# Marine Protected Areas in reality and public perception

by

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# Marine Protected Areas in Reality and Public Perception


## Abstract

The ocean has long been a source of food, a means of travel, and an integral part of Earth's climate. The climate crisis and biodiversity crisis lead to degrading conditions for marine life. Marine Protected Areas (MPA) are seen as an effective tool for conservation and replenishing of stocks but only small portions of the ocean are protected and even less are protected and effectively managed. I have reviewed the literature and discussed the reality of MPA with experts to create an overview of the current state of marine protection, the barriers in the way, and their perception by stakeholders and the general public. Benefits include higher biomass inside MPA, spillover of biomass and larvae to adjacent fisheries, high biodiversity, and increased carbon sequestration. The largest barriers are communicating the benefits to stakeholders, particularly those with economic interests at stake, financing the management and enforcement of such areas, and climate-change related stressors that reduce MPA effectiveness on paper. A case study of the countries in the Peru Current System (PCS) shows both the challenges of MPA creation but also the benefits of them. I suggest a mixed approach with no-take zones in the middle of protected areas, less protected zones around them as buffers, and other effective management methods throughout the entire ocean. With most of the public only marginally aware of the issues faced by marine life and the effects of declining ocean health on humanity, more effective science communication, especially with the general public, will be essential to create the necessary political power for change.



## Abstrakt

Der Ozean ist schon lange eine Quelle von Nahrung, ein Fortbewegungsmittel und ein integraler Teil des Weltklimas. Die Klima- und Biodiversitätskrise führt zu verschlechterten Konditionen für Meereslebewesen. Meeresschutzzonen (Marine Protected Areas, MPA)

werden als effektives Werkzeug für die Erhaltung und Wiederherstellung von Beständen gesehen. Dennoch steht nur ein kleiner Teil der Weltmeere unter Schutz und ein noch kleinerer Teil des Meeres ist stark geschützt und effektiv verwaltet. Ich habe Literatur analysiert und die Realität von Meeresschutzzonen mit Experten diskutiert, um einen Überblick zum aktuellen Stand des Meeresschutzes, den Barrieren, die im Weg stehen und der Wahrnehmung von Stakeholdern und der Allgemeinheit zu erzeugen. Zu den Vorteilen zählen die höhere Biomasse innerhalb von MPA, Spillover von Biomasse und Larven zu nahegelegenen Fischereien, hohe Biodiversität und erhöhte Kohlenstoffsequestrierung. Die größten Schwierigkeiten sind die Kommunikation der Vorteile gegenüber Stakeholdern, vor allem solchen mit beeinträchtigtem wirtschaftlichen Interesse, die Finanzierung von Verwaltung und Durchsetzung solcher Schutzzonen und der Einfluss von Klimawandeleffekten, die die Effektivität von MPA auf dem Papier reduzieren können. Eine Fallstudie der Länder im Perustromsystem (Peru Current System, PCS) zeigt sowohl die Herausforderungen bei der Erstellung von MPA, aber auch deren Vorteile. Ich schlage einen gemischten Ansatz mit No-Take Zonen im Kern des geschützten Gebiets und weniger streng geschützten Zonen um diese herum als Puffer, sowie andere effektive Verwaltungmethoden im gesamten Ozean vor. Da ein Großteil der Allgemeinheit nur marginal mit den Problemen der Meeresbewohner und den Effekten von verminderter Meeresgesundheit in Kontakt kommt, wird effektivere Wissenschaftskommunikation vor allem mit der allgemeinen Bevölkerung von wesentlicher Bedeutung sein, um die notwendige politische Macht für einen Wandel zu erreichen.

## Chapter One: Introduction

The ocean has long been a source of food, a means of travel, and an integral part of Earth's climate. Tens of millions of people rely on marine fish and seafood stocks to meet their nutritional needs (Sumaila et al., 2022; McClure et al., 2020). Many more millions are directly or indirectly employed in the fisheries sector (Sumaila et al., 2022; Reuchlin-Hugenholtz & McKenzie, 2015). For thousands of years, ships have been used to explore, deliver goods, and cross large waters (Ship - History of Ships | Britannica, n.d.).

Less commonly considered is the integral role of the ocean in the global climate. The ocean has absorbed between a quarter and a third of anthropogenic carbon dioxide emissions since

the Industrial Revolution (Watson et al., 2020; Sumaila et al., 2022) and buffered about 90% of the added heat caused by greenhouse gasses (Sumaila et al., 2022). While it is hard to estimate the exact temperature Earth would have without this ocean buffering, temperatures would have increased significantly without the ocean. The deep sea is the largest store of organic carbon which can be stored in deep-sea sediments for millenia (Sala et al., 2021).

## 1.1 Two crises: climate crisis and biodiversity crisis

The world is suffering from two crises that are often seen as two sides of the same issue: the climate crisis and the biodiversity crisis which affect each other negatively.

Rising temperatures as one of the global aspects of the climate crisis[1] have put stress on numerous organisms which fit into thermal niches[2]. Doney et al. (2012, as cited in Smith et al., 2023) found evidence that warming responses can be observed across biological scales from genes to entire regions. They also found that while some organisms are able to find refuge from the upper ranges of their thermal niche others are less migratory or live in areas where refugia are rare.

In addition to the impacts to the natural world, global warming is increasing global economic inequality (Diffenbaugh & Burke, 2019), negatively affecting human health (Rossiello et al., 2019), and lowering global economic output (Burke et al., 2015). Burke et al. (2015) estimate that a business-as-usual approach would lead to a reduction of economic productivity of 23% by 2100 and widen the gap between the wealthier and poorer individuals and nations.

The climate crisis interacts strongly with the biodiversity crisis[3]. The WWF Living Planet Report (2022) which monitors the relative abundance of tens of thousands of terrestrial, freshwater, and marine vertebrate populations, shows an average decline of 69% for the populations of monitored species compared to 1970. They outline that the major drivers for

[1] In this paper, the terms 'climate crisis,' 'climate change,' and 'global warming' are used interchangeably. Global warming is defined as the increase in surface air and sea temperatures over a 30-year period compared to pre-industrial levels and biodiversity is the variety of life considering the interaction of living organisms at all levels from the genetics of individuals to populations and ecosystems. This is notwithstanding the fact that climate change can lead to other extreme weather scenarios such as harsh winters or storms.
[2] Organisms have a range of conditions they perform best in, e.g. temperature. They perform best in the middle of their temperature range with performance declining toward the extremes. Beyond certain values, organisms cannot survive.
[3] In this paper, biodiversity is defined as the variety of organisms living in a certain habitat, both between species and within a species (Paulus, 2021)

this loss in biodiversity are land and sea use changes, overexploitation of natural resources, pollution, and the spread of invasive species. As the climate crisis leads to more warming, this temperature increase is likely to replace these drivers as the dominant driver of biodiversity loss (WWF, 2022). The importance of biodiversity for not only ecosystems but also human health and global economies has been known for decades (Cardinale et al., 2012). Most nations agree on this importance (e.g. Ballatine, 2014; Gelcich et al., 2013; Reuchlin-Hugenholtz & McKenzie, 2015) and a set of targets called the Aichi targets were adopted by the parties of the Conference on Biological Diversity (CBD; Convention of Biological Diversity, 2020), followed by the UN's seventeen Sustainable Development Goals (SDG; THE 17 GOALS | Sustainable Development, n.d.). Both sets of goals aim to protect biodiversity and curb anthropological impacts on the environment.

Compared to the pre-industrial levels of the 1850-1900 period, human-induced global warming passed the threshold of 1 degree[4] (0.8-1.2 degrees) in 2017 (IPCC, 2022). According to the WWF, 1.2 degrees had been reached by 2022 (WWF, 2022).

The effects of these crises can be felt all over the world (see 1.2 and Chapter 2): marine heat waves are increasing, storms are getting more severe, oxygen availability in waters is reduced, sea levels are rising, the polar ice caps are melting, and entire ecosystems are degraded to make room for human needs.

The environmental risk is carried predominantly by poorer individuals and regions. A study by Brouwer et al. (2007) found a clear "positive relationship between environmental risk, poverty and vulnerability".

## 1.2 The effects of anthropogenic stressors on the ocean

The ocean is the largest reservoir of carbon containing an estimated 38,000 Gigatonnes (Gt) in the waters plus approximately 6,000 Gigatonnes in marine sediments (Houghton, 2007). This makes the ocean likely the only net carbon sink of anthropogenic carbon dioxide emissions (Sabine et al., 2004, as cited in Sumaila & Tai, 2020).

While this sequestration has buffered global temperatures, taking up additional carbon dioxide changes the pH of the ocean. According to Roberts et al. (2017), the ocean is on

[4] All temperatures in this report are in degrees Celsius.

average 26% more acidic (a change from the average 8.2 to 8.1 on the logarithmic pH scale) than in pre-industrial times and acidity is expected to increase by 100% (to an average of 7.8 on the pH scale) or more by 2100 if emissions are not curbed.

Multiple parts of the ocean ecosystems help balance the acidity of the water, as Roberts et al., (2017), outlined with three examples: Firstly, coastal wetlands such as mangrove forests or seagrass meadows not only provide important habitats for various species but also raise the pH of the surrounding waters . Secondly, teleost fishes aid in pH regulation through their osmoregulation and, thirdly, mesopelagic fish transport carbonates during their vertical migrations, moving minerals to the surface waters. But they also found that all of these mechanisms are under pressure from anthropogenic effects and suffering, thus leading to a downward spiral of biodiversity loss and global warming.

The combination of rising temperatures and ocean acidification put stress on many organisms and ecosystems. In 2011, a marine heat wave destroyed much of the kelp forest off the west coast of Australia and led to major shifts in ecosystems (Smith et al., 2023). Coral reefs are often seen as biodiversity hotspots (e.g. Paulus, 2021). A warming of just 1.5 degrees, the target of the 2015 Paris Agreement (see Chapter 1.3), is estimated to lead to the loss of 70-90% of warm-water corals and a warming of 2 degrees would likely lead to the loss of 99% (WWF, 2022).

As will be seen in the following chapters, it is not just coral that are affected by ocean acidification. Ocean acidification is a severe threat to anything from calcifying organisms at the basis of marine food webs to large predatory species often commercially fished for by humans.

In addition to the pressures of climate change, overfishing and exploitation of marine ecosystems have put additional pressure on marine life. Most of the ocean is now already affected by multiple human-made stressors (Roberts et al., 2017).

According to the Global Fishing Index (Minderoo Foundation, 2021), almost half of global fish stocks are in decline and a tenth of stocks are near collapse. Clearly, a solution to curb

overfishing and exploitation is needed—especially in the face of climate-crisis pressures on ecosystems.

## 1.3 Government responses to climate change and biodiversity loss

During the 1992 Earth Summit in Rio de Janeiro, Brazil, the first global agenda was formed (THE 17 GOALS | Sustainable Development, n.d.). Agenda 21 was "a comprehensive plan of action to build a global partnership for sustainable development to improve human lives and protect the environment" according to the United Nations (THE 17 GOALS | Sustainable Development, n.d.) and has been seen as the basis for future accords (Council on Foreign Relations, n.d.).

This also produced the first version of the UN Framework Convention on Climate Change (UN FCCC, n.d.) which went into force in 1994 though not legally binding (Council on Foreign Relations, n.d.). In regular meetings called Conferences of the Parties (COP), the member states come together (Council on Foreign Relations, n.d.).

The first legally binding treaty was the Kyoto Protocol signed during COP3 in Japan which required emissions to be lowered by an average of 5 percent below 1990 levels (Council on Foreign Relations, n.d.). In 2007, negotiations for the second version of the Kyoto protocol started at COP13 in Bali, Indonesia (Council on Foreign Relations, n.d.). However, when the second version was finished during COP15, it was again a non-binding agreement which mainly acknowledged that global warming should not reach 2 degrees (UN FCCC, 2010).

In October of 2010, at COP16, a revised and updated strategy plan for the 2011 to 2020 period was signed (Convention on Biological Diversity, 2020). This included a set of goals called the Aichi Biodiversity Targets. These twenty targets spanning five major areas were supposed to be met by 2020 (Convention on Biological Diversity, 2020).

In 2015, 196 parties signed the so-called Paris Agreement, a legally binding international treaty on climate change (UN FCCC, n.d.). The main goal was set to limit global warming to 1.5-2 degrees (UN FCCC, n.d.).

The Paris Agreement set increasingly ambitious targets on 5-year intervals (UN FCCC, n.d.). By 2020, countries had to submit their updated plans for climate action, so-called NDCs or

nationally determined contributions. (UN FCCC, n.d.). However, according to the Climate Action Tracker (2020), an independent scientific project that tracks the Paris Agreement progress,  none of the large emitters submitted updated NDCs by the deadline (2020).

Governments and companies have set net-zero goals for 2050 or later, significantly lowering the 2100 temperature estimates (Climate Action Tracker, 2020). 127 countries responsible for about 63% of global emissions have considered or adopted net-zero targets (Climate Action Tracker, 2020). China announced in September of 2020 that it intends to reach net-zero targets before 2060 (United Nations, 2021). As China is one of the largest emitters, this goal alone would lower warming estimates by 0.2 to 0.3 degrees (Climate Action Tracker, 2020).

On the one hand, these goals are far-off and non-binding. On the other hand, few large emitters have set 2030 goals to stay on track. Overall, even the currently set goals for the far future of 2050 would set the world on a trajectory 0.8 degrees above the targets of the Paris Agreement (Climate Action Tracker, 2020).

Burke et al. estimate that 2.5-3.0 degrees of global warming beyond what was measured in 2000-2010 would reduce per-capita output by 15-25% (2018). Reaching 4 degrees would even lower output by 30% (Burke et al., 2018).

In 2022, at COP27, agreements on compensating poor and vulnerable countries for climate change effects are made though details are undecided. Notably, the goal to reach peak emissions by 2025 is removed from the agreement.

To date, progress toward these goals has been too little and none of the twenty targets for 2020 were fully met. In some cases, the situation was even worse than in 2010 (WWF, 2022).

Similarly, all United Nations member states signed the 2030 Agenda for Sustainable Development in 2015 (THE 17 GOALS | Sustainable Development, n.d.) with 17 sustainable development goals (SDGs). An annual platform follows up on the progress (THE 17 GOALS | Sustainable Development, n.d.).  Unfortunately, like with the Aichi Targets, progress is far from where it should be to meet the targets.

The practice of making promises, waiting for the deadline to pass, and setting new targets for a later date seems prevalent.

## 1.4 Managing the ocean economy with fisheries management and marine protection

An estimated 100 million tonnes of marine fish and invertebrates are caught annually from wild stocks (Pauly and Zeller, 2016, as cited in Sumaila et al., 2022). The related economic impact is estimated at 450 billion USD per year (Sumaila et al., 2010).

Despite the importance of fisheries for the nutrition of billions, stocks have been mismanaged worldwide. According to the Global Fishing Index (Minderoo Foundation, 2021), 52% of global catch since 1990 is from stocks where sufficient scientific data is missing or lacking. This means, decision-makers are unable to make informed decisions.

Overfishing stocks and taking fish from high trophic levels is truncating food webs and weakening ecosystem health and lowering the carbon-storing capabilities of the ocean (Sumaila & Tai, 2020).

A commonly applied method is fishing based on Maximum Sustainable Yield (MSY; Pauly & Froese, 2020), a method in which ecosystem models are used to estimate the surplus of a stock. The basic idea is that fish have an optimal population size for their ecological space and cannot grow beyond this limit, so fishing off a certain amount will not decline the stock long-term.

There are various issues with traditional fisheries management based on these calculated MSY values: first, they rely on scientific data which has to be representative. Then, the scientific data has to be modeled accurately to calculate the MSY and make a scientific recommendation. Next, decision-makers have to set quotas below the total allowable catch corresponding to the MSY. And finally, the quotas have to be followed. Pauly & Froese (2020) explained further that while the original MSY model was based on ecological science, the currently adapted models diverge radically from this model and have not served us well.

As Marshall et al. (2019) outline, fishing decreased the average size of fish. There are three main reasons for this: First, fishing regulations often set lower limits on allowable size, thus protecting the smaller fish while larger fish are extracted. Second, large fish are typically

older and thus die more likely, adding further pressure on the older, larger, and more hyperallometrically[5] fecund individuals. Finally, there is an evolutionary shift as the catching of larger individuals favors smaller fish, allowing them to survive and reproduce.

As the authors found, most traditional fishing management is based on the false assumption that fish size and fecundity[6] have a linear (allometric) relationship. Barneche et al. (2018) showed, however, that average reproductive output of fish species is hyperallometric in more than 95% of fish species. The average scaling factor is 1.18 but scaling factors up to 1.56 have been found for commercially important species. In addition, Barneche et al. found that larger females also produce larger eggs and often spawn more frequently than smaller females, further increasing their importance and affecting traditional fisheries management estimates.

Marine protected areas (MPA) where human activity is restricted are often seen as an alternative or addition to traditional fisheries management. Sala and Giakoumi (2018) found that no-take marine reserves, the most protected form of MPA are also most effective at protecting marine organisms. Their metastudy found that biomass inside MPA is on average 670% greater than in non-protected areas.

A movement by fishers and fisheries scientists, especially those located in the US, began arguing against MPA in the late 1990s. They argued that MPA harmed fishing (Hilborn et al., 2004) and tried to put the burden of proof on conservationists (Dayton, 1998, as cited in Sala & Giakoumi, 2018). Mounting scientific evidence has since shown that MPA are an effective tool for fisheries management and conservation, as this paper will explore in the upcoming chapters. However, there are many socio-political hurdles connected to the creation, financing, maintenance, and enforcement of MPA, making effective planning and communication essential.

## 1.5 The upcoming chapters and research questions

This paper aims to provide an overview of the benefits and issues of MPA and the influence of stakeholders and the public on their implementation.

[5] increasing more than linear, so twice the weight of a fish equals more than twice the number of eggs
[6] A measure of reproductive output, so how many offspring a parent will produce. If an animal is more fecund, the animal produces more offspring.

In the following chapters, I will explore what MPA are and how they affect biodiversity and the climate. Then, I will evaluate how public perception of stakeholders influences the creation and enforcement of marine protected areas showing the importance of public perception and involvement.

Next, these findings will be applied in a case study of the MPA in the Peru Current system where I will outline how the countries with coasts along the Peru Current system are protecting their ocean waters and how stakeholders and the public influenced the history of these countries. This case study will be further supported by expert opinions and experiences.

Finally, I will discuss the findings of the thesis and provide suggestions for successful communication around biodiversity loss and marine protected areas.

# Chapter Two: Background (MPA & Biodiversity)

The equivalent to National Parks and reserves on land, MPA are widely seen as the most effective type of ocean conservation (e.g. Rovellini & Shaffer, 2020)—if done right.

While there is no clear definition and different countries use different frameworks for protection, the IUCN definition of MPA is widely applied by scientists and organizations (Scott, 2016): MPA are "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."

As the ocean covers more than two-thirds of Earth's surface, it is, as Sumaila et al. (2022) put it, "simply too big to mess up." The ocean, along with soils and forests make up the basis for the natural capital of the world (Lange et al. 2021, as cited in Sumaila et al., 2022).

As mentioned above, the ocean provides food for billions of people and the related industry connects to 150-450 billion USD in revenue (Sumaila et al., 2022). Add this to the aforementioned climate benefits, and it should be easy to convince stakeholders of the importance of protection.

## 2.1 The past and present of marine protection worldwide

The declining health of many marine ecosystems and the expectation of further decline with mounting climate-change effects have indeed led to calls for action globally (e.g. Worm et al., 2006, as cited in Friedlander et al., 2016).

To date, there are about 14,000 MPA worldwide spanning approximately 24 million square kilometers, an area equivalent to 6.6% of the ocean surface (MPAatlas.org, n.d.). Of those, only a little over a thousand MPA spanning approximately 10,500 square kilometers or 2.9% of the ocean are highly or fully protected (MPAatlas.org, n.d.). A further ~ 1,000 MPA with an area of ~ 2,200,000 square kilometers have been designated but are yet to be implemented and another 263 have been proposed (MPAatlas.org, n.d.).

A few large-scale MPA make up a large percentage of the current protection of the ocean: 75% of global MPA are in 42 very large MPA (MPAatlas.org, n.d.). 15% of global MPA

coverage is made up by a remote MPA in the Ross Sea region in the Southern Ocean around Antarctica alone. A further 15% are covered by the Papahānaumokuākea Marine National Monument near Hawaii. Pacific remote islands supply another 14%, and the Pitcairn Islands MPA another 12%. Even more remote are the 7.9% of the Tristan da Cunha Marine Protection Zone. These numbers (MPAatlas.org, n.d.) clearly show a current tendency to protect remote areas far from mainlands.

Of the roughly 14,000 MPA, the bottom 11,715 make up about 0.3% of global MPA coverage, showing that they are small or very small, so locally constrained.

Large-scale MPA (LSMPA), so areas of 100.000 square kilometers or more (O'Leary et al., 2018) are still the exception for marine protection. Most LSMPA are multiple-use areas where protection is very relative.

LSMPA can take the entire ecosystem into account and even include protection for migratory species (O'Leary et al., 2018; Friedlander et al., 2016). Nonetheless, especially LSMPA have been met with concerns and criticisms, primarily from a small group of American fisheries scientists (O'Leary et al., 2018). These criticisms and their validity will be explored in Chapter 2.3 in more detail.

The debate mostly surrounds some fisheries scientists claiming fisheries management is the one and only path while others claim MPA or a combination of reactive/traditional fisheries management and proactive protection are the ideal way to deal with the crises.

To make matters more complicated, fisheries management will only get harder with climate change and conflicts between neighboring fishing nations but also consumers with constrained budgets for nutrition are to be expected (Sumaila et al., 2020), especially as species' ranges shift with warming sea temperatures (Favoretto et al., 2022). Previous agreements might no longer work for everyone involved as stocks shift their ranges toward one neighboring country or another.

Some stakeholders seem to have grasped this concept, fighting to avoid protection for regions where fisheries might be feasible in the future, as was seen during negotiations for a cooperative MPA in the Ross Sea.

The Ross Sea Region alone makes up 15% of global MPA coverage (MPAatlas.org, n.d.). After decades of urging from environmental groups and an open letter from more than 500 scientists, a large part of the Southern Ocean was declared an MPA by the Commission for the Conservation of Antarctic Marine Living Resources which comprises 24 countries (National Geographic, 2016). The remote area of 1.9 million square miles of pristine, almost untouched ocean with nutrient-rich waters and a large biodiversity lies remotely in the Southern Ocean around Antarctica. China and Russia had long withstood efforts for protection, as they feared the loss of fishery income in the future (National Geographic, 2016).

The Ross Sea MPA also holds significance, as it is the only large-scale MPA in the high-seas and of the few existing or even proposed open-ocean MPA where more than a few countries had to cooperate to achieve protection (MPAatlas.org, n.d.).

High-sea fishing provides an especially high risk to biodiversity, especially considering fuel use and the higher bycatch of these operations. Marine reserves in the high seas would improve high-sea diversity with little impact on food security (O'Hara et al., 2019).

Global cooperation on marine protection has been an issue for marine conservation for decades. While there are some promising areas where cooperation is increasing (see Chapter 4), failures are still frequent. A recent example of such ineffective cooperation was the AGRIFISH Council meeting in Brussel in December of 2021 where quotas were set for the North-East Atlantic fisheries. The quotas set were 300,000 metric tonnes above the scientific advice (Sumaila & Tai, 2020).

Marine reserves are proactive where most traditional management methods are reactive and MPA have been shown to help buffer such errors in traditional management (Ballantine, 2014).

Marine protection as a conservation tool is nothing new. New Zealand is often seen as a pioneer in ocean conservation (e.g. Rovellini & Shaffer, 2020; Scott, 2016; Gargiulo, 2018). New Zealand's Marine Reserve Act (MRA) in 1971 was one of the first (Gargiulo, 2018). Originally created to preserve nature for scientific study, it now forms the basis for the country's marine conservation.

New Zealand established some of the first fully-protected marine reserves. The MRA was originally created to preserve organisms and their environment as needed by scientists at the Auckland University's Leigh Marine Laboratory (Ballatine, 2014). After the MRA was approved, the first no-take marine reserve was created near Leigh: The Cape Rodney/Okakari Point (CROP) marine reserve was founded in 1975 (Rovellini & Shaffer, 2020) and has since been served as a control or baseline in many studies (Scott, 2016).

Since then, New Zealand has put about a third of their waters (both territorial and EEZ) under some protection, though the extent of protection varies from benthic protection only to fully protected (Gargiulo, 2018). Only 2.2% of their EEZ is currently fully or highly protected (MPAatlas.org, n.d.).

Founded in the same year as the CROP reserve in New Zealand, Australia's Great Barrier Reef (GBR) Marine Park, a ~ 344,000 square-kilometer area covering the UNESCO World Heritage reefs off Australia's west coast, was the first LSMPA and remained the only LSMPA for 23 years (O'Leary et al., 2018).

The GBR was the only LSMPA until the Northwestern Hawaiian Islands Coral Ecosystem Reserve was established in 2000 in a remote, uninhabited area, and then expanded in 2006 as the Papahānaumokuākea Marine National Monument (Friedlander et al., 2016). A third LSMPA joined these in 2008, when the Republic of Kiribati established the Phoenix Island Protected Area (Friedlander et al., 2016). Since then, more LSMPA were added but protection varies between them (Friedlander et al., 2016).

The Aichi targets mentioned in Chapter 1 are thought to have pushed MPA creation from small no-take areas to large managed multi-use areas (Scott, 2016). Nonetheless, small and very small MPA are still the predominant reality today (MPAatlas.org, n.d.). With official goals for conservation, the livelihood of local communities and tourism income, they often are little more than so-called 'paper parks,' i.e. MPA that exist on paper, thus boosting global conservation numbers, but with little management or enforcement in place (Gelcich et al., 2015). The reasons for this ineffectiveness vary but lack of funds for enforcement or regulatory frameworks are among the top issues (Pieraccini et al., 2017), as will be explored in the next sections.

While there is an upward trend in fully and highly protected areas, few countries have met the goal for 10% protection as per the Aichi targets. At this point, only eight countries have met the goals set for 2020:

| Country | Percentage of fully/highly protected area |
|---|---|
| Palau | 78 |
| United Kingdom (incl. 12 territories) | 39 |
| Mauritius | 29 |
| United States (incl. 6 territories) | 24 |
| Panama | 21 |
| Chile | 12 |
| Kiribati | 12 |
| Argentina (incl. 2 territories) | 11 |
| Australia (incl. 4 territories) | 9.6 |
| Mexico | 4.7 |

**Figure 1: The ten countries with the highest percentage of fully and highly protected areas compared to their land area. Source: MPAatlas.org, n.d.**

Scientific evidence has pointed to the serious decline of fish populations and marine biodiversity for quite a while now (Jones, 2013). The scientific community has long agreed that biodiversity loss reduces the efficiency of ecological communities (Cardinale et al., 2012; Paulus, 2021). That biodiversity increases the stability of systems and makes them both more productive and more resilient has been known for decades (Cardinale et al., 2019; Paulus, 2021; McClure et al., 2020), and countries typically officially support their protection but biodiversity loss is still accelerating (Cardinale et al., 2019) and there is a significant gap between science and policy that needs to be bridged urgently to meet the targets set by countries across the globe (Cardinale et al., 2019).

## 2.2 The many stressors affecting the ocean and its inhabitants

Scientific review and anecdotal evidence have both shown the effectiveness of MPA as a conservation tool but also as a buffer for more traditional fisheries management and climate change.

The effects of the climate crisis are felt by humans all over the world and even if countries act to lower emissions as per the 1.5-degree target of the Paris Agreement, most scientific projections expect continuing impacts for at least 50 years (Roberts et al., 2017). Thus, both immediate reductions in emissions but also mitigating measures are urgently needed while underinvestment in environmental protection is still the norm (Roberts et al., 2017).

Most of the ocean is already getting affected by multiple human-made causes (Roberts et al., 2017). Multiple stressors affect the oceans at the same time, most of which can be eased with marine protection: overfishing, habitat destruction, warming sea temperatures, ocean acidification, oxygen and nutrient depletion, sea level rise, intensifying storms, shifting ranges and species abundance patterns, but also timeline mismatches between prey and predators.

### 2.2.1 Overexploitation of marine stocks

Recent studies have suggested that a vast portion of fish stocks globally is overexploited (Pitcher & Cheung, 2013, as cited in Cheung et al., 2017). Some regions fare especially badly: at least 40% of North-East Atlantic stocks and 87% of Mediterranean and Black Sea stocks are fished unsustainably (Sumaila & Tai, 2020).

Froese et al. (2018) found that despite the legally binding Common Fisheries Policy (CFP) signed by all member states of the EU which came into effect in January of 2014, 69% of the European stocks they evaluated were subjected to overfishing. More than half (51%) were even outside safe biological limits. According to their review, only 12% of European stocks were in accordance with the goals of the Common Fisheries policy two years before the deadlines set in the policy.

These practices of overexploitation have major impacts on ecosystems and general ocean health (e.g. Halpern et al., 2015; Gattuso et al., 2018; both as cited in Sumaila & Tai, 2020).

The negative impact of fishing is made worse by the prevalence of destructive fishing methods such as bottom trawling which disturb the benthic substrate (Bailey & Sumaila, 2015).

In 2018, an estimated 4.6 million fishing vessels registered fished the ocean (Sumaila & Tai, 2020). Sumaila and Tai (2020) explain that people overfish because "it pays to do so." With fishing continuing as it is now, Cheung et al. (2018) estimate that 60% of fish species will likely go extinct.

In addition, illegal, unreported, and unregulated (IUU) fishing is a major issue for fisheries management worldwide, even where effective fisheries management schemes are in place (Miller & Sumaila, 2014, as cited in Cheung et al., 2017). A study by Welch et al. (2022) showed that monitoring fishing remains a challenge, especially considering that more of the human activity has moved into the open ocean where legal matters of jurisdiction complicate responsibility and enforcement. They found an estimated global loss of 10-25 billion USD per year from IUU fishing and further explained that one in every five wild-caught fish is likely harvested illegally.

Monitoring is further complicated by fishing vessels disabling their tracking systems. AIS (Automatic Identification System) is not required for all vessels and some disabling happens for legitimate reasons such as avoiding piracy in piracy hotspots or hiding particularly good fishing grounds (Welch et al., 2022).

Welch et al. (2022) estimate that 6%, which is equivalent to more than 4.9 million hours of fishing vessel activity, is done with disabled AIS, most of which happens in four hotspots: the Northwest Pacific, adjacent to Argentina's EEZ and that of West African nations, and near Alaska in the US.

These practices of IUU fishing further complicate fisheries management, as scientific calculations of quota rely on correct and reliable data. The United Nations recognized the threat of IUU fishing when they set the target to eliminate or reduce IUU fishing by 2020, though Welch et al. (2022) point out that these goals remain elusive. In fact, Seas at Risk (2019) lamented that the proposal for the Baltic by the European Commission allowed overexploitation to continue in direct violation of the CFP.

In addition to the direct impacts of fishing on fish stocks, the fisheries sector is responsible for 1% of global emissions (Sumaila & Tai, 2020) further stressing the ocean's ability to buffer emissions and sequester carbon. This number does not include indirect emissions such as a loss of carbon stored inside the extracted organisms.

Especially high-seas fishing has been shown to be unsustainable and uneconomic (Skerrit & Sumaila, 2021). Nonetheless, large sums still subsidize fisheries while funds are low for marine conservation. The chief argument against phasing out these subsidies has usually been that these subsidies are needed to reduce poverty and maintain economic stability (Skerrit & Sumaila, 2021). China, the EU, South Korea, Japan, Russia, Thailand, and Indonesia are responsible for 65% of global fisheries subsidies, the majority of which are thought to be harmful (Skerrit & Sumaila, 2021).

These subsidies often make otherwise unprofitable fishing profitable where lack of economic sustainability would typically lower fishing pressure (Skerrit & Sumaila, 2021). Most of the subsidies are provided to large-scale industrial operations, further worsening the economic stability of small-scale operations (Sumaila & Tai, 2020). In 2001, the World Trade Organization (WTO) began negotiations to phase out harmful fisheries subsidies but no clear deadline was set until the SDGs were created in 2015. The 2020 deadline for this change was widely not met (Skerrit & Sumaila, 2021).

An example of the effects of this can be seen in the China Sea where fisheries have been degraded by exploitations. Landings from the East China Sea increased from 10 million tonnes in the 1950s to 45 million tonnes in the 2000s despite increased fishing effort (Sumaila et al., 2022). Fish communities have changed toward smaller species and individuals and similar happenings took place in the South China Sea (Sumaila et al., 2022). Sumaila et al. (2022) suggest that these issues would be largely reduced by removing harmful subsidies and that biomass would increase as a result.

42% of fish stocks straddle the EEZ of countries and make up 67% of global catches (Cheung et al., 2017). While Cheung et al. (2017) found that properly managed sustainable fisheries in the high-seas fisheries would perform best, Brooks et al. (2013, as cited in Cheung et al., 2017) pointed out that there is a very low likelihood of effective management in the high seas. Thus, they argue that high-sea closures could be a more effective tool. Cheung et al. (2017) predicted that excluding high-seas fishing would likely recover straddling fish stocks

and increase the CPUE in EEZ. White and Costello (2014, as cited in Cheung et al., 2017) suggest that global fisheries production would not decline with high-sea closures.

Finally, fishing pressure is shifting species toward smaller and thus less fecund individuals (Marshall et al., 2019): This is due to both restrictions on fish size, the already higher chance of older fish to die from natural causes, and evolutionary shifts that favor smaller (and thus protected) individuals.

As Marshall et al. (2019) pointed out, bigger fish are more fecund, scaling hyperallometrically. This means a fish twice the weight will be more than twice as fecund as the smaller one.

Fish inside MPA are on average 28% larger than fish outside MPA, clearly pointing to MPA as a solution for at least the size shift of overfishing. More generally, MPA can help mitigate and buffer the effects of overfishing (Afonso et al., 2011, as cited in Sumaila & Tai, 2020). As pointed out previously, traditional fisheries management is reactive while MPA are proactive, and these proactive measures often have the ability to buffer the errors of reactive, traditional fisheries management.

### 2.2.2 Warming oceans, oxygen depletion, and shifting ranges

Organisms, on land and in the ocean, fit into a thermal niche beyond which their performance declines (Smith et al., 2023). From genes to ecosystems and across the globe, warming oceans affect marine life (Doney et al. 2012, as cited in Smith et al., 2023; Moree et al., 2022). Some organisms are more malleable to temperature changes, while others are less able to adapt (Schaum et al., 2018).

Marine heat waves (MHW)[7] have become more frequent and more extreme over the last century with more than 50% increase between 1925 and 2016 which means short-term warming adds to the stressors of chronic warming driven by the climate crisis (Smith et al., 2021).

Ocean warming is leading to changes in the physical and chemical properties in the ocean. In response, organisms change their behavior (Cheung et al., 2017). Some migrate vertically to

[7] Marine heatwaves are defined as discrete periods of unusually high seawater temperatures in this paper (Smith et al., 2021)

deeper waters (Dulvy et al., 2008, as cited in Cheung et al., 2017) while others migrate polewards (Poloczanska et al., 2013, as cited in Cheung et al., 2017). Evidence of these large-scale shifts has been well-documented (e.g. Parmesan and Yohe, 2003; Perry et al., 2005; Dulvy et al., 2008; all as cited in Sumaila & Tai, 2020).

Warming activates cellular stress responses and leads to an increase in energy demand (Smith et al., 2021). This higher energy demand can lead to changes in behavior which in turn put the organism at risk, as e.g. a feeding fish is at a higher risk of predation than a fish hiding in a refuge (Smith et al., 2021). In addition, the temperature changes caused by MHW influence reproductive cycles, as energy is used for more urgent needs rather than reproduction (Smith et al., 2021).

While some organisms can shift their ranges or find refuge in cooler waters, some species are extremely loyal to their breeding grounds. Especially sea birds and sea mammals often return to their traditional breeding grounds for their own breeding (Smith et al., 2021, as cited in Smith et al, 2023). These species will be especially perceptible to the effects of the climate crisis.

Roberts et al. (2017) expect that tropicalization will shift ranges of species by an average of 72 kilometers per decade. As stocks migrate, fisheries will be redistributed with a decrease in the tropical areas and an increase in higher latitudes (Cheung et al., 2013; Jones & Cheung, 2015; both as cited in Cheung et al., 2017) but a general decline is expected  under a business-as-usual scenario (Pitcher & Cheung, 2013).

These shift ranges challenge traditional management of fisheries (Hobbs et al. 2018; Vergés et al. 2019; both as cited in Favoretto et al., 2022), as these reactive methods are often unable to take future expected shifts in composition or range into account (Favoretto et al., 2022).

A commonly known effect of global warming and the connected rise in seawater temperatures is coral bleaching. Especially since the widely watched Netflix documentary "Chasing Coral," coral bleaching has entered public perception (The Film - Chasing Coral, n.d.).

Coral reefs belong to both the most biodiverse and threatened ecosystems (e.g. Knowlton et al. 2010; Fisher et al. 2011; Caley et al. 2014; all as cited in Mellin et al., 2016). The GBR is the largest coral reef ecosystem (Wilkinson, 2008, as cited in Mellin et al., 2016) but coral cover has gone down across the area (De'Ath et al. 2012, as cited in Mellin et al., 2016). A study by Mellin et al. (2016) compared areas of the GBR that were under protection to those that were unprotected and found that recovery was faster in protected areas despite similar recovery rates due to a higher resistance against disturbances in MPA areas.

Bleaching events have become more frequent over the last years with half of the world's corals affected by a global bleaching event between 2014 and 2017 (Eakin et al. 2019, as cited in Smith et al., 2023).

Another often overlooked factor of seawater warming is timeline mismatches of predator and prey species: Roberts et al. (2017) predict that the various stressors for ocean life will lead to a mismatch between developmental stages of predators and their food sources. As Edwards & Richardson (2004) found, functional groups respond to warming at different speeds disturbing the synchrony of timing between the successive trophic levels. They also found that commercially important species are highly affected by this and will continue to be affected in the future.

Warming ocean waters also affect dissolved oxygen. Mostly due to rising water temperatures and anthropogenic nutrient enrichment, oxygen depletion is increasing. Like on land, oxygen is essential to most marine life. Between 1998 and 2006, Roberts et al. (2017) found a 15% increase in so-called 'ocean deserts' or oxygen-minimum zones (OMZ) in the Pacific and Atlantic. The European Environment Agency (EEA, 2022) has found that 36 and 37.5% of the Baltic and Black Sea respectively showed reduced concentrations of dissolved oxygen (6 mg/l or less).

Sea surface temperatures increase stratification (Roberts et al., 2017) which increases the risk for oxygen depletion in the upper ocean layers (EEA, 2022).

In Baja California, Mexico, marine protection has shown to help buffer this risk where more frequent hypoxic episodes were observed. Roberts et al. (2017) found that the larger abalone inside a marine reserve there lead to a faster recovery of protected populations and even lead to spillover benefits to regions around the reserve.

Similarly, kelp forests are suffering from marine heatwaves and urchin overpredation leading to the loss of important, biodiverse habitats. The warming event that coined the term 'marine heat wave' led to the loss of kelp along hundreds of kilometers of coastline (Pearce & Feng 2013, Wernberg et al. 2013; both as cited in Smith et al, 2023). Smith et al. (2023) found that kelp forest dieback is one of the most pervasive warming responses. As kelp forests build the basis for one of the most biodiverse ecosystems on the planet and sequester large amounts of carbon themselves, this is detrimental to ocean health (Smith et al., 2023; Sumaila & Tai, 2020).

Protecting areas with coral reefs, kelp forests, seagrass meadows, and other biodiversity hotspots is thus especially important, not only for biodiversity but also global carbon storage.

### 2.2.3 Ocean acidification

As mentioned in Chapter 1, the ocean is the largest reservoir of organic carbon. An estimated 38,000 Gt of organic carbon are sequestered in ocean waters with an additional 6,000 Gt in marine sediments (Houghton, 2007, as cited in Sumaila & Tai, 2020). Sabine et al. (2004, as cited in Sumaila & Tai, 2020) found that the ocean is likely the only net carbon sink of anthropogenic carbon dioxide emissions. This is particularly interesting considering that tree-planting is widely spread as a solution for carbon offsetting while scientists question the validity of such mass-tree-planting solutions globally (Welz, 2021) .

Carbon sequestration by the global ocean has buffered atmospheric temperatures, slowing global warming. But this buffering comes at a cost: The ocean is already 26% more acidic on average than it was in preindustrial times and acidity is expected to increase by 100% or more by 2100 under a business-as-usual scenario (Roberts et al., 2017).

Mangrove forests and wetlands do not only provide habitat to countless species but also help raise the pH (and thus lower acidity) in surrounding waters. But while coastal ecosystems play a huge role in balancing the pH, so do fish, especially the larger migratory and teleost species[8] Migratory fish transport organic carbon further down the water column, especially during vertical migrations, while teleost fishes reduce the pH during their osmoregulation (Roberts et al., 2017).

[8] Teleost fishes make up 96% of extant species and thus include almost all fish known to humans (Clarke et al., 2016)

Mangrove forests are critically important for their ecosystems but also the surrounding coastal populations (Barbier et al., 2011; Donato et al., 2011; both as cited in Goldberg et al., 2020). Despite their importance, these forests have been heavily impacted by human activity and the effects of the climate crisis with 20-35% of global mangrove cover lost over the last half century (Polidoro et al., 2010, as cited in Goldberg et al., 2020). Goldberg et al. (2020) found that 62% of the mangrove loss between 2000 and 2016 was due to land-use change, especially for agriculture and aquaculture.

In 2011, a joint report written by the World Bank, IUCN, and wetland specialists called for urgent wetland protection (IUCN, 2011). They found that degrading wetlands were likely impacting the global emissions of carbon dioxide and predicted that more carbon dioxide would be released with continued degradation. According to the report, 20% of the world's mangrove forests had already been destroyed. They also found that seven deltas had released more than 500 million tons (about 450 million metric tonnes) of carbon dioxide since they had been drained.

The loss of teleost fishes, especially migratory ones, due to overfishing and species range shifts is further dampening the ability of the ocean to self-regulate the pH (Roberts et al., 2017). The resulting ocean acidification is expected to be detrimental to ocean productivity (Roberts et al., 2017) making the protection of both coastal wetlands and fish stock essential.

### 2.2.4 Habitat destruction

In addition to habitat loss due to warming oceans (see 2.2.2), there are two major drivers of habitat loss to marine life: land-use change that replaces natural habitats with areas for human use and degradation of habitat due to destructive extraction methods.

Steibl et al. (2021) looked at small islands and compared those that were inhabited to those that were not. They found that urban land-use significantly decreased invertebrate communities around the islands compared to uninhabited ones. In the same study, they also found that land-use change for tourism activities was not directly linked to biodiversity loss of invertebrate communities. They also cautioned that these human-driven land-use changes could have "yet unforeseeable long-term consequences for the stability and resilience of oceanic island ecosystems."

But it is not just small islands or invertebrate communities where habitat is destroyed for human land-use. As explored in 2.2.2, mangrove forests were widely destroyed to make room for aquaculture and agriculture.

More and more of the coast is getting lost to human development. Coastal development such as shoreline hardening and armoring accelerates erosion and loss of beaches (Gittmann et al., 2015). Gittmann et al. (2015) estimate that about 14% of US coastlines have been armored and caution against hardening of essential tidal wetlands in the South Atlantic and Gulf of Mexico. They found that engineered seawalls support 23% less biodiversity and provide a home to 45 % fewer organisms than natural shorelines.

And shoreline hardening is a global trend. In general, degradation of wetlands has continued (Davidson, 2014). According to a review by Davidson (2014), more than 50% of wetlands have been lost globally and despite slowing rates of loss in Europe and North America, the rates have remained high in Asia. Tidal flats, i.e. areas with very high tidal fluctuation have been lost, too. 16% of global tidal flats were lost between 1984 and 2016 according to a study by Murray et al. (2019).

Inland dams, deforestation, and agriculture change the composition of river run-off depleting necessary nutrients while increasing the salinity and blocking sunlight in shallow waters (National Geographic, 2010). Container ships and tankers can lead to further issues for coastal and open-ocean ecosystems by damaging ecosystems with their hulls or anchors or, in the worst case, releasing oil into the waters (National Geographic, 2010).

In addition to habitat loss due to land-use changes, be it for coastal development or aquaculture, destructive fishing methods such as bomb fishing, bottom trawling, dredges, and poisoning are wreaking further havoc to marine ecosystems. In the deep sea, first explorations for deep-sea mining are performed and while, to date, deep-sea mining is not yet profitable, desperation might lead companies to explore this option more vigorously in the future.

A study by Sala et al. (2021) explored the effects of bottom-trawling and dredging and found that 1.3% of the ocean was trawled between 2016 and 2019. Despite this low percentage, 1.47 Pg of carbon dioxide were likely emitted, an amount equivalent to about 15-20% of annual global ocean sequestration. While they found that consecutive trawling does not emit

as much as the initial trawl, even the stabilized emission of 40% of the first-year rate leads to a lot of additional carbon dioxide in the atmosphere.

Similarly, Roberts et al. (2017) found that mobile fishing gear alters biogeochemical cycles and re-suspend sediment with sequestered carbon. More directly, they found that trawling and similar methods shift the benthic community.

While bomb fishing, i.e. fishing with explosives, is illegal in large parts of the world, it is still done frequently (Hampton-Smith et al., 2021; WRI, 2011). As a non-selective fishing method, the practice destroys entire ecosystems. Especially lack of enforcement is allowing this practice to continue (Hampton-Smith et al., 2021). Similarly, poisoning is another destructive, non-selective fishing method that affects ecosystems worldwide (WRI, 2011).

But even less destructive fishing methods are often detrimental to marine life. Longline fisheries which dominate much of high-sea fishing (Kroodsma et al., 2018, as cited in Marshall et al., 2019) is known for high bycatch rates for marine mammals, seabirds, and sea turtles (Lewison et al., 2014, as cited in O'Hara et al., 2019). Bycatch in net fisheries is a prevailing threat to marine species (Mangel et al., 2018) and the general plastic waste in the ocean poses a further danger to migrating species. A study by The Ocean Cleanup Project showed that fishing vessels are a major contributor to ocean plastics (Lebreton et al., 2022) which they say is a cause of death for "hundreds of thousands of whales, seals, sea turtles and seabirds [...] every year from entanglement and ingestion."

## 2.3 Benefits and criticisms of marine-protected areas

When it comes to MPA, protection varies widely. When evaluating the benefits and risks of marine protection, it is important to take their level of protection into account.

Fully protected areas (FPMPA) are typically defined as areas where there is no extractive or destructive activity allowed, while highly protected areas (HPMPA) allow light extractive activities (MPAatlas.org, n.d.; O'Leary et al., 2018). In addition, the MPA Atlas has a category for actively managed MPA with "demonstrable and ongoing enforceable rules, monitoring, evaluation, adaptive management, and conservation outcomes."

Another factor is the size of MPA. MPA range from very small to hundreds of thousands of square kilometers. The GBR, a multi-use MPA, i.e. an MPA with mixed protection levels, was the world's largest for 23 years with its 344,000 square kilometers (O'Leary et al., 2018).

Depending on their size and level of protection, MPA have shown the following general benefits: more and larger, more fecund individuals, preservation of genetic diversity, increased human well-being, alleviated poverty and lowered inequality, facilitation of climate-change adaptations and increased catch in adjacent fishing grounds (Manel et al., 2019).

Large-scale MPA (LSMPA) can take entire ecosystems into account, benefiting even migratory species (O'Leary et al., 2018). Due to their size, they also limit anthropogenic stressors and more likely still include species after tropicalization and range shifts (O'Leary et al., 2018).

Davies et al. (2017) found that while LSMPA then only covered 4.4% of the ocean, this included the ranges of 11,900 species (83% of the species they assessed) and 26.9% had more than a tenth of their range protected within an LSMPA. They also found that these areas will increase in importance as almost 90% of species are projected to reduce their ranges by 2100 by an average of 23.3%. They blame the opportunistic creation of LSMPA for the current state of uneven protection but point out that even these non-systematic LSMPA have a higher impact on species than most assume.

With targets aiming for certain percentages, Jones (2013) found a large potential for green marketing both in the tourism and seafood sector. This can lead to a loss of conservation or even be a driving force for depletions. Dr. Kristina Boerder echoed this sentiment when she answered my questions for this thesis (personal communication, February 24, 2023). She is a postdoctoral fellow at Dalhousie University in Halifax on the Canadian East Coast whose current work and PhD focus on better understanding the interactions between fisheries and MPA. She explained that she was worried about the "focus on the quantitative goals without a sufficient discussion and effort to include and ensure quality of the measures implemented." She said that this quantitative approach might cause harm to the overall cause as MPA fail to deliver what is expected of them due to issues with management, enforcement and planning.

To date, MPA sites are often not chosen based on scientific backing but rather opportunistically despite the fact that properly planned MPA are more efficient than ad-hoc MPA (Tognelli et al., 2009). Nonetheless, even ad-hoc MPA can often lead to benefits for the ecosystems (Tognelli et al., 2009).

In a meta-analysis of scientific study, Sala and Giakoumi (2018) compared no-take marine reserves, i.e. fully-protected MPA, with both unprotected and partially-protected MPA. They found that fish biomass was, on average, 670% greater inside FPMPA than in unprotected areas. Fish biomass in partially-protected areas varied widely. On average, they found an 183% increase in biomass compared to unprotected areas, but said there was often no difference at all. Another important finding of that study was that biomass was restored in FPMPA after protection was established but not in partially or unprotected areas. This has been seen time and again:

Urchin barrens, so areas where sea urchins have taken over where kelp forests used to thrive, are becoming more common around the world (Filbee-dexter & Scheibling, 2014). Again, the effects of the climate crisis and increasing pressure from anthropogenic impacts are playing into the dynamic between kelp forests and urchin barrens (Filbee-dexter & Scheibling, 2014).

When sea urchin predators were reduced in New Zealand and the Mediterranean, kelp forests shifted to the degraded urchin barren state but after protection, they slowly returned to their healthy state of algal forests (Shears and Babcock, 2003; Guidetti and Sala, 2007; both as cited in Sala & Giakoumi, 2018). The landscape of the CROP reserve returned from barren rocks with pink encrusting algae and large urchins to seaweeds that provide a habitat to a large range of biodiversity (Ballantine, 2014).

When a strong EL Niño event affected corals in the Line Islands in 1997-1998, protected areas recovered within a decade while they did not in unprotected areas (Sandin et al., 2008, as cited in Friedlander et al., 2016). Other examples of recovery after disaster were already discussed in the previous sections.

Despite these promising findings, the late 1990 brought opposition to the conversation on MPA effectiveness. Some fishers and fisheries scientists, mostly from the United States, began arguing that MPA can harm fishing (Hilborn et al., 2004). This shifted the burden of proof toward conservationists (Dayton, 1998, as cited in Sala & Giakoumi, 2018). This

opposition led to more research over the following decades which showed many benefits of MPA, even for fisheries.

Some argue that displaced fisheries will degrade adjacent areas (Hiddink et al., 2006, as cited in Schratzberger et al., 2019), something that will need to be prevented with proper management. In conversations with experts, I often heard the following sentiment: a combination of FPMPA and HPMPA, as well as proper fisheries management will be needed for success (K. Boerder, personal communication, February 24, 2023; T. Agardy, personal communication, February 24, 2023; A. Frid, personal communication, February 28, 2023). Tundi Agardy (personal communication, February 24, 2023) suggested placing less-protected MPA around no-take zones to create a buffer for fisheries.

In a meta-study O'Leary et al. (2018) reviewed criticism of MPA and evaluated if those criticisms hold up to science-based review. They found that criticism is usually of one of the following categories: (1) placement, governance, and management; (2) political expediency; and (3) social–ecological value and cost.

While critics argue that especially large-scale MPA are usually placed in remote areas far from commercial interests and thus take up limited resources more urgently needed elsewhere, proponents point out that this kind of MPA designation is taking advantage of lower-hanging fruit (O'Leary et al., 2018). O'Leary et al. (2018) add to this by saying that areas that are not of commercial interest might become so in the future, so while those areas might not be the most important to protect at this point, their value might increase in the future, preventing exploitation before it starts. What is too remote to be exploited now, might not necessarily remain so. Protecting areas before they degrade can be seen as insurance.

The trend to protect remote EEZ areas as opposed to nation's coastlines is undeniable: the UK, one of the top-listed countries in Figure 1 above, has protected 1,495,000 square kilometers of their overseas territories but only 7.5 square kilometers, so less than 0.001% of the British Isles' EEZ (O'Leary et al., 2018). Similar numbers can be found for the US (less than 1% of continental US waters but 43% of remote waters) and much of the rest of the world (O'Leary et al., 2018). Thus, coastal protection is urgently needed. So, while remote areas deserve protection, more attention should be paid to protecting coastlines.

One of the chief criticisms against MPA is that it takes away funds from other tools like fisheries management which some argue achieves better outcomes (Hilborn, 2016). Again, this view holds some truth: Effective fisheries management can achieve some of the benefits of MPA, especially when it comes to rebuilding overexploited stocks (O'Leary et al., 2018).

This can be seen in the historically better-managed regions such as the Norwegian and Barents Seas where some stocks are at or near MSY (Gullestad et al., 2014; Froese et al., 2018; both as cited in Sumaila & Tai, 2020). However, this is not the global norm. In 2019, the EU even proposed to continue overfishing past the 2020 deadline of the Common Fisheries Policy (seas-at-risk.org).

In addition, fisheries management focuses on commercially interesting species while MPA take commercially undervalued and unvalued species into account and take a broader ecosystem approach to protection (O'Leary et al., 2018).

Some argue that MPA undermine social justice. There have definitely been cases where stakeholders were not taken into account, especially considering indigenous populations (O'Leary et al., 2018). One example of this was New Zealand's Kermadec Ocean Sanctuary (Newman, 2016, as cited in O'Leary et al., 2018) but also the aftermath of the 2011 Rena oil spill near the Astrolabe Reef (also known by its Māori name Otaiti; Schiel et al., 2016) which resulted in a long legal battle between the local indigenous Māori tribes and the New Zealand government (PMCSA, 2021).

Many of the concerns are not focused on indigenous communities though, but regard the displacement of extractive and consumptive activities of for-profit organizations. Fisheries and related industries worry about their income. While it is true that a short-term loss of income is a real possibility for fishers, these issues are often outweighed by increased profitability in the longer term (Sumaila et al., 2022). One also needs to take into account that declining fish stocks would soon lead to significant short-term and long-term losses even without protection.

It is essential to take people into consideration when planning MPA as properly involved stakeholders help with acceptance, involvement, and early participation. This will be explored in more detail in Chapter 3.

New Zealand created their Marine Fisheries Act as a tool to preserve nature for scientific study (Rovellini & Shaffer, 2020) and while there are many other reasons for protection, this factor should not be overlooked. Marine reserves can act as a control area where fisheries do not impact the ecosystem and only the background effects of such stressors as climate change are noticeable.

As Ballatine (2014) pointed out, that while critics often argue that each MPA needs a precise reason to exist, there should be a lower standard for controls than experimental design. The same holds true for the argument that it is necessary to show that an ecosystem is 'broken' before trying to fix it. As Ballatine explained, humans are often unaware of the damage done until much later down the road.

This could clearly be seen during the establishment of the Poor Knights marine reserve, the second created in New Zealand in 1982 (Ballatine, 2014): Both authorities and citizens felt that some kinds of fishing were not harming the ecosystem around the Poor Knights Islands and in the end, recreational fishing was allowed there (Ballatine, 2014). At first, this seemed to be working but then problems began to show. First, enforcement was harder due to more complex rules, but the MPA status also attracted fishers who believed fishing would be better in the MPA (Denny and Babcock, 2004, as cited in Ballatine, 2014). It took 16 years to fully protect the reserve (Ballatine, 2014) but after full protection, biomass in the reserve recovered (Willis et al., 2003, as cited in Ballantine, 2014).

Similarly, some argue that humans are part of nature and thus their effects are natural which is a mere play on semantics (Ballatine, 2014) and does not really hold any value. Another related argument is that fishing is a basic right but this leads to questions about whose rights are most important. Ballatine (2014) pointed to the rights of children to see nature and not just what is left over when the fisheries have taken what they wanted.

More generally, critical voices claim that MPA will reduce the supply of seafood but food security, especially for low-income areas, is already suffering from the effects of overfishing and this is thought to get worse as the climate crisis progresses (O'Leary et al., 2018).

It has long been shown that fishers, too, benefit from MPA. Studies at the CROP reserve in New Zealand have demonstrated not only a higher biomass inside MPA (e.g. Lester et al. 2009, Sala and Giakoumi 2018; both as cited in Rovellini & Shaffer, 2020), but also that the

protection of spawning stocks creates spillover beyond reserve boundaries (Gell & Roberts, 2003, as cited in Boerder et al., 2017; Le Port et al., 2017; Russ & Alcala, 2011). Manel et al. (2019) found that while pelagic species have the highest potential for spillover, benthic and demersal species also spread their larvae far. Marshall et al. (2019) even suggests that spillover has been underestimated for the same reason much of traditional fisheries management is ineffective: hyperallometric scaling of fecundity, so the fact that a fish twice the size produces more than twice the number of eggs and typically spawns more often with larger offspring.

Sala and Giakoumi (2018) found that no-take MPA are by far the most effective tool but stressed that partially-protected MPA can also have value.

Critics worry that such spillover benefits will be undone by the practice of fishing the line where fisheries relocate to the outside border of MPA (O'Leary et al., 2018). This practice is indeed common though it might be another potential benefit for local fisheries in reality: Nations could end protection just inside local waters to allow only local fishers to fish the line (O'Leary et al., 2018).

In Mauritius, the domestic fleet largely consists of artisanal fishers while a large proportion of their catch is caught by non-Mauritian vessels from the EU, Russia, China, and other countries (Gascuel et al., 2007, as cited in Sumaila et al., 2022). There, placing protection inside their EEZ and controlling access to who can fish in their waters would likely improve conditions for locals and the environment.

And while fishers should definitely be taken into account and their worries heard, fisheries are displaced frequently for a variety of reasons (Ballatine, 2014): market forces, global seafood preferences and trends, the cost per unit effort due to e.g. fuel cost, changes in taxation or subsidies, all require fishers to be adaptive.

In general, the argument that MPA lock up important fisheries resources mostly ignores two obvious facts: spillover to adjacent fisheries and the sustainability of stocks. The current overfishing practices are putting fish stocks at risk globally, as was explained above, and thus fishers are already losing income due to their current practice and will continue to do so in the future. Protection and better fisheries management might worsen such short-term losses but would benefit everyone in the long run.

Sala et al. (2021) compared different scenarios with compromises between biodiversity benefits, climate benefits, and food yield, and found that as much as 71% of the ocean could be placed under protection without lowering food yield. If other benefits were declared completely unimportant, protecting 28% of the ocean would still be necessary to maximize food output.

Financing a more sustainable ocean economy, including the establishment, management, and enforcement of marine protection remains one of the primary issues.

To make this even more complex, biodiversity hotspots and budgets for marine conservation are often not in the same hands. Chile, for example, is among the countries with the most threatened biodiversity but also in the bottom quartile of the countries for relative biodiversity conservation funding alongside three other countries with these characteristics (Gelcich et al., 2015). This creates challenges for MPA creation in Chile. Along with budget issues, low stakeholder buy-in represents one of the premier challenges for Chile (Gelcich et al., 2015).

As local communities carry the opportunity cost of conservation, they should also benefit from conservation, argue Gelcich et al. (2015). They found that tourism income can often help finance MPA. Thur (2010, as cited in Gelcich et al., 2013) suggests surveyed divers visiting the Bonaire Marine National Park would pay up to six times the then current fee. Reid-Grant and Bhat (2009, as cited in Gelcich, Stefan, 2015) found a willingness of visitors of the Monego Bay Marine Park in Jamaica to pay twice the fee. Similar results were found elsewhere (Gelcich et al., 2013). This is, however, not a feasible option for all MPA: The less accessible Lafken Mapu Lahual reserve in Chile seems to have overestimated tourism-related income, confident visitor fees would cover at least 10-13% of ongoing cost (Gelcich et al., 2013). Gelcich et al (2013) concluded that while tourism-income can cover significant portions of ongoing cost for accessible tropical reefs but has limited benefits for more remote areas and thus suggest a more diverse range of income streams.

Tourism associated with the CROP reserve in New Zealand now generates an estimated 8 million NZD (approximately 4.9 million USD[9]) per year (Scott, 2016; Schratzberger et al., 2019). The reserve near Leigh was originally created for scientific study but became popular

[9] Currency conversion throughout the text are based on the exchange rate on March 9, 2023, as per https://www.xe.com/

with people to the point where visitors are helping enforcement and thus lowering enforcement cost (Ballatine, 2014). Animals protected by the reserve have become less shy, allowing people to experience nature, which Ballatine (2014) sees as an essential educational tool especially for children.

Despite such positive examples as the CROP reserve, funding for enforcement of MPA is a global issue dampening their creation (Mora et al., 2006; Gravestock et al., 2008; Thur, 2010; all as cited in Gelcich et al., 2013). Here, again LSMPA have clear benefits over smaller, local MPA. Small MPA can offer local benefits that should not be discounted (Di Franco et al., 2016; Giakoumi et al., 2017; both as cited in O'Leary et al., 2018) but only LSMPA or networks of MPA can protect migratory and mobile species (Mee et al. 2017, White et al. 2017; both as cited in O'Leary et al., 2018). In addition, LSMPA have a lower cost per unit area considering management and enforcement than smaller MPA (O'Leary et al., 2018) making them more efficient tools.

Ecosystem services are slowly getting included in conversations, mostly because failing to do so can lead to severe loss of benefits provided to people (Olander et al., 2018). In other words, people are starting to care because not caring would cost them more. MPA protection is thought to significantly increase ecosystem services (Marcos et al., 2021).

And MPA have been demonstrated to be strongly beneficial for ecosystem services. Indeed, cost of inaction has been shown to far exceed the cost of protection:

Sumaila et al. (2021) estimated that 2.5 trillion USD per year of gross marine product rely on a healthy ocean. They expect the cost of doing nothing to lead to losses of 200 billion to a trillion USD annually by 2100 and suggest climate impacts could add another 332 billion USD per year by 2050.

But to put these matters into perspective: the worldwide estimated cost for managing MPA at their full capacity is estimated at 2 billion USD per year while fisheries are subsidized with 25-29 billion USD per year (Friedlander et al., 2016).

Sea levels have already risen by an average of 19 cm since 1900. An increase of 82 cm compared to the same year is expected by 2100. Meanwhile, storms are getting more frequent and severe (Roberts et al., 2017). Coastal wetlands, mudflats, reefs, and mangrove forests

offer protection against rising sea levels and ocean acidification but also against intensifying storms (Roberts et al., 2017). But those are the very ecosystems getting lost due to human land-use change and climate change effects, as was discussed in the previous sections.

Coral reefs are seen as the most precious ecosystems when it comes to ecosystem functions (Costanza et al. 2014, as cited in Smith et al., 2023). Their storm protection for nearby coastal communities alone is estimated at 4 billion USD annually (Smith et al., 2023).

Widespread loss of seagrass in Western Australia after a 2011 MHW released ~2-9 Tg of carbon dioxide in the three years following the heat wave. Collectively, the economic loss from MHW has been estimated at 3.1 billion USD per year.

Cleanup of the above-mentioned Rena oil spill in New Zealand cost more than 660 million NZD (approx. 370 million USD) for oil cleanup alone (Schiel et al., 2016), not taking the indirect costs into account. More generally, disasters have cost hundreds of millions where natural ecosystem services would have offered protection.

The global cost for protection of 10% of the ocean with HPMPA or FPMPA is estimated to cost at least 7.7 billion USD globally per year (Sumaila et al., 2021) but currently receives the lowest investment of all the SDG (Libes and Eldridge, as cited in Sumaila et al., 2021). The WWF calculated that an expanding network of MPA would pay for themselves and most likely lead to benefits far outweighing the cost (Reuchlin-Hugenholtz & McKenzie, 2015).

Despite the high cost of inactivity and the promise of an economic rate of return, only about 0.002% of global GDP is invested in biodiversity conservation in general (Sumaila et al., 2021). Broader global cooperation and a more scientifically-backed selection of MPA sites would lower cost, too:

90% of the top-ten percent of biodiversity hotspots are within EEZ and a strategic protection of 21% of the ocean (43% of EEZ and 6% of high seas) would significantly improve the protection of endangered and critically endangered species (Sala et al., 2021). And while climate change is shifting those ranges, Sala et al. (2021) found that most of the high-priority areas would still be of high priority in 2050 with only the tropics losing importance.

Protecting only 28% of the ocean strategically, they found, would increase food provisioning by 5.9 metric tonnes annually compared to a business-as-usual scenario. The numbers of

protection needed change drastically with global cooperation compared to protection based on national priorities (21% versus 44% respectively to achieve 90% of the maximum biodiversity benefit).

Naturally, MPA cannot protect against all pressures. Inside MPA, effects like global warming and ocean acidification still have strong effects and climate change can reduce the effectiveness of MPA on paper (Pendleton et al., 2018). Often, the largest threats to ecosystems inside MPA lie outside their protection making it harder for MPA to reach their goals (J. Day, personal communication, March 04, 2023). But as marine reserves have shown enhanced recovery, they are still an important mitigator of the effects of human impacts (Russ & Alcala, 2011; McClure et al., 2020).

Benefits of protection have been found across taxonomic groups:

Mello et al. (2020) found that the invertebrate community differed inside and outside reserves with a higher abundance and size of benthic invertebrates, especially rock lobsters, in no-take zones. Off the Isle of Man, great scallops were seven times more abundant 14 years after protection and a protected area off the Isle of Arran found a significant increase in size of scallops and a greater abundance of juveniles.

Mellin et al. (2016) found that the protection of large herbivorous fish on coral reefs had strong cascading effects, though they are delayed and indirect which complicates public perception. They found that coral reefs in protected areas are more resilient, in general. Edgar et al. (2014, a cited in Frid et al., 2023, and Frid et al., 2023) demonstrated that the total large-fish biomass is, on average, five times higher inside MPA than outside, even 14 times for sharks. Lester et al. (2009) found that protected organisms are larger, populations denser, and biomass higher, though not across all groups to the same extent.

Gormley et al. (2012) found first evidence of protection for sea mammals in a study of Hector's dolphins, a small, endangered dolphin endemic to New Zealand. There, a Marine Mammal Sanctuary was created in 1988 in the Banks Peninsula to help the struggling population of Hector's dolphins which has led to a higher survival rate though it is not yet seen as enough to recover the population (Gormley et al., 2012).

Russ and Alcala (2011) suggest a general increase in species richness and many studies suggest an increase in overall biomass and biodiversity (e.g. Frid et al. 2023, Mellin et al., 2016).

A factor that should not be overlooked is how little we know about the ocean in general. Mora et al. (2011, as cited in Paulus, 2021) estimated that 90% of ocean life is still undescribed, thus we do not even know what we might be missing out on if we destroy ecosystems before they are even explored. And humans have a history of extinction: Humans are often seen as the main cause of biodiversity loss (Burney and Flannery, 2005, as cited in Paulus, 2021). The arrival of humans is thought to have caused the Great Extinctions (Lyons et al., 2004; Sandom et al., 2014; both as cited in Paulus, 2021). The speed of extinction has only increased with modern technology, and the current 'sixth mass extinction' is up to 100 times faster than background biodiversity loss (Ceballos et al., 2015, as cited in Paulus, 2021). Thus, we are losing the benefits of biodiversity lost before we even discovered them.

Considering all of the above, the largest remaining, valid criticisms of marine protected areas is the large gap between protection on paper and in reality.

It will be necessary to safe-guard against the false sense of progress often induced by ineffective 'paper parks' though it would be detrimental to discount the steps already taken with ineffectively managed MPA. They have already taken the hurdles necessary for implementation and improving their management is likely far easier than starting over from scratch.

Agardy et al. (2016) points out that MPA are often still used as vague promises rather than proper tools. She describes MPA as a tool that can be used properly but are not necessarily. The majority of MPA are created opportunistically and not based on any proper systematic (Baldi et al., 2017, as cited in Agardy, 2018)

Enforcement of MPA policy is a major issue for much of the world's MPA. In Chile, the lack of proper enforcement is even delaying the creation of new MPA (Tognelli et al., 2009). MPA monitoring is often not seen as a priority during their creation process, so no or too few resources are set aside (Castrejón & Charles, 2020).

More generally, such ineffective 'paper parks' sully the perception of MPA to the public, further complicating matters of greenwashed MPA and stagnate further protection. Due to their many demonstrated benefits, better communication to the public and all involved stakeholders seems detrimental to the success of ocean conservation.

# Chapter Three: Public Perception and Involvement

MPA affect the lives of countless people. One could even argue, as MPA affect the global climate (see 2.3), that they influence everyone.

As Charles and Wilson pointed out in their 2009 paper, MPA need to take a holistic approach integrating social, economic, and institutional factors in addition to the biological ones.

Marine protection is often a trade-off between the income of those benefiting from exploitation and the benefits of protection (Schratzberger et al., 2019). One of the major issues is that benefits are often long-term while costs are incurred short-term (Schratzberger et al., 2019). Mello et al. (2020) found that reserve successes are visible after a few years but with long-lasting effects thereafter. It is the initial years that often lead to issues. Indirect effects such as filter feeders cleaning waters from pollutants are often completely overlooked (Schratzberger et al., 2019).

The success of MPA strongly depends on the area design, biodiversity before implementation, their management and enforcement, but also the enforcement of fisheries management in surrounding areas (Schratzberger et al., 2019).

While some scientists still argue that benefits for fisheries are either nonexistent or only happen under certain conditions (e.g. when stocks are severely depleted; Hilborn et al., 2006; Buxton et al., 2014; both as cited in Schratzberger et al., 2019), there is mounting evidence that spillover is not only happening but likely largely underestimated (Marshall et al., 2019).

The big issue: As was seen with climate change, one only needs to sew doubt to delay or prevent change and maintain the status quo.

In an interview with me, Tundi Agardy (personal communication, February 24, 2023) explained her worry that current quantitative goals such as the 30x30 goal of the CBD mentioned above might shift focus from other targets that she considers equally or more important. She urges for 100% effective management instead of a certain number of vague protection.

Dr. Kristina Boerder (personal communication, February 24, 2023) who was already introduced above, explained that "Perceptions of MPAs vary widely, partly due to failure to

properly communicate from the side of scientists, managers and governments and also targeted misinformation from interest groups."

Professor Pablo Marquet (personal communications, February 23, 2023), chair of the Biodiversity are of the Climate Change Committee at the Science Knowledge, Technology and Innovation Ministry of Chile, told me that he believes most stakeholders have not internalized that we all have a big problem that all of us need to solve cooperatively and that it will be highly important to better communicate the tragedy of the commons happening everywhere.

In personal communications, Jon Day (March 4, 2023), who was variously involved in the rezoning of the GBR as the GBR MPA Direction from 1998 to 2014, went further to explain that 'backsliding' of already protected areas is a real issue. He pointed to the GBR Outlook Report which assessed the outlook for the GBR as 'poor' in 2009 and 2014, and even as 'very poor' in the 2019 assessment (J. Day, personal communication, March 04, 2023).

The discrepancy between quantity and quality of marine protection was a common theme in responses from experts during the writing of this thesis (e.g. A. Frid, personal communications, February 28, 2023; T. Agardy, personal communications, February 24, 2023). The risk of political powers choosing vague protections that boost numbers on paper was unilaterally seen as an issue with MPA.

## 3.1 The various stakeholders in MPA creation and management

Stakeholders differ widely for each MPA site and not taking their perceptions and needs into account often leads to failures in MPA planning (Cárcamo et al., 2014). Properly involving stakeholders early in the process helps with acceptance, involvement, and early participation (Cárcamo et al., 2014).

The perception of the proposed MPA largely determines the success or failure of designation, as has been seen time and again.

Grorud-Colvert et al. (2010) found that when scientists manage to effectively explain the science behind MPA to the stakeholders, they tend to be more open to collaboration and discussion to find the right path ahead.

Stakeholders typically include resource users, interest groups, coastal communities, managers, and politicians which all have unique perspectives, values, needs, and opinions (Grorud-Colvert et al., 2010). To get everyone to work together, clear communication is essential. Those standing to lose their income often oppose the creation of areas with any kinds of restrictions.

The mere amount of stakeholders involved can often lead to issues. In Chile, for example, multiple agencies are involved in MPA creation, clearly showing that bureaucracy can complicate the creation of new protected zones (Fernández & Castilla, 2005). In addition, Chile has many coastal areas assigned to private hands, usually on a 5-year assignment, further complicating conversations (Fernández & Castilla, 2005). Chile's state of marine conservation will be discussed in more detail in Chapter 4.

Knowing your audience is important when communicating, as each group tends to have a different baseline for understanding (Grorud-Colvert et al., 2010). As Day (personal communication, March 04, 2023) explained, "there are many philosophical and practical differences between managers, scientists, and decision-makers/politicians" which he explored as part of his post-career PhD.

An analysis by Grorud-Colvert et al. (2010) looked at the creation of the MPA around the Channel Islands off the coast of California. When the Channel Islands were first proposed as an MPA, the planning process was designed to involve the public and stakeholders: They created a group of representatives and involved a science advisory panel, as well as a team looking into socioeconomics. The advisory groups created graphics, texts, and a film to explain the scientific basis to the wider public. The most successful part of their science communication was a leaflet created with both scientists and communication experts. Due to its popularity internationally, a new expanded version of a leaflet was created and case studies and further information placed on a website. Their unique approach to include both very simple graphics that contained the key information in an easily digestible format, an expanded bullet-point summary, and longer texts with the details, might have played into the success of the leaflet, as it managed to take all kinds of stakeholders and interested parties into account.

Furthermore, the rights of indigenous people are often overlooked in the process of MPA creation when they should be seen as a resource instead. Indigenous people often have an

increased interest in protection, as their way of life is closely linked to ecosystems (Ban & Frid, 2018). They have also been found to be more affected by the effects of climate change (Ban & Frid, 2018). Their practices of tending to the environment, sometimes even lending a helping hand by improving spawning grounds or transferring larvae make indigenous people important in nature protection (Ban & Frid, 2018).

Some areas have recognized the value of their indigenous communities and involved them in planning and maintenance of MPA to varying degrees, especially in Oceania (Ban & Frid, 2018). New Zealand stressed the importance of their ties to their indigenous people and to involve them in management but there were large representation gaps (Department of Conservation, Ministry of Fisheries, 2011, as cited in Rovellini & Shaffer, 2020), something they looked to correct with their reform to MPA policy in 2016 (Rovellini & Shaffer, 2020).

Alejandro Frid, the science coordinator for the Central Coast Indigenous Resource Alliance in Canada, an alliance formed to provide technical support and coordination for the joint work of four indigenous peoples of Canada on fisheries and marine spatial planning, explained in an interview with the author that recent development there are promising and could become a model for other parts of the world (personal communications, February 28, 2023). For most of its colonial history, he said, Canada was lagging behind on establishment, management, and enforcement of MPA, and the rights of First Nations were frequently undermined but policy improvements beginning in the early 2000s have led to improvements (personal communications, February 28, 2023).

Other scientists and policy-makers are more skeptical towards assigning rights to indigenous communities. Jones (personal communications, February 28, 2023), who started research into marine protected areas in 1991, stressed in our conversation that today's indigenous people were "invariably just modern economic animals" and cautioned that handing out rights to indigenous communities should be done with conditions and oversight attached.

Similarly, indigenous people can be reluctant to share information, as this has led to exploitation in the past, for example when disclosure led to increased fishing pressure for Pacific Herring in the Northern Shelf Bioregion (Ban & Frid, 2018). Finding common ground

and a basis of trust between the parties might turn out to be essential for marine protection, something that will need to be explored in further studies.

The negative perception of MPA is likely worsened by the above-mentioned persistence of 'paper parks' which do not reach the promised results due to ineffective management and enforcement. A lack of enforcement often leads to a lack of compliance (Pieraccini et al., 2017). However, good leadership and an involvement of all stakeholders in a collaborative effort can often be more effective than enforcement alone (Pieraccini et al., 2017). Social pressure can be an effective tool to guide behavior. An example of this was observed at the CROP marine reserve in New Zealand where visitors frequently report suspicious activity and their mere presence in the reserve is thought to deter poachers (Ballatine, 2014).

As Pieraccini et al. (2017) pointed out, enforcement is often a necessary early step but cannot be seen as a long-term sole solution. After an initial period, a more socio-legal approach is indicated. Educational activities, building trust, and increasing environmental knowledge are important factors. People need to feel connected to the environment and the 'causes' to want to act on. If there is too much blockage from players that can invest the time and money, an independent oversight body might be needed initially but long-term socio-legal approaches are most promising.

## 3.2 The salience and influence of the general public on the creation and success of MPA

"Most of the public [...] are oblivious to what is going on underneath the waves (P. J. Jones, personal communications, February 28, 2023)".

When reviewing the policy changes surrounding the EU's CFP, Orach et al. (2020) found that non-state actors and lobbying can stagnate efforts for conservation but also delay or prevent resource collapses. They compared the dynamics between interest groups as a 'tug of war'.

Jones (personal communications, February 28, 2023) explained that a ground-swell of public support is necessary for political progress, as politicians would not want to risk their next election without this public support. He said that one of the biggest challenges to date was the 'Out of sight, out of mind' mindset which it will be essential to overcome. Fortunately, there is an increasing awareness of the public when it comes to environmental issues and the ocean,

something called the 'Blue Planet' effect (Schnurr et al., 2018, as cited in Jones et al., 2019; P. J. Jones, personal communications, February 28, 2023; Hunt, 2017, as cited in Dunn et al., 2020).

This goes back to a wide-spread documentary of the same name by the BBC released in 2001: By the time a deal for a feature-film version was announced in 2003, the original documentary series *Blue Planet* had been sold in over 50 countries and seen by over 12 million people (BBC - Worldwide Press Office - The Blue Planet Set for Movie Release, 2003). Many more have seen the series since and other documentary series have followed in *Blue Planet's* footsteps.

The 2017 sequel, *Blue Planet II* has widely been credited with raising awareness for plastic pollution in the oceans (Jones et al., 2019). In April of 2019, Netflix released the big-budget nature documentary *Our Planet* which they filmed for in over 50 countries (Jones et al., 2019). Julia Jones and her fellow paper authors compared recent documentaries with regards to how much of the total word count was focused on global conservation issues and anthropogenic influences (Jones et al., 2019). They found that *Our Planet* had dedicated almost a sixths of the total word-count to these topics while also frequently sharing conservation successes and recoveries. *Blue Planet II* reached similar levels of conservation-focused language but much of it was concentrated in a final episode while *Our Planet* had these messages woven into the script of all episodes.

Visually, however, little of the series was showing anthropogenic impacts and most of the conservation-related script was read while showing beautiful nature scenes (Jones et al., 2019). Noteworthy is that the *Our Planet* team did have the footage for such impact scenes as they released them in a short clip on the documentary's website. Jones et al. suggest that it was a clear editorial decision to not change the feeling of the documentary.

Unfortunately, the connection between technically knowing about an issue and changing human behavior are complex and uncertain (Braun et al., 2018; Kollmuss & Agyeman, 2002; both as cited in Jones et al., 2019). They have, however, been associated with responsible environmental citizenship (Barbas et al., 2009, as cited in Jones et al., 2019). Such improved public attitudes make policy changes more likely (Jones et al., 2019).

As documentaries about nature are usually not created for environmental but rather economic reasons, there is still a tendency to exclude human impact from them. Jones et al. (2019) even argue that using camera angles to intentionally hide less visually stunning imagery might create a false sense of nature doing well. But showing threats is often seen to lower viewer counts and thus the income of the documentary creators (Mills, 1997, as cited in Jones et al., 2019). The reality of the effects of framing (positive or hopeful framing vs negative or guilt-inducing or shocking framing) are debated widely in science communication circles (Kidd et al., 2019, as cited in Jones et al., 2019).

But due to their wide reach, documentaries are often seen as one of the key tools to reach a wider public. While there is a challenge to experimental design due to documentaries like Blue Planet II primarily getting watched by viewers already interested in environmental and nature topics (Holbert et al, 2003, as cited in Jones et al., 2019) which makes surveys of viewers and non-viewers unreliable (Veríssimo et al., 2018, as cited in Jones et al., 2019), there is an additional raising of awareness with the associated advertising. *Our Planet*, for example, was advertised at the US Super Bowl final, London tube trains, and in various other places (Jones et al., 2019). Support materials such as those created for the *Our Planet* website can be an important part of an on-going conversation and lasting behavior change (Hofman & Hughes, 2018, as cited in Jones et al., 2019)

In any case, documentaries can bring the threats facing nature into the mainstream and thus help change the minds of citizens. Growing research is looking into how science communication affects public behavior (e.g. Gaston et al., as cited in Jones et al., 2019). Joyce (2018, as cited in Dunn et al., 2020) analyzed Twitter activity in 2018 and found that mention of plastic pollution was discussed twice as often as the year before *Blue Planet II* aired. Collins (2018, as cited in Dunn et al., 2020) went further and suggested direct behavioral changes in plastic consumption after the documentary, though this was based on self-reported behavior which can be unreliable as a metric (Kormos & Gifford, 2014, as cited in Dunn et al., 2020). One reason for this gap between reported and actual behavior is suggested as the wish to comply with subjective social norms (Pahl & Whyles, 2017, as cited in Dunn et al., 2020).

Thomas-Walters et al. (2019, as cited in Jones et al., 2019) found that there is an increasing disconnect with nature as urban populations with little access to nature are growing. For these

target groups, documentaries are especially important. Nonetheless, evidence of actual impacts of such documentaries is scarce, largely due to the complexity of studying such relationships (Dunn et al., 2020).

In addition to media such as documentaries and brochures, successful MPA themselves can be an important educational tool (Ballatine, 2014). The CROP reserve was originally designated for scientific study but attracts thousands of visitors each year (Ballatine, 2014). The fish inside the reserve are much less shy than elsewhere (personal observation; Ballatine, 2014) allowing an immersive experience that can lead to an appreciation of nature.

Ballatine (2014) suggested the creation of nature reserves near schools and educational institutions to further education at an early age. A connection to nature has been found to be important to create the mentality necessary to want protection for the environment (Jones, 2013).

Orach et al. (2020) found a direct link between the level of public salience and the effectiveness of interest groups on political processes. And as Jones (personal communications, February 28, 2023) pointed out, politicians are at least partially driven by the influence of their public perception on their next election results. The public holds immense political power. A look at history shows that many of the most influential changes were started as grass-roots projects by few individuals.

As was discussed in 3.1, there are many stakeholders involved in MPA creation and management. The general public does often not even consider themselves stakeholders in these discussions, or as Jones (personal communications, February 28, 2023) put it, 'out of sight, out of mind.' Their influence should not be discounted, though, and goes way beyond the creation and viewing of documentaries.

Greenwashing has become a major issue in marketing. This phenomenon has long been observed in product marketing after studies showed that consumers were willing to pay more for products perceived as environmentally friendly (de Freitas Netto et al., 2020). In a review of the Galápagos Islands, Jones (2013) found a large potential for green marketing with a

"market demand for a 'watered down' or 'green-washed' version of nature tourism or for fisheries products." He even saw these as a potential driver of further depletions.

This view was echoed by Ray Hilborn, a renowned pro-fisheries scientist and author of *Ocean Recovery: A sustainable future for global fisheries* during our conversation: Hilborn (personal communication, February 3, 2023) explained that it was much easier to convince government officials of vague protections that boost their conservation on paper than actual effective measures. The current state of marine protection seems to further validate this with the persistence of ineffective 'paper parks,' as was explained in Chapter 2.

More generally, the language of the public is very different from the language of science. When the general public is involved in MPA creation, communicators often focus on biophysical properties rather than the social benefits of ecosystem services (Olander et al., 2018). An example of the knowledge gap between scientists and laypeople would be the communication of uncertainty (Grorud-Colvert et al., 2010): while scientists understand the meaning of uncertainty in scientific research, explaining this to laypeople can undermine the main message, as they are not familiar with the concepts. It is essential to be honest about what is known and unknown but to do so in a way that does not give a false impression of uncertainty.

To further complicate matters, stakeholders often cannot remain objective or rather, their objectivity cannot be judged without doubt, making it hard for laypeople to know who to trust.

In her book, *On Fire: The (Burning) Case for a Green New Deal*, Naomi Klein calls out environmental groups that she said did a lot of harm by appearing to protect the environment while investing heavily in e.g. fossil fuels. During our conversation, Hilborn (personal communication, February 3, 2023) seconded this issue when he suggested that The Pew Charitable Trusts were receiving funding from the oil industry.

To further skew the view of the public and stakeholders, news outlets often only report on issues directly affecting humans with less coverage of smaller, lesser-known species not regarded as equally important (Régnier et al., 2015, as cited in Paulus, 2021).

With some of the players in the conversation keen on skewing perceptions on purpose and news outlets reporting on what gains attention (and thus economic gains), it can be hard for the public to distinguish between truth and perception. During our conversation, Ray Hilborn explained that some environmental organizations were receiving funding from the oil industry to shift blame onto fisheries while Greenpeace denounced Hilborn for having received supposedly undeclared funding from the seafood industry and going as far as calling him an 'overfishing denier' (Greenpeace USA, 2017). Even with hours of research, it can be hard to distinguish facts from fiction, and the general public is further lacking the language to understand the scientific studies involved.

To return to my conversation with Jones (personal communications, February 28, 2023), political change happens only when the public is creating the 'ground swell' needed for such change. Thus, the role of science communication will become more and more important to successfully communicate the reality of the climate crisis, biodiversity crisis, and the need for nature protection to the general public.

# Chapter Four: A Case Study of Marine Protection in the Peru Current system

The Peru Current System (PCS)[10] is often seen as one of the most vital and productive fishing grounds where approximately 8 percent of global seafood and an even higher percentage of anchovies (10%) is caught (Salvatteci et al., 2022).

The PCS is a cold-water current along the eastern boundary of South America (Peru Current | Ocean Current | Britannica, 2023). The PCS is one of the most productive marine ecosystems due to intense upwelling of nutrients from deeper waters which leads to abundant plankton growth that, in turn, support the higher trophic levels as the basis of the food web (Cunningham et al., 2020).

Research by a team from the Institute of Geosciences at the Kiel University and the GEOMAR Helmholtz Centre for Ocean Research recreated conditions from the last global warming period and showed that seawater warming there will likely replace the commercially interesting anchovies with smaller goby-like species that are harder to catch and less palatable (Salvatteci et al., 2022).

The PCS is highly variable due its dependence on the El Niño Southern Oscillation (ENSO)[11] which affects the global climate. While fisheries in the area are used to this variability, climate change is affecting the system strongly leading to more variability in production, geographic shifts of ranges (and connected fisheries), warming offshore surface waters, and more intense cooling of nearshore waters (Cunningham et al., 2020). An increase in oxygen-minimum zones (OMZ) and a deeper thermocline which affects upwelling negatively are expected during stronger El Niño events under climate change (Cunningham et al., 2020).

The PCS system not only affects conditions on the mainland of South America but also that of offshore islands like the Cocos Islands (Costa Rica) and the Galápagos Islands (Ecuador).

[10] The Peru Current is also known as the Humboldt Current after naturalist Alexander von Humboldt but much like the discovery of America by Columbus, this refers to a discovery rather than the first recovery. Thus, the author has decided to use the more neutral term, Peru Current.
[11] El Niño and La Niña are opposing climate patterns changing conditions in the Pacific and affecting the climate world-wide. These events are quasi-periodic and happen every two to seven years with increasing likelihood (NOAA, n.d.).

Around the Galápagos, the PCS is part of multiple currents causing seasonality beyond what is typical for an equatorial region (Jones, 2013).

The South East Pacific long remained largely unprotected despite the huge importance of the Peru Current ecosystem (Thiel et al., 2007; Guerderas et al., 2008; both as cited in Tognelli et al., 2009). More recently, the three countries, Peru, Chile, and Ecuador, started coming together to work on joint fisheries management and conservation with the goal to pool both knowledge and resources, a shared data platform, and joint efforts for scientific monitoring and forecasting (Cunningham et al., 2020).

Despite recent efforts for cooperation, each of the PCS countries is still largely working on a national scale in their research and monitoring but as Cunningham et al. (2020) point out, climate change will necessitate further cooperation in those areas to create an early-warning system something the nations are actively working on with their plans for a new Coastal Ocean Observing System (COOS) and a shared data platform, as well as joint fisheries management efforts.

The recent expansion of the Galápagos Marine Reserve (GMR) in January of 2022 is a promising next step in the conversation around PCS ecosystem conservation and fisheries management, as will be discussed in section 4.4.

## 4.1 Chile

Chile is one of the leading fishing countries and fisheries are one of the leading sources of income in the country (FAO 1998, as cited in Fernández & Castilla, 2005). About 50% of that catch is caught by their artisanal fisheries (Castilla, 2010, as cited in Gelcich et al., 2015).

As explained above, Chile is one of the countries with the lowest funds for conservation but the most biodiversity to lose (Gelcich et al, 2015). The two leading issues when it comes to protecting the ocean are budget constraints and low stakeholder buy-in.

For a long time, Chile was lacking in marine protection and when Tognelli et al. (2009) reviewed the then current state, they found that even the created sites were lacking scientific

basis. Enforcement was especially lacking in the existing areas and their failures stagnated the creation of new MPA (Tognelli et al., 2009).

Today, 12% of Chile's EEZ are highly or fully protected with a further 27% designated but not yet implemented (MPAatlas.org, n.d.).

Chile established an artisan exclusive zone (AEZ) in the five nautical miles from shore where only their own artisanal fishers are allowed to fish. Further offshore, a large fleet of industrial fisheries is harvesting approximately five million tonnes of fish annually (Cunningham et al., 2020).

Both types of fishing are managed by a variety of tools. In addition to no-take zones (see below), a combination of rights-based fishing, seasonal closures, size limits, and gear restrictions is used (Cunningham et al., 2020). In addition, aquaculture plays an important role in, especially, Southern Chile (Fernández & Castilla, 2005).

Add the multitude of stakeholders to the fact that there is shared responsibility of multiple agencies in MPA creation, and it is no surprise that proper planning was often lacking in MPA processes. Despite this, some of the protected areas are vastly important for local ecosystems (Fernández & Castilla, 2005).

Much of Chile's coast is managed under the TURF (territorial user rights for fisheries) scheme which assigns responsibility for an area to private hands (Gelcich et al., 2015). This has presented both challenges and benefits for conservation in Chile.

The system of making private institutions responsible for management has been used in Chile since 1941 when a research concession was assigned to a Chilean university (Fernández & Castilla, 2005). One such concession lost its protection in 1999 after local fishers depleted stocks against regulations in place but another was declared a coastal MPA in the early 2000s (Fernández & Castilla, 2005).

Gelcich et al. (2012) found that while biodiversity benefits from well-managed TURFs, they are still less effective than no-take MPA areas. Their results suggest that no-take MPA show higher density, biomass and species richness than TURF areas.

Gelcich and Donlan (advancedconservation.org, as cited in Gelcich et al., 2015) evaluated the scaling of conservation efforts by adding no-take zones within TURFs and placing responsibility for enforcement on the TURF holders.

In a case study of Navidad, Gelcich et al. (2015) explored the benefits of municipal and thus local conservation. In Navidad, a joint effort from the municipality, academics, and fishers lead to the creation of a no-take marine reserve in 2009. Local stakeholders applied for the reserve in 2005 and after years of planning and collaboration between the stakeholders, including outreach to the wider public, the first municipal conservation area of Chile was created and formally recognized in 2013.

They further found that Chile's conservation is another example that shows mere top-down conservation efforts lacking. They suggest that scaling up conservation efforts in Chile (and elsewhere) requires an emphasis on socioeconomics and early participation of the civil society. Jones (personal communications, February 28, 2023) shared the view that decentralization of MPA responsibility will be an important part of MPA success.

In other words, as local communities carry the opportunity cost of conservation, they should also benefit from the conversation and feel involved in the effort. Involving stakeholders and the public has clearly paved the way for Chile's conservation efforts.

## 4.2 Peru

Like in Chile, Peru has an AEZ within five nautical miles from their coastlines and a larger industrial fleet, primarily made up of purse seiners (Cunningham et al., 2020).

As one of the world's leading producers of fishmeal and by volume in general, Peru primarily catches small fish. In fact, much of Peru's catch is taken from a single stock of anchovies and another single stock of sardines (Cunningham et al., 2020) making them highly vulnerable to stock declines.

In 2020, Peru enlisted help from Sea Shepherd to create further MPA in their waters (Sea Shepherd, 2020). The creation of the Nazca Ridge National Reserve was met with mixed opinions (Praeli, 2021): on the one hand, the new reserve protected two seamounts rich in biodiversity and also increased MPA coverage in Peru from less than 1% to 8%. On the other

hand, fishing rights transferred prior to the creation of these new protections would remain in effect, thus effectively allowing large-scale fishing in Peru's first 'fully-protected' MPA. In addition, the protection did not exclude fishing in the higher levels of the ocean (vertical zoning[12] ) and new permits will be possible to acquire for e.g. cod fisheries up to 1,800 meters depth.

Applying the label 'fully-protected' to an area that only includes the bottom layers of the ocean might be considered misleading and complicate enforcement compared to full protection of the entire water column.

Nonetheless, protecting the benthos should not be discounted, as it offers protection against destructive methods such as bottom trawling, as Jones (personal communications, February 28, 2023) urged in our conversation. This holds especially true for such diverse ecosystems as sea mounts.

## 4.3 Ecuador

The catch composition of Ecuador is more varied than those of its neighboring countries, largely due to the Galápagos Islands. Ecuador's artisanal fisheries fish predominantly with two types of fishing gear: gill nets and longline fishing (Cunningham et al., 2020). Ecuador is home to 40 shark species, 30 of which are commonly fished, though the most commonly caught are on the IUCN red list (Carr et al., 2013) and the Galápagos are home to numerous endemic species.

While the history of marine protection in Ecuador is long and complex, the recent expansion of their largest MPA is promising, especially when considering the establishment of a cooperative network with the neighboring regions.

Today, 4.2% of Ecuador's EEZ is fully or highly protected with a further 5.5% not yet implemented. An additional 9.3% are under lesser or unknown protection. But most promisingly, mixed-use MPA that would cover 60% of the EEZ have been proposed (MPAatlas.org, n.d.).

[12] Zoning can be horizontally and involve the entire range from the sediment to the ocean surface and/or vertical involving protection for only part of the water column, e.g. the benthos.

The GMR is the largest MPA in Ecuadorian waters currently covering 13% of Ecuador's EEZ (MPAatlas.org, n.d.). The effectiveness of this MPA has been evaluated and they even received the Blue Park award which means that they met stringent science-based standards for conservation effectiveness (“Blue Park Award Criteria » Marine Conservation Institute,” n.d.).

The Galápagos Islands are a unique group of islands straddling the equator about 1,000 km east of mainland Ecuador which governs the island group. Currents make the Galápagos even more unique: the cool Peru current meets the warm Panama current there which leads to uncharacteristic seasonality for an equatorial location (Jones, 2013). The Cromwell current adds nutrient upwelling, and multiple other currents allow biotic inflow of e.g. sharks and seals (Jones, 2013).

A marine reserve was founded around the islands in 1986 but this initial designation was an early example of a 'paper park (Jones, 2013).' It wasn't until 1998 that GMR received some actual protection (Jones, 2013).

Multiple sociopolitical issues on the mainland, as well as the incentive of higher promised income on the island due to a budding tourism industry, lead to a high population influx (Jones, 2013). The population on the island grew rapidly from only a few thousand individuals in 1982 to around 25,000 in 2012 (Jones, 2013).

The main stakeholders of the GMR were tourism, fishing, conservation, science, but also the Ecuadorian Navy and the Galápagos National Park Service. The latter are responsible for managing the reserve and enforcing regulations.

Tourism, as the largest part of the economy on the islands, responsible for 78% of employment, should provide a wide force for conservation benefits, especially considering only 5% of the work is related to the fishing industry (Jones, 2013).

But outside pressures have created a market for illegal fishing in the reserve. Especially Asian markets pay high prices for sea cucumbers and shark fins, incentivizing illegal fishing in the biodiverse GMR. In the past, this has led to issues with depleting stocks even inside the reserve (Jones, 2013). Between 2001 and 2007, 29 illegal shark catches were seized and illegal activities continued until at least 2011 (Carr et al., 2013). In 2011, the Fer Mary I was

seized, leading to a thorough review of the 22 tonnes of catch by Carr et al. (2013). They found that a majority of the catch comprised females and juveniles making it likely they were illegally caught inside the nursing grounds of the GMR.

Despite official marine reserve designation, stocks were still declining and populations of some commercially harvested or fished species collapsed. Income from catch declined by more than half between 2003 and 2008 (Jones, 2013). In addition, there was no effective baseline to compare the results of the GMR (Jones, 2013).

A huge part of the issue was a lack of proper management. The original zoning of the GMR included 75 no-take zones covering about 17% of the coast line but offshore boundaries were not established properly and there was a lot of confusion about where restrictions started and ended (Castrejón & Charles, 2020). Some sections even overlapped in the original plan, an issue that was not addressed until a rezoning in 2014 (Moity, 2018).

This was alleviated with later rezoning. Nonetheless, enforcement remains an issue in the GMR and some push toward a system similar to Chile's TURFs (Castrejón & Charles, 2020).

Until 2022, only 6% of the GMR were fully protected with even tourism excluded, while 11% were designated tourism-zones where extraction was prohibited (Jones, 2013). Tourism remained a strong industry despite the declining biodiversity in the region (Jones, 2013).

As the Galápagos are a province of Ecuador, they are entitled to two representatives, the minimum for an Ecuadorian province. Due to the small population, these two representatives have to deal with a lot of lobbying (Jones, 2013). A few unhappy locals could have a lot of influence. To make matters worse, the representatives also had to withstand pressures from international fish markets and tourism operators looking to earn money from the biodiversity of the region (Jones, 2013).

Jones (2013) blamed a lack of 'island mentality' for a lot of the local issues. Many of the island population were immigrants who still saw themselves as mainlanders. These locals did not understand that the GMR was important for their livelihood and thus did not oppose the fishers.

While fishers initially strongly opposed the creation of the GMR and sometimes even became violent, increasing spillover to adjacent fishing grounds (Gell & Roberts, 2003; Murawski et

al., 2005, both as cited in Boerder et al., 2017; Jones, 2013), as well as anecdotal evidence lead to support from the local fishers. They now perceive the no-take zones as tuna spawning grounds and nurseries important to their livelihood (Kliffen & Berkes 2015, as cited in Boerder et al., 2017).

Studies have shown the success of the GMR showing higher biomass and CPUE around the reserve but the decrease of fish-aggregation devices (FAD) shows this in practice. Where fishers used to rely on tricks to aggregate fish, this is no less necessary for their catch (Boerder et al., 2017). Free schools of tuna are now no longer a rare sight around the islands (Boerder et al., 2017). A qualitative study by Kliffen & Berkes (2015) found that fishers now explicitly recognized the important spillover benefits of the reserve. Castrejón & Charles, (2020) echo the sentiment that involving locals in management and enforcement would enable stewardship.

In a recent survey by the Pew Bertarelli Ocean Legacy Project (Pew Charitable Trusts, 2021), 72% of the 611 polled participants were in favor of expanding the reserve while only 8% were against the expansion. A further 20% were uncertain about the expansion. Both those opposed and those uncertain cited the current monitoring and enforcement capabilities as their main concerns.

This, again, shows how different the perception of stakeholders can be from reality and that proper communications can change opinions.

## 4.4 Cooperation between neighboring nations in the PCS

In January of 2022, the Ecuadorian government announced the expansion of the GMR following the above-mentioned plan for greater cooperation (Galápagos Conservancy, 2022). The new expansion increases the size of the reserve by 60,000 square kilometers and includes a 30,000 square kilometer no-take zone along the Galápagos-Cocos swim way. The swim way connects the GMR with the protected Cocos Islands in Costa Rica.

As reported by the Guardian (Collyns, 2021), this is not the only cooperation planned between Ecuador and Costa Rica: In 2021, Panama, Ecuador, Colombia, and Costa Rica started the Eastern Tropical Pacific Marine Corridor initiative with the aim to protect territorial waters of all four nations.

Surrounding the expansions of the GMR, other Western Latin American countries announced further expansions or MPA creations (Collyns, 2021): Colombia announced a new MPA that more than doubled the existing MPA coverage (120,000 square kilometers before; 160,000 square kilometers added).

With global cooperation in actuality rare, this international cooperation between Ecuador and its neighboring countries could pave the way for other projects around the globe, given the new areas are effectively managed and enforced to allow the MPA benefits to get realized.

# Chapter Five: Discussion

Mounting scientific evidence shows that protecting the ocean will be an integral part of mitigating the effects of the climate crisis and slowing down its progress (Russ & Alcala, 2011; McClure et al., 2020).

The effects of the climate and biodiversity crises are increasingly affecting life on earth. The ocean is buffering some of the anthropogenic effects of these crises but the ocean's balancing mechanisms are struggling to maintain a healthy ocean, mostly due to human impacts (Watson et al., 2020; Sumaila et al., 2022).

Most of the ocean is getting affected by multiple human-made causes (Roberts et al., 2017) and the biggest risk factors for MPA often lie outside the reserves (J. Day, personal communication, March 04, 2023). The most impactful stressors of ocean life are overfishing (e.g. Sumaila & Tai, 2020), habitat destruction (e.g. Gittmann et al., 2015; Davidson, 2014), sea temperatures increasing (e.g. Smith et al., 2021), ocean acidification (Sumaila & Tai, 2020), oxygen and nutrient depletion and nutrient enrichment (Roberts et al., 2017), sea level rise (Roberts et al., 2017), intensifying storms (Roberts et al., 2017), shifting ranges and species abundance patterns (Roberts et al., 2017), as well as timeline mismatches between prey and predators (Roberts et al., 2017).

Most of the stressors interact with each other in positive feedback loops. Rising temperatures of the sea surface waters increase ocean acidification, oxygen availability, and biodiversity loss. Overfishing degrades habitats and endangers the sustainability of stocks. Biodiversity loss, overfishing, and habitat degradation lower the ability of the ocean to self-regulate and lead to more carbon dioxide emissions. All stressors negatively affect human health and economic output decreases as effects accumulate (Cardinale et al., 2012; Burke et al., 2015).

These threats have increasingly been recognized by political powers and the general public and there is growing public demand for action (e.g. Worm et al., 2006, as cited in Friedlander et al., 2016). This demand has increased the potential for green marketing and ineffective 'paper parks' that boost conversation on paper but do little to help conservation in actuality (Gelcich et al., 2015).

The cost of inactivity is tremendous, as the ocean provides key ecosystem services to humanity from nutrition to climate regulation. But due to overfishing and land-use change to feed and make room for the growing human population, the important balancing powers of the ocean are further reduced.

As the climate and biodiversity crises progress, the effects will be felt especially by poorer individuals and nations, further increasing economic inequality (Diffenbaugh & Burke, 2019).

Over the last decades, governments have made pledges for change, such as the Aichi targets (Convention on Biological Diversity, 2020) or SDG (THE 17 GOALS | Sustainable Development, n.d.), but few emitters are currently on track to meet those goals (MPAatlas.org, n.d.). Even if goals are met, warming beyond the 1.5-degree target of the Paris Agreement has to be expected (Burke et al., 2018).

Thus, urgent action is needed to curb emissions while mitigating actions will be increasingly important in the meantime.

MPA are widely seen as an effective tool to mitigate the effects of climate change, recover stocks, and provide refuge to marine life. While there is pushback, especially from a small group of American fisheries scientists and the seafood industry (e.g. Hilborn et al., 2004), most scientists agree that MPA are effective tools for conservation and, to a degree, fisheries management (e.g. O'Leary et al., 2018).

Current quantitative goals to protect certain percentages of the ocean are commendable but qualitative goals are needed to ensure their effectiveness. After countless hours of research and conversations with experts, I have come to the conclusion that a mixed approach will be most effective: protecting spawning grounds and the migratory routes of species, biodiversity hotspots, and areas with endangered species such as coral reefs, kelp forests, seagrass meadows, mangrove forests, tidal flats, and similar systems with core no-take zones while buffering those zones with mixed-use MPA and managing 100% of the ocean with other effective management measures seems the most promising approach.

Currently, there is a clear preference for remote, commercially less interesting areas, and global cooperation (in actuality rather than on paper) is lacking severely (Gelcich et al.,

2015). Large portions of fish stocks are overexploited and many fisheries at risk of collapse, made worse by IUU fishing going beyond what is already imperfect on paper (Welch et al., 2022).

Harmful subsidies allow the continuation of unsustainable fishing practices, especially in the high seas where protection is expected to help recover stocks without lowering food output (Skerrit & Sumaila, 2021; Cheung et al., 2017). Those funds should be redirected to marine protection and other effective management measures. Further, destructive fishing methods such as bottom-trawling which not only destroy habitats but also release emissions should be phased out quickly to limit their negative impacts.

With the expected range shifts and shrinkage of many species expected over the coming decades, current agreements will need to be revisited (Favoretto et al., 2022). This will further complicate the conversations around traditional fisheries management.

Currently, protection inside MPA varies widely and benefits depend on the level of protection and the effectiveness of management and enforcement. Depending on these factors, MPA have shown tremendous benefits from preserving genetic diversity and increasing the biomass and diversity of populations to alleviating poverty, lowering inequality, and increasing human well-being (e.g. Manel et al., 2019). Very importantly, they have been shown to help mitigate the effects of climate change (Afonso et al., 2011, as cited in Sumaila & Tai, 2020). Despite frequent protests against MPA from for-profit organizations and a small group of pro-fisheries scientists, they, too, would benefit from the spillover and generally higher biomass around protected areas (e.g. Marshall et al., 2019).

In the future, MPA might play an increasingly important role for ocean conservation and the health of the planet. With even less enforced, partially-protected and ad-hoc planned MPA showing clear benefits (Tognelli et al., 2009), there will still need to be a strong focus on quality over quantity for marine protection. As the past has shown, even partial protection of the benthos can lead to important effects for the climate, as bottom-trawling is excluded from such areas (personal communications, February 28, 2023).

Despite the benefits of remote LSMPA, urgent protection is needed for coastlines and within the heavily fished territorial waters of countries (e.g. O'Leary et al., 2018).

Documentaries and their related advertising (Jones et al., 2019), leaflets (Grorud-Colvert et al., 2010), but also the MPA themselves (Ballatine, 2014) have been important communication tools for stakeholders and the general public but, to date, much of science communication is much less effective than it could be. Further studies will be necessary to optimize the communication of MPA benefits and defend them against the effective campaigns from for-profit MPA opponents. Most current political systems need public support for action. Without successfully communicating the urgent need for action and the high cost of inactivity to the general public, ocean protection will continue to stagnate.

Financing the protection of the ocean will likely be a key factor in coming conversations. While tourism fees will be able to recover some of the cost of enforcement, most such money will need to come from other sources (Gelcich et al., 2013). Huge sums are still used to subsidize fishing that would otherwise be unprofitable (Skerrit & Sumaila, 2021; Cheung et al., 2017). This money should be redirected to beneficial protection. Furthermore, the cost of inactivity should be taken into account, as a loss of nature will lead to huge losses of ecosystem functions such as storm protection and carbon sequestration. The unknown benefits of the many still undescribed species and ecosystems, especially in the deep sea, are not even calculated into this (Mora et al., 2011, as cited in Paulus, 2021).

Global investment into the protection of marine habitats and coastlines, in general, will need to be increased tremendously. As past experiences in New Zealand, Chile, and the Galápagos have already shown, involving the public early, decentralizing enforcement, and enrolling locals in management and enforcement streamline the creation process and lower the cost of management and enforcement.

Enlisting the help of non-profit organizations, indigenous communities, and the general public will be essential for the success of marine protection, all of which makes effective communication essential.

We need to get from a general mindset of 'out of sight, out of mind' to humans connected to nature and its wonders. MPA should not only be seen as an important tool for conservation and, to a degree, fisheries management, but as an educational tool to further said connection of humans to their natural environment.

But as many of the experts and papers have pointed out: it won't be enough to merely protect the ocean. We will all need to cooperate to create a network of fully and highly protected MPA with less protected areas surrounding them, and other effective management methods governing the rest of the ocean.

With humanity working against a ticking clock, the coming years will be deciding the fate of not only marine life, but all life on earth.

## Methods

I have read at least the abstract and conclusions of more than a hundred papers from various online journals, fully read and interpreted dozens, and skimmed many more, before and during creation of this thesis. Some information had been previously collected for articles and video publications on my website (https://katehildenbrand.com) prior to the start of this work. In addition to extensive literature review, interviews with experts were done both via email and in online-based remote conversations. All this collected information was then carefully reviewed to create this thesis.

## Conflict of Interest

No funding was received that might create a conflict of interest. I have, however, been working as a conservationist educating the public for multiple years, writing articles and producing videos on biodiversity, the ocean, and sustainable living. I have done all due diligence to reduce the effects of this prior perception from this work.

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## Original work

All of the text above was written by me personally without the help of unauthorized tools. All references cited were added both in-text and in the reference list with all due diligence.

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# Abbreviations

AIS: Automatic Identification System

CBD: Convention of Biological Diversity

CFP: Common fisheries policy

COOS: Coastal Ocean Observing System

COP: Conference of the Parties

CROP:  Cape Rodney/Okakari Point marine reserve near Leigh, New Zealand

ENSO: El Niño Southern Oscillation

FPMPA: Fully protected MPA

GMR: Galápagos Marine Reserve

HPMPA: highly protected MPA

IUU fishing: illegal, unreported, and unregulated fishing

LSMPA: Large-scale MPA of 100,000 square kilometers or more

MHW: Marine heat wave

MPA: Marine-protected areas

NZD: New Zealand Dollar

OMZ: oxygen-minimum zones/ocean deserts

PCS: Peru Current System

SDG: Sustainable Development Goals

UN FCCC: UN Framework Convention on Climate Change

USD: United States Dollar

WTO: World Trade Organization

WWF: World Wildlife Fund

# Glossary

**Climate crisis:** In this paper, the terms 'climate crisis,' 'climate change,' and 'global warming' are used interchangeably. Global warming is defined as the increase in surface air and sea temperatures over a 30-year period compared to pre-industrial levels and biodiversity is the variety of life considering the interaction of living organisms at all levels from the genetics of individuals to populations and ecosystems. This is notwithstanding the fact that climate change can lead to other extreme weather scenarios such as harsh winters or storms.

**Biodiversity:** In this paper, biodiversity is defined as the variety of organisms living in a certain habitat, both between species and within a species (Paulus, 2021).

**Thermal niche:** Organisms have a range of conditions they perform best in, e.g. temperature. They perform best in the middle of their temperature range with performance declining toward the extremes. Beyond certain values, organisms cannot survive.

**Hyperallometric:** Hyperallometric means increasing more than linear, so twice the weight of a fish equals more than twice the number of eggs

**Marine heat waves:** Marine heatwaves are defined as discrete periods of unusually high seawater temperatures in this paper (Smith et al., 2021, as cited in Smith et al, 2023)

**Teleost fish:** Teleost fishes make up 96% of extant species and thus include almost all fish known to humans (Clarke et al., 2016)

**Fecundity:** A measure of reproductive output, so how many offspring a parent will produce. If an animal is more fecund, the animal produces more offspring.

**El Niño Southern Oscillation:** El Niño and La Niña are opposing climate patterns changing conditions in the Pacific and affecting the climate world-wide. These events are quasi-periodic and happen every two to seven years with increasing likelihood (NOAA, n.d.).

**Vertical zoning:** Zoning can be horizontally and involve the entire range from the sediment to the ocean surface and/or vertical involving protection for only part of the water column, e.g. the benthos.