BSc thesis – The influence of marine management measures on sustainable development

Final version

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Abstract

Concerns about the environmental impacts attributable to fisheries have increased over recent decades, and have in many instances resulted in the introduction of specific marine management measures. However, these measure are not always effective or do not always meet their objectives.

This research investigates the influence that marine management measures have on the sustainable development of fisheries. The report will first discuss the concept of sustainable development. The triple bottom line of sustainability is used as a deepening of sustainable development, and as a means to operationalize sustainable development in fisheries. Second, the report will discuss different marine management measures, and third, identify the general consequences that each of these measures have. With the information on sustainable development in fisheries, and on the different marine management measures, it could be identified what the influence is of marine management measures on sustainable development in fisheries.

Keywords: Marine management measures, sustainable development, triple bottom line, fisheries

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Chapter 1: Introduction

In the last decades the pressure on fish stocks has increased, leading to concerns. People consume more and more fish (Food and Agriculture Organization of the United Nations (FAO), 2016), therefore also more fish needs to be caught or produced. To create some context, the global tuna catch has risen from one million tons to five million tons between 1950 and 2007 (Miyake, et al., 2010). Around 50% of this caught tuna is harvested in the western and central Pacific Ocean (hereafter: WCPO) (Reid, et al., 2003; Langley, et al., 2009). With the growing fishing effort on tuna in the WCPO, also the concerns on some tuna stocks grown. Mainly because of two problems:

First of all, the growth of the tuna fishery may lead to overfishing. That is ''the depletion of a stock of fish by excessive fishing'' (Oxford Dictionary, n.d.). Fishery scientists have been warning for impending stock conservation problems, as stock assessment showed a decline in biomass for some tuna stocks (Gilman, 2011; Sibert, et al., 2006).
The second problem is bycatch, which is defined as: ''Species taken in a fishery targeting on other species or on a different size range of the same species. That part of the bycatch which has no human value is discarded and returned to the sea, usually dead or dying'' (FAO, 2009). Small bigeye and yellowfin tuna's are caught as bycatch, but also non-tuna species such as, sea turtles, marine mammals, and sharks are caught (Leroy, et al., 2013). As a result juvenal tuna's can't grow to their mature size, and tuna stocks can't reproduce anymore.

The concerns on the environmental impact of fisheries have many instances resulted in managing of fisheries (Revill, 2003). Fisheries management is defined by the Food and Agriculture Organization of the United Nations (FAO) (2009) as: ''the integrated process of information gathering, analysis, planning, consultation, decision-making, allocation of resources and formulation and implementation, with enforcement as necessary, of regulations or rules which govern fisheries activities in order to ensure the continued productivity of the resources and the accomplishment of other fisheries objectives.''.

For the continued productivity of the resources, different marine management measures (hereafter measures) exist. The FAO has placed these measures under three sub-themes (FAO, 1997). First of all technical measures, which are restrictions or constraints to regulate the output which can be obtained from a specified amount of effort, these measures generally attempt to influence the efficiency of the fishing gear (FAO, 1997). The second type of measures are input controls, these directly regulate the amount of effort which can be put into a fishery (FAO, 1997). The third type of measures are output controls, these directly regulate the catch which can be taken from a fishery (FAO, 1997). Although these measures have the objective to reduce the impacts of fisheries, they do not always meet this objective. The following case on marine management of the Pacific Island countries will give a practical example why this might be the case.

1.1 Marine management of Pacific Island countries

The Pacific Island[1] countries have implemented different marine management measure to reduce the impact of fishing that takes place in their national waters. A high proportion of the WCPO catch is taken within the national waters of Pacific Island countries (hereafter: PICs)

[1] Pacific Islands are the islands located in the Pacific Ocean

(Langley, et al., 2009). Approximately 70 per cent of the WCPO purse seine[2] catches by all nations are harvested in the exclusive economic zones (Hereafter: EEZ) of the PICs, New Zealand, and Australia (Reid, et al., 2003). For many of the PICs, tuna represents their only significant natural resource. It provides their only source of foreign revenue via the licensing of foreign fishing fleets. (Langley, et al., 2009).

However, there are two problems for the PICs. The first problem is that the PICs receive only a small share of the resource rents from the tuna fisheries (Chand, et al., 2003). The main reason for this is that negotiating with distant water fishing nations, like China and Japan, is hard for the PICs (Schurman, 1998). This is the case because tuna stocks are geographically spread out across many nations' EEZs, and are highly migratory. This means that if a distant water fishing nations cannot catch the tuna in one location because of blocked access, it can catch them in another (Schurman, 1998).
The second problem is that the distant water fishing nations put high pressure on the tuna stocks located in the waters of the PICs. Resulting in overfishing and more bycatch. As tuna is of great importance to the PICs, depletion of these stocks will do great harm.

Recognizing the economic and ecological challenges associated with managing a highly migratory stock, some PICs took action. In time different types of marine management measures have been put into practice to increase economic advantages and preserve tuna stocks.
In 1990 some PICs introduced limited entry licensing by restricting the total number of purse seine vessels in their EEZ' (Havice, 2013). However it became clear that this measure didn't achieved neither economic nor environmental objectives (Havice, 2013). Three factors explain these outcomes. First, however total vessel number was limited, vessel capacity grew through vessel size and technological improvement (Havice, 2013). Second, the allocation of 'rights' where not controlled by the PICs. This guaranteed the individual fleets a set number of licenses, eliminating competition between the different fleets (Havice, 2013). Third, when a license was not used, the PICs were able to resell the licenses for a 20% premium (Havice, 2013).
To overcome these problems the PICs introduced the vessel day scheme in 2007. The vessel day scheme limits the amount of days that purse seine vessels are allowed to fish in the EEZs of the PICs (Havice, 2013). This has strengthened the rights of PICs over the tuna resources in their EEZs, and has thereby increased economic returns for the PICs (Havice, 2013). Although the vessel day scheme increased returns for the PICs, it failed from an ecological perspective. It has not generated a firm limit on fishing effort and its structure has made it difficult to directly target the biological concerns of individual tuna species (Havice, 2013). Due to the restriction on fishing days, more fish aggregating devices[3] are used by fishers, leading to a greater effectiveness but also to more bycatch. With the vessel day scheme the pressure placed on the tuna stocks in the WCPO has not been reduced, and concerns for some tuna species continue to exist.

1.2 Problem statement & research aim

The development of the tuna fishery in the WCPO has resulted in more pressure on tuna stocks. Due to technological development, increased efficiency and capacity, fishing effort on

[2] Purse seine is a fishing technic: a vertical net is used to surround the school of fish, the bottom of which is then drawn together to enclose the fish (Marine Stewardship Council, n.d.)

[3] ''Fish aggregating device is a permanent, semi-permanent or temporary structure or device made from any material and used to lure fish'' (FAO, 2005)

tuna species has grown. Leading to overfishing and more bycatch of juvenal species, problems that have become concerning for some tuna stocks in the WCPO. Since any fishing activity affects the ecosystem (Jennings & Revill, 2007), these problems are not only concerning for tuna stocks in the WCPO, but for many more fish stocks around the world. These concerns have resulted in the introduction of specific marine management measures (Revill, 2003). However, as the case of the PICs discussed, these measure are not always effective or do not meet their objectives. The problem therefore is that fish stocks can't be sustained without effective marine management measures.

To mitigate this problem it needs to be clear which consequences the different measures have, and what the influence of these consequences is on the sustainable development of fisheries. Then marine management authorities can implement effective measures, to sustain their fisheries.
This report will present the influence that the earlier mentioned marine management measures (FAO, 1997), have on the sustainable development of fisheries.

This has led to the following research question:
What influence do the key marine management measures (FAO, 1997) have, on the sustainable development of fisheries?

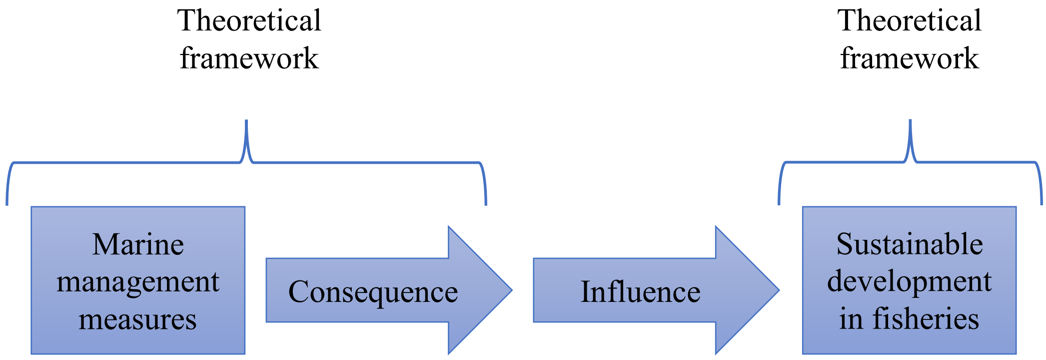
Sustainable development has been defined here as: ''development that seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future'' (Brundtland, 1987). This definition of sustainable development has later been extended by three pillars of sustainability or the triple bottom line, which will be used as a deepening of sustainable development in this report. To be sustainable, companies have to live up to the triple bottom line of economic prosperity, environmental quality an social justice (Elkington, 1998).
Fisheries have been defined here as: the industry or occupation devoted to the catching, processing, or selling of fish, shellfish or other aquatic animals.

1.3 Method

For this research only a qualitative method has been used, due to time restrictions using quantitative methods was not possible for this report. The research is a literature study, which means that a critical review has been given of what is already known in the literature, related to the subject. The main part of the literature study focuses on chapter two and three, because these two chapters will provide the theoretical framework. Themes that will be discussed in these chapters are: sustainable development, the triple bottom line and how these two concepts are operationalized in fisheries, and marine management measures and the consequences that they have. Literature has been found in online databases, such as scopus and web of science.

The themes discussed in the theoretical framework will make it possible to answer the research question. The theoretical framework will make clear what marine management measures are, what the consequences are of these measures, and how sustainable development is operationalized in fisheries. Combining the themes discussed in the theoretical framework, we can score the influence that marine management measures have on sustainable development of fisheries. This is done based on the consequences that marine management measures have. In other words, marine management measures have different consequences, and these consequences have an influence on sustainable development of fisheries (Figure 1). How these influences are scored, will be discussed later in the report.

Figure 1: Themes that will be discussed in this report, and their relation to each other



The theoretical framework of sustainable development is chosen with reason. The three pillar framework of sustainable development is used because it best fits the problems this case faces. It takes in to account the different aspects of sustainability. As mentioned earlier the PIC countries have increased their profit with the vessel day scheme, and have thus increased their economic sustainability. However, the ecological state of the tuna stocks has not been improved, and thus the tuna fisheries in the WCPO are not ecological sustainable. This case shows why it is important to discuss the different accepts of sustainability, for which the three pillar framework is a good concept.

The report will consist of six chapters. The next chapter – chapter two – will provide an overview of what sustainable development and the triple bottom line are, and how these two concepts are operationalized in fisheries. The sub question used in this chapter will be: How is sustainable development operationalized in fisheries? Chapter three will give a review of the marine management measures stated by the FAO (1997). The sub question to guide this chapter will be: what are the consequences of implementing marine management measures? The fourth chapter will give the answer to the research question, based on the information provided in chapter two and three. It will discuss the influence of the consequences that measures have, on the sustainable development of fisheries. The last two chapters will present the conclusion, and discussion.

Chapter 2: Sustainable development, and the triple bottom line in fisheries

This chapter will provide an overview of sustainable development and the triple bottom line, and how these two concepts are operationalized in fisheries. The guiding question for this chapter is: How is sustainable development operationalized in fisheries?
The first section will give an explanation of what sustainable development is. The second section will explain how the rising awareness of sustainable development turned into the creation of the triple bottom line, and what its meaning is. The third section will present how the two concepts in section one and two are operationalized in fisheries.

2.1 Sustainable development

Sustainable development brought under attention the need for meeting the needs of the present and the future, and that there should be limit to the growing eternal effects of economic development. Since the 1960s environmental concerns on industries has grown, and more and more companies became criticized by environmentalists (Elkington, 1994). It started with criticism on mining, detergents, pesticides, and water industries, but in the years that followed more industries became a matter of concern[4] (Elkington, 1994). The main drivers for this were the rapid pace of production and consumption aided by advanced technologies, and the increased exploitation and pollution of natural resources for economic development (Rajeev, et al., 2017). With this growing concern on the environment, companies started looking for an alternative to neoliberal economics, which tends to focus upon short-term profitability with little or no focus upon the long-term (Lozano & Huisingh, 2011). A term that since then has grown in importance is sustainable development.

The Brundtland Report mentioned the growing external effects of economic development, and came up with a definition for sustainable development. In 1987 the World Commission on Environmental Development published the report ‘Our common future’, later known as the Brundtland Report named after the chair of the commission. The report called for an international consensus to re-orient economic activity in order to prioritize the urgent developmental needs of the poor and to prevent irreversible damage to the global environment (Meadowcroft, 2000). It was required that countries committed themselves to making development ‘sustainable’. In a well-known passage the report defines sustainable development as:

Development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:
- *the concept of ‘needs’, in particular the essential needs of the world’s poor, to which overriding priority should be given; and*
- *the idea of limitations imposed by the state of technology and social organization in the environment’s ability to meet present and future needs. (Brundtland, 1987, p. 38).*

The definition of sustainable development used in the Brundtland Report, proposes that there should be some sort of limit to development. This can for example mean that the current generation does not overexploit natural resources. So there will still be resources left in the future for future generations to fulfill their needs.
Most important are the needs of people in developing countries, because their basic needs for food, clothing, shelter, and jobs are not being met (Brundtland, 1987). Added to this, a world

[4] Appendix 1 provides a list with criticized industries by decade.

in which poverty and inequity are present is prone to ecological and other crises (Brundtland, 1987). Sustainable development is therefore an important objective that the world must try to achieve.

Although the Brundtland Report did say little new for insiders, it was important in bringing major issues to public attention (Mitlin, 1992). Following the publication of the Brundtland report, the term ‘sustainable development’ was relatively quickly taken up by national governments, research, and companies (Meadowcroft, 2000; Carter & Rogers, 2008; Rajeev, et al., 2017). Also an increase can be seen in the publication of sustainability concerned articles (Rajeev, et al., 2017). According to Hajer (1997) already in de first five years after the Brundland papers had been published, more than 40 working definitions of sustainable development have been produced (Livesey, 2002).

Although the Brudtland Report brought sustainable development to public attention, it also led to confusion. The Brundtland Commission’s definition on sustainable development is far reaching, and provides little guidance. It did not specify “what should be preserved and what should be altered” (Livesey, 2002). Therefore, the concept of sustainable development became a source of confusion and precipitated debate (Livesey, 2002). Companies often found it difficult to determine their individual roles within this broader, macro-economic perspective (Carter & Rogers, 2008; Gimenez, et al., 2012).

In sum, over a time period of some 60 years, increasing concerns of environmentalist on company activities led to some change in perspective from focusing on short-term profitability to a focus on long-term profitability. An important concept in this changing perspective is sustainable development. Sustainable development as: ‘’meeting the needs of the present without compromising the ability of future generations to meet their own needs’’ (Brudtland, 1987), was quickly taken up by public bodies, research and companies. However it also led to confusion, on which role organizations had to play in this development. The triple bottom line – presented in the next section – gives more direction to sustainable development.

2.2 Triple bottom line

The three dimensions of the triple bottom line of sustainability – economic, environmental, and social sustainability – where a deepening on the concept of sustainable development. They have become part of sustainable agenda of companies.
The 1990s saw the emergence of separate reports form large companies, reporting environmental information alongside the conventional annuals report (Milne & Gray, 2013). These reports initially emphasized only environmental issues, but around the mid-1990s reports also started to emphasize on social issues. (Milne & Gray, 2013).
In that time there was development in the role that companies played, in achieving the goals of sustainable development (Elkington, 1994). Business leaders had to get actively involved in defining and managing the process of environmental communication (Elkington, 1994). Companies had to manage and communicate more than only their conventional business. Elkington (1994) was looking for a new language to express the expansion of the environmental agenda that sustainability had mainly focused upon to that point (Elkington, 2013). The article considered some of the ways in which business was developing new ‘’win-win-win’’ strategies in sustainable development to benefit as company, customers and the environment (Elkington, 1994). This was the first time these three dimensions – economical, environmental, and social – were mentioned together in relation with sustainable

development. Elkington (1994) expanded the environmental agenda of sustainability with the three dimensions of sustainability, thereby the concept of the triple bottom line was born.
To be sustainable, companies have to live up to the so-called ‘triple bottom line’ of economic prosperity, environmental quality an social justice (Elkington, 1998). They should not only conserve and use nature and natural resources for the benefit of present and future generations, but also respect a range of human rights in the process (Elkington, 1998). At the intersection of social, environmental, and economic performance, there are activities that companies can engage in, which not only positively affect the natural environment and society, but which also result in long-term economic benefits and competitive advantage for the firm (Carter & Rogers, 2008). According to the principle of the triple bottom line, to be sustainable all the three dimensions need to be taken into account. Firms not only need to engage in socially and environmentally responsible behavior to be sustainable, but positive financial gains can also be made in the business process (Gimenez, et al., 2012).

The three different dimensions of the triple bottom line relate to three different sustainability issues. First of all economic sustainability, mostly well understood, as it relates to keeping a company financial feasible. Key consideration here might include the long-term sustainability of a company’s costs, the demand for its products or services, its pricing and profit margins, or its innovation programs (Elkington, 1998). Secondly environmental sustainability, this dimension is harder to embody, because natural ecosystems are complex, therefor environmental sustainability can be case specific (Elkington, 1998). The dimension often related to ‘’waste reduction, pollution reduction, energy efficiency, emissions reduction, a decrease in the consumption of hazardous/harmful/toxic materials, a decrease in the frequency of environmental accidents, etc.’’ (Gimenez, et al., 2012). Thirdly social sustainability, which means that ‘’companies or public bodies provide equitable opportunities, encourage diversity, promote connectedness within and outside the community, ensure the quality of life and provide democratic processes and accountable governance structures’’ (Gimenez, et al., 2012). In sum, the triple bottom line consists of three dimensions of sustainability – economic, environmental- and social sustainability.

During the early 2000s triple bottom line reporting gained popularity in businesses’ management, measurement and reporting processes (Milne & Gray, 2013; Hahn & Kuhnen, 2013). It became clear that communicating effectively with stakeholders on progress towards economic prosperity, environmental quality and social justice, i.e. the triple bottom line, is a defining characteristic of corporate responsibility (Elkington, 1998). When not communicated correctly, corporate responsibility can lead to criticism on a company (Morsing, 2017). Therefore, more and more companies started adopting the triple bottom line in their annual reporting. Even the most widely used standard for sustainability reporting – the Global Reporting Initiative (GRI) Sustainable Reporting Standards – adopted the triple bottom line in their standards (Lozano & Huisingh, 2011; GRI, n.d.). According to the GRI Standards, sustainability reporting is a company’s practice of reporting publicly on its economic, environmental, and/or social impacts (GRI, 2016). It is clear that the triple bottom line is globally accepted and adopted by companies as a useful concept to give direction to sustainability.

In sum, in the 1990s companies started to publish environmental reports concerning their business, and the role of companies in sustainable development grow. The triple bottom line gave direction to this expansion of the sustainability agenda of companies. According to the triple bottom line organizations are sustainable, when they live up to the ‘triple bottom line’ of economic prosperity, environmental quality and social justice. When these three dimensions of the sustainable development are taken into account, long term sustainability can be accomplished. The following section will discuss how the triple bottom line is operationalized in fisheries.

2.3 Sustainable development and the triple bottom line in fisheries

Also in fisheries the triple bottom line has become important, it has brought opportunities for long term sustainability within fisheries, and opened up for a vision that was broader than making profit alone, which made fisheries also more complex.
In line with the slow change in the general perception on sustainability, the perception on sustainability in fisheries has also changed. Before 1950s the rationalization paradigm prevailed, focusing on the achievement of an economically rational or efficient fishery (Charles 1994). However, since the 1950s fisheries managers and society have changed their perception of nature, from that of a robust system with inexhaustible resources, to one with limited and fragile resources (Garcia & Staples, 2000). The need for balancing present and future yields, and conserving the marine resources became important from then on (Garcia & Staples, 2000). Controls over exploitation were introduced, legislation transformed un-owned resources into the collective property of the nation's citizens, and in most cases non-ownership gave way to state property (Charles, 1994). At first the focus was primary on resource and environmental protection, but from the 1980s social and community concerns, and the well-being of people in fisheries became also important (Garcia & Staples, 2000). From then on most concerns on the different aspects of fisheries, were in line with the triple bottom line of economic, environmental, and social sustainability.

The interaction between the three dimensions of sustainability in managing fisheries is highly complex, and nonlinear (Dichmont, et al., 2012). The challenge for marine management is to use the resources and services provided by the marine environment to meet development objectives, without degrading the quality of the environment or exhausting stocks of living resources (IUCN, UNEP & WWF, 1991). The problem with this challenge is that different stakeholders have different interests. The different stakeholders want their fishery to be 'efficient', but the meaning of this goal depends entirely on the desired objectives, which in turn vary between the fishery stakeholders (Charles, 1992). The fishing industry is most concerned with maximizing industry profits, conservation groups are most concerned with minimizing the environmental damage from fisheries, and social scientists are most concerned with minimizing externalities (Pascoe, et al., 2009). This diversity in goals may lead to conflicts, which create tension between the three dimensions of the triple bottom line. The ultimate goal of a fishery should be to reduce this tension, and live up to all the three dimensions of the triple bottom line. Such a balance of the three dimensions will create fisheries which are relatively conflict-free, and promotes long-term sustainability of the fishery (Charles, 1992).

In sum, the different stakeholders within a fishery have different interest, which gives a negative tension. To reduce this tension a balance between the three sustainability dimensions has to be created. For creating such a balance, it is important to know where the triple bottom line of sustainability consist of. Therefore, the next three sections will operationalize each of the dimensions of sustainability in fisheries.

2.3.1 Economic sustainability

Economic sustainability in fisheries can be met when the fishery is economical feasible. As mentioned before organizations have to live up to the bottom line of economic prosperity. It emphasizes the pursuit of economic efficiency and increased wealth in the fishery (Charles, 1992), and the maintaining of suitable financial, administrative and organization capabilities over the long-term (Charles, 1994). For companies in fisheries to be economic sustainable, they need to stay economically feasible, by maintaining company resources and capabilities in the long-term.

A way to keep fisheries economically feasible is to harvest at maximum economic yield (MEY) level. This is a sustainable catch or effort level that maximizes the economic profit for a fishery (Crafton, et al., 2010). Fisheries will than likely achieve economic and conservation objectives, yielding the highest rent from a non-endangered stock (Lleonart, & Merino, 2010). However, in most of the worlds fisheries the MEY level is ignored. In non-regulated fisheries, the fishery will attract exploiters until their capacity exceeds ecosystem productivity. Exploitation will continue until fishing costs exceed revenues, and exploiters discontinue the activity (Lleonart, & Merino, 2010). It is therefore important that marine management authorities set regulations on fishing effort, so that economic benefits can be optimized.
In sum, for fisheries to be economic sustainable, they need to stay economically feasible. A sustainable catch or effort level at MEY level is therefore recommended.

2.3.2 Environmental sustainability
Environmental sustainability of fisheries is based on the premise that the primary duty of marine management is to take care of the marine resources (Charles, 1992). This involves conservation of individual stocks and species at levels that do not foreclose future options, and maintaining the capacity and quality of marine ecosystems (Charles, 1994).
This is needed because the planet's capacity to support people is being irreversibly reduced (International Union for Conservation of Nature (IUCN), 1980). If exploitation of fish stocks is uncontrolled, fish stocks have the potential to be driven to extinction (Charles, 1994). In such a situation where stocks collapse, a great source of income and proteins will become unavailable.

There are two major harmful issues for conservation of marine stocks and so environmental sustainability. The first issue is that there is not one clear definition of conservation, and that reference points for conservation are sometimes limited (Shelton & Sinclair, 2008). This means that the level at which stocks have to be conserved, is often not know. However, returning aspects of the definition are the protection, maintenance, and restoration of fish stocks. The goal should be to maintain or restore stocks at levels capable of producing maximum sustainable yield (FAO, 2011).

Maximum sustainable yield (MSY), is defined as: ''the highest possible annual catch that can be sustained over time for a given fish stock, by keeping the stock at the level producing maximum growth'' (WWF, 2011). Striving for an exploitation level below MSY is best for fish stocks, otherwise they will be depleted in time. Harvesting at MSY level generates the largest value of sustainable catch in kilograms. However, it will not necessarily lead to an economically healthy industry that can support the community in which it is implemented (Anderson, et al., 2015). Since MSY takes only the conserving of fish stocks into account, and not the economic impact associated with this harvest level. The MSY level is above the MEY level, and will thus not optimize economic profit for a fishery. Therefore it might be better to harvest at a MEY level, as explained in the previous section.
The concept of MSY has already been used since the 1950s (Carcia & Staples, 2000), but its use have changed over time. Until the 1970s MSY was seen as a target for fisheries (Caddy, 1994), because this gave the highest short term economic value. MSY is now treated as an upper limit, and no longer as a target (Caddy, 1994). This means that fishing management

need to ensure that fishing mortality does not exceed the MSY level, so that the biomass of a stock does not fall below a predefined threshold (Shelton & Sinclair, 2008).

The second issue for environmental sustainability is the bycatch of untargeted species. Gilman (2011) defined bycatch as consisting of: ‘’(i) retained catch of non-targeted, but commercially valuable species, referred to as ‘incidental catch’ or ‘byproduct’; (ii) discarded catch, whether the reason for non-retention is economic or regulatory; plus (iii) unobserved mortalities.’’. These non-target species are caught because modern fishing gear is very efficient, covers an extensive area, and can be highly unselective when regulations for fisheries are lacking (WWF, n.d.). Bycatch can create conservation problems when endangered species are affected (Hall, et al., 2000). It can also affect the biodiversity, and disturb the ecosystem through impacts on top predators and so the elimination of pray, and by catching juvenile and undersized individuals before they reach their optimal size. This disturbs the regeneration of fish stocks (Hall, et al., 2000).

In sum, for fisheries to be environmental sustainable, marine stocks need to be conserved. In theory MSY should be the upper level for conservation, unfortunately reference points are sometimes limited. Next to that bycatch of untargeted species is another harm to conservation of marine stocks.

2.3.3 Social sustainability

The social dimension focuses on community welfare, fair distribution of resources, and other social and cultural fishery benefits. However, there are three reasons why the social dimension of sustainability is a more difficult dimension to embody. First of all, the economic and environmental dimensions of sustainability are mostly explicit and their objectives clear, however this is not the case for the social dimension. Social objectives are rarely explicit, vary widely by fishery, and sometimes even within fisheries (Anderson, et al., 2015). To make the problem even more complex, there are likely to be several social objectives that may not be compatible with each other (Mangel, & Dowling, 2016). Therefor a wide range of different definitions and objectives for social sustainability in fisheries exist.
Second, social sustainability is hard to measure, therefore there is a mismatch between quantitative metrics and more qualitative social information (Plagányi, et al., 2013). That is why social objectives are sometimes missing and not explicitly included in the definition of fishery objectives (Plagányi, et al., 2013).
Third, the social aspect of a fishery is in part captured through the other two dimensions of the triple bottom line (Dichmont, et al., 2013).

Although the social dimension of sustainability is hard to embody, there are some returning aspects in the different explanations of the dimension. Social sustainability has to do with maintaining some level of the social benefits, preserving certain lifestyles, and maintaining the regional community structure which rely on employment on fishing vessels as well as land-based upstream and downstream economic activities (Pereau, et al., 2012). It focuses on social capital, bequest of culture, protection of shoreline, trust, community involvement, the distribution of fish, and sense of self-control (Mangel & Dowling, 2016). How a person or group perceives the proportional availability of goods and services, and how these are divided (Halpern, et al., 2013).
To summaries, the social dimension focuses on community welfare, fair distribution of resources, and other social and cultural fishery benefits (Charles, 1992).

Even if the social dimension is in part captured by the economic, and the environmental dimension, it is still important that the social dimension is taken into account. A profitable fishery can maintain better onshore facilities and employment, and therefore a region's social capital. However, to sustain the economic and environmental dimensions, social objectives must be achieved. Social norms, and comparison of losses of other fishers, are important factors to determine social equity (Brown, et al., 2018). Highly unfair solutions are more likely to fail, because those who are disenfranchised from the benefits or outcomes of the process often feel little motivation to adhere to the agreement (Halpern, et al., 2013). Including the social dimension in conservation may increase buy-in, reduce conflict and costs associated with negotiation, and yield better alternatives that address concerns of those most affected by environmental and institution changes (Poe, et al., 2014).
To sum, it is important to include the social dimension, otherwise stakeholders will not be motivated to participate in actions associated with economic and environmental sustainability objectives.

To summaries this section, even if the social dimension of sustainability is hard to embody, it is important for a fishery to live up to its objectives. Central aspects of social sustainability in fisheries are community welfare, fair distribution of resources, and other social and cultural fishery benefits. These are important aspects to keep stakeholders motivated and create long-term sustainability for a fishery.

2.3.4 Conclusion sustainable development and triple bottom line in fisheries

Concluding this section, the different objectives of the triple bottom line dimensions make achieving long-term sustainability in fisheries complex. Fisheries need to be economical feasible to gain economic sustainability. Conserve marine stocks, to gain environmental sustainability. A useful upper level of the conservation of marine stocks is the MSY level, but the reference point for this for this level is sometimes not known. Fisheries also need to take community welfare, equal distribution of resources, and other social and cultural fishery benefits in to account, to gain social sustainability. For a fishery to gain long-term sustainability, all the three dimension of the triple bottom line need to be included in the sustainable objectives of a fishery. It requires a sustainable resource stock, but also economic feasible businesses, and communities that accept and support those industries and the people involved in them (Anderson, et al., 2015).

2.4 Conclusion

To conclude this chapter, and give answer to the question: 'How is sustainable development operationalized in fisheries?' Through the years the paradigm of the role that companies have, changed from focusing on short-term profitability to a focus on long-term sustainability. Meeting the needs of the present without compromising the ability of future generations to meet their own needs, became an important objective for organizations. The triple bottom line extended the concept of sustainable development with three dimensions, and gave more direction to achieving long term sustainability. The concept states that companies are sustainable, when they live up to the 'triple bottom line' of economic prosperity, environmental quality an social justice. In fisheries the three dimensions are operationalized as follows. First, economic sustainability emphasizes the pursuit of economic efficiency and increased wealth in the fishery (Charles, 1992), and the maintaining of company resources and capabilities over the long-term (Charles, 1994). Second, environmental sustainability of fisheries is based on the premise that the primary duty of marine management is to take care of the marine resources (Charles, 1992). This involves conservation of individual stocks and species at levels that do not foreclose fishery options for future generations, and maintaining the carrying capacity and quality of marine ecosystems (Charles, 1994). Third, the central aspects of social sustainability in fisheries are: community welfare, fair distribution of resources, trust, and community involvement.

To sustain fisheries in line with the triple bottom line, different tradeoffs between the dimensions will arise. On the one hand marine stocks have to be conserved, to gain environmental sustainability. On the other hand conservation must not make short-term economic needs impossible, because people also have to fulfill their needs (IUCN, 1980). Besides that the growing world population demands for more protein resources (Caddy, 1999), for which fish is an important one (IUCN, 1980). It might also be more economical efficient to reduce the number of fishermen, but this can be seen as unfair and reduces the commitment to sustainability goals. These are just some examples of existing tradeoffs, a lot more tradeoffs are present in fisheries. These tradeoffs make sustainability in fisheries complex and difficult to achieve.

Chapter 3: Marine management measures

Concerns about the environmental impacts attributable to fisheries have increased over recent decades, and have in many instances resulted in the introduction of specific marine management measures (Revill, 2003). Since any fishing activity affects the ecosystem, it is necessary to identify and mitigate those effects (Jennings & Revill, 2007). In this way it is possible to continue productivity of marine resources (FAO, 1997).

The different marine management measures (hereafter: measures) can be divided into three main groups, namely: technical measures, input control, and output control (FAO, 1997). First of all, technical measures are restrictions or constraints to regulate the output which can be obtained from a specified amount of fishing effort (hereafter: effort) (FAO, 1997). Effort is defined as: ''The amount of fishing gear of a specific type used on the fishing grounds over a given unit of time'' (FAO, 1997). Technical measures contain controls on where and when fishers may fish and the size of fish they may harvest (Selig, et al., 2016). Second, input controls directly regulate the amount of effort which can be put into a fishery (FAO, 1997). Third, output controls directly regulate the catch which can be taken from the fishing grounds (FAO, 1997). Input controls limit the amount of fishing effort as a way to control the amount of fish caught, while output controls are direct limits on the amount of fish harvested (Selig, et al., 2016). In this chapter the three groups of measures will be discussed, dividing the chapter in three sections. In each section the different measures that fall under the overarching measure groups will be explained, and their positive and negative consequences will be identified. The chapter will answer the sub-question: what are the consequences of implementing marine management measures?

3.1 Technical measures

Technical measures are restrictions or constraints to regulate the output which can be obtained from a specified amount of effort (FAO, 1997). One of the main reasons for imposing technical measures, has been to create conditions that minimize the capture of juveniles species, or incidental catches of non-target species (Suuronen & Sarda, 2007). The measures that fall under technical measures are: marine protected areas (MPAs), time- areas closures, and limits on the size of fish that can be caught (Selig, et al., 2016). For this report MPAs and time- area closures, will be discussed as one type of measure. This is done because, the term MPAs has different definitions, varying from no-take zones in which no fishing effort is allowed, to areas which are protected by some form of marine management (Agardy, et al., 2003). With the definition that is used for this report, there is no distinction between MPAs and time- area closures. Next to that, the consequences that both measures have are quite the same. Based on these two reasons, the decision has been made to discus MPAs and time- area closures as one measure. The measures that fall under technical measures are thus for this report, MPAs, and fish size limits.

3.1.1 Marine protected areas (MPAs)

Marine protected areas can have different levels of protection, and the activities within their boundaries varies too. As said before, the definitions of MPAs vary widely. For this report the definition of Kelleher & Kenchington (1999) is used: ''Any area of the intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment''. This means that a MPA can have different levels of protection, it might be a closed area for fishing all year round, or closed for a specific time a year. In the latter case the MPA is the same as a time- area closure. Time- area closure is a measure by which a certain area is closed for fishing activities for a certain time, this can for example mean that a specific fishing ground is closed for a season. (Selig, et al., 2016). Next to time-area closure, also other measures are overarched by MPA measures. An example is territorial use rights for fisheries (TURFs), which operate as a spatial form of property rights in which individuals or a group of fishers are granted access privileges and fishing right to exploit fisheries resources within a specific area (Quynh, et al., 2017). With the definition of Kelleher & Kenchington (1999) for MPAs, both time- area closure, and TURFs fall under the same measure, which will be referred to as MPA in this report.

That MPAs can have different forms is in line with their objective, which varies from place to place (Agardy, et al., 2003). Even so much that one could almost say that every MPA is unique, having been tailored to meet the specific circumstances of the place where it is established. Thus, MPA should be used as a general umbrella term, which can apply to the wide range of different marine protection strategies that are used for a specific area. (Agardy, et al., 2003).
MPAs are generally designated with biodiversity conservation objectives, to protect a component of a stock or community such as spawning adults or juvenile stages, or habitats, or they are used for broader ecosystem purpose (FAO, 2011; FAO, 1997). The most important objective may be the sustainable use of a particular resource (Agardy, et al., 2003).

Sometimes MPAs form a network, in such a case the MPAs complement each other through connections between them (FAO, 2011). This is useful because, the marine environment is made up of many geographical spaces with different physical, chemical and biological features, and is populated by communities of marine species that persist through time by interacting across the region. It can for example be that species spawn on a sand seabed, then move to corals where they grow up. In such a case, two MPAs can be create, one for the sand seabed area, and one for the coral area, creating a network of MPAs. By creating a network of MPAs, species can thus be protected in different live stages (FAO, 2011).

There are two main positive consequences for MPAs. First of all, when designed appropriately, there are more fish and bigger fish, with a higher biomass, inside MPAs than outside (FAO, 2011). MPAs reduce the amount of fish caught within the MPA (Poisson, et al., 2016). Therefore fish stocks have the opportunity to grow in biomass (Pawson, 2005). This has also a positive effect on the amount of fishery resource available to fishing grounds outside the MPA (FAO, 2011). Due to fish that moves from MPAs to the area around them, and so contribute to a higher yield for fishers.
Second, MPAs can provide a mechanism for recognizing and protecting traditional fishing grounds and places of cultural importance and practices (FAO, 2011). In such a case MPAs can for example, be used by only giving access to fishers that make use of traditional fishing practices.

There are three major negative consequences for MPAs. First of all, fleet displacement, due to a MPA fishers can't fish anymore on the fishing ground where they used to fish. This leads to fleet displacement, the fishers will move to other grounds for fishing. That could increase the fishing impact on other fishing grounds (Poisson, et al., 2016), and increases the relative costs for fishers, due loss of fishing ground and thus loss of earnings (Pawson, 2005). Coming along with fleet displacement, is an increase in fuel consumption for reaching further lying fishing grounds. Fleet displacement might also cause problems to fleets with limited range

capacity (Poisson, et al., 2016), for example small scale fisheries that are dependent on nearby fishery resources (FAO, 2011).
Second, MPAs may also impose increased costs, for marine managers and fishers. Assuring compliance with area closures can be costly for marine managers, if at sea enforcement is required (Holland, 2003). Because it is hard to control if fishers comply to the regulations set for the MPAs. However, these costs associated with assuring compliance may be lower if vessel monitoring systems are required on board (Holland, 2003).
Third, for MPAs to be effective, large amounts of information is needed, among others information on the patterns of habitat use by fish, where they spawn, and how fast they grow (Poisson, et al., 2016). Also information to understand what will happen to the fishers behavior if a MPA is put into practice (Poison, et al., 2016). Will the fishers start fishing somewhere else? And what would be the impact of that? Therefore a MPA can best be used in fisheries where there is a high degree of available information (Selig, et al., 2016).

To conclude, MPAs are marine areas that are protected by marine management, with the main objective to sustain marine resources. The level of protection depends on the objective of protection. Networks of MPAs can be used to protect species in different life stages.
The positive consequences of a MPA are: increased biomass inside a MPA, and increased protection of traditional fishing grounds. Although, MPAs seem a useful measure for conservation of fish stocks, there are two issues that make them less effective. First, MPAs might be less effective when fish stocks are highly migratory. In other words, if fish stocks move from place to place they will not be located in the MPA, which makes it less effective. MPAs would work best in fisheries with low-mobility species, or consistent spawning seasons (Selig, et al., 2016). Second, MPAs can be difficult to enforce in high sea areas (Poisson, et al., 2016). Regulation in international waters is restricted to international agreement (Poisson, et al., 2016), because no specific country has the control of these waters. This makes it hard to deny access to fishers, for high sea areas.
Next to those two issues MPAs have three negative consequences, which are: fleet displacement, assuring compliance with the measure, and gathering of information,.
Since, MPAs do not address key issues for the overall management of the area beyond the boundary of an MPA (FAO, 2011). MPAs should not be viewed as a solution for all marine management problems. Other management measure may be used in combination with MPAs.

3.1.2 Fish size limits

Fish size limits (hereafter size limits) focuses on the efficient capture of individuals greater than a given minimum size (Jennings & Revill, 2007). So that juvenile individuals that have not grown to their mature size, and non-targeted smaller fish are not caught as bycatch. Such regulation is implemented with a minimum allowable size at landing (hereafter minimum landing size), which means that every fish harvested has to be bigger than the minimum landing size. Fishers are not allowed to land fish different than the regulated landing size.

There are two positive consequences for minimum landing size regulations. First of all, minimum landing size regulations can encourage fishing to occur on fishing grounds that carry less small fish (Poisson, et al., 2016). This results in less small fish caught, therefore also less juvenile fish caught. Second, by regulating minimum landing size, fishers may improve gear selectivity, by for example increasing mesh size, to reduce capture of juvenile fish (Poisson, et al., 2016). Both are pleasant consequences for marine managers, because then they do not have to designate MPAs for specific areas, or set gear restrictions.

There are three negative consequences for size limit regulations. First of all, increased discards – those components of a fish stock thrown back after capture (FAO, 1997). Accidently caught fish that is below the size limit is mostly discarded, because fishers recognize it as wasteful, and it creates additional work in sorting the catch (FAO, 2011). Size limit conservation measures are based traditionally on the assumption that fish that escape, survive (Suuronen & Sarda, 2007). However, this survival rate is largely unknown (Suuronen & Sarda, 2007). It is therefore important to determine the survival of discarded individuals to determine the efficiency of these size limit measures (FAO, 1997).
Second, catching fish above a minimum size increases the relative mortality on fast-growing individuals and, therefore, selects for slow growth and early maturity (Jennings & Revill, 2007). In other words, the fast growing individuals will be harvested, and the more slow growing species will remain. This encourages the truncation of age structure, increase the sensitivity of the population to poor recruitment events, and environmental variation (Jennings & Revill, 2007).
Third, when gears are made more selective through size limits, this is typically accompanied by some loss of the targeted fish (Jeanings & Revill, 2007). This will lead to a loss of earnings in the short term (Pawson, 2005). However, in the long term earnings might grow, because with the size limit regulations juvenile species can grow to mature size, which will eventually increase the size of the individuals caught (Pawson, 2005).

To conclude, size limits focus on the efficient capture of individuals greater than a given minimum size. This can be done by regulating the minimum landing size. The objective of this measure is to prevent that juvenile individuals that have not grown to their mature size, and non-targeted smaller fish are caught as bycatch. Positive consequences of regulating minimal landing size are: that fishing in areas that carry less smaller fish is encouraged, and that fishers improve the selectivity of their gear. Negative consequences for size limits consist of: increased discards, the truncation of age structure, and lost harvest of targeted fish. Although size limits improve selectivity, it has become clear in may fisheries that regulating selectivity alone is not sufficient to provide sustainable conservation (Suuronen & Sarda, 2007). Therefore other measures than size limit regulations should be implemented in marine conservation management. Implementation of mesh size regulations can be useful measure to support a minimum allowable size at landing (Pawson, et al., 2005).

3.1.3 Conclusion for technical measures
To conclude on this section, MPAs and fish size limits are used as technical measures, with the objective to regulate the output which can be obtained from a specified amount of effort. However different negative consequences are in place for both measures, and effective implementation and enforcement of technical measures can be extremely difficult, particularly in multispecies fisheries (Suuronen & Sarda, 2007). In practice improvements in resource conservation, and discard reduction due to introduction of technical measures are usually smaller than that had been predicted or assumed before their implementation (Suuronen & Sarda, 2007). Therefore technical measures can best be used in combination with input-, and output controls.

3.2 Input control
Input control directly regulate the amount of fishing effort that can be put into a fishery (FAO, 1997). Input controls are generally considered to be limits on the amount or type of effort fishers put into their fishing activities, indirectly controlling the amount of fish caught (Selig, et al., 2016). Input controls can include restrictions on the number of fishing units through limiting the number of licenses, restrictions on the amount of time units can spend fishing,

and restrictions on the size of vessels and/or gear. (FAO, 1997; Selig, et al., 2016). Restriction on the amount of time units can spend fishing, can for example be a restriction on the amount of days that vessels are allowed to fish (Selig, et al., 2016). The negative consequence of this measure is that fishers can increase their efficiency, which makes the measure not always effective (Havice, 2013). This might be the reason why time restrictions are the least used input control measure (Selig, et al., 2016). The amount of literature available for this measure is also neglectable, which makes it hard to say something valid about the measure. For this reason, time restrictions will not be discussed in this report. This section will thus discuss the following measures: limited entry (e.g. licensing), and gear restrictions.

Whatever other control measures are in place, some degree of input control by the management authority is a pre-requisite for responsible fisheries (FAO, 1997). Experience has shown that in the absence of a input control, the amount of effort by fisheries cannot be effectively controlled (FAO, 1997). When no regulations are present, a fishery is open for everyone. In an open access fishery, every fisher is allowed unlimited access to harvest as many fish as it wants by whatever means it chooses (Eliston & Cao, 2006). This creates a 'tragedy of the commons' or a 'race to fish', where fishing fleets of increasing size and power try to be the first to harvest the fish, and so maximize their harvest (Emery, et al., 2012; Emery, et al., 2014). The result could be the depletion of fish stocks. To overcome the problems associated with open access, input control needs to be established (Eliston & Cao, 2006).

3.2.1 Limited entry

Limited entry is a measure used for marine management programs that restricts a fisher's access to open fisheries (Lansford & Howorth, 1994). Various approaches can be used to limit overall fishing effort, such as limiting the number and sizes of vessels participating in a fishery, or the number of hooks. These measures are mostly enforced by license limitation programs (Poisson, et al., 2016). A license limitation has the objective to reduces fishing effort by restricting the amount of a major input used in the fishery (Anderson, 1985). Thereby, fostering the economic health of the fishing industry, while at the same time ensuring that stocks will be able to replenish themselves (Lansford & Howorth, 1994). License limitations can apply to communities, companies, vessels, or even individuals (FAO, 1997).

Despite the range of possibilities in implementing systems of limited entry, there are four principles to keep in mind when applying such measure. First of all, the nature of the recipients (Sharuddin, 1995). Who do you want to have access to the fishing grounds? Second, the initial method of allocation (Sharuddin, 1995). How do you select the recipients of the access license? Third, whether or not the license should be transferable (FAO, 1997). Should it be possible for recipients to sell their access license? Fourth, the duration of the allocated license (FAO, 1997). For how long are the access licenses valid?

There are five major positive consequences for limited entry by license limitations. First of all, a positive consequence of granting access licenses is that they encourage a sense of ownership to the recipient, which leads to a greater sense of long-term responsibility to the resources and fishery (FAO, 1997). This encouragement is stronger when access licenses have a long duration, and aren't transferable. The recipient of an assess right is in such a case aware that he or she will gain the benefits for responsible actions.

Second, long-term licenses also make it easier for access recipients to gain financing for their ventures (FAO, 1997). With more financing opportunities it is more likely that they stay in business.
Third, in contrast to the previous two positive consequences, transferable licenses encourage evolution of the fishery (FAO, 1997). They provide a mechanism for innovations, and new entrants into the fishery (FAO, 1997). Under limited access without transferability, this would be problematic.
Fourth, transferable licenses allows fishers to make better economical profitable decisions, because transferability allows the value of licenses to fluctuate according to their market price (Lansford & Howorth, 1994).
Fifth, license limitations on vessel size could reduce fuel when vessel sizes are reduced (Poisson, et al., 2016).

There are three major negative consequences for limited entry by license limitations. First of all, limited entry as only measure neither directly controls fishing effort nor controls the actual amount of harvest for a fishing fleet (Smith, 2004). Since the remaining fishers will attempt to make their vessels more efficient, thereby defeating the conservational goals of limited entry (Lansford & Howorth, 1994).
Second, where a marine management authority is moving from a system of open access to one of limited access, a problem is determining which of the previous users should be granted access and which denied access (FAO, 1997). Fishers could feel that they are discriminated against each other, and unequally treated (Sharuddin, 1995). A simple solution to this problem can be a lottery, selections based on an individual's fishing history, or to sell or auction the access licenses (Lansford & Howorth, 1994; FAO, 1997).
Third, if the marine management authority makes licenses freely transferable, the risk arises that most of the licenses will eventually be gathered into the hands of a few, possibly creating a monopoly (Lansford & Howorth, 1994). Where social goals are important, such as the provision of employment to communities, a monopoly can negate progress towards achieving these goals (FAO, 1997).

To conclude, limited entry restricts access to open fisheries, by license limitation. License limitation restricts the number of vessels, fishers, gear, areas, or any combination thereof that are allowed to participate in fishing operations (Lansford & Howorth, 1994). This has the objective to reduce fishing effort. Different positive- and negative consequences are present for limited entry measures, which depend on the implementation of the license limitations. The positive consequences are: increased long-term responsibility, increased financing opportunities, innovation of fisheries, allows better economic decisions, and reduces fuel consumption. The negative consequences are: no decrease of fishing effort, unfair distribution of access license, and the creation of a monopoly.
Although, limited entry has several positive consequences, the effectiveness depends on the implementation of the license limitations. The issue whether or not licenses are transferable, or have long duration, has implications for responsible fishing (FAO, 1997). Somewhere between transferable against non-transferable, and long- against short term, there is a level that would make license limitation most effective (Landsford & Howorth, 1994). That the effectiveness depends on the implementation of the measure, means also that not all the positive or negative consequences will always be present.

3.2.2 Gear restriction and -modification

Gear restriction, and -modification affect the type, characteristics, and operation of a fishing gear (FAO, 1997). Gears are restricted for mainly two reasons: first, to avoid increased fishing effort through increased efficiency (FAO, 1997). Second, to avoid unwanted impact on non-commercial sizes, species or critical habitats (FAO, 1997). An example of a gear restriction is the regulation of mesh sizes. Since, a major reason for capturing non-target species is that nets are made from mesh sizes that are too small (Valdemarsen & Suuronen, 2001). Regulating a minimum mesh size gives non-targeted species the opportunity to escape from the nets.

Next to gear restriction, gear modification can be used to increase selectivity and reduce by-catch of non-target species (Worm, et al., 2009). Gear technologists have been particularly active in developing fishing methods that reduce bycatches of vulnerable species (Jennings & Revill, 2007). Another objective of gear modification is to reduce the impact on the seabed, and habitats (Jennings & Revill, 2007).
Every fishing ground has its own characteristics, fishing practices, and conservation objectives, therefore many different gear modifications exist (Box 1)[5]. Also technical modifications, such as electronic detections instruments and navigation, fall under gear modifications (Valdemarsen & Suuronen, 2001).

Box one
Examples of gear modifications

The bycatch of crustaceans and other benthic animals in gillnet fisheries (fishing by placing a wall of nets on the seabed) can be reduced by raising the ground line a little above the seabed (Valdemarsen & Suuronen, 2001).

The impact of bottom trawls (fishing by towing a net over the seabed) on the seabed can be reduced if trawls are made lighter, and have less contact with the seabed (Valdemarsen & Suuronen, 2001).

Species- and size selectivity of a longline (fishing by placing a line full of hooks below the surface) can be modified by bait size and type. The design, and size of hooks can also affect selectivity (Valdemarsen & Suuronen, 2001).

Gear restriction, and -modification have three main positive consequences. First of all, gear restrictions, and -modifications increase the selectivity of the fishing gear (Suuronen & Sarda, 2007). They can better select between species (Campbell, et al., 2017), and result in less blocking of the meshes, and less injuries to the escaping fish (Suuronen & Sarda, 2007). Therefore, gear restriction, and -modification have proved to be successful in many fisheries that are facing bycatch problems (Valdemarsen & Suuronen, 2001). However, a mesh-size designed to capture mature individuals of a smaller species will still catch immature individuals of a co-occurring larger species (FAO, 1997). In multispecies fisheries, no single mesh size suits all species, and any change may favor one species at the expense of another. (Suuronen & Sarda, 2007). Fish size limits are therefore more effective in fisheries targeting single species (Selig, et al., 2016).
Second, gear restrictions, and -modifications decrease the use of destructive gears. Strong evidence exists for the recovery of fish biomass in fisheries where restrictions on destructive gears are strong (Campbell, et al., 2017). For example, with the help of electronic detection instruments and accurate navigation, fishers can be guided to fish rich areas, without using their gear. Hereby minimize fishing interactions with sensitive bottom habitats (Valdemarsen & Suuronen, 2001).

[5] Appendix two, contains a list of gear innovations that can reduce the fishing impact on bycatch

Third, gear modification can increase the efficiency of fishing vessels, therefore reduce fuel consumption, and -costs (Valdemarsen & Suuronen, 2001).

Although these positive consequences of gear restrictions, and -modification seem very attractive to fishers, the uptake of new gears on a voluntary basis can be expected to be low where no incentives are in place or disincentives exist (Jennings & Revill, 2007). Reasons for this include an unwillingness to risk losing marketable catch, the absence of uptake by all fishers, additional work for fishers, conservation "benefits" that do not benefit the fishers, and the cost of investing in the new gear (Jennings & Revill, 2007).

There are two major negative consequences for gear restriction, and -modification. First of all, gear restrictions and -modifications require bigger investments in gears. Although overall exploitation patterns may be improved, gear modifications generally make net construction more expensive, and modified gears are often more difficult to operate and maintain (Suuronen & Sarda, 2007). This make gear restriction, and -modification more costly. Second, due to the increased selectivity of the gear, there is also a loss in targeted species caught (Jennings & Revill). This happens because some marketable species, or sizes are not caught anymore.

To conclude, gear restriction, and -modification change the status quo of the gear that is used in fisheries, by restricting, or modifying specific types of gear. Gear restrictions, and -modifications have three main positive consequences, which are: increased selectivity, decreased use of destructive gears, and reduced fuel consumption. The measure has also two negative consequences, which contain: increased investments, and lost catch of target species. Although gear restrictions, and -modifications mostly require bigger investments, increasing mesh size is a relative simple constructional change (Valdemarsen & Suuronen, 2001). Therefore setting mesh size regulations is a relative cheap measure.
The greatest environmental benefits from gear restriction, and -modification will usually be achieved when used in combination with other measures (Jennings & Revill, 2007; Selig, et al., 2016).

3.2.3 Conclusion input control

To conclude on this section, limited entry, and gear restrictions and -modifications are used as input control, with the objective to directly regulate the amount of effort which can be put into a fishery. However, both input control measures have their own positive-, and negative consequences. Two issues exists for both input control measures.
First of all, input controls on any input may lead to a compensatory increase in another input, in order to maintain the catching ability (Pascoe & Robinson, 1998). This can lead to investment in less efficient inputs, reducing the net returns to operators and the fishery as a whole (Eliston & Cao, 2006).
Second, it is hard to determine how much effort is actually represented by each fishing unit (FAO, 1997). Even discrete fleets within a fishery are characterized by considerable variation in the size of vessel, the nature of gear and technical and technological aids used, quality of maintenance of vessel and gear, skipper skills and strategies and other factors. Input controls therefore require administrative and monitoring capacity to determine how much effort is really being exerted by each fishing unit (Selig, et al., 2016).
Although, these two issues make it hard for input controls to reduce effort. Some form of input control is needed (FAO, 1997), to increase selectivity, and decrease fisheries impact on the environment. To better overcome problems associated with fishing, input controls might be used in combination of other measures.

3.3 Output control

Output control directly regulate the catch which can be taken within a fishery (FAO, 1997). Output control measures prescribe what is allowed by a fishery to be harvest from the fishing grounds (Morison, 2004). Output controls may be designed to restrict the quantity of fish being caught, but they may also be designed to restrict other qualitative characteristics of the catch (Morison, 2004). For example, constraints for fin cutting and removal in shark fishery (Poisson, et al., 2016). The purpose of a output control measure is to harvest the optimal amount of fish, which depends on the objectives set by the marine management (FAO, 1997). The measures that are overarched by output controls are: total allowable catch (TAC), and quota or catch share (hereafter referred to as quota) (Selig, et al., 2016).

3.3.1 Total allowable catch (TAC)

Total allowable catch (hereafter: TAC) is a catch limit for a fishery that applies for a defined period of time (Militz, et al., 2018). For example, a maximum amount of kilos fish from a specific specie that is allowed to be taken from a fishing ground. TACs are used separately or as the basis for more refined techniques such as quotas (Anderson, 1991), which will be discussed in the next section. A TAC counts for all the fishers within a fishery, which implies that total amount of fish caught by all the fishers within a fishery, may not exceed the TAC. In the case a TAC is surpassed, fisheries are sometimes closed, or fishers are fined for the additional caught fish (DiCosimo, et al., 2010). The objective of a TAC is to harvest the optimal amount of fish from a specific fishing ground. These optimum differ by species, thus TACs are set for specific species (Militz, et al., 2018).

In theory TACs should have a positive consequence on the amount of fish that is harvested within a specific fishing ground, by setting an optimum. However, the use of TACs as only marine measure was often found to be ineffective (Selig, et al., 2016). The negative consequences will explain why.

TACs have three major negative consequences. First of all, when TACs are not divided among the fishers within a fishery, they lead to a 'race to fish' (Eliston & Cao, 2006; Selig, et al., 2016; Emery, et al., 2014). Fishers will try to obtain the greatest possible share of the TAC before it is filled. (FAO, 1997). With an incentive to catch the greatest share of the TAC and gain a competitive advantage over their competitors, fishers are motivated to invest in additional fishing inputs. However, in the long-term, any innovation that produces a competitive advantage for a fishers, would be similarly adopted by others, resulting in a cycle of increased fishing costs, and dissipation of economic profit (Emery, et al., 2014).
Second, ensuring high compliance with TACs may require expensive monitoring and control systems (Selig, et al., 2016). This is due to two main reasons, the first is that the incentive on fishers to misreport their catches is high (FAO, 1997). In this way they can take more fish out of the sea than the TAC allows. The second, fish is often landed after sea processing. Since TACs are denominated in terms of total biomass, the processed weight of the fish must be converted to the biomass (Anderson, 1991). This is not a problem if all firms have the same recovery rate. However, often firms will have different recovery rates due to differences in processing abilities, or because they produce different types of landed-weight products (Anderson, 1991). Next to monitoring the fish that is landed, also the stocks need to be monitored. Regular reviews of TACs need to be carried out to assess whether existing limits on fishing are sustainable (militz, et al., 2018). This ongoing monitoring is expensive and requires much effort.

Third, in multi-species fisheries TACs lead to the problem of discarding (FAO,1997). As fishing results in a mixed catch of fish, that may include different TAC species (Klaer & Smith, 2011). The untargeted fish is thrown overboard, because this fish has less value to the fishers. It would therefore be easier to implement TACs in fisheries that have a single target species (Selig, et al., 2016).

In sum, total allowable catch (TAC) is a catch limit for a fishery that applies for a defined period of time. With the objective to harvest the optimal amount of fish from a specific fishing ground. However, in practice TACs are not effective, due to three major negative consequences, which contain: a 'race to fish', increased monitoring, and increased discards. To overcome some of these problems, TACs can be sub-divided into quotas (FAO, 1997).

3.3.2 Quota

With a quota measure, fixed proportions or shares of the TACs are allocated to individual fishers, enterprises or vessels (Emery, et al., 2014). Quota holders are then allowed to catch up to the portion of fish for which they have the rights (Lansford & Howorth, 1994). The objective of a quota is to harvest the optimal amount of fish from a specific fishing ground. Mostly quotas are transferable and can thus be bought, sold, or traded (Anderson, 1991). Quota holders can maximize their return by catching their quota and/or engaging in trade (Emery, et al., 2012).

Quotas have four major positive consequences. First of all, quotas have been largely effective in eliminating the race to fish inefficiencies (Emery, et al., 2014). With a quota every fisher has its own portion of the TAC, so trying to capture as much of the TAC as possible is not allowed.
Second, quotas reduce the fishing mortality on the most vulnerable bycatch species (Poisson, et al., 2016). Introducing quotas may change targeting behavior of fishers, otherwise fishers can't efficiently meet their quotas (Pascoe, et al., 2010). Without changing their targeting behavior, they will catch untargeted fish that are of less value with the quota.
Third, quotas lead to a more economical efficient fishing fleet (Lansford & Howorth, 1994). This is because of three reasons: first, transferability of quotas encourages less efficient holders to sell their quota to more efficient holders (Emery, et al., 2014). So the more efficient holders will remain in the fishery. Second, providing a guaranteed share of the TAC allows fishers to maximize value by increasing the quality of product through improved handling, adding value to the product, changing product form, or fishing when market prices are high (Emery, et al., 2014). Third, a guaranteed share allows flexibility in temporal effort allocation, allowing fishers to give greater consideration to weather conditions, vessel condition or other safety factors in deciding whether to fish (Emery, et al., 2014). However, transferability of quotas can reduce the effect of the last two reasons (Emery, et al., 2012).
Fourth, providing a guaranteed share of the TAC acts as an incentive for fishers to become stewards of the resource (Emery, et al., 2012). This is because a guaranteed share of the TAC will cause fishers to have an interest in ensuring that the value of their asset remains protected through sustainable management of the fishery (Emery, et al., 2014).

Quotas have three major negative consequences. First of all, quotas may lead to increased discarding of untargeted fish (Suuronen & Sarda, 2007; FAO, 1997; Pascoe, et al., 2010; Lansford & Howorth, 1994). Second, to ensure compliance with quotas expensive monitoring and control systems are required (FAO, 1997; Emery, et al., 2012; Lansford & Howorth, 1994; Pawson, et al., 2005). These two consequences are the same as under TACs, because the principle of limiting catches is the same. Therefore these two consequences will not be

discussed further for this measure. For more information there is referred to the previous section 3.3.1.
Third, transferable quotas might create situations where catch shares are unequally distributed (Lansford & Howorth, 1994). Small fishers fear losing access to the fishery, due to the transferability of quotas the quota system tends to create a fishery dominated by large quota holders (Lansford & Howorth, 1994). Where social goals are important, a fishery dominated by large quota holders can negate progress towards achieving these goals (FAO, 1997).

In sum, with a quota measure, fixed proportions or shares of the TACs are allocated to individual fishers, enterprises or vessels as quota units. With the objective to harvest the optimum amount of fish from a specific fishing ground. Quotas have four major positive consequences, they lead to: reduction of the race to fish, reduction in mortality of bycatch species, increases economic efficiency of the fishery, and increases the responsibility perception of fishers. Quotas have three major negative consequences, which are: increased discarding, increased monitoring, and unequal distribution of catch shares.

3.3.3 Conclusion output controls

To conclude on this section, TAC and quota are output control measures that regulate the catch which can be taken from a fishing ground. With the purpose to harvest the optimal amount of fish, and to reduce the race to fish. Although, the absence of such measures can result in lower profits, high discards, habitat impacts and other adverse effects (Suuronen & Sarda, 2007), output control may also result in increased discarding and monitoring. Switching to output controls therefore, will not necessarily eliminate the problems associated with managing a fishery through input controls (Eliston & Cao, 2006). Best is thus to make use of different measures in combination with output controls.

Table 1: Positive-, and negative consequences of marine management measures

		Positive consequences	Negative consequences
Technical measures			
	Marine protected areas (MPAs)	-Increased biomass inside a MPA -Increased protection of traditional fishing grounds	-Fleet displacement -Assuring compliance with the measure -Gathering of information
	Fish size limits	-Encourages fishing on fishing grounds that carry less smaller fish -Improved selectivity	-Increased discards -The truncation of age structure -Lost harvest of targeted fish
Input control			
	Limited entry	-Encouragement of long-term responsibility -Increased financing opportunities -Innovation of fisheries -Allows better economic decisions -Reduces fuel consumption	-No decrease of fishing effort -Unfair distribution of access licenses -Creation of a monopoly
	Gear restriction and -modification	-Increased selectivity -Decreased use of destructive gears -Reduced fuel consumption	-Increased investments -lost catch of target species
Output control			
	Total allowable catch (TAC)	-	-A 'race to fish' -Increased monitoring -Increased discards
	Quota	-Reduction of the race to fish -Reduction in mortality of bycatch species -Increases economic efficiency of the fishery -Increases the responsibility perception of fishers	-Increased discarding -Increased monitoring -Unequal distribution of catch shares

3.4 Conclusion

To conclude, there are three measure groups to reduce the impact of fisheries, these are: technical measures, input control, and output control. First, technical measures are restrictions or constraints to regulate the output which can be obtained from a specified amount of effort. The measures that fall under technical measures are: marine protected areas (MPAs), and limits on the size of fish that can be caught. Second, input control directly regulate the amount of effort which can be put into a fishery. The measures that fall under input control are: limited entry, and gear restriction and -modification. Third, output control directly regulate the catch which can be taken within a fishery. The measures that fall under output control are: total allowable catch (TAC), and quotas. The measures that are implemented in a fishery may be depended on the context, and the objective of marine management authority (Selig, et al., 2016). Therefore the measures used, differ per fishery.

Although, these measures have positive consequences, and are obviously necessary, they also often have negative consequences and cause additional problems for the fishery (table 1) (Valdemarsen & Suuronen, 2001). Since each measure has its own negative consequences it might be better to implement multiple measures (Selig, et al., 2016). In this way the negative consequences of one measure can be overcome by another (Stefanson & Rosenberg, 2005). However, minimizing impacts is almost never cost-neutral in the short-term, so any measure may cause reluctance among fishers to commit to such regulations (Jennings & Revill, 2007). Broad acceptance and practical implementation may depend largely on the ability of the industry to deal with the losses in the long-term (Suuronen & Sarda, 2007). The key to success is to be clear about the objectives and potential consequences when planning and implementing measures (FAO, 2011).

Chapter 4: The influence that measures have on sustainable development

Different marine management measures are implemented to reduce the negative impacts associated with fishing, as was discussed in chapter three. The objective of these measures match with the concept of sustainable development that was discussed in chapter two. Sustainable development was defined as: 'meeting the needs of the present without compromising the ability of future generations to meet their own needs'' (Brudtland, 1987). This definition formed the basis of the triple bottom line, which stated that organizations are sustainable, when they live up to the 'triple bottom line' of economic prosperity, environmental quality, and social justice. Also in fisheries the triple bottom line has become important, and has brought opportunities for long term sustainability within fisheries. This chapter will merge the themes discussed in chapter two and three, by giving answer to the research question: *What influence do the key marine management measures (FAO, 1997) have, on the sustainable development of fisheries?*

The main consequences of the all measures presented in chapter three (hereafter consequences), will be scored based on their influence on the triple bottom line of sustainability. From the literature it has become clear what the consequences are of marine management measures, and how sustainable development is operationalized in fisheries. Based on these information we can score each influence. This will be done by giving each consequence a rating for their influence on each of the dimensions of the triple bottom line. In other words, every consequence has an influence on each dimensions of the triple bottom line. These influences will be rated in this chapter. The rating contains four options:

- Positive – which means that the sustainability level of the triple bottom line dimension has increased. This will be marked with a plus sign (+).
- Negative – which means that the sustainability level of the triple bottom line dimension has decreased. This will be marked with a minus sign (-).
- Neutral – which means that the sustainability level of the triple bottom line dimension is maintained. This will be marked with a zero (0).
- Can't say – which means that adequate information is not available to assess the influence on the triple bottom line dimension. This will be marked with no sign.

It might be possible that an consequence has more than one influence on a triple bottom line dimension, in such a case this is marked with more than one sign.

To correctly asses the different influences of the consequences, the operational definitions should be specified for the three dimensions of the triple bottom line of sustainability. Based on these definitions the ratings for the influence can be given. They are the requirements which need to be met for receiving a specific rating.
First, economic sustainability emphasizes the pursuit of economic efficiency and increased wealth in the fishery (Charles, 1992), and the maintaining of company resources and capabilities over the long-term (Charles, 1994), as was explained in section 2.3.1. Therefore, to assess the different consequences on economic sustainability there is examined if company resources and capabilities are increased, decreased, or maintained.
Second, environmental sustainability of fisheries is based on the premise that the primary duty of marine management is to take care of the marine resources (Charles, 1992), as was explained in section 2.3.2. This involves conservation of individual stocks and species at levels that do not foreclose fishery options for future generations, and maintaining the carrying capacity and quality of marine ecosystems (Charles, 1994). Therefore, to assess the

different consequences on environmental sustainability there is examined if the carrying capacity and quality of marine ecosystems are increased, decreased, or maintained. The quality of the marine ecosystem contains the biomass of species, biodiversity, productivity of the ecosystem, habitats, and landscape of the seafloor.
Third, the central aspects of social sustainability in fisheries are: community welfare, fair distribution of resources, trust, and community involvement, as was explained in section 2.3.3. Therefore, to assess the different consequences on social sustainability there is examined if the community welfare, fair distribution of resources (e.g. access licenses), trust, and community involvement are increased, decreased, or maintained.

When assessing the different consequences, there are two other factors that will be taken into account. First, the consequence needs to be considered in the long term perspective, to be assessed on sustainability. When the influence of an consequence is not clear on the long term, or only has influence on the short term, no rating will be given. Second, consequences will be assessed partially on their direct influence on each of the dimension of the triple bottom line, detached from the other indirect influences of the same measure. For example, fish size limits has among others the following two consequences: 1) it encourages fishing on fishing grounds that carry less smaller fish, and 2) the truncation of age structure. The first has a direct positive influence on the environmental sustainability, the later has a negative direct influence on the environmental sustainability. However, the first stimulates also the second consequence, and thus has indirectly a negative influence on the environmental sustainability. This indirect influence will not be taken into account for this report.

4.1 Marine protected areas (MPA)

In section 3.1.1 MPAs were defined as: ''Any area of the intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment'' (Kelleher & Kenchington, 1999). In other words, MPAs are marine areas that are protected by marine management, with the main objective to sustain marine resources. They have different positive and negative consequences when implemented; these consequences are listed in table 2 (for more information see chapter 3.1.1). Table 2 also contains the ratings of each consequence on the three dimensions of sustainability.

Table 2: Ratings of the influences that the consequences of MPAs have on the three dimensions of sustainability. The left column contains the consequences that MPAs have, as presented in section 3.1.1

	Economic sustainability	Environmental sustainability	Social sustainability
Positive consequences			
Increased biomass inside a MPA	+	+	
Increased protection of traditional fishing grounds	0/-		0/+
Negative consequences			

Fleet displacement	-	-	-
Assuring compliance with the measure	-		
Gathering of information			

This paragraph will substantiate and discus the main different influences that the consequences of MPAs have on the dimensions of sustainability. First of all, increased biomass inside a MPA. The economical sustainability is positively rated because more fish can be harvested in and around MPAs. This leads to an increase in organization's capabilities. Next to this the environmental influence that this consequence has is also positively rated, because the capacity of the marine ecosystem is increased. However this only applies to the areas within, and close to the MPAs.
Second, the increased protection of traditional fishing grounds, the influences that this consequence has only apply to MPAs set with the objective to protect traditional fishing grounds. It has a neutral influence on economic sustainability of the traditional fishers. Since they are not competed out of the market by large scale fishers, the traditional fishing organizations can maintain their capabilities. However, this measure has a negative influence on the large scale fishers, which are denied access from specific MPAs. Therefore economic sustainability has a double rating. Next to that, increased protection of traditional fishing grounds has a neutral or positive influence on social sustainability, depended on the situation. Cultural fishery benefits of traditional fishing, and community welfare are maintained with the protection of traditional fishing grounds. However the measure could also strengthen cultural benefits of traditional fishing, as these practices get the opportunity to grow with protection.
Third, MPAs cause fishers to move to other fishing grounds, leading to the negative consequence of fleet displacement. This has a negative influence on all the dimensions of sustainability. Economic, because fishers capabilities are reduced, since their access is denied to some areas. Environmental, because fleet displacement increases fuel consumption, and thus the emission of greenhouse gasses. This reduces the quality of the ecosystem. Social, because equal distribution of resources is decreased, as small scale fishers with limited range capacity can't reach for more distant fishing grounds (Poisson, et al., 2016).
Fourth, assuring compliance with the measure increases costs, as it needs to be monitored if fishers comply to the regulations set for the MPA. This has a negative influence on economic sustainability, as the consequence reduces the financial capabilities of the marine management authority in a fishery.
Sixth, it is not clear what influence increased gathering of information has on the different dimensions of sustainability. It is likely that this increases costs as more monitoring has to be done. However that has not become clear by our research.

4.2 Fish size limits

As discussed in section 3.1.1, size limits focuses on the efficient capture of individuals greater than a given minimum size (Jennings & Revill, 2007). So that juvenile individuals that have not grown to their mature size, and non-targeted smaller fish are not caught as bycatch. Such regulation is implemented with a minimum landing size, which means that every fish harvested has to be bigger than the minimum landing size.

Table 3: Ratings of the influences that the consequences of fish size limits have on the three dimensions of sustainability

	Economic sustainability	Environmental sustainability	Social sustainability
Positive consequences			
Encouragement of fishing on fishing grounds that carry less smaller fish		+	
Increased selectivity		+	
Negative consequences			
Increased discards	-		
Truncation of age structure	-	-	
Lost harvest of targeted fish			

In this paragraph the influence of the five consequences that size limit regulations have, will be substantiated and discussed. First, size limit regulations encourages fishing on grounds that carry less smaller fish. This has a positive influence on environmental sustainability. Since less smaller fish is harvested, fish stocks can grow, which increases the carrying capacity of the marine ecosystem.

Second, increased selectivity has a positive influence on environmental sustainability, as less untargeted species are caught (Poisson, et al., 2016).

Third, increased discards has a negative influence on economic sustainability. Due to the size regulations fishers throw caught fish back into the sea (FAO, 2011), which they otherwise would have landed to sell. The size regulations thus reduce fishers organizational capabilities, therefore this consequence is rated negative for economic sustainability. Next to this, the discarded fish might not survive, due to increased predation into surface waters (Alverson, 1994). This should give the consequence a negative influence on environmental sustainability. However, these survival rates are largely unknown (Suuronen & Sarda, 2007), so no adequate assessment could be made for environmental sustainability.

Fourth, the truncation of age structure has a negative influence on both the economical- and the environmental dimension of sustainability. The consequence ensures that less big fish can be harvested by fishers (Jennings & Revill, 2007). Since this reduces fishers organizational capabilities, the influence on economic sustainability is rated negative. The consequence is also rated negative for environmental sustainability, because it reduces the environmental variation (Jennings & Revill, 2007), and thus the capacity and quality of marine ecosystems.

Fifth, the lost harvest of targeted fish, might lead to a decrease in earnings. However the consequence is not rated, because the influence is only for the short-term (Pawson, 2005). In the long term earnings might even grow, because with the size limit regulations juvenile species can grow to mature size, which will eventually increase the size of the individuals harvested (Pawson, 2005). This would influence economic sustainability in a positive way, as bigger fish can be sold.

4.3 Limited entry

As discussed in section 3.2.1, limited entry restricts access to open fisheries, by license limitation. License limitation restricts the number of vessels, fishers, gear, areas, or any combination thereof that are allowed to participate in fishing operations (Lansford & Howorth, 1994). The objective of limited entry measures is to reduce fishing effort.

Table 4: Ratings of the influences that the consequences of limited entry have on the three dimensions of sustainability

	Economic sustainability	Environmental sustainability	Social sustainability
Positive consequences			
Increased long-term responsibility		+	+
Increased financing opportunities	+		
Innovation of fisheries			+
Allows for better economic decisions	+		
Reduces fuel consumption	+	+	
Negative consequences			
No decrease in fishing effort	-	0	
Unfair distribution of access licenses	-		-
Creation of a monopoly	+/-		-

The eight consequences that limited entry has, have different influence on the dimensions of sustainability. First of all, the increased long-term responsibility to the resources and the fishery has two positive influences on sustainability. Due to the encouragement of responsibility to the resources, quality of marine ecosystems will increase. This has a positive influence on environmental sustainability. Next to that, the responsibility to the fishery increases social benefits for the fishery, and thus has a positive influence on social sustainability.

Second, increased financing opportunities will increase the financial capabilities of the organizations within a fishery (FAO, 1997), thus economic sustainability is positively influenced.

Third, innovation of the fishery might lead to increased capabilities for the organizations within a fishery. However, many innovations fail (Brix, 2015), which would in such a case reduce capabilities of organizations. Therefore no rating can be given to this consequence with regard to economic sustainability. Although, the innovation of a fishery might not have a positive influence for individual organizations, it does have a positive influence on social

sustainability. It provides a mechanism for new entrants into the fishery (FAO, 1997), which might be good for the community of a fishery.
Fourth, that limited entry allows for better economic decisions, increases the organizational capabilities, and thus has a positive influence on economic sustainability.
Fifth, reduced fuel consumption has a positive influence on both economic- and environmental sustainability. When fuel consumption is reduced, also the costs associated with fuel are reduced. Hereby the financial capabilities are increased, because the money saved on fuel can be spend on something else. Therefore, this consequence has a positive influence on economic sustainability. Since, it was mentioned before that increased fuel consumption had a negative influence on the environment, it seems evident that a decrease in fuel consumption has positive influence on the environment. With a reduction in fuel consumption also the greenhouse gasses emitted by vessels are reduced, which has a positive influence on environmental sustainability.
Sixth, limited entry measures do not decrease the fishing effort (Smith, 2004), this has a negative influence on economic sustainability. Fishers will invest more in their vessels to make them more efficient (Lansford & Howorth, 1994), so they can harvest at the same level as before the limited entry measure was implemented. Since the fishers will have more costs but no more revenues, their financial capabilities are reduced, which has a negative influence on economic sustainability. Next to that, because the limited entry regulation will not reduce the fishing effort, the impact on the marine ecosystems will remain the same. Capacity and quality of the marine ecosystem will be maintained, and therefore the influence that this consequence has on environmental sustainability is rated as neutral. However, when the level of fishing effort was already depleting fish stocks without the limited entry regulation, maintaining of this level will have a negative influence on environmental sustainability, while rated neutral. In such a case, the capacity and quality of marine ecosystems is degraded, and should be rated with a negative influence on environmental sustainability.
Seventh, the unequal distribution of access licenses has a negative influence on social sustainability. This because, some fishers will feel discriminated, due to unfair distribution of resources. Those who are excluded from the benefits or outcomes of the process often feel little motivation to adhere to the agreement (Halpern, et al., 2013). Therefore, unequal distribution of access licenses is rated negative for social sustainability. The measure has also a negative influence on economic sustainability, as those who are excluded from the benefits are reduced in their organizational capabilities.
Eighth, the creation of a monopoly can negate the progress towards achieving social goals (FAO, 1997), and thus has a negative influence on social sustainability. Next to that, it leads to a shift of economic benefits from more players to one player in the market. For the monopolist this is a positive influence on economic sustainability. However for the player that are competed out of the market this is a negative influence. Therefore the economic sustainability is double rated.

Although, the different consequences of limited entry measures have different influences on the dimensions of sustainability. These influences are depended on the implementation of the limited entry measure. Whether or not licenses are transferable, or have long duration, has implications for the consequences that the limited entry measure has. For more information there is referred to section 3.2.1.

4.4 Gear restriction and -modification

As discussed in section 3.2.2 gear restriction, and -modification change the status quo of the gear that is used in fisheries, by restricting, or modifying specific types of gear. This is done with the objective to avoid increased fishing effort through increased efficiency, and to avoid unwanted impact on non-commercial sizes, species or critical habitats.

Table 5: Ratings of the influences that the consequences of gear restriction and -modification have on the three dimensions of sustainability

	Economic sustainability	Environmental sustainability	Social sustainability
Positive consequences			
Increased selectivity		+	
Decreased use of destructive gears		+	
Reduced fuel consumption	+	+	
Negative consequences			
Increased investments	-		
lost catch of target species	-	+	

In this paragraph the influence of the five consequences that gear restriction and -modification have, will be substantiated and discussed. First of all, increased selectivity has already been substantiated and, discussed under section 4.2, and will thus not be further discussed here (for more information there is referred to section 4.2).

Second, gear restriction and -modification can decrease the use of destructive gears. Therefore fish biomass have the opportunity to recover (Campbell, et al., 2017), and habitats are not destructed. This has a positive influence on environmental sustainability, because the capacity and quality of marine ecosystems can increase.

Third, reduced fuel consumption is already substantiated and, discussed under section 4.3, and will thus not be further discussed here (for more information there is referred to section 4.3).

Fourth, gear restriction and -modification require more investments in gears, and thereby increase the costs. This has a negative influence on economic sustainability, because the financial capabilities of the fishers are reduced.

Fifth, lost catch of target species has negative influence on economic sustainability, because some marketable species or sizes are not caught anymore (Jennings & Revill, 2007). Without the gear restriction and -modification, these species would have been harvested and sold. With the measure these revenues are lost, decreasing the financial capabilities of the fishers. Although the consequence has a negative influence on economic sustainability, its influence is positive for environmental sustainability. With less fish caught, the capacity of the marine ecosystem can increase.

4.5 Total allowable catch (TAC)

As discussed in section 3.3.1 total allowable catch (TAC) is a catch limit for a fishery that applies for a defined period of time. With the objective to harvest the optimal amount of fish from a specific fishing ground.

Table 6: Ratings of the influences that the consequences of TACs have on the three dimensions of sustainability

	Economic sustainability	Environmental sustainability	Social sustainability
Negative consequences			
A 'race to fish'	-	-	
Increased monitoring	-		
Increased discards	-		

The three negative consequences that limited entry has, have different influence on the dimensions of sustainability. First of all, a race to fish will lead to a cycle of increased fishing costs, as was explained in section 3.3.1. This will reduce the financial capabilities of fishers, and thus has a negative influence on economic sustainability. Since, fishing effort will increase due to additional investments in fishing inputs (Emery, et al., 2014), more and more fish will be harvested. Leading to a decrease in capacity of marine ecosystems. Therefor a race to fish has also a negative influence on environmental sustainability.
Second, the increased monitoring to ensure that there is compliance with TACs, is expensive and requires much effort. It thus reduces the financial, and organization capabilities within fisheries. Therefore, the consequence has a negative influence on economic sustainability.
Third, increased discards has already been discussed in section 4.2 and will thus not be discussed here (for more information there is referred to section 4.2).

4.6 Quota

As discussed in section 3.3.2, with a quota measure fixed proportions or shares of the TACs are allocated to individual fishers, enterprises or vessels. With the objective to harvest the optimum amount of fish from a specific fishing ground.

Table 7: Ratings of the influences that the consequences of quotas have on the three dimensions of sustainability

	Economic sustainability	Environmental sustainability	Social sustainability
Positive consequences			
Reduction of the race to fish	+	+	
Reduction in mortality of bycatch species		+	
Increases economic efficiency of the fishery	0		+
Increases the responsibility perception of fishers		+	+

Negative consequences			
Increased discards	-		
Increased monitoring	-		
Unequal distribution of catch shares			-

In this paragraph the influence of the eight consequences that quotas have, will be substantiated and discussed. First of all, the reduction of the race to fish, will break the cycle of increased fishing costs associated with a race to fish (Emery, et al., 2014). Fishers will therefore have more financial capabilities, which is a positive influence on economic sustainability. The consequence will also reduce the fish harvested from the fishing grounds, which give fish stocks the opportunity to grow again. This leads to increased capacity for marine ecosystems, and thus the consequence has a positive influence on environmental sustainability.

Second, reduced fishing mortality of bycatch species will increase the capacity and quality of marine ecosystems, and thus has a positive influence on environmental sustainability.

Third, increased economic efficiency of the fishery has a positive influence on social sustainability. The most efficient quota holders will remain in the fishery, therefore the community welfare will increase. This is a positive influence for social sustainability. Since, the economic capabilities of the individual fishers is maintained, the influence on economic sustainability is neutral.

Fourth, the increase of responsibility perception of fishers has a positive influence on both environmental- and social sustainability. Fishers become stewards of the resource (Emery, et al., 2012), and will take care of the quality of the marine ecosystem. Resulting in a positive influence on environmental sustainability. The increased responsibility perception leads to more community involvement, and thus has a positive influence on social sustainability.

Sixth, increased discards has already been discussed in section 4.2 and will thus not be further discussed here (for more information there is referred to section 4.2).

Seventh, increased monitoring is already discussed in section 4.5, and will thus not be further discussed here (for more information there is referred to section 4.5).

Eighth, the unequal distribution of catch shares is an unequal distribution of resources, and thus a negative influence on social sustainability.

4.7 Conclusion

To conclude on this chapter, the different consequences have different influences on the three dimensions of sustainability. The influences were rated with four option – positive, negative, neutral, and can't say. In total 33 consequences were discussed, all having an influence on each dimension of the triple bottom line . Thus in total there were 99 influences. From these 99 influences, 52 were rated with 'can't say', which means that adequate information was not available to assess those influence. Most of the can't say ratings were given to influences on social sustainability. Further 24 influences were rated positive, indicating that sustainability had increased for this dimension. In total 22 influences were rated negative, indicating that sustainability had decreased for this dimension. And four influences were rated neutral, indicating that the sustainability level had been maintained for this dimension.

Ratings of the influences differ with the three dimension of sustainability (Table 8). First, influences on economic sustainability had the most negative ratings. From 33 consequences, fifteen had a negative influence on the economic sustainability. This is mostly because marine management measure restrict organizations in deploying their capabilities or they increase costs. For example, gear restrictions and -modifications increase the investments in gear that fishers have to make. However, next to those fifteen negative ratings, there were also seven positive-, and two neutral rated influences for economic sustainability.
Second, the influence that the different consequences had on environmental sustainability were mostly positively rated. From the 33 consequences, twelve had a positive influence on environmental sustainability, three had a negative influence, and one influence was rated neutral for this dimension. That the different consequences mostly have a positive influence on the environmental sustainability, is associated with the objective of marine management measures. Since marine management measures have the objective to reduce the impact of fishing activities, these measures will mostly have a positive influence on environmental sustainability. It is therefore notable that there are still three consequences that have a negative influence on environmental sustainability. These consequences are: fleet displacement for MPA measures, truncation of age structure for fish size limits, and a race to fish for TAC measures. Observing these three consequences, we could not found a general reasons why these three measures have a negative influence on environmental sustainability.
Third, for many consequences adequate information was not available to assess the influences that they have on social sustainability. From the 33 consequences, five had a positive influence, four had a negative influence, and one had a neutral influence on social sustainability. It is therefore hard to state something conclusive about the influence that marine management measures have on social sustainability.

A measure that stands out is TAC, which has only negative influences. It is therefore evident that this this measure is not effective for sustaining fisheries, and reducing the impact that fisheries have. Other results that stand out are the ratings on the consequences of limited entry, and quotas. The consequences of those two measures seem to have the most positive influences on all of the three dimensions of the triple bottom line.

Based on these assessment we can say that measures have relatively most negative influence on economic sustainability, and relatively most positive influence on environmental sustainability. To find a balance between these positive and negative influences, and sustain fisheries as effective as possible. It might be best to implement different measures, to compensate the negative consequences of one measure with the positive consequences of another measure.

Table 8: Distribution of ratings for each dimension of sustainability

	Economic sustainability	Environmental sustainability	Social sustainability	**Total**
Positive	7	12	5	24
Negative	15	3	4	22
Neutral	2	1	1	4
Can’t say	9	17	23	52
Total	33	33	33	99

Chapter 5: Conclusion

Concerns about the environmental impacts attributable to fisheries have increased over recent decades, and have in many instances resulted in the introduction of specific marine management measures (Revill, 2003). However, these measure are not always effective or do not always meet their objectives. The problem with this is that fish stocks can't be sustained without effective marine management measures. Therefore, we did research on the influence that marine management measures (FAO, 1997) have, on sustainable development of fisheries.

Sustainable development seeks to meet the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987). The triple bottom line of sustainability (Elkington, 1994) extended the concept of sustainable development with three dimensions of sustainability – economic, environmental, and social. Within fisheries these three dimensions of sustainability have also increased in importance, each dimension with its own objective. First of all, economic sustainability emphasizes the pursuit of economic efficiency and increased wealth in the fishery (Charles, 1992), and the maintaining of company resources and capabilities over the long-term (Charles, 1994). Second, environmental sustainability of fisheries is based on the premise that the primary duty of marine management is to take care of the marine resources (Charles, 1992). This involves conservation of individual stocks and species at levels that do not foreclose fishery options for future generations, and maintaining the carrying capacity and quality of marine ecosystems (Charles, 1994). Third, social sustainability is based on maintaining community welfare, fair distribution of resources, trust, and community involvement. Since, every dimension has its own sustainability objective, tradeoffs arise, making sustainability in fisheries complex and difficult to achieve. This can be seen from the different positive and negative influences that marine management measures have on the dimensions of the triple bottom line.

Three different groups of marine management measures can be distinguished – technical measures, input control, and output control (FAO, 1997). Each group contains different measures that can be implemented to reduce the impact that fisheries have. All these different measures have different consequences. For example, the measure 'fish size limits' has as consequence that selectivity is improved. Additional every consequence has its own influence on each of the dimensions of the triple bottom line. For example, the consequence of increased selectivity has a positive influence on environmental sustainability.

What influence the measures have on the sustainable development of fisheries, depends on what measure is implemented. Every measure has its own consequences, and thus its own influence on sustainability. It is therefore hard to give an unambiguously answer to the research question: *What influence do the key marine management measures (FAO, 1997) have, on the sustainable development of fisheries?*
However, we can say that measures have a positive influence on environmental sustainability of fisheries. As they improve the carrying capacity, and quality of marine ecosystems. On the other hand, measures have a negative influence on economic sustainability of fisheries. As measures restrict the fishery organizations in their capabilities, and cause for additional costs. Although measures have a negative influence on economic sustainability, without such measure fisheries could neither be economical sustainable. In such a case, fish stocks would be dramatically depleted, resulting in less fish to harvest, and therefore reduced capabilities for fishers (Standal, 2004). To say something conclusive on the influence that measures have

on social sustainability, too little information is available. It is therefore that we cannot make a statement on the influence that measures have on social sustainability.

Overall, we could say that marine management measures have a direct positive influence on the sustainable development of fisheries. Especially on the environmental sustainability, as most influences are positive for this dimension. However, influences on economic sustainability are particularly negative, and it is hard to state something conclusive on social sustainability. Nevertheless we can state that overall marine management measures have a positive influence on the sustainable development, as they are implemented with the objective to reduce ecological impacts of fisheries.

Chapter 6: Discussion

Although marine management measures have an overall positive influence on sustainable development, this influence is depended on which measure is used. As the case of the Pacific Island countries – presented in the introduction – explained, sometimes measures do not reach their goal. Some measures only have a positive influence on one dimension of sustainability, and a negative influence on another dimension.

All measures are prone to errors, therefore implementation of a single measure is not enough to ensure a sustainable fishery (Stefanson & Rosenberg, 2005). The source of these errors include implementation problems or measurement errors (Stefanson & Rosenberg, 2005). Management measures can for example: 1) be overwhelmed by increasing numbers of fishers (Selig, et al., 2016). Or 2) the other way around, catch capacity can grow due to increased efficiency, even though the number of vessels has been reduced (Stadal, 2004). Or 3) the lack of effective enforcement tools and activities will diminish the benefits of measures (lucchetti, et al., 2015). These errors create uncertainty on the effectiveness of the implemented measure. Implementing a single measure does therefore not ensure a positive influence on sustainable development of fisheries.

6.1 Multiple measures

Implementing multiple marine management measures can lead to greater success (Selig, et al., 2016). One measure will provide a 'backstop' for the other measure (Stefanson & Rosenberg, 2005), because of two reasons. First, the negative consequences of one measure would be compensated by the other measure (Stefanson & Rosenberg, 2005). Second, multiple measures reduce uncertainty on the effectiveness of the measures. This is because different measures are based on different sources of information and have different sources of uncertainty. These uncertainties are unlikely to be the same in practice. Combinations of measures may therefore provide a means of buffering against uncertainty, and reduce overall uncertainty of the measures (Stefanson & Rosenber, 2005). Next to that the implementation of multiple measure reflects a growing awareness that overcapacity in the fishing fleet is not profitable and a waste of society's resources (Stadal, 2004).
However, assessment tools and data collection programs are often inadequate to determine the expected outcomes from a given mix of multiple measures (Holland, 2003). Most fishery assessment models are designed only to make predictions on individual species. But, assessing the utility of a particular management measure such as the choice of mesh size or the location of an area closure usually cannot be done in isolation. This is because the biological and economic effects of one measure are dependent on how other measures are being used (Holland, 2003). Therefore an ecosystem approach to fisheries should fit better for assessing measure impacts.

6.2 Ecosystem approach to fisheries (EAF)

Ecosystem-based fishery management, also referred to as an ecosystem approach to fisheries (EAF), has emerged from the widespread feeling that traditional types of natural resource management have failed and that a new, more holistic way of understanding how ecosystems work is needed (Curtin & Prellezo, 2010). The reason why traditional management has failed, is that they have solely focused on specific stocks or sectors (Curtin & Prellezo; Degnbol & Jarre, 2004). Of all the various activities taking place in or around the seas such as shipping, energy exploration, fisheries, tourism and coastal development among others, there has only been management for each particular activity (Curtin & Prellezo, 2010), and for each fish stock specific (Degnebol & Jarre, 2004). EAF has been proposed as a more effective and holistic approach for managing world fisheries (Zhou, et al., 2010). It takes a broader perspective to that of conventional management by recognizing all ecosystem components and their interactions, and by focusing on the importance of ecosystem health in the exploitation of resources (Emery, 2012). This implies a corresponding extension of the scope, from the single stock being the target of marine management, to the ecosystem being the target (Degnbol & Jarre, 2004). EAF emphasizes a management regime that maintains the health of the ecosystem alongside appropriate human use of the environment for the benefit of current and future generations (Jeannings & Revill, 2007). EAF has thus two key goals: 1) conserving the structure, diversity, and functioning of ecosystems, and 2) satisfying societal and human needs and economic benefits (Zhou, et al., 2010). However, the difficulty of simultaneously addressing social, economic, and ecological objectives remains with EAF (Jeannings & Revill, 2007). Marine managers tasked with implementing EAF therefore always seek win – win solutions, where short-term catches or profits are not compromised by the requirement for long-term sustainability (Jeannings & Revill, 2007).

6.3 Limitations of the research

There are five major limitations in this report. First, the positive and negative consequences that marine management measures have, may depend on the implementation of the measure, or on the characteristics of the fishery. The consequences are thus context specific. For example, the consequences of limited entry measures depend on the implementation of the license limitation. The issue whether or not licenses are transferable, or have long duration, has implications for the consequence that the measure has. Hereby, it becomes hard to give a valid rating on the influence that the consequences have, as these influence differ per implementation of the measure. A means by which this could have been overcome, would have been to only use one type of implementation per measure. However, this would have made the report very specific, and might have omitted useful information. Another means by which this could have been overcome, would have been to split each measure, based on their implementation. However, due to time restrictions, it would have been impossible to put this into practice for this report.

Second, the rating that was used in chapter four, did not deploy a continuous measurement scale. No information was given on how strong each influence was. Therefore the scope of the influences within each dimension of sustainability has not become clear, and it might be that conclusive statements on the influences are not significant. For example, if the negative influences on environmental sustainability are stronger then the positive influences. It might be that a statement as: 'measures have a positive influence on environmental sustainability', is not true. This problem could have been overcome by using a continuous scale for the ratings. However, there was no information used to assess the strength of the influences in relation to each other. Next to that, if we would have used a continuous scale, than we should have used quantitative data – such as percentage increase in earnings or biomass – for operationalizing the influence on the dimensions of sustainability. Although, quantitative data could have been used to assess economic, and environmental influences. Social sustainability is operationalized with qualitative data, which would have made it very hard to create a continuous scale.

Third, related to the previous limitation, we did not use a scale to address the importance of each dimension for sustainable development. It is not clear how the different dimension relate to each other, and what their contribution is to sustainable development. However, creating such a scale was out of our reach for this report.

Fourth, although the three dimensions of sustainability were operationalized, and a procedure for assessing the influences was used. The final assessment was done at own discretion.

Therefore the assessment of the influences might be biased in some cases. This reduces the reliability of the report, as the assessment might not have been stable and consistent. However, we substantiate every assessment for each of the influences presented in this report, so our reasoning has been made clear.
Fifth, the research did not consider the indirect influences that the consequences of measures could have. Therefore it might be that some consequences do not have the influence on sustainability as rated in this report. This could have been overcome by including the indirect consequences in the assessment of the influences. However, this would have made it hard to give an unambiguously rating to the influences. Next to that, it is also not expected for a research as this. First the primary or direct influences need to be examined, before more in dept research can be done to the secondary or indirect influences.

6.4 Scientific relevance
The report gives an overall impression of the influence that marine management measures have on sustainable development. The information can be used by marine management authorities, when deciding what measures to use for sustaining their fishery. The report divides sustainable development in three dimensions – economic, environmental, and social. Therefore, marine management authorities can select the measures based on their influence on the different dimensions of sustainability. This is useful for management authorities, as implementation of measures depend on the objective of the marine management. If the marine management authority want to increase their economic position, then they select for measures with a positive influence on economic sustainability. Nevertheless, the danger with this is that in the long term sustainability might not be achieved, as the other two dimensions of sustainability are neglected.

Although, the report is useful for giving an overall impression of the influences that different measures have. More research is needed on the influence that different measures have in specific cases. As the characteristics of different fisheries and fishing grounds are diverse, the consequences that measures have will also be different in each case. Therefore the influence on sustainable development will be different in every fishery. Luckily a large body of literature on case specific measures already exists. However, these literature mainly focus on the implementation of one measures. It would be more useful if research had an ecosystem approach to fisheries, taking a broader perspective. More research on the ecosystem approach to fisheries will add value to the existing body of research.

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Appendix

Appendix 1

Figure 1: Criticized industries by decade. *Source:* Elkington (1994)

1960s

- Coal (mining and air pollution)
- Detergents
- Mining and quarrying
- Pesticides (eg DDT)
- Water (dams)

1970s

- Aerosols
- Airports
- Asbestos
- Automobile fuel efficiency
- Biotechnology (accidental release)
- Chemicals (eg dioxins, PBBs, PCBs)
- Coal (mining and air pollution)
- Deep sea fishing
- Detergents
- Heavy lorries
- Metals
- Motorways
- Nuclear power
- Oil tankers
- Packaging (eg glass bottles
- Passenger jets
- Pesticides/herbicides
- Pulp mills
- Tobacco
- Toxic waste
- Transport
- Water
- Whaling

1980s

- Aerosols
- Agriculture
- Airports
- Animal testing
- Automobiles exhaust emissions eg. lead)
- Biotechnology (deliberate release)
- Chemicals (eg dioxins, PBBs, PCBs)
- Coal
- Computers
- Deep sea fishing
- Detergents
- Fertilisers
- Forestry
- Incineration
- Insurance
- Landfill
- Motorways
- Nuclear power
- Oil tankers
- Onshore oil and gas
- Packaging
- Paints
- Pesticides/herbicides
- Plastics
- Pulp and paper
- Refrigeration
- Supermarkets
- Tobacco
- Toxic waste
- Tropical hardwoods
- Tuna fishing
- Water
- Whaling

1990s

- Aerosols
- Agriculture
- Air conditioning
- Airlines & airports
- Animal testing
- Armaments
- Automobiles (fuels, cars)
- Banking
- Biotechnology
- Catering
- Chemicals
- Coal
- Computers
- Crematoria
- Deep sea fishing
- Detergents
- Dry cleaning
- Electricity supply
- Electrical equipment
- Fashion
- Fertilisers
- Fish farming
- Fishing
- Forestry
- Incineration
- Insurance
- Investment
- Landfill
- Meat industry
- Mining
- Motorways
- Nuclear power
- Office supplies
- Oil tankers
- Onshore oil and gas
- Packaging
- Paints
- Paper
- Pesticides/herbicides
- Plastics
- Property
- Pulp and paper
- Refrigeration
- Schools
- Shipping
- Supermarkets
- Textiles
- Tobacco
- Tourism
- Toxic waste
- Transport
- Tropical hardwoods
- Tyres
- Water

Appendix 2

Table 1: Examples of gear innovations that may reduce the environmental impacts of fishing on bycatch species. *Source:* Jennings & Revill, (2007)

Reducing unwanted catches of fish and invertebrates
Larger diamond mesh
Escape panels
Square mesh codends/T90 codends
Grids
Sieve nets
Separator panels
Cutaway trawls
Blow-out panels
Headline/footrope manipulation
Sweepless trawl
Fykenet excluder
Selective longline hooks
Escape vents, traps, and pots
Benthic release panels
Magnetized gear components to repel elasmobranchs
Reducing unwanted catches of mammals
Grids
Altered float lines
Back down manoeuvre
Fykenet excluder
Pingers
Reduced unwanted catches of reptiles
Longline circle hooks
Grids (TED)
Sunken longlines
Reduce unwanted catches of birds
Streamers lines
Sinker weights
Setting tubes
Warp fixed bird scarers