: Typology and Use in Reporting. (EEA)	Due to pressure on the environment, the state of the environment changes. These changes then have impacts on the functions of the environment, such as human and ecosystem health, resources availability, losses of manufactured capital, and biodiversity In the strict definition impacts are only those parameters that directly reflect changes in environmental use functions by humans. As humans are a part of the environment, impacts also include health impacts
Mateus, M., & Campuzano, F. (2008). The DPSIR framework applied to the integrated management of coastal areas.	Impacts correspond to the effects resulting from the change in the state of the ecosystem - changes in the components of the environment (e.g. water quality, biodiversity etc.) → health of the ecosystem - impacts on society → human health
Borja et al. (2006). The European Water Framework Directive and the DPSIR, a methodological approach to assess the risk of failing to achieve good ecological status.	which then 'Impacts' upon human health and ecosystems
Lewison et al. (2016). How the DPSIR framework can be used for structuring problems and facilitating empirical research in coastal systems.	Human impacts, environmental impacts or a mix of human and environmental
Gregory, A. J., Atkins, J. P., Burdon, D., & Elliott, M. (2013). A problem structuring method for ecosystem-based management: The DPSIR modelling process.	this may lead to actual or potential Impacts on society (e.g. degraded habitats, removal of species, reduction of food availability, loss of biodiversity, etc). To avoid any misunderstanding between impact on the natural system (State Change) and on society (Impact), the EU KnowSeas project has proposed that DPSIR becomes DPSWR where Impact on society has been replaced by Welfare (KnowSeas Website) and whilst the focus tends to be on adverse changes this does not necessarily have to be the case.
Atkins, J. P., Burdon, D., Elliott, M., & Gregory, A. J. (2011). Management of the marine environment: Integrating ecosystem services and societal	Impacts on society (e.g. degraded habitats, removal of species, loss of biodiversity, etc.), which through its links with human welfare can have positive and/or negative implications (the actual implications is, in part, dependent on whether we are viewing this from the perspective of society as a whole or from that of specific stakeholders).

benefits with the DPSIR framework in a systems approach.	
Elliott et al. (2017). "And DPSIR begat DAPSI(W)R(M)!" - A unifying framework for marine environmental management.	result from changes in the natural system, but which have consequences for societal Welfare. Impacts (on Welfare) reflect changes (positive or negative) to the provision of goods and benefits for society (as define by Turner et al., 2015, see below) and therefore it would again be appropriate to apply a practicable set of indicators to detect such changes in societal welfare
Kristensen, P. (2004). The DPSIR Framework.	The changes in the physical, chemical or biological state of the environment determine the quality of ecosystems and the welfare of human beings. In other words changes in the state may have environmental or economic 'impacts' on the functioning of ecosystems, their life supporting abilities, and ultimately on human health and on the economic and social performance of society.

Response Societal and/or policy reactions to impacts In order to … - reduce or reverse - mitigate - compensate - reinforce … the effects of the impact	
Gabrielsen, P., & Bosch, P. (2003). Environmental Indicators: Typology and Use in Reporting. (EEA)	by groups (and individuals) in society, as well as government attempts to prevent, compensate, ameliorate or adapt to changes in the state of the environment.
Mateus, M., & Campuzano, F. (2008). The DPSIR framework applied to the integrated management of coastal areas.	a societal action related to an actual environmental problem or perceived risk reaction to the negative effects of impacts - mitigate impacts - reverse impacts in an attempt to re-establish the "normal" state of the system
Borja et al. (2006). The European Water Framework Directive and the DPSIR, a methodological approach to assess the risk of failing to achieve good ecological status.	causing society to 'Respond' with various policy measures, such as regulations, information and taxes

Lewison et al. (2016). How the DPSIR framework can be used for structuring problems and facilitating empirical research in coastal systems.	changes in policy, legislation and enforcement; behavioural change; institutional strengthening; investment (both for coastal infrastructure and institutional capacity); new pricing strategies; and conducting further research
Gregory, A. J., Atkins, J. P., Burdon, D., & Elliott, M. (2013). A problem structuring method for ecosystem-based management: The DPSIR modelling process.	human Responses to actual and potential Impacts are then needed to reduce, mitigate, or compensate for these created problems.
Kristensen, P. (2004). The DPSIR Framework.	A 'response' by society or policy makers is the result of an undesired impact and can affect any part of the chain between driving forces and impacts.

D. Overview interviews

Projects					
Name	**Project**	**Affiliation**	**Date**	**Topic**	**Format**
Matteo Ruocco	Seaforest LIFE	D.R.E.Am. Italia (coordinating organization)	16/06/2020	Drivers, Pressures, State, Impacts	Skype
			31/07/2020	Responses and challenges	Skype
Xavier Seglar	Projecte Alguer de Mataró	Escola del Mar de Badalona	23/06/2020	Drivers, Pressures, State, Impacts	Written
			14/07/2020	Responses and challenges	Written
			23/07/2020	Clarifications	Skype
Experts					
Teresa Alcoverro & Researcher UoB	-	Centre d'Estudis Avançats de Blanes University of Barcelona	29/05/2020	Informal talk, exchange of ideas	Skype
			16/07/2020	DPSIR	Skype
Núria Marbà	-	Institut Mediterrani d'Estudis Avançats	04/06/2020	Informal talk, exchange of ideas	Skype
			08/07/2020	DPSIR	Skype
Researcher	-	Institut Mediterrani d'Estudis Avançats	16/07/2020	Impacts – Ecosystem services	Skype
Michele Scardi	-	Università di Roma 'Tor Vergata'	07/07/2020	DPSIR	Skype
Ivan Guala	-	International Marine Centre	07/07/2020	DPSIR	Skype

E. Interview outline (round 1)

INTRODUCTION

Introduce yourself and the objective of the research

*The overarching objective of my research is to get a better understanding of the **challenges faced in the conservation of Posidonia oceanica** by analysing whether there are differences in the challenges faced by **islands and mainland** in order to formulate recommendations for policy, practice and research for overcoming these challenges, catered towards the different contexts.*

*By means of a **DPSIR (Driver-Pressure-State-Impact-Response) approach** this research will look at what the main pressures affecting Posidonia meadows are and what the drivers and impacts of these different pressures are and whether these, as well as other challenges, are different for an island than for a mainland context. The purpose is to formulate recommendations for policy, practice and/or research in support of more effective seagrass conservation.*

First about the conservation project

Summary about understanding of the project

- ➔ Person's role within the project
- ➔ Origins, history, geographical boundaries, aims/objectives
- ➔ Anything else that should be added?

Additional questions

- Who is involved in the project? E.g. employees, staff, other (local) stakeholders
- Are there any other important stakeholders/actors for the conservation of *Posidonia oceanica* (but that are not necessarily involved in the project)?
    - tourists, economic actors, policy makers, others

Definition stakeholders
Persons, social entities or organizations that have an interest or stake and/or that are able to act or exert influence on Posidonia conservation strategies, policies and projects E.g. citizens, tourists, economic actors, policy makers, others

STATE

Can you tell me something about the state of *Posidonia oceanica* at the project site?

- Wat is the earliest known status of seagrasses/Posidonia at the project site
- What was the status at the project start date?
- What is the ideal state?
- What is the target state for the project?
- What status is taken as the baseline for measuring conservation and/or project effectiveness?

How are you measuring the state of *Posidonia* at the project site?

DRIVER-PRESSURE-IMPACT

Pressures

- What are the main pressures Posidonia at the project site?
  (not just the ones that the project focusses on)

Definition pressure
Means through which drivers (human activities) exert pressures on/cause changes to the natural system

- Can you tell a bit more about the pressures?
    - What do they entail?
    - Which of these pressures have a more local scope?
      Which ones of these pressures have a more general scope?
        - Which geographies are affected?
        - How wide is their scope?
          Do they only affect certain parts of the Mediterranean? If so, which ones?
          Or do they affect the Mediterranean as a whole?
    - Which ones of these pressures are constant/occur all year round?
      Which ones occur intermittently?

Go through pressures one by one
If constant pressure
- What are the drivers behind this pressure?
    - Who or what causes the pressure?
        - Are there certain local activities that cause or reinforce the pressure?
        - What is the main motivation for this behaviour?
        - Have there been any considerable changes in the area of project (i.e. social changes, economic changes, infrastructural changes) that can be linked to this pressure?
        - If there are different drivers, is it possible to distinguish their respective contributions to the pressure?
    - Where does the pressure come from?
        - Local or general scope?

Definition driver
Both the human activity that causes the pressure and the motivation behind/reason for that activity
- **Motivation**
  Human needs and social and economic developments in society based on/as a consequence of human needs
- **Action/activity**
  The human activity that takes place as a consequence of the human need or social and economic development

- Are those responsible aware of it?
- Do they acknowledge their responsibility? Do they accept their responsibility? If so, in what way?

- What is the impact of this pressure? What changes does the pressure cause at the project site?
  What consequences does the degradation/decrease of *Posidonia* at the project site have?
    - For the ecosystem? How does the state of the *Posidonia* change?
    - For society? In terms of ecosystem services?

If intermittent pressure
- What are the drivers behind this pressure?

    - Who or what causes the pressure?
        - Are there certain local activities that cause or reinforce the pressure?
        - What is the main motivation for this behaviour?
        - Have there been any considerable changes in the area of project (i.e. social changes, economic changes, infrastructural changes) that can be linked to this pressure?
    - Where does the pressure come from?
        - Local or general scope?

- Are those responsible aware of it?
- Do they acknowledge their responsibility? Do they accept their responsibility? If so, in what way?

- How often does the pressure occur? How common is this pressure?

- What is the impact of this pressure? What changes does the pressure cause at the project site?
  What consequences does the degradation/decrease of *Posidonia* at the project site have?
    - For the ecosystem?
    - For society?

Definition impact
(Direct and indirect, positive and negative) consequences for society as a result of changes in the natural system
→ Implies: consequences for society are linked to the deterioration/disappearance of ecosystem services

Possible pressures
- Water pollution
    - What kind of pollution (industrial, household, other)?
- Construction of coastal infrastructure
    - What kind of infrastructure?
- Fishing
- Modification of marine currents, hydrography
- Invasive species
    - What species?
    - How was it introduced?
- Shipping

- Does the taking away of banquettes on the coast affect the conservation of Posidonia? Or only its ecosystem services?

General
- Does the taking away of banquettes on the coast affect the conservation of Posidonia? Or only its ecosystem services?
- Does this play a role in your project?

- Is there any interaction between different pressures? Do they influence each other?

- Is there any interaction between their impacts? Do the impacts of certain pressures accumulate?

- How did you identify the pressures?
- How do you know about the drivers of these pressures?
    - If there are different drivers, is it possible to distinguish their respective contributions to the pressure?
- How do you know about the impacts of pressures on the seagrasses? How is this measured?

- Are there any pressures that used to occur, but that have been successfully addressed? If so, which ones? How were they addressed?

- What are the pressures [the project] focusses specifically on?
    - Why these?
        - Constant or intermittent occurrence?
        - Local or general scope?
        - Big impact?
        - Interaction with other pressures?

        - How common are these different pressures? Can you rank these threats according how common they are?

Are there differences between the pressures faced by islands and those faced by the mainland? / Are any of these pressures specific to islands?
Are there differences between the impacts faced by islands and those faced by the mainland? / Are any of these impacts specific to islands?

RESPONSES AND CHALLENGES
In terms of addressing drivers, pressures and impact
Second interview to discuss Responses more in depth
However, I do want to ask something regarding conservation efforts already:

- Have there been conservation efforts around the project area before?
  Generally speaking, have these conservation efforts been adequate? Are there factors have contributed to deficiencies in conservation efforts?

- Are there any particular difficulties that conservation efforts have to deal with? (E.g. …)

- Are the challenges of protection and conservation different between the mainland and island sites? If yes, how?

Factors that could contribute to deficiencies in conservation:

- Lack of data, knowledge gaps in science/amongst scientists
- Issues of monitoring/surveillance
- Lack of awareness of people (locals, tourists), economic actors, policy makers, other
- Lack of knowledge of people (locals, tourists), economic actors, policy makers, other
- Regulation/measures
    - Lack of measures
    - Lack of a unified framework/strategy
    - Lack of sufficiently comprehensive measures/policy
    - Lack of margin for differentiation/specific action
    - Lack of enforcement of measures

- Divergence of opinions, inability to compromise be actors/stakeholders
- Lack of participation/support/stakeholder inclusion
- Lack of resources/means/investment
- Other (policy) priorities

Is there anything you want to add, that did not come up?

F. Interview outlines (round 2)

Seaforest LIFE

THREATS

Have there been conservation efforts around the project area before?
Generally speaking, have these conservation efforts been adequate? If not, are there certain factors have contributed to deficiencies in conservation efforts?

So, project is focusing on anchoring/mooring, because that is the most obvious threat?
And so other threats have not specifically been looked into?

POLICY

What (local, national and international) regulations are applicable to the conservation of *Posidonia* in the project area?

- Besides the prohibition to anchor on Posidonia, are there any other regulations?
- What is the influence of the project areas being a MPAs?
    - Who are the MPAs managed by?

You mention say that the application of the rule (of the prohibition to anchor) should be improved.

- How?

How aware is the government/policy makers at the different levels in Italy? (so, the national level, the regional level and the local level)

- Are policy makers (at the local level) doing anything else to conserve Posidonia?

CONSERVATION MEASURES OF THE PROJECT

What is the process of developing conservation measures?

- What steps were taken for their development?
- Who was involved?

Can you tell a bit more about

- The sustainable management of Posidonia banquettes on the beach
    - What does it entail?
    - Considering the role of Posidonia on the beach in countering erosion?
- The revegetation of stranded Posidonia seeds and sprouts
    - How?
    - Given the low success of Posidonia transplantation?

- The socio-economic impact monitoring
    - What will you be looking at?
- Carbon credit market
    - Who are you trying to involve in this?
    - What is the purpose? What are you trying to achieve?

SOCIETY

The issue of the anchoring is caused by people wanting to anchor in a certain place and not knowing what the consequences of their behaviour are, correct? And so that why is you will be undertaking dissemination actions?

- What kind of dissemination will you be doing?
- Who will the dissemination actions focus on?
- What would the effect of that be?

Projecte Alguer de Mataró

BADALONA

- Have any further actions been undertaken in Badalona when you found out that there was no living Posidonia there?

- How do you know that the Posidonia meadows in Badalona died because of chemical spills? What kind of chemical spills were they?
- Were there other threats that contributed to the meadows in Badalona dying?

- Have there been any noticeable consequences of the Posidonia dying? (e.g. connected to ecosystem services)

MATARÓ

When you say that "hundreds of actions along the coastline that have altered the coastal dynamics" what kind of actions do you mean?

- The building of Infrastructure both on the coast and inland?
- Recreational activities?
- The cleaning of Posidonia banquettes of the beach?
- Others?

And so, the consequence of these actions altering coastal dynamics is (presumably) that the effects of the storms (sediments, turbidity etc.) are stronger/worse on the Posidonia or that the Posidonia does not recover as quickly

- These are only suspicions, However, the relation between the coastal and inland infrastructure and the impact of the storm OR the reason why the Posidonia does not recover as quickly cannot be proven?
- Why can this not be proven?
- Which of both suspicions do you think is most likely? The impact of the storm being bigger? Or the Posidonia not recovering as quickly?

- Because they are only suspicions, policy-makers do not take responsibility because they think the main/only cause is climate change.

What kind of actions would you expect/want from them?

Trawling used to affect the meadows in Mataró, but not anymore because the fishermen have become more sensitive and aware of Posidonia's value.

- How did they become more aware? have active steps been taken to make them more aware?

POLICY

If I understand correctly, the Projecte Alguer de Mataró is financed by the Mataró town council and has been doing sampling there for a long time. Whenever the town council asks, you will give them advice regarding the Posidonia, however this is very little (there is very little feedback).

- Correct?
    - If yes, why is there almost no feedback or involvement of government/policy-makers?
    - If no, what kind of interaction is there between the town council and the project?

You mention the involvement of different governments

- Who is responsible/has the competence?
    - What competences do the different levels of government have?
    - How aware or concerned are the different levels of government of the issue?
    - How has the fact that there are different levels of government influenced the conservation of Posidonia in Mataró? If yes, in what way?

- Do I understand correctly that there is no integrated framework for coastal management? And that this has affected the conservation of Posidonia?
- What kind of framework would be necessary according to you? What rules are missing at the moment? What effect would this kind of regulations have?

Another thing you mention is that local authorities give priority to economic, logistic and social issues over the environmental ones.

- What kind of economic, logistic and social issues does this involve?
- Why do you think they get priority?
    - Does the lack of concrete proof of the causes and consequences of the Posidonia disappearing play a role?
    - Does the influence of certain actors pushing certain issues play a role? If yes, which actors? And what issues do they push?

SOCIETY

Volunteer divers have an important role in the project. You note that the divers collective is not easy to involve.

- Why is that?
- In what way are they difficult to involve?

“the last decade this situation is changing and people are beginning not only to know this plant and habitat, but to understand the importance of its preservation”

- How are people becoming more aware of its importance?
- What is the effect of people becoming more aware? Is there any?

ECONOMY

Tourism is very important for the economy of Maresme

- In what way is the local economy connected to/dependent tourism? What businesses etc. benefit from the presence of tourism?
- What kind of tourism is there in Mataró?
- What are the most important tourist attractions or activities in/around Mataró?
- Is it only because of the tourists that locals demand the removal of Posidonia from the beach? Or are there other reasons?

- Diving activities rarely visit the Posidonia meadows, but prefer rock bars.
    - Is the ecosystem around the rock bars in any way connected to the Posidonia meadows? e.g. marine organisms that live on both places; some of the functions of

Posidonia, like water filtration or sediment stabilization, that benefits the rock bars; etc.?

CONSERVATION MEASURES

Is there any (direct or indirect) pressure from (local) economic actors on the (local) authorities related the preservation of Posidonia?

- Who exerts pressure?
- In what way do

Are there any other actors that exert pressure on the (local) authorities?

What measures should be taken for the conservation of Posidonia according to you?

The Balearic Islands

No second round of interviews

G. Codebook

Stakeholders Partnership	Academics/science		
	Government		
	Society		
	Economy		
	Other		
Drivers	Motivation	Social	Food Clean water Protection from elements Recreation/relaxation Employment Comfort
		Economic	Profit, tourist attraction Protect or upgrade infrastructure
		Political	Wish to be re-elected Status
	Action	Tourism Recreation	Boats - Anchoring - Mooring (Pollution - Sewage discharge - Waste - Other) Recreational activities
		Fishing	Trawling
		Agriculture	Fertilisation in waterways
		Aquaculture	Nutrients

		Urbanisation Coastal Development[15]	Sewage discharge Building of infrastructure - Touristic infrastructure - Seawalls, dykes - Barriers/dams Beach regeneration Dredging Beach cleaning
		Marine transport	
		Climate change	Storms - Sewage overload Global warming
Pressures	Pollution	Chemicals, nutrients	Sewage Nutrient runoff/polluted sediments Other discharges
		Heath	
	Hydrology	Water abstraction	Hydro energy
		Flow regulation	Aquaculture water abstraction
		Restoration activities	Irrigation
	Morphology, physical disturbance	Sediment dynamics	
		Sweeping of sand	
		Piling up of sand	
		Sediment composition	
		Physical impact	
	Biology	Changes in biodiversity	Resource exploitation (fishing)
		Recreation	Invasive species
State	Physical Biological	Shoot density Area cover	

[15] Coastal development constitutes is a more specific form of urbanization, however coastal development that does not necessarily constitute urbanization exists

	Chemical	Eutrophication Water quality Water clarity/turbidity	
Impacts (Campagne, Salles, Boissery, & Deter, 2015)	Provisioning services	Use as material	
		Use as bioindicator	
	Regulation and maintenance	Protection from coastal erosion (stabilising sediments)	Coastal erosion
		Wastewater treatment - Water filtering sediments - Water filtering pollutants/nutrients	Water quality
		Carbon sequestration and storage	Decrease of carbon sink
		Water clarity	
		Wave sound decrease	
		Habitat (incl. nursery and feeding ground)	Habitat and biodiversity loss
		Biodiversity	
		Fishery contribution - *Nursery grounds* - *Feeding grounds* - *Habitat* - *Food web component (dead)*	
		Tourism's contribution - *water clarity* - *sequestration of nutrients and contaminants* - *coastline erosion*	
	Cultural services	Knowledge contribution	
		Tourism (visiting meadows)	

		Education opportunities	
		Cultural value and heritage	
		Willingness to preserve for future generation	
Responses	Regulation	Overall, integrated coastal management (ICM)	
		Specific protection	
	Further research		
	Awareness raising, information campaign		
	Further research		
	Participation		
	Infrastructure		
	Political pressure		
	Network creation		
	Beach regeneration		
	Monetary measures	Increase resources	
		Tax or fine	
		Carbon credits	
	Posidonia transplantation		
	Composting, re-use		
Challenges	Lack of awareness	Invisibility of ecosystem	Policy, authorities Society Economy, business Science
	Lack of knowledge		
	Complexity of the issue	Cumulative effects	
	Administrative complexity, fragmentation of authority		
	Politics		
	Self-interest		
	Other priorities		

	Politics		
	Denying responsibility		
	Lack of regulation	Specific	
		Overall, integrated regulatory framework	
	Regulatory unclarity		
	Enforcement		
	Diverging opinions		
	Lack of resources		
	Lack of involvement or communication		

H. Coding tables

Seaforest LIFE

Drivers

we are focusing on mooring and anchorage because they are the main threats for our study areas	**Action**	**Tourism**	**Mooring** **Anchoring**
fishing is also another threat, but as I told you before we don't really have this kind of problem at the moment, I think in our study area	**Action**	**Fishing**	
there is like one around 1000 boats per day in La Maddalena in August and there is not enough space to moor all of them	**Action**	**Tourism**	**Mooring**
but when there are too many boats and not enough Posidonia friendly anchors. I'd say then people usually don't say okay, I'm just moving away and going in another place because I want to be there. You know you're planning your day you decide to go in that island or in that little Bay, and even if it's full you stay there	**Action**	**Tourism**	**Mooring** **Anchoring**
La Maddalena is the more impacted from boats.	**Action**	**Tourism**	**Anchoring**
Probably pollution also can a little bit yes effect. I mean, in an area where for 10 months per year you have, I don't know, let's say 10 people and in two months you have 1000 people, you know pollution it's clear. It clearly affects some somehow this situation.	**Action**	**Tourism**	(Pollution)

the area study areas along the coast during the winter you have like 4000 people. During the summer you have like 40,000, maybe 100,000 of people spending their days in the area and you know, even bathroom pollution it would be a problem because they were built for a for a certain amount of waste and then starting from July and August they sometimes they cannot afford all the water that they have to purify.	**Action**	**Tourism**	(Insufficient sewage capacity Waste)
Well, probably the climate change is also part of the problem, but more uncontrollable Because of course, you know that turbidity of the of the waters, the, the warming of the waters and so on, could affect the growth of Posidonia oceanica.	**Action**	**Climate change**	

Pressures

And so, it is mainly the physical impact of the anchors that causes the problem, right? Yes, yes, the physical impact of the anchors on the seagrass. And the problem is (…) once you make a scar on the seabed, then it's really difficult for Posidonia to grow again. (…) because the currents just keep on just keep digging this scar.	**Physical disturbance**	**Physical impact**	**Anchorage**
of course, pollution we can say	**Pollution**	**Chemicals**	**Sewage** **Other discharges** - **Waste**

			Boats - **Oil, gas**
I'm talking about the pollution that people can produce. So, waste or most of the boats there they go with fuels, so gases and so on oil or whatever I'm talking about this kind of pollution.	**Pollution**	**Chemicals**	**Other discharges** - **Waste** **Boats** - **Oil, gas**
During the summer you have like 40,000, maybe 100,000 of people spending their days in the area and you know, even bathroom pollution it would be a problem.	**Pollution**	**Chemicals**	**Sewage**
Because of course, you know that turbidity of the of the waters, (…), could affect the growth of Posidonia oceanica.	**Physical disturbance**	**Physical impact**	
the warming of the waters and so on	**Pollution**	**Heat**	

Impacts

one of the ecosystem services that we are we as humans (…) not thinking off so much is that it has – you know that the Sardinia pictures of the sea, the sea is always so green blue with beautiful colour. This is partially due also to Posidonia so if it disappears, also the beautiful places that tourists want to see will disappear	**Regulation and maintenance**	**Water clarity** ***Tourism contribution***	**Turbidity**
It is a barrier against the erosion … You know that in Italy at least, (…) we have a problem with the erosion of the coast	**Regulation and maintenance**	**Protection from coastal erosion**	**Coastal erosion**

because of course production of oxygen and so on.	**Regulation and maintenance**	**Carbon sequestration and storage**	**Decreased carbon sink**
there is a… it affected biodiversity	**Regulation and maintenance**	**Biodiversity**	**Habitat and biodiversity loss**
affects also fishermen, indirectly, probably a little bit	**Regulation and maintenance**	***Fishery contribution*** **Biodiversity**	**Habitat and biodiversity loss**

Responses

National park/ MPA management	**Regulation**	**Overall**
previous actions were focused on researches about the conservation status of Posidonia oceanica more than really conservation action	**Further research**	
Accurate quantification of carbon deposits and estimation of the rate of change in relation to the degradation of the habitat due to the impacts generated by anchorages and moorings of boats in the study areas of the project [are] carried out.	**Further research**	
Actions to reduce the degradation of habitat: In particular, to reduce the degradation of the Posidonia seagrasses, we will prepare a Plan for the management of anchors and moorings in Protected Areas, in order to regulate the access of the boats to the areas where the Posidonia meadows are present;	**Regulation**	**Specific protection**
moreover we will install eco-compatible moorings, more suitable for habitat conservation, to replace the moorings that may already exist, and we will remove the mooring structures no longer functioning, called "dead bodies", which caused the dead of the Posidonia oceanica	**Infrastructure**	

meadows creating an empty inside the prairie		
The anchoring on the Posidonia. Yes. Probably it's European. I don't know. Surely, it's a national one. Yeah. Okay. So, in fact, you couldn't anchor on the Posidonia meadow within or outside national parks or marine protected areas	**Regulation**	**Specific protection**
application of a mooring plan	**Regulation**	**Specific protection**
We will use the stranded seeds and sprouts of Posidonia oceanica, in order to make a revegetation of the habitat. Therefore, natural nurseries will be created inside the Protected Areas, where the seedlings will be germinated, in order to make the dead "matte" once the prairie erosion has occurred.	**Posidonia transplantation**	
So, we want to remove the dead bodies replant locally, the Posidonia in order to reinforce its new growth.	**Posidonia transplantation**	
we wanted to involve local people for dissemination in dissemination activities	**Awareness raising, information campaign**	
sensitize the people with promotional events and information events	**Awareness raising, information campaign**	
but at least we cannot we are not working on you know, controlling the situation, but we can showing which are the rules, why they are important, what can you do to respect them and why you should respect them.	**Awareness raising, information campaign**	
trying to imagine a different way to collect like, involving local people, for example, or involving tourists in collecting seeds and collecting, for example, small plants, that they could bring to the national parks and then the National Park bring it to ISPRA. It's not simple. We know, but it's more	**Participation**	

at the most demonstration action		
webinar on the topics of Posidonia and of course, our life project.	**Awareness raising, information campaign**	
involve the local touristic [industry actors] to disseminate our products so we are printing, in these days. New fliers and promotional postcards	**Awareness raising, information campaign**	
action with some activities with schools. So, we are thinking about, you know, making like video lessons for the next year.	**Awareness raising, information campaign**	
And to sensitize also local people, not only the tourists	**Awareness raising, information campaign**	
[*about carbon credit market*] with local operators, let's say, or just a dissemination action, kind of, and promotion action for the most	**Awareness raising, information campaign** **Participation**	
[*about carbon credit market*] about involving two kinds of main actors, which are big companies and small tourist operators and local tourist operators	**Monetary measures**	**Carbon credits**
try to convince them to reduce their carbon footprint. So, evaluate their carbon footprint and then reduce their impact by buying (…) Posidonia blue carbon credits	**Monetary measures**	**Carbon credits**
Actions for the management of the beached vegetation residues: We will also deal with the residues of Posidonia, the so-called "blanquettes", which represent a problem along the coasts with a high tourist vocation. In particular we will try to promote a sustainable management of these residues, providing for the production of compost and acoustic panels.	**Composting, re-use**	
[*about composting*] it will be like a really small demonstration action within only one National Park, which is Cilento national Park	**Composting, re-use**	

So, we will try to work with them. And you know to make like instead of thinking about a waste but think about something that you can reuse in a proper way.	**Composting, re-use**		

Challenges

The big dream would be that, well, that everybody would understand why it is so important and that everybody would act more correctly so and add the possibility the possibility to act more correctly	**Lack of awareness**		Society
But I think that people locals (…) that they are the ones who should better understand the problem and we will be focusing on them with some dissemination activities of course.	**Lack of awareness**		Society, local population
improve the knowledge about Posidonia oceanica, to improve the sensibility on the on the theme that would also, you know, just justify, for example, to spend money on this topic. Public money, so, yes, indirectly it's really important. Also, the dissemination activities are really important to, to show how big could become this problem	**Lack of awareness**		Society Policy
And so, at the end, would you then say that sort of the lower you go, the less awareness there is? So, the national level has some awareness, and then there's a regional government, if I	**Lack of awareness**		Policy

understand correctly, and then there's the local town councils? Ruocco – Yes. Yes, there is a regional government and yes, I think it's correct what you're saying. Yes.			
because of course production of oxygen and so on. They don't really, you know, affect directly locals because they are not like "I'm not breathing like once because there is no more Posidonia".	**Lack of awareness**	**Invisibility of ecosystem services**	Society
Everybody knows that pollution is a problem for big cities and going with cars around the city is a problem but, not, even if you're conscious some sometimes you just "I shouldn't but…" Me - Yeah, so it is sort of acknowledging that you have the same impact, though it is not just you and everyone has their own little part in it. Ruocco – Exactly	**Denying responsibility** **Lack of awareness**		Society
But let's say the application of the regulation that should be improved. I wouldn't say controls, (…) And so, yes, I wouldn't say that the regulation are weak, as I said, But that the application of the regulation we should improve that the application more than that up	**Enforcement**		
the local mayor it is not his main objective to protect the environment for example. I mean, it is	**Other priorities**		Policy

one of [the objectives] but yes lots of things to do and so probably this is one of the last they are thinking about.			
the best thing is probably to leave the leaves on the beach, but it's not always possible because you have the beach managers which don't really like the situation because it for tourist is not appealing to this kind of leaves on the seashore	**Other priorities**		Policy Society, tourists
You have not the double but 10 times the job that you do during winter, for example. And of course, it's always the same, they also have to do a lot of other things and they are not like the Posidonia Meadow police.	**Lack of resources** - **Enforcement** - **Other priorities**		Policy, authorities
Maybe, But I'm not sure, maybe, when you live in an island or in an archipelago more than an island you have a much deeper contact with the sea. Then… if I compare La Maddalena and Asinara for example with Campania probably people are more linked with the sea while in in the mainland in Campania they are more linked with the land, but as I said before this is probably due to a culture heritage	**Awareness** **Cultural heritage**		Society

Projecte Alguer de Mataró

Drivers

pressure generated by the trawl fishing boats	**Action**	**Fishing**	**Trawling**
Trawling fishing	**Action**	**Fishing**	**Trawling**
tourism from all Europe is very important for the economy of Maresme	**Motivation**	**Economic**	**Profit, tourist attraction**
beaches with no sand are a severe handicap to attract tourists in spring and summer, the economic impact of this lack of sand can be very harmful.	**Motivation**	**Economic**	**Profit** **Tourist attraction**
incomes from tourist activity are one of the most important ones regarding coastal towns. One of the main attractive of these villages are their beaches, since they are focused on what's called the "sun and beach" tourism. Beaches without sand will have a severe impact on the town financial balance. That's why beach regeneration and protection structures construction are undertook despite the damaging effects they can entail.	**Motivation**	**Economic**	**Profit** **Tourist attraction**
There are other coastal actions that are also related to economic issues - like for example the extension of ports - The railway that runs along the Maresme coast is just next to the sea for a long stretch. It obviously has a breakwater to protect it from waves, but the same	**Motivation**	**Economic**	**Protect and upgrade infrastructure**

strong storms that effect Posidonia meadows are also capable to damage this infrastructure. Instead of considering moving the railway a little bit inland, the decision to reinforce and enlarge the breakwater has been made. This will obviously mean a great movement of sediments that may have an impact on the prairie			
Moving the railway would mean a greater investment than to just protect it with a larger breakwater. In addition, since there is no free place to set a new railway, it would have to be moved quite far from the sea or buried. The first option would mean that it would not be so practical for the residents, since a lot of people would stop using it, and the second one is too expensive. In this case we have social, logistic and economic implications all together.	**Motivation**	**Economic**	**Protect and upgrade Infrastructure**
while in Catalonia this matter is usually considered as dirt and eliminated because "it smells bad"	**Motivation**	**Social**	**Comfort**
since even the residents from the cities and towns of the region demand to have useful beaches.	**Motivation**	**Social**	**Comfort** **Recreation/relaxation**
stronger and more severe effects of storms.	**Action**	**Climate change**	**Storms** (intensity and frequency)

two extremely strong storms that devastated the shallowest part of the meadow.	**Action**	**Climate change**	**Storms**
strong storms that periodically strike our coast	**Action**	**Climate change**	**Storms**
intensified by some human activities	**Action**	**Climate change**	**Storms**
we think that they usually occur every 7 to 10 years according to what we have recorded (2002, 2008, 2017) and to what elder people have told us	**Action**	**Climate change**	**Storms** (frequency)
when the sewage is fulfilled then it's directed to another pipe *...* they are bigger pipes that directs the water directly to the sea. That's when there is a problem of the sewage water into the sea. It's not usual but it happens several times a year. And in addition, with the idea of climate change. We are seeing that these episodes happen more often	**Action**	**Climate change**	**Storms** (frequency) - **Rain – Sewage**
hundreds of actions along the Catalan coastline that have altered the coastal dynamics and the longshore drift	**Action**	**Urbanisation** **Coastal development**	

The most important among these activities is the coastal or beach regeneration, which uses sand from deeper zones, away from the coast, to replace in spring the one that has been lost in autumn due to storms. The problem of these actions […], is that the new sand has a particle size much smaller than the original sand and is easily carried away by the waves and moved to other places, like for example Posidonia prairies.	**Action**	**Coastal development**	**Beach regeneration**
To start with, lots of riverbeds have been altered and have become more artificial and less natural.	**Action**	**Urbanisation**	**Building of infrastructure** (artificial riverbeds)
Rocks, gravel and stones have been replaced with roads, streets and buildings, thus reducing the amount of sediment that reaches the outlet	**Action**	**Urbanisation**	**Building of infrastructure** (roads, streets and buildings)
lots of human constructions, like breakwaters, dikes, docks or ports, have been built all along the coast.	**Action**	**Coastal development**	**Building of infrastructure** (coastline infrastructure)
Inland activities include all the actions that had changed the natural bed of the rivers to an artificial one. Some beds have been buried and become artificial subterranean beds, others have been covered with streets and others have been channelled with artificial means.	**Action**	**Urbanisation**	**Building of infrastructure** (artificial riverbeds)
actions to prevent floods	**Action**	**Urbanisation**	

		Coastal development	
Actions along the coast include ports, docks, piers, breakwaters, dykes, all of them structures that	**Action**	**Coastal development**	**Building of infrastructure** (coastline infrastructure)
Ports in this region are usually for recreational navigation	**Motivation**	**Economic** **Social**	**Tourism** **Recreation**
	Action	**Coastal development**	**Building of infrastructure** (coastline infrastructure)
some breakwaters and dykes are used to protect structures placed along the shore like railways, roads or buildings	**Motivation**	**Economic**	Protect infrastructure
	Action	**Coastal development**	**Building of infrastructure** (coastline infrastructure)
others are designed precisely to alter the longshore drift and protect the beaches from the loss of sand with little concern about their impact on other zones.	**Motivation**	**Economic**	**Tourist attraction** **Protect infrastructure**
	Action	**Coastal development**	**Building of infrastructure** (coastline infrastructure)
(…) have been replaced with hotels, apartments, streets and promenades, so this storage of sand has disappeared.	**Action**	**Coastal development** **Urbanisation**	**Building of infrastructure** (tourist infrastructure, such as hotels, apartments, streets and promenades)
other actions like port inlet dredging,	**Action**	**Coastal development**	**Dredging**
Other actions like (…) building of dykes or other defensive structures, or the extension of some coastal constructions	**Action**	**Coastal development**	**Building of infrastructure** (coastline infrastructure)
A road built over the bed of a river thirty kilometres away, a dyke stopping the waves several miles far from the prairie, the reconstruction of the defensive barrier of a railway are actions that unnoticeably	**Action**	**Urbanisation** **Coastal development**	**Building of infrastructure**
centuries ago, these beaches used to have	**Action**	**Coastal development**	**Building of infrastructure**

what we call a "backbeach", with chains of sand dunes that acted like sand stores supplying sand to the front part of the beach when there was a lack of it. Unfortunately, these chains of dunes have also disappeared (…)			

Pressures

In some places like Mataró the sudden sweeping of incredibly large amounts of sand is the main responsible	**Morphology, physical disturbances**	**Sweeping of sand**
also generate a great amount of suspended sand that's carried by waves as well	**Morphology, physical disturbances**	**Sweeping of sand**
that reduce the amount of sediment that get to the sea	**Morphology, physical disturbances**	**Sweeping of sand**
it has completely wiped out all the sand that was around the meadow.	**Morphology, physical disturbances**	**Sweeping of sand**
This means that all the sediment that was there is no longer available and, in addition, the change in water current speeds also has an effect on its capacity to carry the sediment	**Morphology, physical disturbances**	**Sediment dynamics**
while in others it is the burial of the plants under a thick layer of new sand the responsible for the mortality in the meadow	**Morphology, physical disturbances**	**Piling up of sand**
As a result, sand usually gathers in the northern part of these structures and it's carried away from the southern part, thus creating gaps and discontinuities in sand distribution. That's why lots of beaches lose their sand, especially after autumn storms.	**Morphology, physical disturbances**	**Sediment dynamics**
As a result, the sediment dynamics has been modified as well.	**Morphology, physical disturbances**	**Sediment dynamics**
are actions that unnoticeably may have an influence on the overall balance of the sediment dynamics.	**Morphology, physical disturbances**	**Sediment dynamics**

impact on the sediment dynamics	**Morphology, physical disturbances**	**Sediment dynamics**
that disrupt, change or stop its distribution along the shore due to the longshore drift	**Morphology, physical disturbances**	**Sediment dynamics**
have also an effect in this sediment transport processes	**Morphology, physical disturbances**	**Sediment dynamics**
hundreds of actions along the Catalan coastline that have altered the coastal dynamics and the longshore drift	**Morphology, physical disturbances**	**Sediment dynamics**
all of them structures that disrupt the longshore drift carried out by waves and that consequently has an effect on sediment transport	**Morphology, physical disturbances** **Hydrology**	**Sediment dynamics**
These structures tend to stop the sand flows driven by the waves	**Morphology, physical disturbances** **Hydrology**	
sewage water into the sea	**Pollution**	**Nutrient input** (very local effect)

Impacts

when storms happen all this sand is carried away. As a result of the 2008 storm, almost 20 cm of sand disappeared, which was more or less the amount of sand that had been gathered during the previous 6 years.	**Regulation and maintenance**	**Protection from coastal erosion**	**Coastal erosion**
also generate a great amount of suspended sand that's carried by waves as well	**Regulation and maintenance**	**Protection from coastal erosion**	**Coastal erosion**
that has led the coastline to a serious lack of sand	**Regulation and maintenance**	**Protection from coastal erosion**	**Coastal erosion**
Regarding social and economic consequences, the impacts are almost inexistent. Mataro's coast has a long tradition of diving activities, but	**Cultural**	**Tourism (visiting meadows)**	

Posidonia meadows are rarely visited by scuba divers who prefer rock bars instead			
that if the fact is a habitat that has a high diversity, a high abundancy of animals than the sand habitat that surrounds the meadow obviously this would have an impact in the abundance of the animals, in the diversity and probably some of the species have problems to survive, because they have they have feeding and breeding	**Regulation and maintenance**	**Habitat (incl. nursery and feeding ground) Biodiversity**	**Habitat and biodiversity loss**
So that would have an effect the fishing industry. But as I'm telling you, the fishing industry now is not working so close to the coast, a typical more traditional fishing has disappeared.	**Regulation and maintenance**	**Habitat and biodiversity loss**	**Habitat and biodiversity loss**

Responses

Fortunately, some actions that were undertaken around the vicinity of the prairie took into account the advices and warnings that we had informed, though not all of them were accepted.	**Information (awareness raising)**	
bottom trawling fishing over the meadow, which had been a problem in the past, was eliminated due to a two directions policy, making fishermen aware of the impact that they were generating and (…)	**Awareness raising**	
The second step is to spread even more the knowledge about Posidonia. It's true, as I've explained, that Posidonia is	**Awareness raising (information campaign)**	

more known than in the past, but there is not yet a real awareness of how important for the marine environment it is, and the effects that its disappearance could have over other ecosystems, the coastal environment and the water quality. So, consciousness-raising is also important to preserve these habitats		
even when we go to election and we vote our politicians, our decision of which party we are voting has an effect on the environmental *...* so people is aware and some parties are more sensitive with the problems of Posidonia than other party has a role trying to elect this kind of parties that probably will have a more active role when trying to deal with the problem	**Awareness raising**	
Awareness would mainly make that the people are more supportive of environmental positive policies and that they're more aware of the actual issue rather than we have this beautiful plant	**Awareness raising**	
For me education is very important. I think, in fact, the role we are playing here in Escola del Mar in child education and we try to explain them not only about Posidonia, [why] it is essential.	**Awareness raising**	
Increase in the number of studies and researches about this subject and this has not only generated more papers and articles but has also lead to occasional news, comments or articles in mass medias that have made this topic a little bit more popular. With the popularization of the net during the last twenty years, it has become easier to publish, share or find information about the plant and	**Further research** **Awareness raising**	

its problems which has also help to extend its knowledge. Some books, notebooks, brochures, leaflets or triptychs with different degree of complexity, thoroughness and depth have also been printed in order to disseminate information about these habitats, and some environmental educational centres have also stressed their importance		
The first step to protect and preserve anything is to know it well, know its nature, how it behaves in different circumstances and what are its main threats and damages. There's no way to protect something if you don't know it well.	**Further research**	
design a new project to study the whole Catalan coast in order to know the real state of the meadows, to know which are the main threats, pressures and impacts, and to know their behaviours in at least a ten years long period	**Further research**	
Alternative solutions to beach regeneration should be studied. These actions are useless, expensive and have a great impact on sediment dynamics	**Further research**	
The river courses should also be analysed in order to see if the sediment transport downstream can be partially recovered	**Further research**	
key is to study and know these habitats and their peculiarities and singularities	**Further research**	
analyse whether the water quality in our coast is good enough for the meadows, or if a more restrictive rule should be adopted.	**Further research** **Regulation**	**Overall**
bottom trawling fishing over the meadow, which had been a problem in the past, was eliminated due to a two	**Infrastructure**	

directions policy, (…) and hindering to fish there		
Fixed mooring spots for anchorage should be more spread, but there should also be guarantees that these items do not have an impact in turn, since the chains that are used might damage the plants.	**Infrastructure**	
Furthermore, big submerged structures were placed in strategic locations to avoid trawling boats to get too close to this habitat.	**Protective infrastructure**	
local authorities demand and urge the proper Ministry to give them an answer, which usually comes in form of beach regenerations.	**Beach regeneration**	
In addition, laws that protect these habitats, European directives about them and their use as environmental indicators have made that politicians and managers take this subject more seriously	**Regulation**	**Specific protection**
current situation is difficult to make an accurate diagnostic. The meadow is included in the Natura 2000 network from the EU, but this does not grant, at least in Catalonia, any additional protection to the one that European and national laws provide	**Regulation**	**Specific protection**
legislative frame, since any fishing activity in the prairie is forbidden	**Regulation**	**Specific protection**
meadow conservation is a part of the Agenda 21 Attenuate the impacts on marine ecosystems	**Regulation**	**Specific protection**
Posidonia is a species protected in Catalonia by the Order 91.210.098 (DOGC num. 1479, pag. 4395 from 8/12/1191) which declares all marine phanerogams present in the littoral as protected	**Regulation**	**Specific protection**
Mataro's meadow is in the protected littoral area that was	**Regulation**	**Specific protection**

established in 2014 and that, as a decision from the Catalan government, was defined as Especial Conservation Zone (Zona d'Especial Conservació-ZEC in Catalan) and named "ZEC Costes del Maresme". This area is around 3000 Ha large and forms part of the group of the Catalan marine and terrestrial zones from the net Natura 2000		
Regulations and legislation should be even more restrictive if needed to ensure the prairie's protection	**Regulation**	**Specific protection**
The tightening of laws, rules and regulations regarding the quality of water and the discharge of substances to the water also helped to reduce the water turbidity and made the water column more transparent	**Regulation**	**Overall**
There should be a new design of policies related with actions that can affect the coastal area and also with those that have an impact on the river courses. We must obviously flee from maximalist objectives that will immediately face the opposition of some economic and social actors. It would be crazy and useless to propose to eliminate all the artificial structures that are interfering with the longshore drift or the river sediment transport. That's why we have to promote preventive measures in order to minimize the long term and long-range effects of the new actions undertaken	**Regulation**	**Overall**
Coastal construction works should also be minimised and reduced to those considered essential	**Regulation** **Infrastructure**	**Overall**
Port extensions, shore promenades or piers should be thoroughly analysed in order to know their real necessity before giving the mandatory	**Regulation** **Infrastructure**	**Overall**

authorization, and always trying to locate these infrastructures land inward instead of seaward, i.e., avoiding to affect the marine coastal environment and the sediment dynamics		
For those actions considered indispensables there should be corrective measures in order to avoid their impact on the sediment transport	**Regulation** **Infrastructure**	**Overall**
other measures should also be implemented to increase the minimum distance between sewage pipes or residual water discharges and the prairie. This is probably necessary in some areas of the Costa Brava where, in the past, constructions were made with not a proper control and regulation.	**Regulation** **Infrastructure**	**Overall**
Some activities around meadows, like scuba diving, underwater fishing or even swimming, should also be regulated and adjusted if there are evidences that they have an impact. This doesn't mean to forbid them but to control or limit them	**Regulation**	**Overall**
other measures that should be happening is one the beach generation and then second, a more coastal aware infrastructure management at a higher level.	**Regulation**	**Overall**
We also expect them to press other administrations when actions that would alter the prairie are designed, so that they consider less harmful alternatives.	**Exert political pressure**	
Main pressures are exerted by diving centres and clubs that know the importance these habitats have and are aware that the disappearance of the meadow could have direct consequences to other ecosystems that could finally damage their business	**Political pressure**	

involved in the initial groundworks to demarcate the meadow because of their knowledge of the area and in order to make them sensitive to this problem and to make them understand that they are main actors in the preservation of the habitat.	**Participation**		
In addition, this project should coordinate all the researches about Posidonia in operation and promote the cooperation between them	**Network creation**		

Challenges

However, fishermen have become more sensitive and aware of Posidonia's value and have stopped doing so.	**(Lack of) awareness**		Economy, business
almost no contact or feedback with them or any of their departments, agencies or institutions. These however may be not only their fault but also ours. Town councils should also be more involved with regard to Posidonia's management.	**Lack of involvement or communication**		
when you talk to political managers or administrators about it, they consider it a natural issue, not related to human activity, and not of their responsibility.	**Denying responsibility**		
So, they are aware of the problem, but they believe they have no chance to solve it or even to help us to do so.	**Denying responsibility**		
Even when all the problems regarding the sediment transport are explained, they still feel overwhelmed since they	**Administrative complexity, fragmentation of authority**		

have no competencies in such matters, which are usually responsibility of other administrations			
politicians and managers are reluctant to assume any responsibility since they feel that this is an issue that escapes from their responsibilities	**Administrative complexity, fragmentation of authority**	**Denying responsibility**	
Another problem is that in Catalonia we have a lot of different administrations. For example, beach regenerations are a competency of the proper Ministry from the Spanish Government and we do not have any kind of contact with them. Though local authorities do have the possibility to talk with them, […]	**Administrative complexity, fragmentation of authority**		
The complexity of the problem is, as I've explained before, so great and involves so many actions, towns and administrations that to find a solution is almost impossible	**Administrative complexity** **Complexity of the issue**		
no direct cause-effect In fact, all we have are suppositions that are the result of more than 20 years of observations, but we cannot prove them	**Complexity of the issue**		
And is not easy to determine which of these actions have a real and noticeable effect, extremely difficult to establish their intensity, magnitude or length and almost impossible to know the level of synergy that exists between them	**Complexity of the issue**	**Cumulative effects**	

When we talk about interaction between pressures or impacts we have to keep in mind that we are not facing the typical pressures that have often been described as the most usual affecting Posidonia, like dragging a net over the bottom, throwing an anchor or spilling some chemical product into the sea, which can be isolated and analysed individually	**Complexity of the issue**		
An extremely complicated and intricate phenomenon that involves different kind of pressures, actions, impacts and effects of different time and space scales, which can be regional or local, present or past.	**Complexity of the issue**		
difficult to study all the interactions that affect this meadow and look for a solution that might minimize these impacts. We can only conjecture that large scale actions and those that are undertaken closer to the meadow will have a greater effect than others	**Complexity of the issue**	**Cumulative effects**	
we cannot prove the relation between these impacts and the effects of the storms over the prairie, though we have clues and hints that show this relation	**Complexity of the issue**		
Regarding the cause-effect relation between the coastal and inland actions and the prairie's setbacks, it's difficult to	**Complexity of the issue**	**Cumulative effects**	

prove this connection since it is an indirect and multivariate relation […] We are talking about actions that occur at distances of tens of kilometres and with some years between each other and that individually might not have a significant effect, but when they happen jointly some synergies appear and effects are multiplied			
To establish a proven relation between all these actions and the increased effects of storms over the meadow is almost impossible.	**Complexity of the issue**	**Cumulative effects**	
But when the relation between and action ant its final effect is so intricate, diffused and tangled it's easy that many other aspects become more determinant than this one.	**Complexity of the issue**	**Cumulative effects**	
Some pressures may have different impacts on different meadows	**Complexity of the issue**		
it's very difficult to establish a direct relation between a loss of clarity and the disappearance of the meadow	**Complexity of the issue**		
[…] This means, as I stated, that there was neither knowledge about a previous state of the prairie nor any research about these environments	**Lack of knowledge**		
So, I think that they don't even have the clear about what's the reason behind this? They haven't carried this	**Lack of knowledge** **Complexity of the issue**		

study long enough as to have some conclusion. We can make this conclusion because we have been working in it for a very, very long period of time			
To sum up, since there are no previous references about the sediment dynamics around the prairie, it is unfeasible to prove that the currently more devastating effects of storms are an outcome of the variation of this dynamics, and, if we cannot even prove this, is totally impossible to link these effects with coastal and inland infrastructures	**Lack of knowledge** **Complexity of the issue**	**Cumulative effects**	
an awful geographical, coastal and urban management	**Lack of regulation**	**Overall, integrated regulatory framework**	
and, in addition, laws don't ask them to carry out any further research or investigation.	**Lack of regulation**	**Overall, integrated regulatory framework**	
[the Catalan government's] policies and actions are often unclear, probably because they are not well publicized.	**Regulatory unclarity**		
[…] when you suggest that it would be better to stop beach regenerations, they prioritise economic guidelines than environmental ones. The same happens with other kind of actions that are not stopped or changed just because they could have or not a role in a future hypothetical impact over the prairie.	**Other priorities** **Complexity of the issue**	**Denying responsibility**	

as I've stated before, economic, logistic and social issues usually prevail over the environmental ones.	**Other priorities**		
What people will not accept is that the beach is without sand and that they cannot go to bath in summer.	**Other priorities**		
There is little feedback between the project and the town council. My feeling, which I cannot prove at all, is that there is not a real consciousness of the problem and its consequences. That's probably not the case for municipal environmental workers but it is for politicians. It seems that they provide funds just to have peace of mind and because perhaps it would be somehow unpopular to retire them, but it doesn't seem it is an essential issue for their policies, even for the environmental ones	**Lack of awareness** **Other priorities**		Policy
What we expect from policy-makers is, first of all, to be aware of the problem and to take it into account whenever they have to take decisions that can affect the meadow.	**Lack of awareness**		
As I suggested in my previous writing, the sensitive to Posidonia in our country was almost non-existent before 1990. […]	**Lack of awareness**		
Another problem is that, if we have little feedback with the town council, this feedback is even less	**Lack of awareness** **Lack of involvement or communication**		Policy

with the regional government and even less if possible with the state one, so it's very difficult to know whether they are aware of the threats in regard with impacts on Posidonia prairies or to explain them this threats and impacts.			
The effect of this better knowledge of the plant has had very little effect. People know about the plant, about some of its problems, but they do not consider it a serious or worrying problem yet.	**Lack of awareness**		Society Policy
But the sense that I have is that people do know Posidonia and when you talk to them and you talk about Posidonia they say "yeah, I know, it's not a seaweed, it's a plant and I know that it's important." But their awareness of the problem stops there. They know that it exists. They know that's important, but they don't realize that there is something to do in order to protect them.	**Lack of awareness**		
those responsible of these activities may be aware that this massive movement of sand may have some impact on other coastal places, but they probably don't know its intensity and extension	**Lack of awareness**		Policy
knowledge about this plant is not widespread, and even less known is its ecological and sedimentary role in the marine environment	**Lack of awareness**		Society

in Baleares people are more aware of the importance	**Lack of awareness**		Society
I think that they are not as you are saying so fond of new infrastructures and new buildings and new harbours. I think that they are really aware and, and if things are explained properly, I think that people can understand that, for example, there is no need to make a harbour of a port a little bit bigger	**(Lack of) awareness**		Policy Society
the last decade this situation is changing and people are beginning not only to know this plant and habitat, but to understand the importance of its preservation	**(Lack of) awareness**		Society
none of them can be proved at least with the very limited tools and resources we have. Remember, as I explained, that our project has very little support, very limited funds and relies mainly on a reduced group of volunteers. A study to prove this kind of cause-effect relation would require a project that would be utterly unaffordable for us.	**Lack of resources**	**Lack of knowledge**	
the fact that you cannot do measurements on the sediment itself is because of the resources? Seglar – Yes.	**Lack of resources**		
We have very limited resources so it's very difficult to cover all these duties and though we would like to do	**Lack of resources**		

more things it's almost impossible.			
government changes every four years or less may lead to changes in coastal management policies depending on the ideology of this new government	**Politics**		
Disagreement between different governments because of ideological reasons also rise difficulties in coastal management.	**Politics** **Administrative complexity, fragmentation of authority**		
Unfortunately, sometimes projects and programmes are linked to certain governments or, even worse, concrete persons, instead of being conceived as long-term strategies independent of who is ruling	**Politics**		
of beach regeneration. We could say that it's a different one because here the town Councils press a lot to the authorities to carry out these regenerations because it's very important for the beaches to be properly prepared for the summer season	**Politics** **Other priorities**		

The Balearic Islands

Drivers

global warming. What we see is that after summers that this has been very hot, that here in the in Majorca is when we when the water exceeds 28 degrees of temperature, then the	**Action**	**Climate change**	**Global warming**

mortality increases substantially			
anchoring of boats of leisure boats	**Action**	**Tourism Recreation**	**Anchoring**
But in this area that is also one of the loading of treated water sometimes because there is a lot of visitors in Formentera, but also in Ibiza and then the waters are getting more nutrient enriched. So, this also is making damage to the Posidonia	**Action**	**Tourism**	**Sewage discharge**
is the construction of buildings on the dune systems (…). So, all the sediment that would be coming from land, from the dunes to the water and also from the water to the dunes, this this communication is not anymore.	**Action**	**Coastal development**	**Infrastructure**
eutrophication of the water or particles that come from land And this is very well correlated with the increase of the population in terms of visitors, also residents but mostly visitors, and so on.	**Action**	**Tourism**	**Sewage discharge**
For me and for my knowledge, invasive or exotic species, marine exotic species in now in in the Balearic Islands. I would not list it as a main threat to the Posidonia.	**Action**	**Invasive species**	

Pressures

excess of nutrient input and organic matter in the coastal areas	**Pollution**	**Nutrients**

But in this area that is also one of the loading of treated water sometimes because there is a lot of visitors in Formentera, but also in Ibiza and then the waters are getting more nutrient enriched. So, this also is making damage to the Posidonia	**Pollution**	**Nutrients**
So, all the sediment that would be coming from land, from the dunes to the water and also from the water to the dunes, this this communication is not anymore.	**Morphology**	**Sweeping of sand**
input of organic matter	**Pollution**	**Nutrients**
Posidonia on the other hand, it's really sensitive to warming. Because it's really another threat for the conservation of Posidonia actually.	**Pollution**	**Heat**
what has caused the change in the sediment dynamics in the island	**Morphology**	**Sediment dynamics**

Impacts

carbon sink. In terms of mitigation of climate change mitigation, it's really a big thing	**Regulation and maintenance**	**Carbon sequestration and storage**	**Decreased carbon sink**
Núria – the Posidonia it's really a **carbon sink**. (…) Me - And do people know this? Núria – Here in the Balearic Islands, I think there are people that yes. Probably not everybody, but I think quite a few parts of the residents they acknowledge it. I don't know if they know really the big thing that they have here, that really good benefit of in terms of carbon sequestration. But yes,	**Regulation and maintenance**	**Carbon sequestration and storage**	**Decreased carbon sink**

they are starting to be aware of that			
So, this is one and then in terms of the coast, the coastal protection, it also fixes the sediment in the water. So, it prevents coastal erosion	**Regulation and maintenance**	**Coastal protection**	**Coastal erosion**
enhancing the risk of erosion.	**Regulation and maintenance**	**Coastal protection**	**Coastal erosion**

Responses

Last year, the measures that are in place to prevent these losses... There is this law that I think it was already in place last summer, that prohibits the anchoring on Posidonia	**Regulation**	**Specific protection**
fines to the boat that were anchoring on Posidonia.	**Regulation**	**Specific protection**
but also, this law is contemplating the other pressures on Posidonia to change.	**Regulation**	**Specific protection**
but also, this law is contemplating the other pressures on Posidonia to change. But of course the change I mean, they contemplate the water quality in the coastal areas, it's also something that must be improved if it's an area that have problems in order to preserve Posidonia and avoid losses. But this is not as easy or as rapid to implement or to achieve the goal as prohibiting the anchoring	**Regulation**	**Specific protection**
to reinforce conservation measures in areas where the local pressures are high both from anchoring or from nutrient delivery. These are areas where I think that they should try to reduce the nutrient inputs and prohibit really strong, strongly prohibiting anchoring (…) Also limiting the number of boats that can go to a place	**Regulation**	**Specific protection**

aquaculture it's forbidden	**Regulation**	**Specific protection**
I think we should also involve more Posidonia in our climate change laws or actions, because now well, the government here in the Balearics islands is also aware that we have all these very important natural carbon sinks. But the conservation of the Posidonia is still not directly linked climate change mitigation	**Regulation**	**Overall**
Me – [Is there sort in the Balearic Islands sort of a more integrated coastal management] Núria – I think there is. Because well, actually here, the construction of new harbours, for instance, it's really restricted. And, of course, they do some and some they make them bigger, but it's different in the mainland, for instance, in other regions in the mainland. Here it's really restrictive. I believe that when they do a promenade or these walking streets by the sea, yeah, for sure, they do some impact assessment. I don't know the impact assessment how strict it will be, but yeah. I think now the constructions on the land that have effect directly on the sea or harbours. I think there are quite strict regulations	**Regulation**	**Overall, ICM**
buoys or fixed moorings spots	**Infrastructure**	
(…) or putting in areas where there is a lot of demand for anchoring really put permanent buoys.	**Infrastructure**	
about the quality of the water what I was talking about, that arrives to the plan, sometimes it depends on the municipality on how, for instance, how the water is collected in the city. Sometimes it would require quite a lot of works to really collect the water of the rain separated from the water wastes from the house and then make big deposits. So, they	**Infrastructure**	

require a lot a lot of infrastructure.		
trying to convince or inform people that this is not allowed. But this information works well to the residents, but to the tourists.	**Information campaign, Awareness raising**	
inform the boats that are anchoring in wrong places that they have to move the boat and so on	**Information campaign, Awareness raising**	
because the media and also dissemination campaigns and also from science, we are communicating also our results	**Awareness raising, Information campaign**	
LIFE project from the EU, this type of program, at the beginning of the 2000s. And I think that also really fuelled to disseminate better or more the importance of Posidonia	**Awareness raising, Information campaign**	
It's some subject or some ecosystem that is teached at the schools even from the very young ones. So, the even before the primary school up to the highest school, and of course at the university	**Awareness raising, Information campaign**	
there is a campaign to convince the people, trying to convince the residents and the municipalities and also the hotels that to leave the Posidonia on the beaches, it's actually a good thing and that to have Posidonia on the on the beach. It's like a quality indicator of the beach and the environment.	**Awareness raising, Information campaign**	

Challenges

control all the anchoring around the island, it's impossible because there are not enough surveillance people to be able to do that	**Lack of enforcement**	
I think, here in the Balearic Islands, everybody, the government, the authorities	**(Lack of) awareness**	Policy Society

responsible of the conservation of Posidonia, and even the residents and I think all the stakeholders in the Balearic island really know that Posidonia is something that we must preserve and that we have to do actions to avoid the losses.		
for instance, the port authorities or the yacht associations, they are quite reluctant... they are saying no the problem, the ones that are causing the decline is the is the water quality so it's the government who has to do that. Then some others say "no, it's the anchors. it's the boats."	**Denying responsibility**	Policy Economy, business
but the improvement not only depend on one administration, things about the water, the water treatment. It depends on the region, the regional government. But then for instance, in Palma Bay it's about the decades already that they are trying to make bigger the treatment plan but also to change the pipe to deliver the sewage into the sea. And this pipe thing n I guess it's more than two decades. I don't know the date of the project that they are still trying to put in place dates but it's already old and for doing that they need the authorisation of the administration that deals with the coastal areas from the main government in Spain. And the infrastructures, the Minister of infrastructure. So, there are different administration and they have to agree.	**Administrative complexity, fragmentation of authority**	
especially in things that deal with a coastal area, here there are many administrations that are responsible of the actions taken. And then this is a problem	**Administrative complexity, fragmentation of authority**	

about the quality of the water what I was talking about, that arrives to the plant, sometimes it depends on the municipality on how, for instance, how the water is collected in the city. Sometimes it would require quite a lot of works to really collect the water of the rain separated from the water wastes from the house and then make big deposits. So, they require a lot a lot of infrastructure. (…) I think it's an issue, the resources	**Lack of resources**	
there's a good collaboration between the island governments and the regional one? Núria – Sometimes not always. It depends on who is the politician	**Administrative complexity, fragmentation of authority** **Politics**	
Well, there are not many quantifications on that. Well, it depends. For instance, about the coast, the coastal retreat and the presence of Posidonia, I don't think that there is really very consistent work that has analysed it.	**Lack of knowledge**	
Because do you think that maybe cultural history and the fact that [at the Balearic Islands] you are all surrounded by the sea and that there is a closer connection to the sea. Can that have played a role? Núria – I believe, I guess Yes. Yeah. Probably. I arrived in 2000-'99. But during these 20 years I have the difference of perception from people about the Posidonia and I think the knowledge of the people has changed, but it's because they were more receptive than in other regions, because they are	**(Lack of) awareness**	Society

really in contact with the sea. And they know the ecosystem		
resident people are accepting it, but not everybody, because last summer, actually a group... But it was more of a political issue. There was in one area in one beach that it's very typical. It was small group of people, but they made a lot of noise and they were in all the newspapers saying "oh, look how much how bad the government is keeping the beaches, because there is dirt and so on and how can we receive the tourists with all this mess."	**Politics** **Other priorities**	
I think that many of the tourists arriving they expect to have the clean beaches and transparent beaches. Maybe they see Posidonia and leaving the Posidonia probably they may not appreciate it. But I think it's just all about information.	**Lack of awareness**	Society, tourists
every four years then we've got the election the government changes and then one un-does what the what the previous did. Because of that in a few years, we don't have this decree anymore	**Politics**	
Because they prioritize the needs of tourism and the tourism industry over nature.	**Other priorities**	
It was very difficult to implement this decree because of that. Because they thought "Well, then what are we going to do? Are we going to tell tourists not to go with a boat anchor here and there, that's not good because then then they are going to go elsewhere, and they are not going to leave their money here.	**Other priorities**	
that it depends a lot on what side of the spectrum the political party belongs to	**Politics**	
Because there wasn't any money? Or because the money	**Lack of resources**	

is being invested into different things? Here in the Balearic Islands, one of the problems that we've got is, I guess that is the way the system works. We are in theory, I was going to say we are one of the richest areas of Spain, but no, that's not true. We are one of the areas that generates the most money within Spain, but then that money is sent to Madrid, the central government. The central government then distributes that money.		

I. Overlap tables DPSIR and challenges

	Challenges	Driver	Pressure	State	Impact	Response	Challenges
Seaforest LIFE	Lack of awareness	Unrealistic expectations of tourists which stimulates an 'wrong' motivation behind tourism (Posidonia on beaches)	Causes physical impact anchoring		Not all impacts are visible	Awareness can lead to … Individuals changing their own behaviour and making others aware of the pressure caused by incorrect anchoring	Lack of integrated regulatory framework
						… Create support base for responses from policy	
						Awareness of policy makers can prompt responses from policy	
	Lack of resources						Lack of enforcement
	Other priorities					Delay or lack of (proper) response	Lack of enforcement
	Lack of enforcement					Ineffective response (anchoring prohibition)	

	Challenges	Driver	Pressure	State	Impact	Response	Challenges
Projecte Alguer de Mataró	Lack of awareness	Inability of reducing or eliminating the driver of coastal development and urbanisation	Inability of reducing or eliminating the pressure of coastal development and urbanisation		Not all impacts are visible	Delay or lack of (proper) response from policy	
	Administrative complexity					Delay or lack of (proper) response	Lack of integrated regulatory framework
	Politics						
	Other priorities						
	Lack of resources						Lack of knowledge
	Lack of Knowledge	Knowledge uncertainty				Lack of (proper) response	
	Complexity of the issue - Cumulative effects - Indirect and multivariate relations					Lack of (proper) response	Denying responsibility
	Lack of an integrated regulatory framework	Inability of reducing or eliminating the driver of coastal development and urbanisation	Inability of reducing or eliminating the pressure of coastal development and urbanisation				

	Challenges	Driver	Pressure	State	Impact	Response	Challenges
Balearic Islands	Lack of Awareness	Altering tourist expectations, hence changing the motivation behind tourism? (Posidonia on beaches)	Inability of reducing or eliminating the pressure of coastal development and urbanisation		Not all impacts are visible		
	Stakeholders denying responsibility					Delay or lack of (proper) response	
	Administrative complexity					Ineffective response	Lack of enforcement
	Politics						
	Other priorities					Delay or lack of (proper) response	