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Estimation of threats and recommendations for restoration improvement of *Cystoseira* macroalgal forests in the Mediterranean Sea.

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Author’s declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ABSTRACT OF THESIS submitted by:
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Cystoseira meadows are one of the crucial habitats in the Mediterranean Sea as they provide protection and structural complexity, enhance biodiversity and productivity and food, shelter and spawning grounds for coastal marine ecosystems. However, due to the increasing anthropogenic effects these keystone habitats are rapidly declining. In order to rehabilitate these endemic species, the AFRIMED project was established by the Mediterranean coastal nations in 2019. To increase the project's effectiveness and outcome, Modified Threat Reduction Assessment (MTRA) was selected to evaluate the changes in threats regarding *Cystoseira* species as well as evaluate the management effectiveness and restoration methods for the populations of Ancona, Port de la Selva and Cala Bona. The aim of this research was to determine the nature of threats to Mediterranean *Cystoseira* species and the changes between 2019 and 2021 in all three sites. The research revealed 13 threats and determined negative MTRA Indices of -75.09% in Ancona, -18.33% in Cala Bona and -13.33% in Port de la Selva. Combined with the results of the interviews the research indicates that the scale of the threats has not improved since the beginning of the AFRIMED project.

Keywords: Modified Threat Reduction Assessment (MTRA), *Cystoseira sp.*, Mediterranean Sea, AFRIMED, biodiversity, marine protected areas, restoration methods

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Table of Contents

List of Tables

List of Figures

List of abbreviations

AFRIMED	Algal Forest Restoration In Mediterranean Sea
ABNJ	Marine Areas Beyond National Jurisdiction
CBD	Convention of Biological Diversity
EEZ	Exclusive Economic Zones
FRA	International Fisheries Reserve Area
IMP	Integrated Maritime Policy
IUCN	International Union for Conservation of Nature
MAP	Mediterranean Action Plan
MPA	Marine Protected Area
MTRA	Modified Threat Reduction Assessment
NSAP	National Strategic Action Plans
N2k	Natura 2000 Sites
SAC	Special Areas of Conservation
SPA	Special Protection Areas
SPAMI	Special Protected Areas of Mediterranean Importance
TRA	Threat Reduction Assessment
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea

1. Introduction

1.1 Background

Anthropogenic activities have a strong increasing impact on Earth's vulnerable and complex system which pose a risk to both human societies worldwide and biodiversity in general. Therefore, the importance of biodiversity conservation is more urgent than ever. One of the areas with the highest biodiversity around the world is the Mediterranean Sea (Bianchi et al. 2012). It is an important area for life history stages, such as the reproduction of different species as well as providing habitat for high numbers of endemic species (Abdulla et al. 2008). Moreover, it is also beneficial for human populations as it has a significant importance for its provision of commercial fish (Guerriero et al. 2017) and tourism (Drius et al. 2019). Indeed, tourism is so popular in the Mediterranean Sea that by 2030 a growth of 2.6% is expected compared to the data from 2016 (Plan Blue 2016).

However, during the last decades, the pressure of growing human populations, increasing maritime activities and overexploitation of marine resources caused a loss in marine biodiversity and accelerated the effects of climate change (IUCN 2020).

Habitat destruction has become one of the most recurring threats to biodiversity, especially affecting the midlittoral zone of the world's seas (De La Fuente et al. 2019). *Cystoseira* macroalgal forests, one of the most important, endemic habitats across the Mediterranean Sea, are also threatened (AFRIMED 2021). Typically, the change in habitats implies a transition from a complex habitat to a less complex one, which in this case are macroalgal canopies replaced by turf-forming seaweeds (Mangialajo et al. 2008). Macroalgal forests are responsible for a great part in primary productivity across coastal regions as well as they play an important role within complex marine food webs (De La Fuente et al. 2019). Moreover, they contribute to the reproductive success of many Mediterranean fish species as they provide shelter and nursery grounds (Cheminée et al. 2013). However, due to anthropogenic effects of growing coastal human populations and climate change, these habitats are under risk (AFRIMED 2021). Although most studies focus on the effects of climate change and the fishing industry regarding the *Cystoseira* canopy, the nature and scale of other anthropogenic threats are lesser known. In order to restore these endemic habitats in 2019 the AFRIMED project was established by the Mediterranean coastal nations. To assist the management team and researchers to assess the current threats a Modified Threat Reduction Assessment (MTRA) was carried out in three areas of interest, as this tool focuses on direct anthropogenic threats to biodiversity and conservation (Salafsky and Margoulis 1999).

1.2 Justification for the research

The importance of *Cystoseira* forests in the Mediterranean Sea has only been recently recognized, while in the meantime the canopy is declining. In order to restore and monitor the status of the habitat, countries around the Mediterranean Sea joined efforts by the AFRIMED project. However, there is a clear need for assessing how the threats to these habitats might have changed since the beginning of the project in order to help the AFRIMED partners evaluate their current restoration effort plans.

By combining archival research, semi-structured interviews and the MTRA approach this thesis identifies the nature of the threats to *Cystoseira* forests as well as measuring the mitigation intervention approaches of two different research and management institutions in the Mediterranean Sea.

1.3 Research problem

The research addresses the following research question

To what degree have anthropogenic threats been mitigated since the beginning of the AFRIMED project of the Cystoseira populations at the selected Mediterranean sites?

1.4 Aims and Objectives

This research aims to identify the scale of threats to *Cystoseira* forests in the Mediterranean Sea, while recommending methods for restoration improvement.

The following objectives were chosen to assist achieving the aim of the research:

1. Identify the threats and the sources of these threats to the macroalgal forests.

2. Analyse potential increasing and existing anthropogenic threats and trends in relation to macroalgal forests.

3. Identify potentially successful restoration methods

1.5 Research contribution

This research will contribute to the AFRIMED project. Moreover, the research will greatly benefit the UNEP-WCMC working group as it will (i) identify the threats which may be incorporated into management monitoring, and (ii) recommend restoration efforts. It will also benefit the research and management institutes who agreed to participate in the MTRA workshops as apart from the above mentioned advantages it will assist the relevant teams to reflect on their management action so far and adapt it if necessary.

1.6 Organisational structure

The thesis is organised around six main chapters. The thesis begins with an introductory chapter which provides information on the background of the research, introduces the aim and the objectives of the study and identifies the importance of the research. Chapter two provides an overview of an extensive review of important literature about the local context in which the research was undertaken and summarizing the main concepts explored in the research. The third chapter introduces the methodology used for data collection and analysis as well as presents the limitations of the study. Chapter four presents the result of the MTRA workshop and the interviews. These results are discussed in chapter five including a brief synthesis of relevant supplementary findings. Chapter six will conclude the thesis, summarising research findings and providing recommendations for future research in the area.

2. Literature Review

2.1 Introduction

This chapter provides justification for the chosen topic as well as creates a synthesis of the key concepts explored in this research. It explains biodiversity, biodiversity threats, marine protected areas, *Cystoseira* species and their importance. It also explains the advantages of using the Modified Threat Reduction Assessment (MTRA) for this context. The second part contextualises the study and justifies the choice of study area.

2.1 Biodiversity and Marine Protected Areas

2.1.1 Biodiversity

The protection of global biological biodiversity is one of the greatest concerns of our time (Kindsvater et al. 2018). Growing human populations, urbanization, industrialization, increasing pollution rates and anthropogenic climate change has proven to have negative impacts on our ecosystems and is responsible for a significant loss of biodiversity (Hader et al. 2020). Some scholars have even indicated that if the rate of biodiversity loss continues to be this substantial, it is possible to consider it as the next mass extinction (Thomas et al. 2004, Ceballos et al. 2015). The first evidence of extinction events caused by anthropogenic impacts date back to 50000 years approximately when populations were migrating out of Africa (Nayeri 2017). Biodiversity extinction rates are correlated with the number of people and our ecological footprint which has greatly increased due to the spread of industrial capitalism and exponential population growth (Sodhi et al. 2009). Humans have such a significant impact on our ecosystem that by 2010 already 75% of the land's surface was being impacted by us (Ellis et al. 2010). Considering that the environment has not been influenced and transformed by human civilizations at this rate, it is important to understanding the linkages, monitor and conserve biological diversity worldwide (Rutz et al. 2020).

The Convention of Biological Diversity was adopted in 1992 and has become one of the most important international non-binding instrument to reduce biodiversity loss (Laikre et al. 2010). CBD recognizes three levels of biodiversity that needs to be conserved and sustainably used including ecosystems, species and genetic diversity (Hoban et al. 2020). This can be explained by the fact that the current and historical declines in biodiversity are associated with reductions at every level of biological diversity (Gaston and Spicer 2004). In order to raise awareness about the concept and importance of biodiversity as well as the need for conservation and to monitor the changes these different levels have to be measured (Humphries et al. 1995). Genetic diversity of the examined populations is a critical component of measuring biological diversity (Gaston and Spicer 2004), however some argue that CBD neglects the implementation of genetic diversity as action to reduce the declines are substantially lacking (Laikre et al. 2010).

The CBD set a number of global 2010 Aichi Biodiversity Targets to reduce the degree of biodiversity loss by different action plans by the end of 2010. However, Target 11, which aimed to improve the status of biodiversity by safeguarding genetic diversity, species and ecosystems, failed to meet its targets (CBD 2010a) therefore they revised the plan and The United Nations Strategic Plan for Biodiversity 2011-2020 including the Aichi Biodiversity Targets set a new deadline by the end of 2020 (Amengual and Alvarez-Berastegui 2018). Yet again, these refined targets were failed to be reached as the Marine Protected Areas (MPAs) lacked effective management plans and the needed networks between them (UN/CBD 2020). The COP15 of the UN CBD which aimed to review the above mentioned CBD Strategic Plan for Biodiversity 2011-2020 and to design the post-2020 global biodiversity framework had to be postponed until 2021 due to the COVID-19 outbreak (UN/CBD 2020). The new strategy will have revised, intermediate targets to reduce biodiversity loss and halt ecosystem integrity by 2030 as well as "ensure ecosystem resilience with a vision for living harmony with nature by 2050" (Hoban et al. 2020). Target 2. of the zero draft of the post 2020 global biodiversity includes an increase in protected area coverage as they aim to effectively conserve and manage at least 30 % of the planet with the special focus to important areas to biodiversity (CBD 2020).

2.1.2 Marine biodiversity threats

The pressures on marine ecosystems and biodiversity are expected to increase in the following decades. According to an OECD policy report (2017) these pressures could potentially re-enforce each other causing cumulative impacts on marine biodiversity. The main pressures identified by the OECD report are: overfishing, pollution, habitat destruction, climate change and invasive alien species (Table 1).

Table 1. Main threats on marine biodiversity

Overfishing and exploitation	Overfishing and harmful fishing subsidies are causing the world's fisheries to collapse as sustainable measures are not implemented everywhere (Sumaila et al. 2019). Moreover, there is still a great problem with illegal fishing and mislabelling of prot3ected marine species (Giovos et al. 2020).
Pollution	Due to the rapid increase in production, use and disposal of plastic (Wilcox et al 2016) 6-12 million tonnes of plastic waste is calculated to enter the oceans every year (Jambeck et al. 2015). Consequently nearly 700 marine organisms were estimated to have interacted with marine litter (Gall and Thompson 2015).
Habitat destruction	Habitat destruction can be caused by fishing activities such as dredging and trawling, poor land use practices in agriculture, coastal development and increasing marine tourism (OECD 2017).
Climate change	Climate change has also various impacts on marine ecosystems and species. These include for example 20% decline in the world's seagrass ecosystems (Doney et al. 2012).
Invasive alien species	Invasive species have rapidly increasing impact on biodiversity as well such as, decreased water quality, increasing competition with native species, spread of diseases and altering native ecosystems (OECD 2017).

However, identification of threats to global biodiversity could differ based on the organisation, or the scale and scope of the research. Salafsky et al. (2008) created a standardised lexicon of threats as a proposition for common definition of the threats and to create standardised language for conservation science. Threats were divided into two groups defined as:

1. Direct threats - "The proximate human activities or processes that have caused, are causing, or may cause the destruction, degradation, and/or impairment of biodiversity targets".

2. Contributing factors – "The ultimate factors, usually social, economic, political, institutional, or cultural, that enable or otherwise add to the occurrence or persistence of proximate direct threats".

The contributing factors then are further separated into different categories including: indirect threats, factors with negative effect, opportunities or factors with positive effects.

International Union for Conservation of Nature (IUCN) has adopted the lexicon since then and it is frequently used in conservation studies (Milatovic 2017). Direct threats defined by Salafsky et al. (2008) and the threat lexicon will be used for the purpose of this study and is found in the Appendix C.

2.1.2. Marine Protected Areas

Marine ecosystems are also heavily influenced by the increasing human presence. The exploitation of marine resources dates back to the establishment of the first civilizations (Boonzaier and Pauly, 2015) and has exponentially increased throughout the years. The industrial revolution enabled the quick modernization of fishing vessels which consequently caused an increase in fishing activities (Claudet, 2011). For a long time, humans regarded the ocean as an inexhaustible source of resources and ecosystem services (Roberts, 2003). However, fishing stocks began to collapse globally, while at the same time marine pollution increased (Hutchings 2000, Lima et al. 2020) which had severe socio-economic and ecological consequences (Hillborn, 2007). Simultaneously leaders of various nations realized that marine resources are not infinite therefore they have to be conserved and sustainably managed (Spalding, 2016).

To tackle these issues marine protected areas (MPAs) were established around the world's oceans. By one of the most well-known and accepted definitions a marine protected area is

"A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values". (Dudley and Stolton 2008).

Moreover, IUCN informs about the various reasons why these protected areas are established such as species protection, biological diversity conservation and conserving economic resources. Protected areas are generally considered as one of the most effective tools to tackle the biodiversity crisis (Ervin et al. 2010). This notion is supported by the fact that they were included in the latest CBD action plan by which governments agreed to commit to conserve 10% of coastal and marine areas and 17% of the terrestrial and inland water (CBD 2010b).

There are different categories of MPAs. The IUCN has developed a scheme to categorize protected areas, which was primary made for terrestrial protected areas it can also be used to categorize MPAs (Table 2.) (Dudley 2008). The rows shaded grey indicates the categories that are more common in marine ecosystems according to the author. Towards the last decades there has been a trend of increasing MPAs that fall under Ia. referred to as no-take zones as they are considered to be the most effective tools to achieve the objectives of restoring ecosystem services and increasing the connectivity between the MPAs (Jones 2014).

Table 2. IUCN Protected Area Management Categories related to MPAs. (Dudley 2008, 55-58)

IUCN Category	Application to MPAs	Most important objectives
Ia. Strict Nature Reserve	Strictly no-take MPAs or no-take zones within the designated MPAs, focusing on the preservation of biodiversity and geological/geomorphological feature. They can serve as control areas for scientific research and management monitoring.	Restore ecosystem health, fish stocks and cultural values while contributing to increased MPA network systems.
Ib. Wilderness Areas	Areas free from human disturbance and developments with high value, which are managed to preserve this condition. Concept of "marine wilderness" is not as clear as for terrestrial protected areas.	Control the impacts of anthropogenic activities such as marine tourism and recreation as well as restore cultural values.
II. National Park	Large areas conserved for ecosystem protections, ecological processes, while providing space for educational, recreational activities and tourism, excluding fishing activities or other extractive activities	Restore ecosystem health, fish stocks and cultural values while contributing to increased MPA network systems and control the impacts of tourism
III. Natural Monument	Protection of a particular natural feature for instance submarine caverns as well as cultural such as submerged archaeological sites. They provide high visitor values.	Promote outreach projects, research and education
IV. Habitat/Species Management	It includes the protection of areas of importance of different life stages such as breeding, feeding or spawning areas for vulnerable species. It sometimes includes the prevention of dredging and trawling.	Conserve rare and vulnerable species and habitats
V. Protected Land and Seascape	Areas where the interactions of people and nature created a an area with distinct characteristics	Promote traditional knowledge and uses: cultural symbolic value of set-aside areas

	that have important ecological, cultural and scenic value as well.	
VI. Protected Area with Sustainable Use of Natural Resources	Protection of natural habitats with controlled ecologically sustainable collection of particular things such as types of food or shells for tourist trade	Maintain traditional uses; restore fish stocks

Over recent decades the spatial and number extent of MPAs have grown rapidly. (Figure 1.). Since 2000 there has been an increase of 7.68% of the ocean being protected by MPAs (Protected Planet 2021.). The ones indicated with the purple line (ABNJ) stand for Marine Areas Beyond National Jurisdiction, therefore nations have to share the responsibility for managing these areas. On the other hand, national waters represent areas of the sea until the limit of the Exclusive Economic Zone (EEZ) (Protected Planet 2021).

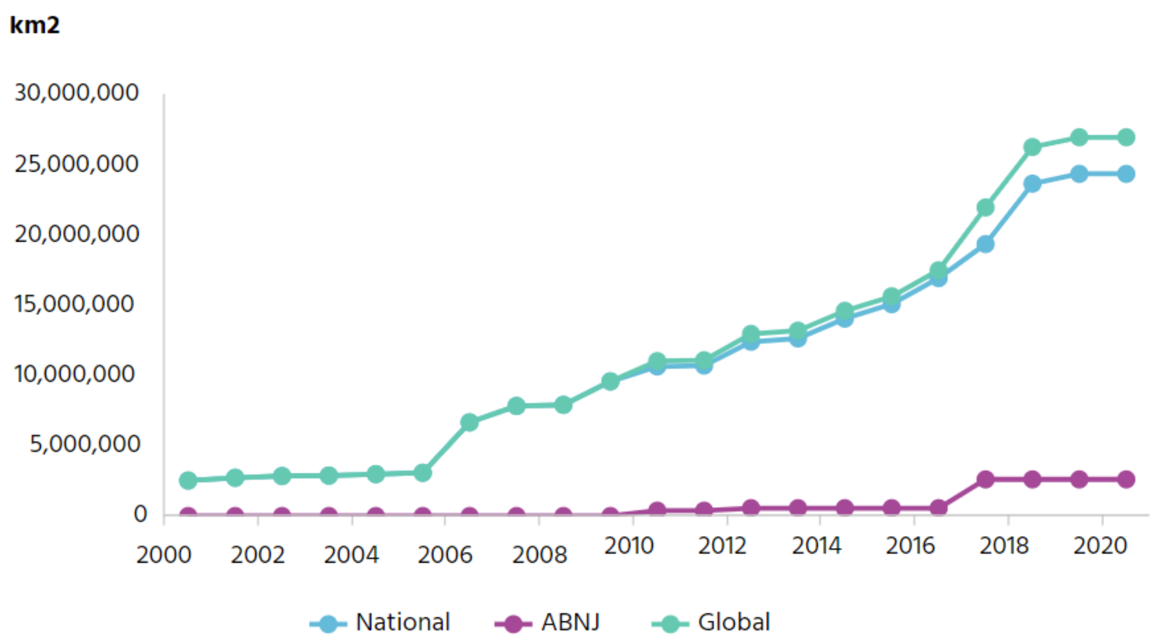

Figure 1. Growth in marine protected area coverage from 2001-2020. (Source: UN WCMC, 2021).

2.1.3 Marine Protected Area Effectiveness

There are various advantages of establishing MPAs to conserve the marine ecosystem while at the same to sustainable manage the ecosystem services. Well designed and managed MPAs can improve the survival rates of juvenile fish (García-Rubies et al. 2013) and as a consequence increase fish biomass (Agardy, 2018). Moreover, it can positively influence the complexity of marine habitats and species diversity in general (Lester et al. 2009). Nevertheless, despite the growing number of MPAs worldwide the overall loss in biodiversity and habitat quality and quantity are still increasing as well as the impact of anthropogenic activities (Bertzky et al. 2012). Moreover, the indicated advantages are mostly true of no-take marine protected areas. In 2019 about 4.8% of the global marine area was designated as MPA and out of those MPAs only about 2.2% was established as a no-take zone (Marine Conservation Institute, 2019).

In general, measuring the effectiveness of MPAs is challenging as the quantification of indicators of success is difficult and there is no universal method to do it (Fox et al. 2014). One of the challenges is deciding the indicators for measuring the effectiveness of PAs/MPAs. Only in recent years was the importance of management of a protected area acknowledged (IUCN-WCPA 2009), before which the evaluations were based on for example species conservation. However, this method solely does not guarantee the success of the conservation effort as in some cases MPAs were established around "charismatic species" with no arguable theoretical foundation (Hooker and Gerber, 2004). Moreover, even if the MPAs were established for a threatened species such as the vaquita (*Phoceona sinus*), since the MPAs was not effectively managed in this case the species had to be upgraded to critically endangered in 1996 (Rojas-Bracho et al. 2006). Another indicator used is the size of the coverage and location of the MPA (Rodrigues et al. 2004), however some scholars argue that the increase in surface area should not be the main indicators for conservation success as it not necessary includes adequate management plans (Singleton and Roberts 2014; Boonzaier and Pauly 2015). Another conservation strategy is focusing on representing all ecoregions which could also be counterproductive by favouring political views on the different locations instead of scientific reasoning (Spalding et al. 2016). To conclude, for an effective MPA and successful conservation effort, all the different indicators for the evaluation should be taken in to account. This inclusiveness of various targets is also underpinned by the Aichi 11's *qualitative targets* for 2020 which stated that MPAs should be: well connected, effectively managed, ecologically representative, integrated into the current surrounding land and seascapes and favour areas of particular importance for ecosystem services and biological diversity (Rees et al., 2018). Moreover, the increasing importance of focusing on the management effectiveness of the MPAs is also acknowledged by the Aichi 11 target:

> "By 2020, at least 17 per cent of terrestrial and inland water, and 10 percent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes" (CBD 2010b).

However, a decade has passed and MPAs still look better on paper, than real life, hence the name "paper parks". The target to effectively manage these conservation tools are just as important and urgent as ten years ago, when the Aichi 11 target was established.

> "For each MPA, define conservation measures and formally adopt and implement-long-term and integrated management plans that are based on SMART objectives and include adequate, fully protected areas."(Gomei et al. 2019)

As indicated, measuring conservation effectiveness of PAs and MPAs is complex and challenging, however extremely important as there is a growing need for transparency, accountability and effective strategies in relation with the increasing number of MPAs (Amengual and Alvarez-Berastegui 2018).

In general, there are two main ways to measure conservation success: by using biological indicators or management indicators (Tucker 2005, Margoluis et al. 2009). Using biological indicators are generally more expensive and difficult to implement as collection of the data is more challenging because it requires trained personnel and advanced equipment (Margoluis and Salafsky 2001, Anthony 2008). Considering the Mediterranean Sea, it is particularly challenging for the Southern parts due to the lack of trained personnel and equipment (Amengual and Alvarez-Berastegui 2018). They also require baseline data which is not always available (Margoluis and Salafsky 2001). The effects of climate change and frequent natural fluctuations could cause biased and skewed results that can result in misinterpreted results and flawed conservation management (Margoluis and Salafsky 2001). However, biological indicators play an important role in prioritizing conservation actions when the right indicators are chosen (Giakoumi et al. 2018).

One of the tools to measure management effectiveness was developed by Salafsky and Margoulis (1999). The Threat Reduction Assessment (TRA) measures the management effectiveness indirectly through measuring the changes in direct biodiversity threat within a PA/MPA. By using this tool, the limitations caused by biological indicators is excluded, while the identification of successful management strategies and direct threats are identified (Salafsky and Margoluis 1999). Moreover, compared to methods using biological indicators, it is more sensitive to changes over short periods of time and reflect these changes throughout the whole protected area (Salafksy and Margoluis 1999, Anthony 2008) which is useful for this particular research.

The TRA approach has many other great advantages. It is relatively quick compared to other approaches as it usually takes 1-1.5 hours with the most knowledgeable managers and researchers, therefore they are also more willing to participate in it. It is also cost effective (Loughney 2013) and as it creates quantifiable results (TRA Index) it is easy to understand and compare across sites or timelines. Most importantly for this research, TRAs can also be used with the lack of baseline data (Salafsky and Margoluis 1999) as the AFRIMED project was established in 2019 and its results are comparable between sites (Anthony 2008).

On the other hand, using the TRA can cause bias as the threat reduction and the ranking of the threats rely on the knowledge and opinion of the participants (Salafsky and Margoulis 1999, Tucker 2005). Moreover, TRA does not include the threats that have worsened or newly appeared throughout the chosen time period. Therefore, to address this weakness of the tool by adding negative scoring for emerging and worsening threats, Anthony (2008) developed the Modified Threat Reduction Assessment (MTRA). The validity and reliability of this method has been demonstrated through a number of studies in South Africa (Anthony 2008; Milatovic 2017), Lebanon (Matar 2009), Mongolia (Ganbaatar 2011) Ghana (Anderson 2012) Ukraine (Kovalenko 2012) and an MPA in Grenada (Loughney 2013).

Using MTRA can make the evaluation of the chosen MPAs more accurate as well as finding the main biodiversity threats and the threats of *Cystoseira* sp., therefore it was chosen as the best method for the research. More through justification of the method and the steps are discussed in detail in Chapter 3.

2.2 *Cystoseira* species in the Mediterranean Sea

Marine habitat forming species have a crucial ecological relevance as they provide protection and structural complexity, food and enhance biodiversity and productivity for coastal marine ecosystems (Bruno et al. 2003). Due to their role in determining patterns of spatial and temporal variability by interacting with their associated biota these species should be given a more important role regarding conservation management programs (Benedetti - Cecchi et al. 2001).

Macroalgal forests are one of these canopy-forming benthic species. Apart from the general advantages and importance of habitat forming species macroalgal forests also enhance the structural complexity of rocky bottoms (Thibaut et al. 2017). In the Mediterranean Sea, *Cystoseira* species are one of the most important canopy-forming algae with about 42 species present in the area (Guiry and Guiry 2013). *Cystoseira* is a brown algae of the Fucales order and is widely distributed in the Mediterranean Sea (Buonomo et al. 2018). *Cystoseira sp*. play a key role in determining the diversity patterns in a given area (Sales et al. 2012) as well as being great indicators of water quality as they are sensitive to any types of pollution (Mangialajo et al. 2008; Sales et al. 2011). They are fucaleans which are characterized by slow-growth and short propagules dispersal which makes them especially prone to climate change and anthropogenic effects (Benedetti-Cecchi et al. 2001).

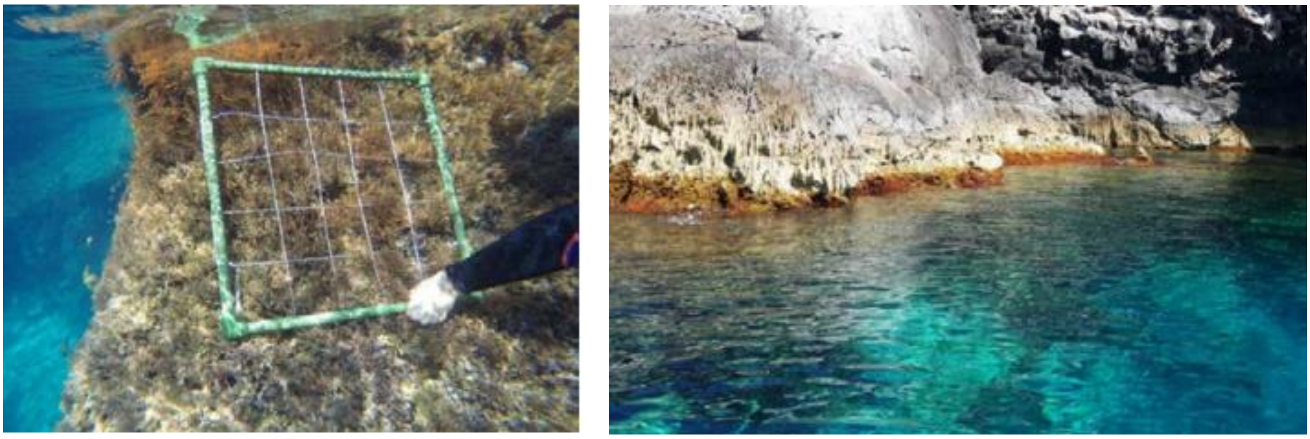

Figure 2. *Cystoseira* meadows in Grama Bay (Orfanidis et al. 2019).

2.2.1 Main pressures of *Cystoseira sp*. in the Mediterranean Sea

The main threats of the Mediterranean Sea are very similar to the overall marine threats discussed in chapter 2.1.2. The sea's rich biodiversity has been altered in many ways throughout its history. Nowadays in the region eutrophication, habitat loss and degradation, pollution and the increased numbers of alien species are the threats that affect the greatest numbers of species in the Mediterranean Sea (Coll et al. 2010).

Moreover, there is a growing concern about the rapid loss of *Cystoseira species* around the world due to the increasing anthropogenic effects such as overfishing and increased pollution (Sales et al. 2011, Blanfuné et al. 2016), especially around urbanized areas (Bianchi et al. 2014, Connel et al. 2014, Piazzi et al. 2018).

The threats affecting *Cystoseira sp*. are quite similar to the overall threats effecting marine biodiversity in the Mediterranean Sea. To begin with, marine pollution is currently one of the greatest threats to marine biodiversity worldwide (Lotze et al. 2006). Due to urbanization and industrial activities, the amount and variety of pollutants in coastal waters are rapidly increasing. Inorganic nutrients, pesticides, detergents and heavy metals are getting more abundant especially around urban areas (Scavia and Bricker 2006). These pollutants could affect littoral communities in different ways (McGlathery et al. 2007). For example, the higher amounts of inorganic nutrients lead to eutrophication which stimulates phytoplankton production that changes the species composition in a given ecosystem (De Senerpont Domis et al. 2014). Moreover, Sales et al (2011). have proven that across heavy metal polluted areas decreased survival or reduced growth was found regrading different species of *Cystoseira.*

Another issue is the overpopulation of a number of native species in the area. Although, these harmful outbreaks of e.g. sea urchins can be due to natural fluctuations in number, these are mostly due to the overfishing of their predators in the Mediterranean Sea (Guidetti and Dulcic 2007). The increased numbers of sea urchins will result in overgrazing of marine algae which can cause regime shift among marine ecosystems (Ling et al. 2015). They cause depletion of the macarolagal forest and consequently form extensive barren grounds (Guidetti and Dulcic 2007). Moreover, a recent study by Gianni et al. (2017) claims, that although there is a significant loss of macroalgae due to sea urchins in the Mediterranean Sea, the effect of an herbivorous fish, *Sarpa salpa* has been overlooked and could also potentially play a crucial role in the recent loss of *Cystoseira* forests recorded.

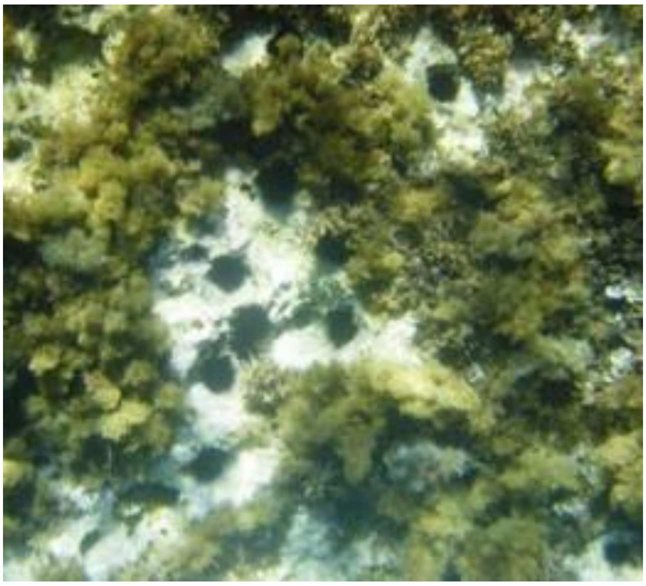

Figure 3. Degradation of *Cystoseira* forests in the Rocky island meadow due to sea urchin grazing (Orfanidis et al. 2019).

Not only overpopulated native species could threaten the viability of these endemic macroalgal forests, but invasive alien species as well. Invasive alien species are considered to be one of the major threats as they both impact marine biodiversity, ecosystem services, ecosystem structure and function (Galil 2018). Regarding the Mediterranean Sea there is an ongoing crisis related to growing numbers of alien species that is mainly due to the increasing shipping traffic at the Suez Canal – the main place for the introduction of the invasive species to the region (Galil 2018). In fact, the Suez Canal is thought to be responsible for 53 % of all exotic species entering the Mediterranean Sea (Coll et al. 2010). Although, not as influential as shipping, aquaculture also represents a vector for introducing alien species due to accidental release of species (Mannino et al. 2017). For instance, the grazing of invasive fish species *Siganus luridus* and *S. rivulatus* has been causing a strong reduction in the biomass, algal growth and biodiversity in the Mediterranean Sea (Sala et al. 2011). Controlling or eradicating these invasive species is especially difficult as they do not have natural predators therefore their numbers can grow extremely quickly (Zenetos et al. 2020).

Moreover, changing climatic conditions will most likely affect the Mediterranean populations of *Cystosira sp.* more than in other populations around the world due to their limited availability of new suitable habitats and no possibility for northern expansions (Buonomo et al. 2018). Unfortunately, the anthropogenic threats could potentially amplify the negative effects of climate stressors. This further hinders the categorization of the threats consequently leading to challenges in management decisions and conservation priorities (Buonomo et al. 2018). Therefore, under this quickly changing and uncertain environment there is a crucial need to study and better understand these threats and trajectories of biodiversity change.

2.2.2 Algal Forest Restoration in Mediterranean Sea (AFRIMED)

During the past years there has been an increase in the attention toward the state of macroalgal forests from the conservation side (Annex II of the Barcelona Convention, COM/2009/08/FIN) as well as from the restoration point of view (MERCES and AFRIMED) (Fabbrizzi et al. 2020).

Due to the populations' slow growth rate and the low dispersal abilities related to the size of their zygotes, natural recovery is almost impossible (Ballesteros et al. 2009). Many of the restoration efforts so far have been unsuccessful (Tamburello et al. 2019) mainly due inadequate site selection. In order to gain more insight into the successful restoration efforts of these important yet degraded habitats in the Mediterranean Sea the AFRIMED project was established in 2019 of which this research forms a part. The project is expected to run for 36 months, however due to the COVID-19 pandemic delays are already expected.

To achieve the project's objectives this multidisciplinary research aims to refine and implement novel restoration actions, formulate guidelines, measure any changes in the health and distribution of the species and gather knowledge from the neighbouring countries across the Mediterranean Sea (AFRIMED 2021). To ensure the interdisciplinary nature of the project for the best possible outcome, different working groups were established.

Working group one (WP1) aims to identify suitable locations for restorative actions in the context of current natural distribution of macroalgal forests and anthropogenic context. WP2 will optimise restoration techniques, develop indicators, monitoring frameworks and targets to evaluate the restoration success and will model future possible distribution patterns while exploring the responses of *Cystoseira* species to possible future climatic conditions. These restoration methods then will be revised by Working Group 3 in the field. WP4 aims to transform the knowledge from the field and laboratory work into policy needs as well as identify contextual factors and frameworks to improve the delivery of the restoration project. Finally, Working Group 5 will carry out outreach projects with local stakeholders to increase awareness of these crucial habitats and their ecosystem services.

2.3 Study area

2.3.1 Mediterranean Sea

The Mediterranean Sea represents a number of unique physical, chemical, biological and socio-economic features which divides it from other marginal seas (Tovar-Sánchez et al. 2019). Its name in Latin is *Mare medi terraneum* which means "sea in the middle of the land (Coll et al. 2010). It is the world's largest semi-enclosed sea where evaporation exceeds river discharges and precipitation, and which hydric deficit is covered by the water exchange with the Atlantic Ocean (Tovar-Sánchez et al. 2019). Compared to other seas around the world, the Mediterranean Sea is relatively small even though the number of residents living along the coast has reached 150 million (Casale and Margaritoulis 2010). There are 21 countries enclosing the sea, being one of the most popular tourist destinations in the world receiving 330 million tourists in 2016 (Tovar-Sánchez et al. 2019). Due to the increasing effects of coastal human populations and tourism in relation with the sea's small surface area the anthropogenic threats on the biodiversity and ecosystem services are expected to further increase (Coll et al. 2010, Tovar-Sánchez et al. 2019).

2.3.2 Mediterranean Sea's biodiversity

The Mediterranean Sea is a global biodiversity hotspot providing home for about 20000 marine species out of which every fourth is an endemic species (Bianchi et al. 2012) of conservation concern such as several cetaceans, sea turtles and the critically endangered Mediterranean monk seal *(Monanchus monanchus)* (Coll et al. 2010). It also accommodates for important areas of life stages of these endemic species such as reproduction (Abdulla et al. 2008). Moreover, it is one of the most important spawning grounds for Eastern Atlantic Bluefin tuna (*Thunnus thynnus*) (Ingram Jr. et al. 2017). Endangered habitats of *Cystoseira sp*. and *Posidonia oceanica* are also endemic to the region. Generally, biodiversity is higher in coastal areas and continental shelves than the deeper areas (Sardá et al. 2009). The same applies for the level of endemism (Bianchi et al. 2012).

Despite the biological, cultural and economic importance of marine biodiversity in the Mediterranean Sea, our knowledge about the different taxa and ecosystem services is limited especially compared to the knowledge about Mediterranean terrestrial biodiversity (Blondel and Médail 2009). Thus, for effective conservation actions more research is needed on the marine biodiversity of the region.

2.4 Conservation in the Mediterranean Sea

2.4.1 Legislative backgrounds

In general, Mediterranean policy is affected by the diversity of the political and economic factors related to the large number of countries located in the region (Suárez de Vivero and Rodríguez Mateos 2015). Beyond the waters affected by various national jurisdiction, the high seas belong to the United Nations Convention on the Law of the Sea (UNCLOS) high sea regime (Röckmann et al. 2018). This allows free and equal access to marine resources to nations including non-coastal states.

There are two main governance processes in the Mediterranean Sea: a regional sea level governance which is the United Nations Mediterranean Action Plan (MAP) and the Barcelona Convention, along with the regionalization of the management (Suárez de Vivero and Rodríguez Mateos 2015). To enhance the objectives of environmental regional sea governance in 1975 the Mediterranean Action Plan (MAP) was adopted (Franzti et al. 2009). Its main goals are to assess and control marine pollution, formulate national environmental policies, optimize resources and allocations and to improve governance (Röckmann et al. 2018).

On the other hand, the EU level governance aims to enhance the development and implementation of the EU's integrated Maritime Policy and marine policies/legislation relating to fisheries, coastal management, maritime spatial planning and the EU's strategy for the Mediterranean Sea basin (Cinnirella et al. 2014). These both affect national policy actions such as the national implementations of EU framework directives and national strategic action plans (NSAP) (Röckmann et al. 2018). Moreover, the basin's strategy of the EU's Integrated Maritime Policy (IMP) emphasizes the need for stronger improved cooperation between the Mediterranean countries (European Commision 2021).

The main marine conservation strategy in the Mediterranean Sea is focused on the establishment of MPAs. This is in line with the Aichi Biodiversity Target 11 of the Convention of Biological Diversity where the participating countries agreed to establish and effectively manage 10% of coastal and marine areas by 2020. Moreover, the World Parks Congress (IUCN, 2014) and the European Biodiversity Strategy to 2020 (European Commission 2011) have also proposed similar guidelines which include establishing MPAs.

Particularly, *Cystoseira* forests are endangered and listed as Annex II species (Barcelona Convention-Annex II, United Nations Environment Programme/Mediterranean Action Plan – UNEP/MAP) due to their rapid decline in the last decades (Blanfuné et al. 2016).

In conclusion, the MAP, Barcelona convention and the country specific Mediterranean policies, regulations and frameworks are considered globally as a strong governance framework (Röckmann et al. 2018). However, their implementation is critical for the preservation of marine biodiversity and at the moment its deliverables are far from being met in reality (Coll et al. 2010).

2.4.2 Marine Protected Areas of the Mediterranean Sea

There are different types of MPAs in the Mediterranean Sea including Natura 2000 (N2k) sites, national MPAs, international fisheries reserve areas (FRAs) and international MPAs.

Natura 2000 network is a site-based protection tool which was established for biodiversity protection in Europe. It consists of Special Areas of Conservation (SACs) under the Habitats Directive (Council directive 92Ö/43/EEC, HD) and Special Protection Areas (SPAs) under the Birds Directive (Council directive 79/409/EEC, BD). The N2k network currently includes over 27500 marine and terrestrial sites which makes it one of the world's most extensive networks of protected areas (Agnesi et al. 2017). That's the equivalent of covering 19% of the territorial waters of EU countries, however less than 4% of their EEZs (Fortuna et al. 2018). Furthermore, although the success of a number of Natura 2000 sites cannot be diminished, since they are designed to protect European areas they lack the comprehensive regional perspective (Amengual and Alvarez-Berastegui 2018).

National MPA is a collective name to different types of MPAs that are situated in the territorial waters of Mediterranean countries (Amengual and Alvarez-Berastegui 2018). According to the data of MEDPAN-MAPAMED (2016) there are 186 national MPAs in the Mediterranean Sea which are mostly managed as a multi-site conservation tool with a number of different regulated activities such as fishing.

International Fisheries Reserve Areas are established to protect the benthic habitats. The General Fisheries Commission for the Mediterranean has declared extensive areas located deeper than 1000m as new FRAs, from where trawls and dredges are forbidden (Amengual and Alvarez-Berasteguei 2018). However, these tools are often criticised as they are not affecting the whole marine ecosystem which is a criterion for a "true" MPA (Fenner 2016).

Lastly international MPAs are conservation areas that fell under the legislation of an international convention or law but declared by the national jurisdiction of a country (European Commission- DG MARE 2013). They are mostly located in coastal waters, but could be also designed in an Economic Exclusive Zone or in Waters Beyond National Jurisdiction (European Commission- DG MARE 2013). Ramsar sites, biosphere reserves and Specially Protected Areas of Mediterranean Importance (SPAMI) are all recognized as international MPAs by the signatory countries of the Barcelona Convention (Amengual and Alvarez-Berasteguei 2018).

2.5 Research sites

Workshops were carried out with teams from Ancona, Italy (Figure 4. A), Cala Bona, Spain (Fig. 4. B) and Port de la Selva, Spain (Fig. 4. C).

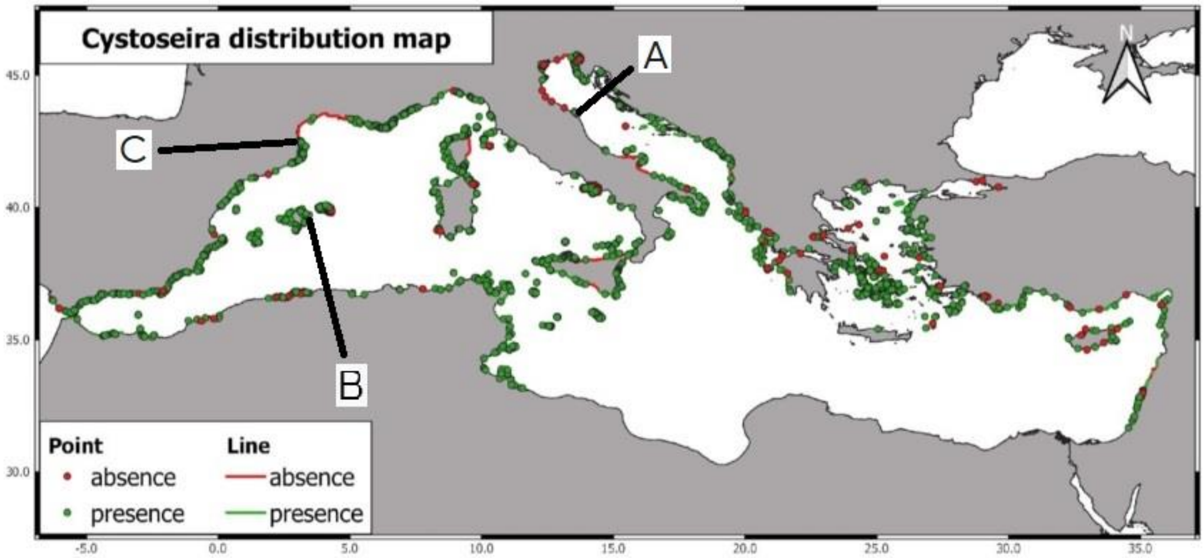

Figure 4.: Distribution of *Cystoseira* species in the Mediterranean Sea. The locations of the workshops are shown with A; Ancona, B; Cala Bona and C; for Port de la Selva (Orfanidis et al. 2019).

2.5.1 Ancona, Italy

The area where the *Cystoseira* meadows are found is located in the south of the city of Ancona, western coast of the central Adriatic Sea in Italy. *Cystoseira barbata, Cystoseira compressa and Cystoseira humilis* are found in the examined Italian coast.

Ancona is located in the Adriatic coast being the capital of the Marche region in central Italy (UrbAct 2021). Although the city has relatively low number of inhabitants (100 000) its port is one of the most important and the busiest in the Adriatic Sea for fishing, passenger and freight traffic (Fileni et al. 2019). The Natura 2000 park where the local *Cystoseira* populations are extant is located between Portonovo bay and Sirolo (Natura 2000 Database, 2020).

2.5.2 Cala Bona and Port de la Selva, Spain

Two different sites of *Cystoseira* habitats in Spain is also examined and take part in the AFRIMED project. The populations in Cala Bona is not protected nor under any types of management activities at the moment. On the other hand, the populations in Port de la Selva falls under the protection of Cap de Creus Nature Reserve.

Cala Bona is a small Mallorcan fishing town. located in the north east of Mallorca in the province of Girona (ABC Mallorca, 2021). The population of the town is approximately 1200 inhabitants and it gives gome to a small harbour a cove and numerous bars, hotels and restaurants due to its popularity as a holiday spot (Institute Nacional de Estadística 2021).

Port de la Selva is also a small fishing town located in northern Costa Brava (Spain Info 2021). The *Cystoseira* meadows are located inside the Cap de Creus Nature Reserve, which was established in 1998 and managed by the Department of Environment of the Autonomous Government of Catalonia, includes 3056 ha of sea (Lloret et al. 2008).

2.5 Conclusion

Considering the importance of the evaluation of how successful is the AFRIMED project so far and possible changing threats due to the effects of the pandemic the need to evaluate the threats and restoration methods was recognized. It is especially important due to the increasing biodiversity threats worldwide and especially in the Mediterranean Sea due to the nature of the area as the literature review pointed out. The MTRA will reveal the possible changes which can act as a basis for the final years of the restoration project across the Mediterranean basin. Combined with records review, legislations and interviews the results will help the areas to meet their objectives and further exposing the protected areas' threats. Analysing the results will help to find the successful management interventions, restoration efforts and identification of the emerging threats.

3. Methodology

3.1 Introduction

This chapter introduces the methodology used to collect and generate data for this research. Furthermore, it will present how the research was carried out and provides justification why the applied methods were chosen. The chapter then introduces the preparatory activities including preliminary interactions with stakeholders from the AFRIMED project and data collection through archival review and analysis. Subsequently it presents the data collection through interviews and MTRAs, while it closes with the limitations and the justification of the chosen tools.

3.2 Research design

The research combines both qualitative and quantitative methods. The quantitative part included MTRA workshops at two selected sites. The qualitative part of the research combines relevant archival analysis to provide better understanding of the background of the study as well as semi structured interviews to complement the results of the MTRA workshops.

3.3 Qualitative methods

3.3.1 Archival analysis

Relevant literature was analysed understand information that will be used to create the workshops of the MTRA. Review of the basic literature about the important concepts for the study such as biodiversity, ecosystem services, management effectiveness and conservation mainly included peer reviewed scientific journals, books and reports from WWF, IUCN, UNEP-WCMC. Lastly, previous MTRA researches were consulted to fully understand how the tool works and how to administer the data (Anthony 2008,-; Matar 2009,-; Anderson 2012,-; Kovalenko 2012,-; Loughney 2013; Milatovic 2017).

3.3.2 Semi structured interviews

To better understand to what degree do different threats affect the Mediterranean *Cystoseira* species and its ecosystem services a number of stakeholders were interviewed.

Semi structured interviews allow flexibility as the questions could be slightly modified depending on the direction of the interview (Brown and Danaher, 2019). Another advantage of including this method is that the interviewee might mention something that is valuable for the research but was not considered in the preliminary research design phase. The interviews then were transcribed to support the main argument.

3.4. Quantitative methods

3.4.1 MTRA

Threat Reduction Assessment (TRA) aims to assess the direct threats of biodiversity at a given area at a chosen time period to measure conservation success within the PA or MPA (Margoluis and Salafsky 2001, 10-11). In order to conduct a TRA the following assumptions have to be made:

1. "All destruction of biodiversity is human-induced;
2. All threats to biodiversity at the given site can be identified and ranked according to the area, intensity and urgency at any point in time;
3. Changes in all threats can be measures or estimated" (Margoluis and Salafsky 2001).

However, TRAs fail to incorporate scoring mechanism to allow for new threats or those that have worsened during the assessment period, therefore the modified version of the tool, MTRA was selected because as it includes worsening and emerging threats it increases the accuracy and representativeness of the results (Anthony 2008).

3.4.2 Justification

The aim of the research was to identify current threats affecting selected *Cystoseria* macroalgal forests in the Mediterranean Sea. At the same time due to using the MTRA method, as an aspect of the management effectiveness of the AFRIMED project is also measured and restoration methods are also discussed. Considering the various advantages of this tool explained in section (3.4.2), it was chosen as the main method for the study. It was suitable for the research as:

- It does not require previously collected data
- It is cost and time-effective
- It allows for comparison between different sites
- Can be conducted online due to travel restrictions

Previous MTRAs by Anthony (2008) and Matar (2009) identified workshop style group discussions as the most effective ways of applying the tool, which was successful due to:

- It allows everyone's opinion to be taken into account, as the workshop moderator will facilitate the discussion
- Workshop setting allows the participants to take part in the project with different levels of experience and knowledge
- It creates a relaxed and safe space where participants can confidently share their thoughts
- It is not time-consuming as the workshops usually lasted for 2 hours.

3.4.3 Preliminary preparations

In order to facilitate the workshop, introductory emails including the workshop materials were sent out in advance of the workshops. The emails included a brief summary of the research aims and how it will contribute to the AFRIMED project. The workshop package included a brief introduction of the MTRA tool, a detailed step-by-step summary of how the workshop is going to take place (Appendix A.) (Margoluis and Salafsky 2001), the most recent version of the IUCN standard lexicon of threats (Appendix C.) (Salafsky et al. 2008) and the worksheets that facilitates the MTRA Index calculation (Appendix B.)

The email also included that the participants at each research site should:

- Have experience in the area, meaning that they should have worked in the area during the assessment period to be able to indicate the scale and nature of the threats
- Be knowledgeable about *Cystoseira* species and the site
- Be familiar with basic concepts such as biodiversity, ecosystem services and habitat conditions of the Mediterranean Sea

Moreover, English speakers were preferred although it was not required. After confirmation of the date and time of the workshop each team was asked to review the workshop package and bring previous management effectiveness evaluations to minimise bias and increase the validity of the research. Additionally, they were advised to print out the IUCN threat lexicon for the facilitation of the workshop.

3.4.4 Workshop administration

In total three MTRA workshops were conducted: one in a Natura Reserve site in Port de la Selva, one in Cala Bona and one in a Natura 2000 site in Ancona. Each workshop started with a brief Power Point presentation to introduce the research, methodology, key concepts as well as the step-by-step guide of the workshop. The workshop followed the steps and structure by Margoluis and Saladksy (2001).

1. *Define the area and the assessment period;* was done by the workshop moderator. During the workshop the areas of Port de la Selva, Cala Bona and Ancona were assessed. These areas were chosen due to the aim of the research which is to identify and compare the threats of *Cystoseira* sp. in the Mediterranean Sea and attempt identify

the sources of these threats as well as restoration methods. The assessment period for both protected areas was chosen to be the start of the AFRIMED project from 2019 until present date to allow for comparison.

2. *Developing a list of threats found in the MPA;* participants were asked to identify the direct threats present at the beginning of the assessment period (and the AFRIMED project) in the area. Subsequently, when the list was made the top ten threats were chosen and categorised according to the IUCN lexicon of biodiversity threats, including 2 sub-categories (Salafsky et al. 2008). In order to avoid the possibility to lose information resulting from threat standardisation, the participants were also asked to describe the threats in details (Anthony 2008).
3. *Defining the threats and 100% reduction target;* during the following step, participants were asked to determine what a 100% reduction of each threat would be as well as they agreed on a detailed definition of each threats. The 100% threat reduction was defined 'as the complete eradication of a given threat' followed by the findings of Anthony (2008) in order to eradicate any ambiguity. In case of the participants claiming that the total elimination of a given threat is not feasible a different definition of a 100% reduction was made.
4. *Ranking the threats according to their area, intensity and urgency;* in this exercise, experts were asked to collectively rank the listed threats based on how they impact the *Cystoseira sp*. in the protected areas related to area, intensity and urgency. The scoring scale was defined depending on the number of identified threats, with number 1 being the minimum scoring. Equal scoring was not allowed.
5. *Creation of total ranking;* the ranking scores then were added up for each individual threat. After having all the total rankings, the participants were asked to look at the

results and modify it if they felt that it was not the perfect representation of the threats. This increased the legitimacy of the results.

6. *Determining the change of each threat;* participants were asked to come up with a percentage independently of how much has the threat increased or decreased over the assessment period. Subsequently, during a group discussion they decided on the final percentage of each threat (Anthony 2008). If the threat has been mitigated, a positive score was given with the maximum score being +100 % if the threat was completely eradicated according to their definition. On the other hand, if the threat has worsened the score was negative. There was no maximum negative score, therefore if some threated had worsened by 3 times, the threat was given a score of -300%. Moreover, if the given threat was not present at the beginning of the assessment period, but has emerged since, then the threat was given a score of -100%.
7. *Calculating raw scores;* these were calculated for each threat where the total ranking was multiplied by the estimated percentage of change (Margoluis and Salafsky 2001).
8. *Calculating the MTRA Index;* the calculation was done according to the formula by Margoluis and Salafsky (2001) and Anthony (2008): MTRA index = ∑raw scores / total rankings * 100.

All information was collected by the researcher who was also the moderator during the workshop. At the end of the workshop, the management interventions and possible reasons for the changes in the threats were discussed.

3.5 Data analysis

For the results gained by MTRA workshops the identified threats were compared across the sites. The interviews were transcribed and coded after each of them.

3.6 Research ethics

Central European University's ethical approval was granted for this study. All the interviewees and the workshop participants were informed of the ethics approval before the interviews and the MTRA began.

In order to protect each participant's anonymity and confidentiality no names are connected to the statements and quotes presented in the research.

All the workshops and interviews were conducted in a respectful and professional manner. They began with the researcher introducing herself and the research introducing the aims and objectives. The email address of the researcher was made available to the participants to allow to withdraw from the participation at any point of the research.

3.7 Limitations

There are several limiting factors of the research that should be noted. Firstly, time constraint is one of the main limitations for completing the study as there is about 4 weeks to conduct fieldwork, which is further complicated by Covid-19.

The second limitation is people's general behaviour towards answering emails and having time for Zoom calls which combined with the effects of the pandemic might make the data gathering challenging. Generally, it took the participants 2-3 weeks to schedule the workshops and interviews which slowed down the process.

As previously mentioned, there are limitations due to the nature of the MTRA method with subjectivity being the main challenge (Margoluis and Salafsky 2001; Anthony 2008). This was also noticed by the participants during the workshop and they asked to further consult with other colleagues who could not make it to the workshop for possible changes in their assessments. However, sending information and hand outs before the workshops, encouraging the participants to consult supporting documents about threats and the short assessment period (2 years) all aimed to reduce the bias.

4. Results

4.1 Introduction

In the following chapter the results from the MTRA workshop and the interviews are presented and discussed for each of the sites assessed. First, brief summaries of the MTRA workshop results from each sites will be presented followed by the analysis and comparison of the threats across the sites, with special focus on the source of the threats and the possible restoration methods.

4.2 Natura 2000 site, Ancona

4.2.1 Workshop results

The workshop was conducted online by Zoom, due to the global pandemic and was attended by 3 participants who work on the field. Moreover, after the workshop the leader of the group forwarded the results of the workshop over to the colleagues who could not make it to the event to double check the results. All the participants were fluent in English therefore there was no need to invite a translator to the workshop.

The results of the workshop including the MTRA calculations and the list of identified threats are shown in Table 3 below. Ten major threats were identified to the area's *Cystoseira* populations during the assessment period. The MTRA index has a negative value of -75.09% showing that the total threats have worsened since the beginning of the assessment period. This is largely due to the radically worsened "problematic native species" which has worsened 5 times according to the participants. In addition, "temperature extremes" and "storms and flooding" have seemed to worsen since the beginning of the project. Although the effect of "fishing and harvesting aquatic resources" has not changed since 2019 it was recognized as the most harmful threat according to the total ranking, followed by "tourism and recreational areas" which has not changed either, while the third being the earlier mentioned "problematic native species". "Shipping lanes", "garbage and solid waste", "habitat shifting and alteration", "invasive non-native /alien species" and "earthquakes/tsunamis" were also listed as threats to *Cystoseira sp*. by the participants although no change was identified during the assessment period. Surprisingly, the participants gave the same rank to area, intensity, urgency for all threats, therefore I explained the criteria again, but they did not want to edit the results.

Table 3. MTRA workshop results from the site near Ancona, Italy.

No.	**Threat**	**IUCN threat code**	**Ranking Criteria**			**Total Ranking**	**% Threat Change**	**Raw Score**
			Area	**Intensity**	**Urgency**			
1.	Fishing and harvesting aquatic resources	5.4	10	10	10	30	0%	0
2.	Tourism and recreational areas	1.3	9	9	9	27	0%	0
3.	Problematic native species	8.2	8	8	8	24	-500%	-120
4.	Habitat shifting and alteration	11.1	7	7	7	21	0%	0
5.	Garbage and solid waste	9.4	6	6	6	18	0%	0
6.	Storms and flooding	11.4	5	5	5	15	-10%	-1.5
7.	Temperature extremes	11.3	4	4	4	12	-20%	-2.4
8.	Invasive non-native species	8.1	3	3	3	9	0%	0
9.	Shipping lanes	4.3	2	2	2	6	0%	0
10.	Earthquakes/tsunamis	10.2	1	1	1	3	0%	0
		Total	55	55	55	165		-123.9
						MTRA Index		-75.09

4.3 Cala Bona, Spain

4.3.1 Workshop results

The workshops with the experts from the Spanish sites were also conducted via Zoom. It was attended by 7 participants and we reviewed two different areas which are inhabited by *Cystoseira sp.* The comparison is indeed interesting as one of the areas is part of a biosphere reserve whereas the other does not have any protection or management action as of today. The score of the "area" for both sites were given the same numbers as the participants claimed that they cannot distinguish and rank between the threats as the area is so small that all of threats effect the same area equally. Therefore, an average was given in both cases.

The results of the first MTRA are seen in Table 4. below. Seven significant threats were identified regarding the *Cystoseira species* during the assessment period. The MTRA index has a negative value of -18.33 which states that the threats have worsened since the beginning of the AFRIMED project in the area as well. There was a new threat, "Storms and flooding" associated with the assessment period. The participants mentioned that they have always dealt with storms, however the scale and the effect of the recent storms in the area is unprecedented. "Tourism and recreational areas" and "recreational activities" have also worsened by -30% and -40% respectively. Although "household sewage and urban waste water" represents the greatest threat to *Cystoseira* populations the scale of the threat does not seem to change throughout the assessment period. Additionally, the effect of "problematic native species", housing and urban areas", and "fishing and harvesting aquatic resources" has not changed either in the given time period.

Table 4. MTRA workshop results from the site near Cala Bona, Spain.

No.	Threat	IUCN threat code	Ranking Criteria			Total Ranking	% Threat Change	Raw Score
			Area	Intensity	Urgency			
1.	Household sewage and urban waste water	9.1	4	7	7	18	0%	0
2.	Tourism and recreational areas	1.3	4	6	4	14	-30%	-4.2
3.	Recreational activities	6.1	4	4	5	13	-40%	-5.2
4.	Problematic native species	8.2	4	5	3	12	0%	0
5.	Housing and urban areas	1.1	4	2	6	12	0%	0
6.	Fishing and harvesting aquatic resources	5.4	4	3	2	9	0%	0
7.	Storms and flooding	11.4	4	1	1	6	-100%	-6
		Total	28	28	28	84		-15.4
						MTRA Index		-18.33

4.4 Nature reserve, Port de la Selva

4.4.1 Workshop results

The same participants reviewed the following site, which is a nature reserve, as the previous one in a different coast in Spain.

In this area only five major threats were identified which are presented in Table 5. The MTRA index has a value of -13.33 which again shows that the threats in overall have worsened since the beginning of the assessment period. This negative change is due to the change of the intensity of the “temperature “extremes” which has worsened by -50% during the project. The rest of the identified threats; “household sewage and urban waste water”, “problematic native species”, “recreational activities” and “storms and flooding” remained the same.

Table 5. MTRA workshop results from the site near Port de Selva.

No.	Threat	IUCN threat code	Ranking Criteria			Total Ranking	% Threat Change	Raw Score
			Area	Intensity	Urgency			
1.	Temperature extremes	11.3	3	5	5	13	-50%	6
2.	Household sewage and urban waste water	9.1	3	3	4	10	0%	0
3.	Problematic native species	8.2	3	4	1	8	0%	0
4.	Recreational activities	6.1	3	2	2	7	0%	0
5.	Storms and flooding	11.4	3	1	3	7	0%	0
		Total	15	15	15	45		-6
						MTRA Index		-13.33

5. Discussion and interpretation of the threats

5.1 Introduction

Several common threats were identified during the MTRA workshops (Table 6). The following chapter attempts the analyse the common threats to better understand their source(s) and the possible management actions in relation to them. Below (Table 6), there is a summary of the 13 threats identified during the three workshops.

Table 6. Summary of the identified threats including the results of all workshops

IUCN Threat code	Name of the threat	Ancona	Cala Bona	Port de la Selva	Total sites
8.2	Problematic native species	x	x	x	3
5.4	Storms and flooding	x	x	x	3
1.3	Tourism and recreational areas	x	x		2
5.4	Fishing and harvesting aquatic resources	x	x		2
11.3	Temperature extremes	x		x	2
6.1	Recreational activities		x	x	2 (only Spain)
9.1	Household sewage and urban waste water		x	x	2 (only Spain)
11.1	Habitat shifting and alteration	x			1
9.4	Garbage and solid waste	x			1
8.1	Invasive non-native species	x			1
4.3	Shipping lanes	x			1
10.2	Earthquakes/tsunamis	x			1
1.1	Housing and urban areas		x		1
TOTAL	13	10	7	5	22

5.2 Common threats

5.2.1 Problematic native species

The threat of problematic native species was recognized in all three sites, ranked 3rd twice and it was also given the 4th position once. At the site in Ancona, the participants reported that the situation has worsened five times (-500 %) which is mostly due to the grazing of native sea urchins in the area as the number of sea urchins have dramatically increased since the beginning of the project. Although the reasons for this significant increase are uncertain there are various effects that could influence their numbers. It could be a consequence of natural fluctuation of sea urchin recruitment, however it could also be due to anthropogenic effects such as consequences of global warming. However, the most likely cause of shifts from *Cystoseira* beds to barren states in the Mediterranean Sea is the overexploitation of the natural predators of sea urchins (Giakoumi et al. 2012, Boada et al., 2017).

One of the most serious consequences related to the habitat shift of *Cystoseira* canopy dominated areas to sea urchin barrens leads to a decrease in biodiversity and productivity of the coastal areas (Thiriet et al. 2016). As a consequence, the algal beds are more prone to any disturbance (Piazzi and Ceccherelli, 2019). These transitions usually occur when there is a change in the grazing intensity of the sea urchin, which consequently also transfers the community's state to a less stable form (Filbee-Dexter and Scheibling 2014). Moreover, the management actions are also hindered by the nature of the problem. When sea urchin barrens persist, it creates a stable state in the system followed by the perturbation, which has been reduced since the phase shift occurred (Lauzon-Guay et al. 2009). As a consequence, the benthic systems are able to exist with different multiple stable states separated by the unstable equilibria (Watson and Estes 2011). This phenomenon when multiple states exist at a given area, can be described by hysteresis which is the lack of possibility to reverse to the previous state when the critical parameter is disturbed (Melis et al. 2019).

At the other two sites in Spain where the workshop has been conducted, the locals experienced issues with overgrazing of herbivorous fish (*Sarpa salva*) in the area. Although the participants did not report any changes in the threat they emphasized the importance of the problem. However, this threat is solely based on their field observations as they have not tested whether the scale of the present herbivory is significant. The interviewees from Naples and Nice also mentioned the effect of herbivory. In the French site they reported that the loss of open-coast *Cystoseira* population are partly due to the grazing of *E. amentacea* and *C. compressa*, while smaller invertebrates such as hermit crabs, crabs and molluscs damage the populations at the rock pools.

The main restoration action that will be used as part of the AFRIMED project, that all the workshop participants and interviewees mentioned is the replantation of damaged *Cystoseira* sp. in various suitable habitats. However, one of the experts from Université Nice Sophia Antipolis mentioned, that even though these practices generally work, the success is closely linked to the presence of these native herbivores. Piazzi and Ceccherelli (2019) have demonstrated the same as well as they have proven that harvesting sea urchin populations for commercial reasons in the Mediterranean Sea increased the effects of the *Cystoseira* habitat restoration). Nonetheless they added that more profitable sea urchin harvesting is, less successful the restoration will be which creates a conflict between marine conservation and business (Piazzi and Ceccherelli, 2019). Moreover, others claim that predator removal is most likely to be most effective when it is continued over years as that is the only way to ensure that extensive habitat recovery has taken place (Sanderson et al. 2015). The expert from Université Nice Sophia Antipolis also added that in the two Natura 2000 sites where the restoration is taking place; Baie et cap d'antibes – Iles de Lérins and Cap Ferrat sea-urchins are not very abundant and they are traditionally consumed in France.

5.2.2 Storms and flooding

The threat of „storms and flooding" has also been recognized in all three sites that were examined during the workshop. All of the sites have mentioned the damaging effect of storms regarding the viability of the *Cystoseira* populations. At the Italian site the effects of more frequent and stronger storms has worsened by 10%, while in Cala Bona it was recognized a threat that has emerged since the beginning of the project. Naturally, storms have occurred before the start of the project as well, however it was not considered as a threat because it did not significantly damage the populations by creating stronger wave actions. In Port de la Selva there was no change reported regarding the threat.

During the last years there has been a significant increase in the numbers and intensity of storms in the Mediterranean Sea (Wernberg et al. 2016). These severe sea storms have damaging effects as they cause the movement of gravel and even larger rocks that crush soft benthic organisms like macroalgae (Rindi et al. 2020). Even the smallest erosion of *Cystoseira* populations enables the habitat shift of sea grass and turf dominated assemblages. These turfs are characterized by fast growth and multiple reproductive events therefore it is relatively easy for them to outcompete *Cystoseira* species which are sensitive to changes and have a slow rehabilitation (Benedetti-Cecchi et al. 2001). Moreover, one of the interviewee reported that storms cause "sedimentation which increases the turbidity affecting the photosynthetic performance" of the individuals. These shifts from canopy to turf dominated habitats usually go hand in hand with a decrease in biodiversity, species composition and biomass of organism (Wernberg et al. 2016). In consequence, there is a decrease in the ecological, aesthetic and economic value of the habitat (Benedetti-Cecchi et al. 2015).

5.3 Threats shared by two sites

5.3.1 Tourism and recreational areas

The effect of tourism and recreational areas is considered as a top threat in Ancona and Cala bona as for both places it was ranked as second, based on the area, urgency and intensity of the threat. In Ancona there was no change reported, whereas in Cala Bona there was a -30%, which indicates that the threat has worsened since the beginning of the project. Although due to the global pandemic, there were less international tourists visiting the sites, the number of domestic tourism has increased extremely. In fact, although Cala Bona used to be a small fishing town, nowadays it is a popular holiday destination for both locals and international tourists with many hotels, restaurants, bars and clubs.

Mediterranean countries are the world's leaders in tourism, receiving more than 300 million tourists in 2016. Spain is the second while Italy is the third most popular destination within the region (UNWTO, 2017). During the workshops we discussed that the Mediterranean tourist season is usually the busiest consequently from the months from June to September. There are a number of impacts associated with the high levels of coastal tourism which are also discussed in this chapter. These are including increased littering (UNEP/MAP 2015), insufficient sewage treatment capacity (Kent et al. 2002) and emerging contaminants from sunscreens (Tsui et al. 2014)

5.3.2 Fishing and harvesting aquatic resources

The impact of recreational and commercial fishing was mentioned in Ancona and Cala Bona, moreover it was ranked as the priority threat for the former. Direct damage from fisheries affecting the coastal areas such as beam trawls, dredges and anchors were mentioned during the workshop and the evidence is supported by primary literature as well (De Biasi and Pacciardi, 2008; de Juan and Lleonart 2010). Overfishing of predators of the herbivores that predate on

Cystoseira has one of the most crucial cascading effect on benthic communities, as the presence of herbivorous fishes can lead to extension of local macroalgae populations (Williams and Polunin 2001). However, the total exclusion of herbivores can lead to the overgrowth of macroalgae which can cause eutrophication in coastal areas (Hughes et al. 2007). Human induced top-predator alteration cascading effects are not rare in marine environments as the same phenomenon was proven by Byrnes et al. (2006) whereby he demonstrated similar cascading risk effect in kelp forests consequently to human induced marine predator removal. These findings suggest overarching governance issues and fisheries regulations in the Mediterranean region. Indeed, the evidence of poorly regulated fisheries in the area is widely documented (Vasilakopoulos et al. 2014) as well as the evidence of the negative impacts of the fishing industry in Mediterranean trophic webs (Colloca et al. 2017). The lack of adequate management measures regarding Mediterranean fisheries is causing a general concern among scholars and NGOs, however the overall picture of fisheries in the area is still rather confusing due to many unregulated fishing vessels (Amengual and Alvarez-Berastegui, 2018). Due to the presence of multi-species, multi-fleets fisheries, management is indeed challenging especially in a fast changing ecosystem like the Mediterranean Sea (Mackinson et al. 2009). This issue requires urgent update of the management regime in Mediterranean fisheries to prevent unregulated fishing.

5.3.3 Temperature extremes

Temperature extremes were reported from Ancona and Port de la Selva. For both sites, the effects were reported to have worsen by -20% and -40% respectively, since the start of the AFRIMED project. This does not come as a surprise, as according to Bianchi (2007) "the Mediterranean Sea is under a process of "tropicalization" and high-temperature conditions are proven to have an impact on mass mortalities of various marine species. These heatwaves are becoming more and more frequent and they have the strongest effect on the populations of kelps and fucoids (Wernberg et al. 2016). Moreover, they are projected to further increase in the coming decades (Oliver et al. 2018). Due to the semi-enclosed form of the Mediterranean basin, shifting to more favourable climatic conditions is limited (Burrows et al. 2014). This projection is especially critical for sessile organisms such as *Cystoseira* sp. which are extremely sensitive to changes in the environment and their populations are already fragmented which further decreases their adaptive capability (Verdura et al. 2020). As it was noted down during one of the interviews, "increasing temperature affects the reproduction and settlement of germlings of *Cystoseira*". Moreover, photosynthetic efficiency was also proven to be reduced after two weeks of exposures at 28°C, while after 25 days even the tissues were damaged in the populations of Port de la Selva (Verdura et al. 2020). To tackle the impacts of marine heatwaves in Mediterranean, Verdura et al. (2020) suggests that opened and connected nature of the macroalgal habitats could enhance the cooling effect. Consequently, they support the promotion of active rehabilitation and restoration of the species (Verdura et al. 2018), however the habitats vulnerability for heatwaves should be accessed first for a successful management outcome (Wood et al 2019).

5.3.4 Recreational activities

The impact of recreational activities such as motorboats, jet-skis, dive boats and scuba divers were reported from both of the sites located in Spain with no change in the threat reported from Port de la Selva, whereas there has been a -40% change in Cala Bona. As it was discussed in 5.3.1, although international tourism has decreased due to the global pandemic, the number of local tourists has increased dramatically. Moreover, nowadays extreme sports such as diving and surfing is popular, therefore many people would like to enjoy these activities at the coast. However, this mechanical disturbance can damage both the old and the recruit *Cystoseira* plantations. The experts mentioned that it would be useful to have seasonal "no entry zones" especially during the germination of the individuals to minimize the risks of negative impacts.

Until that is achieved by policies and different regulations, outreach projects to educate both local and international tourists of how to enjoy various activities while respecting the marine wildlife could be promoted by NGOs and the government.

5.3.5 Household sewage and urban waste water

Household sewage and urban waste water was noted as a top threat to *Cystoseira* populations for both Spanish sites. At Cala Bona it was ranked first whereas in Port de la Selva it was ranked second based on the area, intensity and urgency of the threat. Not surprisingly, marine pollution is currently one of the most serious threats to marine biodiversity worldwide (Lotze et al. 2006). As a consequence of the increase in coastal urban populations, the quality of the water is rapidly degrading. The amount and variety of the pollutants such as detergents, heavy metals, herbicides, pesticides and inorganic nutrients entering the sea are high and common, especially in coastal waters (Köcke et al. 2010). The increasing amounts of inorganic nutrients near urban areas stimulates phytoplankton production which increases turbidity which subsequently alters the structure and species composition of littoral communities (McGlathery et al. 2007). Moreover, it has been long known that these changes in water quality cause decline in perennial macroalgae while they favour opportunistic species. (Schramm 1999).

Historically, the government of Spain especially in Mallorca, has been struggling with water shortage particularly during the tourist seasons (Roberts 2002). Moreover, the growing number of households increase the sewage pollution (Fraschetti et al. 2006) and nutrient enrichment (Arevalo et al. 2007). There is also a flaw with the sewage system in the European Mediterranean as only 30% of municipal wastewater from coastal towns receive any treatment before it is discharged back to the sea or to coastal grounds (Kent et al. 2002). This problem was mentioned by the participants as well. According to them, the sewage and waste water from the coastal bars in Cala Bona are directly discharged to the coastal waters. They mentioned the importance to establish some sort of management of protection of the coastal waters in the area to prevent this harmful discharge before the effects are irreversible. The interviewees agreed with this statement and added that although the MPAs do not have specific management plans for *Cystoseira* species, at least discharging wastewater to the populations' surroundings is prevented.

5.4 Other threats

5.4.1 Habitat shifting and alteration

The threat of habitat shifts and alteration was reported from the Italian site near Ancona. The nature and scale of this threat was discussed in 5.1.1 and 5.1.2 in details. Under high anthropogenic stressors, such as pollution and urbanization (Conell et al. 2014) *Cystoseira* communities can be replaced by alternate stable states and dominated by turf algae, sea urchin barrens or other erect macroalgae (e.g. *Dictyotales*) (Bonaviri et al. 2011). Due to the alternative stable state that these new habitats form, the recolonization of native canopy forming species such as *Cystoseira* is challenging (Gorman et al. 2009). These habitat shifts could negatively affect the recruit of adult population of various fish species including commercial interest for recreational and professional fisheries due to the nursery value and source of food of *Cystoseira* species in the Mediterranean Sea (Cheminée et al. 2013). However, the exact nature and scale of impacts of habitat shifts within the area are still largely unknown (Cheminée et al. 2011), thus more research is needed to better understand the nature of the threat.

5.4.2 Garbage and solid waste

The issue with the increased marine pollution due to garbage and solid waste entering the seas were mentioned and ranked as 5th out of the 10 threats at the site in Ancona, Italy. Although it is a global issue, the Mediterranean Sea has been identified as one of the most polluted areas around the world (Compa et al. 2019). During one of the interviews it was noted that "due to solid waste pollution a high concentration of nutrients, pesticides, herbicides and chemical compounds enter the sea daily, which has to be dealt with". There a number of initiatives by the locals to organize beach cleans however, especially during the tourist season, it is challenging to make these activities regular. This suggests a deeper governance problem in the country regarding waste management. Although Italy has a good recycling rate reaching almost 44%, the landfill levels are still high therefore there is a room for making plastic waste management most efficient (Lombardi et al. 2021).

5.4.3 Invasive non-native species

The issue with invasive non-native species was reported from the Italian site, with no change in the threat recorded since the beginning of the AFRIMED project. As previously discussed there is an undergoing crisis regarding invasive non-native species in the Mediterranean Sea (2.2.1). Although, there are significantly more issues with the overgrazing of native herbivores in the area, the effect of invasive, non-native species should not be overlooked either. The participants and interviewees reported that there is limited literature on the effect of invasive species regarding *Cystoseira* sp., however the available research suggest, that the invasive macroalgae *Caulerpa* whose common name is "killer algae" tend to outcompete the native species (Claudet and Fraschetti, 2010).

5.4.4 Shipping lanes

Shipping lanes were identified as a threat in Ancona because the port is closely located to the examined *Cystoseira* populations. Although Cala Bona and Port de la Selva have ports as well, those are significantly smaller and less busy compared to the one in Ancona. Moreover, the shipping lanes are not directly above the populations in question. The greatest issue with shipping lanes located so close to these remaining populations is that they "both affect the adult plants and recruits due to the mechanical disturbance of anchoring" according to the notes of the participants. However, research concerning the mechanical damage of shipping lanes on macroalgal habitats in the Mediterranean Sea is lacking.

5.4.5 Earthquakes and tsunamis

The threat of earthquakes was reported from the site near Ancona, however it does not seem to have changed since the beginning of the examination period. The area is located in an active seismic zone therefore, earthquakes are quite frequent within the region. This becomes a threat as due to the seismic activities, larger rocks could fall into the sea damaging the coastal *Cystoseira* populations.

5.4.6 Housing and urban areas

The issue with growing urban areas, vacation homes and shopping areas was noted as a threat for the *Cystoseira* populations near Cala Bona. As a consequence to the growing popularity of the area amongst tourists, there is an increase in the number of vacation home and shopping streets that attract more people. As it was noted in one of the interviews "urbanization usually implies the destruction of coastal habitats which creates habitat fragmentation preventing gametes dispersion." This is even more problematic in Cala Bona where the existing population of *Cystoseira* sp. is relatively small, as well as they have limited population connectivity and longer generation times (Bates et al. 2014). Consequently, they can be exposed to loss of genetic diversity (Neiva et al. 2015) which loss may result in genetic drift and bottlenecks in small populations (Nicastro et al. 2013). This is especially concerning as the loss of genetic variability could result in loss of adaptive potentials and decrease the populations' resilience to changing environmental conditions (Pearson et al. 2009).

5.5 Restoration efforts

Once the populations are destroyed over larger areas the natural restoration of *Cystoseria* habitats is challenging due to the short distance dissemination of eggs and ongoing regime shifts

(Melis et al. 2019). Apart from the nature and scale of the different threats the potential restoration methods were also discussed during the workshops and interviews. *Cystoseira* species are considered endangered or threatened by the Barcelona Convention (Annex II) (UNEP/MAP 2013). Therefore, the disturbance of the remaining populations should be minimized for the purpose of the replantation (Gianni et al. 2017). This restoration plan includes the harvest of small fertile branches from wild individuals and the subsequent replantation of the new individuals. This technique is considered to be non-destructive as less than 5% of the plant is being removed for the sake of the restoration (Gianni et al. 2017). Verdura et al. (2018) has proven the success of these techniques both *in*- and *ex situ* with high rates of restoration success including dispersal capacity. The *in situ* method consist of the collection of fertile apical branches which are transported to the restoration sites and subsequently replaced 2-3 metres from each other. During the *ex situ* recruitment, the collected fertile apical branches were stored in laboratories in cold and dark conditions to promote zygote liberation. Subsequently the young plants were grown under laboratory circumstances. The success of the restoration techniques was analysed by comparing the final densities and site distribution between the two examined populations (Verdura et al. 2018). The results suggest that there were no significant differences between the final densities of the restored populations nor between the dispersal capacities. The price of the restoration method is more affordable *in situ* as using the *ex situ* method costs almost three times more than the former. However, the *ex situ* method minimizes the high mortality rates due to exclusion of predators, disturbances and competition (Capdevila et al. 2015).

Nevertheless, as it was mentioned in the interviews as well, before any restoration action is carried out, the first step should be the mitigation or removals of the stressors. The presence of intense herbivory is proven to prevent any recovery of *Cystoseira* population (Bulleri 2013). The removal of commercial sea urchin or fish species can positively influence the outcome of the restoration projects (Piazzi and Ceccherelli, 2019). Nevertheless, since not all sea urchin species are edible, promoting removal and harvesting of predatory species is not the most effective nor the most sustainable management tool (Piazzi and Ceccherelli, 2017).

Lastly, oligotrophy was proven to be another factor that is essential for *Cystoseira* recruitment and therefore the recovery of *Cystoseira* beds (Piazzi and Ceccherelli, 2017). This is due to the fact that even a slight increase in coastal eutrophication is a major driver for habitat shift to fucoids to less complex communites (Arevalo et al. 2007). Moreover, nutrient regime is resposible to regulate the structure of macroalgal assemblages which is crucial to control the sea urchin grazing capacity and stabilizing barrens (Piazzi et al. 2016).

In conclusion, the evidence supports that there are multiple factors involved in algal recovery as well as in the resilience of the habitat. One of the most urgent challenges today is restoring natural habitats worldwide (Piazzi et al. 2016). These endemic habitats are critical for the preservation of biodiversity and ecosystem services (Balmford et al. 2002).

5.6 Conclusion

According to the result the selected method successfully fulfilled the aim of the research. Across the three sites that were examined my MTRA, 13 threats were identified in total out of which 7 were shared among multiple sites. The negative TRA Indices of -75.09% in Ancona, -18.33 in Cala Bona and -13.33 in Port de la Selva shows that the overall threats have worsened since the beginning of the AFRIMED project. This is partly due to the global pandemic which paused the project for half a year, therefore the restorations have not been carried out fully as well as the lack of management activities aiming at the restoration and protection of *Cystoseira* sp. in the Mediterranean marine protected areas. The top threats identified during the workshop include problematic native species, storms, marine tourism and the effect of fisheries and aquaculture within the regions. Using the data from records review, the MTRA workshops and interviews with local experts the threats were interpreted and compared across the sires. In all sites the tool could further be used to monitor the changes in threats to help prioritising management and restoration actions.

6. Conclusion

6.1 Introduction

This chapter summarises the main findings of the thesis and demonstrates how the aims and objectives of the research were fulfilled by the chosen methodology. Moreover, it provides recommendations for future research in the area and the future application of the tool.

6.2 Fulfilment of the research aims and objectives

The aim of the research was to identify the scale and nature of threats to *Cystoseira* forests in the Mediterranean Sea, while recommending methods for management and restoration improvement. In order to achieve this aim, several objectives were set. After throughout review of available literature the MTRA tool was selected as the most suitable method for the research. After using the selected method, 13 threats were identified across three sites that are part of the AFRIMED project. These threats were ranked according to their area, urgency and intensity as well as a percentage of change was assigned to each of them. This data was collected to subsequently calculate the TRA Index for each site, which indicates the overall change in threats to the *Cystoseira* populations in the given sites. Moreover, interviews with some of the other AFRIMED partners who were available (another site in Italy and in France) were also conducted to understand other parts of the Mediterranean Sea as well to have a better, more comprehensive idea of the region. Lastly, the results of the workshops, record reviews and interviews were compared across the assessed sites.

TRA Indices show a negative value for all the examined sites which could be partly due to the fact that at this stage of the project the participants just started testing the restoration techniques. Moreover, it can take years for *Cystoseira* forests to significantly regenerate and create a viable population. For the Natura 2000 site in Ancona a negative value of -75.09 %, for the first site in Spain, Cala Bona -18.33% was noted whereas in Puerto de la Selva -13.33 % was measured. Considering that the research was based on the threats of *Cystoseira* sp. and sites have similar characteristics, 7 threats out of 13 were identified in more than one site. "Problematic native species" and "storms and flooding" was noted for all three sites that were examined by the MTRA tool. Moreover, the interviewees also mentioned the problem of extensive herbivory of native species. Other threats that were shared by two sites are tourism and recreational areas, fishing and harvesting aquatic resources, temperature extremes, recreational activities and household sewage and urban waste water. The threats which were only reported in one site were: habitat shifting and alteration, garbage and solid waste, invasive non-native species, shipping lanes, earthquakes/tsunamis, housing and urban areas. Out of these 6 threats the first 5 were only reported from the coasts of Italy. The most popular restoration methods in the area are replantation of *Cystoseira sp*. to adequate sites where the discussed threats are minimized. However, evidence has proven that for the most successful restoration projects the limitation of large herbivores should be included in the management action. Management interventions and protection measures are lacking in all the sites examined by the MTRA tool and interviews as the MPAs, Natura 2000 sites and Nature Reserves are mostly focused on fisheries. Moreover, as reported by one of the interviews, even though all the *Cystoseira* species (except of *Cystoseira compressa*) are protected under the Annex II of the Barcelona convention and Annex I of the Bern convention, specific managements are not present today within MPAs.

6.3 Suggestions for future research

Considering the scope of the study and the limitations there are a number of recommendations for research in the area and for future application of the tool.

Recommendations concerning MTRA:

- When conducting the workshop, it is vital to keep all the participants' attention making sure everyone is heard. This was especially challenging this year as due to Covid-19 the tool and interviews had to be taken place online. Very often the leader of the group might dominate the discussion which should be minimized for unbiased data
- Higher numbers of participants would be more desirable for the outcome of the research, which again was quite difficult due to the online meetings.
- Lastly it is important to arrange your time according to availability of the experts which might limit the number of workshops due to the available time for the research, but it increases the viability and quality of the thesis.

Recommendations for further research in the area:

- In order to fully understand the effect of the most crucial common threat "grazing" further research would be needed on the effect of the different types of herbivory present at the AFRIMED sites. This is especially important due to the link between the success of the replantation and the number of herbivores present.
- Due to controversy about the establishment and effectiveness of MPAs and other types of protected measures in relation to the viability and successful restoration of *Cystoseira sp*. further research would be crucial whether the indirect effects of protected areas positively affect the *Cystoseira* populations.

- In order to monitor the outcome of the restoration project and the subsequent change in threats to *Cystoseira* sp. the tool should be applied on a frequent basis or at least by the end of the AFRIMED project.

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Appendices

Appendix A - MTRA Workshop Information Sheet

What is a Modified Threat Reduction Assessment (MTRA)?

All protected areas face threats. Modified Threat Reduction Assessment (MTRA) is used to measure biodiversity threats and their changes over time. By measuring threats, it is possible to get an indirect measurement of conservation efforts.

When thinking about the biodiversity threats, it is important to keep in mind the three components that constitute biodiversity for the purpose of MTRAs:

1. **Species present;**
2. **Habitat condition and the area;**
3. **Ecosystem functions.**

The MTRA approach is based on three key assumptions:

1. **All threats to biodiversity are human-induced**.
2. **All threats to biodiversity can be identified**..
3. **It is possible to measure or estimate the changes of these threats**.

Modified Threat Reduction Assessment (MTRA) is a modified version of TRA that inlcudes new or worsening threats. It was proposed by my thesis supervisor, Brandon Anthony, and has been conducted for a number of protected areas in Ghana, Lebanon, Mongolia, Ukraine and South Africa.

Steps of MTRA:

1. Define the study in space and time.

2. Identify all direct threats present at the site, both historically and at present.
Threats are defined as those human activities that cause some degree of deterioration or destruction of the biodiversity (species, habitats, ecosystem function) in the site. Threats can be divided into:

a. *Internal Direct Threats*: caused by stakeholders living on site,
b. *External Direct Threats*: caused by people outside the PA.
c. *Indirect Threats*: Social, economic and political aspects that provoke direct threats. These are not to be included.

3. Define the threats. As a group, discuss threats and define each according to the IUCN lexicon of threats categories.

4. Define 100% reduction for each threat. 100% reduction is assumed to be a complete elimination of a threat.

5. Rank each threat for the defined start date, based on the following:

a. Area – how much of the habitat is affected by the threat?
b. Intensity- how severe is the impact of a threat in the site? Does the threat completely destroy the habitat or just cause minor changes?
c. Urgency – how urgent should the threat be addressed? Is it likely to increase?

6. Add the scores to calculate each threat's total rank.

7. Decide how much (%) the threat changed since the chosen start date.

a. If a threat was present at the start date and has been reduced, the score will be positive. If it is completely eliminated, the top score is 100%.

b. If a threat has worsened since the start date, the score will be negative. There is no top line for a negative score so if you think that something has worsened 4 times, that threat can be given a score of -400%.

c. If a threat was not present at the start date, but has emerged since then, that threat can be given a score of -100%.

8. Calculate each threat's raw score by multiplying its total rank with percentage of change.

9. Calculate the MTRA index by dividing the total raw score with the total ranking and then multiplying it with 100 to get a percentage.

10. Discuss the reasons behind the changes. What were the positive actions taken? Which management strategies have changed since the start date? How is management effectiveness measured in your area?

Appendix B – MTRA Calculation Sheet

MTRA Index calculaion sheet

Site name:

Site description:

Assessment Period:

Completed by:

Completed on:

No.	Threat	IUCN threat code	Ranking Criteria			Total Ranking	% Threat Change	Raw Score
			Area	Intensity	Urgency			
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								
		Total						

TRA Index Formula	Total Raw Score		Total Ranking		Convert to %		TRA Index (%)
TRA Index Calculation		÷		=	X 100	=	

Appendix C – Lexicon of threats

A Standard Lexicon for Biodiversity Conservation: Unified Classification of Threats and Actions

by

Salafsky, Salzer et al. 2008

1. **Residental and commercial development**: human settlements or other nonagricultural land uses with a substantial footprint

1.1 Housing an urban areas: human cities, towns, and settlements including nonhousing development typically integrated with housing
Urban areas, suburbs, villages, vacation homes, shopping areas, offices, schools, hospitals

1.2 Commercial and industrial areas: factories and other commercial centers
Manufacturing plants, shopping centers, office parks, military bases, power plants, trains and ship yards, airports

1.3 Tourism and recreation areas: tourism and recreation sites with a substantial footprint
Ski areas, golf courses, beach resorts, cricket fields, county parks, campgrounds

2. **Agriculture and aquaculture:** threats from farming and ranching as a result of agricultural expansion and intensification, including silviculture, mariculture, and aquaculture

2.1 Annual and perennial nontimber crops: crops planted for food, fodder, fiber, fuel, or other uses
Farms, household swidden plots, plantations, orchards, vineyards, mixed agroforestry systems

2.2 Wood and pulp plantations: stands of trees planted for timber or fiber outside of natural forests, often with non-native species
Teak or eucalyptus plantations, silviculture, christmas tree farms

2.3 Livestock farming and ranching: domestic terrestrial animals raised in one location on farmed or nonlocal resources (farming); also domestic or semidomesticated animals allowed to roam in the wild and supported by natural habitats (ranching)
Cattle feed lots, dairy farms, cattle ranching, chicken farms, goat, camel, or yak herding

2.4 Marine and freshwater aquaculture: aquatic animals raised in one location on farmed or nonlocal resources; also hatchery fish allowed to roam in the wild
Shrimp or fin fish aquaculture, fish ponds on farms, hatchery salmon, seeded shellfish beds, artificial algal beds

3. **Energy production and mining:** threats from production of nonbiological resources

3.1 Oil and gas drilling: exploring for, developing, and producing petroleum and other liquid hydrocarbons oil wells, deep sea natural gas drilling

3.2 Mining and quarrying: exploring for, developing, and producing minerals and rocks

coal mines, alluvial gold panning, gold mines, rock quarries, coral mining, deep sea nodules, guano harvesting

3.3 Renewable energy: exploring, developing, and producing renewable energ

geothermal power production, solar farms, wind farms (including birds flying into windmills), tidal farms

4. Transportation and service corridors: threats from long, narrow transport corridors and the vehicles that use them including associated wildlife mortality

4.1 Roads and railroads: surface transport on roadways and dedicated tracks
Highways, secondary roads, logging roads, bridges and causeways, road kill, fencing associated with roads, railroads

4.2 Utility and service lines: transport of energy and resources
Electrical and phone wires, aqueducts, oil and gas pipelines, electrocution of wildlife

4.3 Shipping lanes: transport on and in freshwater and ocean waterways
Dredging, canals, shipping lanes, ships running into whales, wakes from cargo ships

4.4 Flight paths: air and space transport
Flight paths, jets impacting birds

5. Biological resource use: threats from consumptive use of "wild" biological resources including deliberate and unintentional harvesting effects; also persecution or control of specific species

5.1 Hunting and collecting terrestrial animals: killing or trapping terrestrial wild animals or animal products for commercial, recreation, subsistence, research or cultural purposes, or for control/persecution reasons; includes accidental mortality/bycatch
Bushmeat hunting, trophy hunting, fur trapping, insect collecting, honey or bird nest hunting, predator control, pest control, persecution

5.2 Gathering terrestrial plants: harvesting plants, fungi, and other nontimber/nonanimal products for commercial, recreation, subsistence, research or cultural purposes, or for control reasons
Wild mushrooms, forage for stall fed animals, orchids, rattan, control of host plants to combat timber diseases

5.3 Logging and wood harvesting: harvesting trees and other woody vegetation for timber, fiber, or fuel
Clear cutting of hardwoods, selective commercial logging of ironwood, pulp operations, fuel wood collection, charcoal production

5.4 fishing and harvesting aquatic resources: harvesting aquatic wild animals or plants for commercial, recreation, subsistence, research, or cultural purposes, or for control/persecution reasons; includes accidental mortality/bycatch

Trawling, blast fishing, spear fishing, shellfish harvesting, whaling, seal hunting, turtle egg collection, live coral collection, seaweed collection

<u>**6. Human intrusions and disturbance**</u>: threats from human activities that alter, destroy and disturb habitats and species associated with nonconsumptive uses of biological resources

6.1 Recreational activities: people spending time in nature or traveling in vehicles outside of established transport corridors, usually for recreational reasons
Off-road vehicles, motorboats, jet-skis, snowmobiles, ultralight planes, dive boats, whale watching, mountain bikes, hikers, birdwatchers, skiers, pets in rec areas, temporary campsites, caving, rock-climbing

6.2 War, civil unrest and military exercises: actions by formal or paramilitary forces without a permanent footprint
Armed conflict, mine fields, tanks and other military vehicles, training exercises and ranges, defoliation, munitions testing

6.3 Work and other activities: people spending time in or traveling in natural environments for reasons other than recreation or military activities
Law enforcement, drug smugglers, illegal immigrants, species research, vandalism

<u>**7. Natural system modifications**</u>: threats from actions that convert or degrade habitat in service of "managing" natural or seminatural systems, often to improve human welfare

7.1 Fire and fire suppression: suppression or increase in fire frequency and/or intensity outside of its natural range of variation
Fire suppression to protect homes, inappropriate fire management, escaped agricultural fires, arson, campfires, fires for hunting

7.2 Dams and water management/use: changing water flow patterns from their natural range of variation either deliberately or as a result of other activities
Dam construction, dam operations, sediment control, change in salt regime, wetland filling for mosquito control, levees and dikes, surface water diversion, groundwater pumping, channelization, artificial lakes

7.3 Other ecosystem modifications: other actions that convert or degrade habitat in service of "managing" natural systems to improve human welfare
Land reclamation projects, abandonment of managed lands, rip-rap along shoreline, mowing grass, tree thinning in parks, beach construction, removal of snags from streams

<u>**8. Invasive and other problematic species and genes:**</u> threats from non-native and native plants, animals, pathogens/microbes, or genetic materials that have or are predicted to have harmful effects on biodiversity following their introduction, spread and/or increase in abundance

8.1 Invasive non-native/alien species: harmful plants, animals, pathogens and other microbes not originally found within the ecosystem(s) in question and directly or indirectly introduced and spread into it by human activities
Feral cattle, household pets, zebra mussels, Dutch elm disease or chestnut blight, Miconia tree, introduction of species for biocontrol, Chytrid fungus affecting amphibians outside of Africa

8.2 Problematic native species: harmful plants, animals, or pathogens and other microbes that are originally found within the ecosystem(s) in question, but have become "out of balance" or "released" directly or indirectly due to human activities
Overabundant native deer, overabundant algae due to loss of native grazing fish, native plants that hybridize with other plants, plague affecting rodents

8.3 Introduced genetic material: Human-altered or transported organisms or genes
Pesticide resistant crops, hatchery salmon, restoration projects using nonlocal seed stock, genetically modified insects for biocontrol, genetically modified trees, genetically modified salmon

9. Pollution: threats from introduction of exotic and/or excess materials or energy from point and nonpoint sources

9.1 Household sewage and urban waste water: water-borne sewage and nonpoint runoff from housing and urban areas that include nutrients, toxic chemicals and/or sediments
Discharge from municipal waste treatment plants, leaking septic systems, untreated sewage, outhouses, oil or sediment from roads, fertilizers and pesticides from lawns and golf-courses, road salt

9.2 Industrial and military effluents: water-borne pollutants from industrial and military sources including mining, energy production, and other resource extraction industries that include nutrients, toxic chemicals and/or sediments
Toxic chemicals from factories, illegal dumping of chemicals, mine tailings, arsenic from gold mining, leakage from fuel tanks, PCBs in river sediments

9.3 Agricultural and forestry effluents: water-borne pollutants from agricultural, silivicultural, and aquaculture systems that include nutrients, toxic chemicals and/or sediments
Including the effects of these pollutants on the site where they are applied nutrient loading from fertilizer runoff, herbicide runoff, manure from feedlots, nutrients from aquaculture, soil erosion

9.4 Garbage and solid waste: rubbish and other solid materials including those that entangle wildlife
Municipal waste, litter from cars, flotsam and jetsam from recreational boats, waste that entangles wildlife, construction debris

9.5 Air-borne pollutants: atmospheric pollutants from point and nonpoint sources
Acid rain, smog from vehicle emissions, excess nitrogen deposition, radioactive fallout, wind dispersion of pollutants or sediments, smoke from forest fires or wood stoves

9.6 Excess energy: inputs of heat, sound, or light that disturb wildlife or ecosystems
Noise from highways or airplanes, sonar from submarines that disturbs whales, heated water from power plants, lamps attracting insects, beach lights disorienting turtles, atmospheric radiation from ozone holes

10. Geological events: threats from catastrophic geological events

10.1 Volcanoes: volcanic events
Eruptions, emissions of volcanic gasses

10.2 Earthquakes/tsunamis: earthquakes and associated events
Earthquakes, tsunamis

10.3 Avalanches/landslides: avalanches or landslides
Avalanches, landslides, mudslides

<u>11. Climate change and severe weather:</u> long-term climatic changes that may be linked to global warming and other severe climatic or weather events outside the natural range of variation that could wipe out a vulnerable species or habitat

11.1 garb shifting and alteration: major changes in habitat composition and location
Sea-level rise, desertification, tundra thawing, coral bleaching

11.2 Droughts: periods in which rainfall falls below the normal range of variation
Severe lack of rain, loss of surface water sources

11.3 Temperature extremes: periods in which temperatures exceed or go below the normal range of variation
Heat waves, cold spells, oceanic temperature changes, disappearance of glaciers/sea ice

11.4 Storms and flooding: extreme precipitation and/or wind events or major shifts in seasonality of storms
Thunderstorms, tropical storms, hurricanes, cyclones, tornados, hailstorms, ice storms or blizzards, dust storms, erosion of beaches during storms