# GHOSTING GHOST GEAR

## BIODEGRADABLE FISHING GEAR AS A MITIGATIVE SOLUTION TO ALDFG

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To my family and my partner, thank you for rooting for me always.
To my SIE family, thank you for a year that I will treasure for my lifetime.

**ABSTRACT**

Ghost fishing – otherwise known as abandoned, lost, or discarded fishing gear (ALDFG) – is a global problem that threatens the viability of the marine environment as a source of life for marine animals, and as a source of livelihood for those working within the industries that depend on it. Current remediation efforts are fragmented, lacking the global cohesion needed to address the problem at a macro-level. One mitigative measure that has been considered is the use of biodegradable fishing gear to replace conventional plastic-based gear currently used by the fishing industry. Biodegradable material, which, unlike plastic, disintegrates in the marine environment within a controlled timespan without toxifying it, serving two core functions with respect to ALDFG: 1) reducing the rate of plastic pollution by derelict fishing gear in the marine environment; and 2) reducing the kill rate of marine animals by derelict fishing gear given its shortened life span, as compared to plastic. Despite consideration of this potential solution, however, biodegradable fishing gear is not commonly available in the commercial fishing gear market. In light of this gap, this study sought to assess the appropriateness of biodegradable fishing gear as a solution for ALDFG through the design of a value creation framework for a potential social enterprise to undertake. Informed by primary and secondary research, the findings of the study revealed that filling the gap in the market with biodegradable fishing gear requires the development of a bio-based biodegradable material that is as technically efficient as conventional fishing gear, and that is price competitive in the current market. To create optimum value for the end user, an offering must be accompanied by extensive testing and proven results to ensure buy-in from the fishing industry; further, the product should provide an opportunity for the fishing industry to enhance its public image.

**TABLE OF CONTENTS**

**LIST OF FIGURES**

**LIST OF ABBREVIATIONS**

| Abb. | Abbreviation |
|---|---|
| ALDFG | Abandoned, lost, discarded fishing gear |
| GGGI | Global Ghost Gear Initiative |
| GESAMP | Group of Experts on the Scientific Aspects of Marine Environmental Protection |
| SE | Social Enterprise |
| SBMC | Social Business Model Canvas |
| VP | Value Proposition |
| MARPOL | International Convention for the Prevention of Pollution from Ships |
| IUU | Illegal, unregulated and unreported |
| UNEP | United Nations Environment Programme |
| FAO | Food and Agriculture Organization |
| IMO | International Maritime Organization |
| WWF | World Wildlife Fund |
| INdIGO | Innovative Fishing Gear for Ocean |
| RBV | Resource Based View |
| TOC | Theory of Change |
| GT | Global theme |
| T | Tenet |
| A | Activity |

# 1. INTRODUCTION

## 1.1 Context

### 1.1.1 The problem

Ghost fishing is a term used to describe "the ability of fishing gear to continue fishing after all control of that gear is lost by the fisherman[1]" (Smolowitz, 1978, pp.3). It occurs when fishing gear is either abandoned, lost somehow, or otherwise discarded into the marine environment, and is thus appropriately monikered: abandoned, lost, or discarded fishing gear (ALDFG) (Stelfox et al., 2016, pp.7). Considered to be "the most harmful form of marine plastic debris", ALDFG poses a major threat to the marine environment, as well as to the industries and livelihoods that depend on the ocean's resources (GGGI & Ocean Conservancy, n.d., pp.2).

Ghost fishing "unselectively catches wildlife, entangling marine mammals, seabirds, sea turtles, and sharks, subjecting them to a slow and painful death through exhaustion and suffocation" (Nicolas, 2020). With estimates of up to "1 million tons of fishing gear… discarded or lost in the ocean every year" (Nicolas, 2020), ALDFG depletes commercially valuable fish stocks, destroys marine life and habitats (Thomas et al., 2019, p.11), produces microplastics that negatively impact human health (Abelvik-Lawson, 2020), and poses an economic risk to a range of other industries, including fishing, tourism, and shipping (World Economic Forum, 2016, p.14).

ALDFG is not new; it has existed since the practice of fishing began. However, "increases in the scale of fishing operations and technologies used in recent decades mean that the extent and impact of ALDFG debris have increased significantly with the use of synthetic materials, the overall increase in fishing capacity, and the targeting of more distant and deepwater grounds" (Mcfadyen et al., 2009, pp.xiv).

[1] The term 'fisherman' in this context is used to identify an individual that sources fish from the ocean to sell for profit, and is used inclusively of all genders, despite the word 'man' as its suffix.

ALDFG is also not geographically discriminatory: “wherever humans practice fishing, gear can become abandoned, lost, or discarded” (GGGI & Ocean Conservancy, n.d., pp.4). It is estimated, for instance, that “11,436 tons of traps and 38,535 tons of gillnets [are] abandoned every year in South Korean waters” (World Wildlife Fund, 2020). Further, in the European Economic Area, around 12,000 tons of fishing gear accumulates each year, adding to the existing “550,000 tons of debris from the fishing industry[2]” that has amassed in the region since the 1950s (GGGI & Ocean Conservancy, n.d., pp.4).

### 1.1.2 Remediation efforts to date

The impacts of ALDFG are large in scale and global in scope. And, despite international recognition of the phenomenon, “there is currently no dedicated international instrument in place” to address the challenges posed by ghost fishing from a global perspective (GGGI & Ocean Conservancy, n.d., pp.4). Instead, most remediation efforts to date have existed in fragmentation, regulated in regional or national silos (GGGI & Ocean Conservancy, n.d., pp.4).

The measures that have been taken at these regional, national, and local levels to attempt to solve ALDFG are described in relevant literature as falling into one of three camps: preventative, mitigative, or curative (GESAMP, 2021, pp.61):

- **Prevention** of ALDFG aims “to avoid the introduction of ALDFG to the marine environment”, and includes strategies like “improvements in fisheries management (e.g. requirements for gear-marking and spatial and temporal management measures), implementation of best practices, and education and awareness raising initiatives” (GESAMP, 2021 pp.61-62).
- **Mitigation** of ALDFG aims to reduce “the impacts from ALDFG once it is in the ocean”, and typically involves a focus on gear design (GESAMP, 2021 pp.62).
- **Curative** approaches “focus on removing ALDFG from the environment”, taking the form of “lost gear reporting, identification, and recovery” (GESAMP, 2021 pp.62).

[2] ‘Fishing industry’ encapsulates fishermen and fishery management organizations and authorities.

### 1.1.3 Biodegradable fishing gear as a mitigative solution

The Global Ghost Gear Initiative (GGGI), the world's only and "foremost international collaboration working to address the problem of ghost gear" (NOAA, 2020) maintains a best practice framework as a guide for the management of fishing gear. As a best practice, GGGI recommends the use of biodegradable materials in fishing gear design as a mitigative measure to reduce the effects of ALDFG once it has been left at sea (GGGI, 2021).

When biodegradable fishing gear is left in the ocean, the idea is that it will completely break down "by microbes typically found in the aquatic environment" within a controlled timeframe (GGGI, 2021, pp.33) and essentially disappear. Instead of existing in the marine environment for indefinite periods of time as discarded fishing gear made from plastic does (Napper & Thompson, 2020), wreaking havoc on the marine environment in myriad ways, replacing the plastic in fishing gear with biodegradable materials would significantly reduce the negative and harmful impacts of ghost fishing.

In theory, this solution seems like a 'no-brainer'. For one, it is of the opinion of the researcher that, so long as we continue to operate under capitalist modes of production, in which profit-seeking is paramount, competition will exist, including at a geopolitical level between nations. The global community is not coordinated on the matter of ghost fishing (GGGI & Ocean Conservancy, n.d.); we cannot rely on – nor can we wait for – large-scale international regulation to address ALDFG, despite its apparent need.

Secondly, using alternative materials to replace plastics in response to the pressing threat of plastic pollution is a movement that is already underway. There is a growing market for products made from plastic alternatives, from organic cotton shopping bags, bamboo toothbrushes, and beeswax food wraps, to food packaging, disposable utensils, and automotive parts made from bioplastics (Green Value, 2023; and Earth.org, 2021). Developing biodegradable fishing gear would, thus, contribute to this growing movement.

Finally, “some degree of gear loss is inevitable given the hostile conditions of aquatic (especially marine) environments” (GGGI, 2021, pp.24). To that end, in accepting that no prevention method can fully solve the problem of ALDFG, a mitigative solution such as biodegradable fishing gear becomes all the more apt.

## 1.2 The gap

Interestingly, however, while some have considered the application of biodegradable fishing gear as a solution for ALDFG, biodegradable fishing gear is not commonly used in the commercial fishing industry today. This apparent gap in the market is, thus, the focus of this dissertation.

## 1.3 Project scope

### 1.3.1 Objectives

This dissertation proposes the development of biodegradable fishing gear as a mitigative solution to the challenges caused by ghost fishing. To assess whether this solution is appropriate, the researcher will investigate how a social enterprise (SE) might go about designing a profitable business for this purpose.

The dissertation will use the social business model canvas (SBMC) (Figure 5) as a design framework to build two of its eight elements: 1) key activities; 2) value proposition (VP).

### 1.3.2 Research question

To inform the design of these two elements of the social business model canvas, the researcher will conduct both primary and secondary research focused on understanding the fishing industry, guided by the following core question:

*How can a social enterprise fill the gap in the existing commercial fishing gear market with biodegradable fishing gear?*

## 2. LITERATURE REVIEW

The literature review is organized according to the following thematic structure:

| Topic groups | Concepts in review |
|---|---|
| Ghost fishing: Abandoned, Lost, Discarded Fishing Gear (ALDFG) | - An overview of the causes, impacts, costs, and efforts to solve ALDFG |
| Fishing gear design as a mitigative measure to ALDFG | - Mitigation<br>- Circular economy<br>- Natural materials<br>- Bioplastics industry<br>- Development and adoption of biodegradable fishing gear |
| Theories of competitive advantage | - Porter's Five Forces<br>- Barney's Resource Based View |
| Social Business Design | - Social business model canvas<br>- Value creation |

### 2.1 Ghost fishing: Abandoned, Lost, Discarded Fishing Gear (ALDFG)

#### 2.1.1 Defining ALDFG

The acronym ‘ALDFG’ intends to capture the various ways in which fishing gear is left at sea. The GESAMP – the “Group of Experts on the Scientific Aspects of Marine Environmental Protection” – clarifies this delineation:

- “‘Abandoned fishing gear’ means fishing gear over which that operator/owner has control and that could be retrieved by owner/operator, but is deliberately left at sea due to force majeure or other unforeseen reasons.
- ‘Lost fishing gear’ means fishing gear over which the owner/operator has accidentally lost control and that cannot be located and/or retrieved by owner/operator.
- ‘Discarded fishing gear’ means fishing gear that is released at sea without any attempt for further control or recovery by the owner/ operator” (GESAMP, 2021, pp.12).

### 2.1.2 Defining ‘fishing gear’

As defined by the International Convention for the Prevention of Pollution from Ships (MARPOL), ‘fishing gear’ indicates “‘any physical device or part thereof or combination of items that may be placed on or in the water or on the seabed with the intended purpose of capturing or controlling (for subsequent capture) or harvesting, marine organisms’” (GESAMP, 2021, pp.11) including “surrounding nets, seine nets, trawls, dredges, lift nets, falling gear, gillnets and entangling nets, traps, hooks and lines, and miscellaneous gear” (GESAMP, 2021, pp.13).

As Mcfadyen et al. note, generally “gillnets and pots/traps are most likely to ‘ghost fish’ while other gear, such as trawls and longlines, are more likely to cause entanglement of marine organisms, including protected species, and habitat damage” (Mcfadyen et al., 2009, pp.iv). Acknowledging these differences in fishing gear types, for the purposes of this dissertation, the term “fishing gear” is used non-discriminatorily, encompassing all types of fishing gear .

### 2.1.3 Causes of ALDFG

A study examining global rates of fishing gear loss estimates that “5.7% of all fishing nets, 8.6% of all traps, and 29% of all [fishing lines]” are abandoned, lost, or discarded into the environment every year (Richardson et al., 2019, pp.1218); further, “46% of the Great Pacific Garbage Patch[3] is made of fishing gear” (Lebreton et al., 2018, pp.1).

So, why is this happening?

ALDFG can be caused by a range of factors: “adverse weather; operational fishing factors including the cost of gear retrieval; gear conflicts; illegal, unregulated and unreported (IUU) fishing; vandalism/theft; and access to and cost and availability of shoreside collection

[3] Also known as the ‘Pacific trash vortex’, the Great Pacific Garbage Patch is a massive collection of marine debris in the North Pacific Ocean, accumulating “because much of it is not biodegradable” (National Geographic Society, 2023).

facilities", citing "weather, operational fishing factors, and gear conflicts" as the most significant of the reasons (Mcfadyen et al., 2009, pp.iv). See Figure 1.

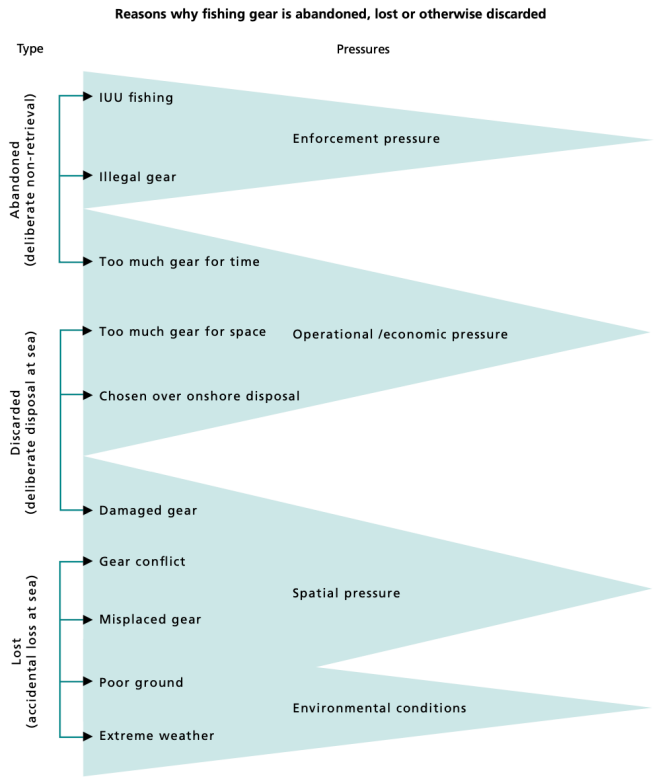


Figure 1: Causes of ALDFG (Mcfadyen et al., 2009, pp.48)

### 2.1.4 Impacts of ALDFG

The global marine ecosystem "provides a wealth of ecosystem services… including food provision for billions of people, carbon storage, waste detoxification, and cultural benefits" (Beaumont et al., 2019, pp.189). ALDFG poses a threat to the "continued supply of these ecosystem services" (Beaumont et al., 2019, pp.189) by contributing to plastic pollution in the ocean. A reduction in the marine ecosystem's service delivery would "impact the wellbeing of humans across the globe, owing to the loss of food security, livelihoods, income and good health" (Beaumont et al., 2019, pp.189).

Beyond service delivery for humans, ALDFG is detrimental to the well-being of marine animals, their ecosystems, and their habitats through its physical longevity in the ocean. Given the extent of impacts that ALDFG generates, this dissertation summarizes them thematically in two sets: 1) ramifications of plastic pollution; 2) impacts of ghost gear as a killing device.

#### 2.1.4.1 Plastic pollution

ALDFG is a "major component of sea-based marine litter", a concept widely studied and defined as "'any persistent, manufactured, or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment as a result of human activity'" (GESAMP, 2021, pp.9). Plastic litter is a subset of marine litter; it is a type of pollution that is particularly concerning "given [plastic's] inherent strength and durability that allows it to persist in the marine environment for indefinite periods of time" (GESAMP, 2021, pp.9), and is now universally "recognized as a major global environmental burden" (Feary et al., 2020, pp.4).

And, because most fishing gear today is made from "fossil-based plastics" (Impact Solutions, 2020), ALDFG increases the accumulation of plastic pollution in the ocean (GESAMP, 2021, pp.9), "with disproportionate negative impacts to wildlife, marine and coastal habitats, and food security" (Richardson et al., 2022, pp.1). There is currently no definitive "figure for the proportion of ALDFG in marine litter", but a "crude approximation" is 10% (Mcfadyen et al., 2009, pp.1). With that said, the Ocean Conservancy discounts this outdated estimate, noting that, on North-East Atlantic beaches alone, fishing gear represents 20% of the litter found (GGGI & Ocean Conservancy, n.d., pp.2), suggesting a higher proportion globally.

Figure 2 details the direct risks that plastics pose, citing the various impacts to which ALDFG contributes provided its plastic construction. As corroborated by the GESAMP, the "harm caused by plastic marine litter is **social** (e.g. causing a reduction in aesthetic value and public safety), **economic** (e.g. conferring cost burdens to tourism, damage to vessels, fishing gear and facilities, losses to fishing operations, cleaning costs) and **environmental** (e.g. morbidity and mortality caused to living resources, habitat degradation and destruction)" (GESAMP, 2021, pp.10). Figure

2 adds to the GESAMP's summary by citing another critical effect of plastic pollution: the biological threat that plastics cause to **human health** when they enter the marine environment.

#### 2.1.4.2 Ghost gear as a killing device

In addition to the destruction posed by plastic pollution, ALDFG is dangerous given its ability to exist in the marine environment for hundreds of years after its intended use. Perhaps the "most visible effect" of ALDFG is the "entanglement" of marine animals which hinders their "ability to move, feed, and breathe" (Napper & Thompson, 2020, pp.4). Additionally, marine animals can ingest marine plastics, either mistaking them for food or ingesting them as microplastics (Napper & Thompson, 2020, pp.4).

Further, "marine litter can also cause damage to benthic environments (Moore 2008), affect biodiversity (Derraik 2002) and potentially lead to the loss of ecosystem functions (Ten Brink 2009)" (Mouat et al., 2010, pp.9). The 'rafting' of invasive non-native species on floating ghost gear is of particular concern, and has been "recognised as one of the greatest threats to global biodiversity" (Mouat et al., 2010, pp.12).

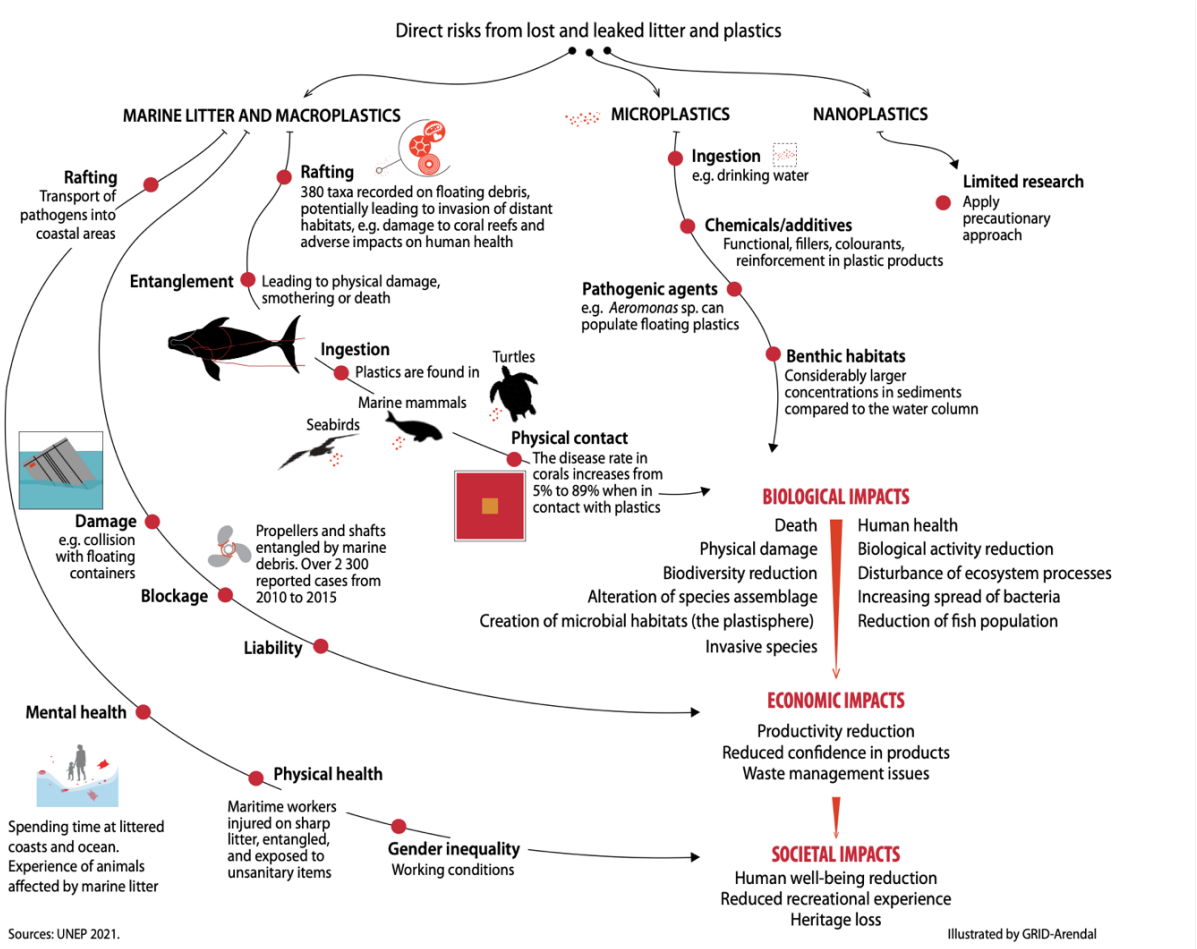


Figure 2: Risks associated with plastic litter (UNEP, 2021, pp.7)

### 2.1.5 Costs of ALDFG

In terms of identifying the specific costs of ALDFG - and not just of plastic pollution in general - the data is disparate and challenging to quantify, “owing to insufficient available research” (UNEP, 2021 pp.11). As such, “‘we do not have a complete picture of the magnitude of economic damages associated with’” marine litter, let alone with ALDFG specifically (Mouat et al., 2010, pp.21). With that said, Appendix 3 lists several individual examples of reported costs generated from ALDFG to provide a broad sense of its financial impacts to various actors and industries.

### 2.1.6 Efforts to address ALDFG

ALDFG has received increasing attention across the globe as “exacting a substantial toll on the world’s oceans” (Richardson, 2022, pp.1). As such, several international organizations have responded with the development of “hard and soft law measures to prevent and reduce ALDFG” (Richardson, 2022, pp.1), including the “United Nations (UN) Food and Agriculture Organization (FAO), the International Maritime Organization [(IMO)], and the UN Environment Programme [UNEP]” (Richardson, 2022, pp.1).

In fact, the intent of Goal 14.1 of the United Nations 2030 Agenda for Sustainable Development, for instance, is to “significantly reduce marine pollution of all kinds, including marine debris, by 2025” (GESAMP, 2021, pp.9). Another example of paramount importance is the Convention for Prevention of Marine Pollution (MARPOL), which is an IMO-led initiative “against sea pollution from boats” (oikos Lisbon, 2021).

Yet, despite widespread international recognition, there is a “paucity of ALDFG legislation, legislative elements, or even implementing rules” on a global scale (Broderick et al., 2020, pp.39). Further, the legislation that does exist with respect to ALDFG is “immensely fragmented and ineffective” (oikos Lisbon, 2021). WWF agrees, noting that “there are still glaring gaps in global regulation, and existing frameworks lack articulated and clear global targets” (World Wildlife Fund, n.d.).

Noting the lack of global cohesion on the matter, the measures that in fact have been pursued generally fall under one of three approaches, as described in 1.1.2: preventative, mitigative, or curative. The following section of this dissertation will focuses specifically on mitigation, given its association with biodegradable fishing gear design.

## 2.2 Biodegradable fishing gear as a mitigative approach to ALDFG

### 2.2.1 Mitigation

A list of remediation measures organized by type is noted in Figure 3. Grimaldo et al. note that "many scientists argue that efforts focusing on preventive methods… are likely to be" the most effective (Grimaldo et al., 2018, pp.2246); others note that "preventing fishing gear loss is the top priority" (World Wildlife Fund, n.d.). Curative approaches are also growing in popularity (WWF, 2020, pp.11). Mitigation, on the other hand, which seeks to "minimize the damage caused by fishing gear if and when it does become ALDFG" is comparatively less pursued (GGGI, 2021, pp.32).

**It is the researcher's position, however, that mitigation is an equally important tactic to consider alongside preventative and curative measures.** As further discussed in 1.1.3**,** the rationale for this perspective is three-parted: 1) true global cohesion is unrealistic; 2) there is a growing market for plastic alternative products; and 3) losing fishing gear at sea is inevitable to a certain extent.

For these reasons, this dissertation focuses exclusively on mitigation as an approach to combatting ALDFG, and specifically on improving fishing gear design through the use of biodegradable materials to "reduce the incidence and duration of ghost fishing" (GESAMP, 2021, pp.62).

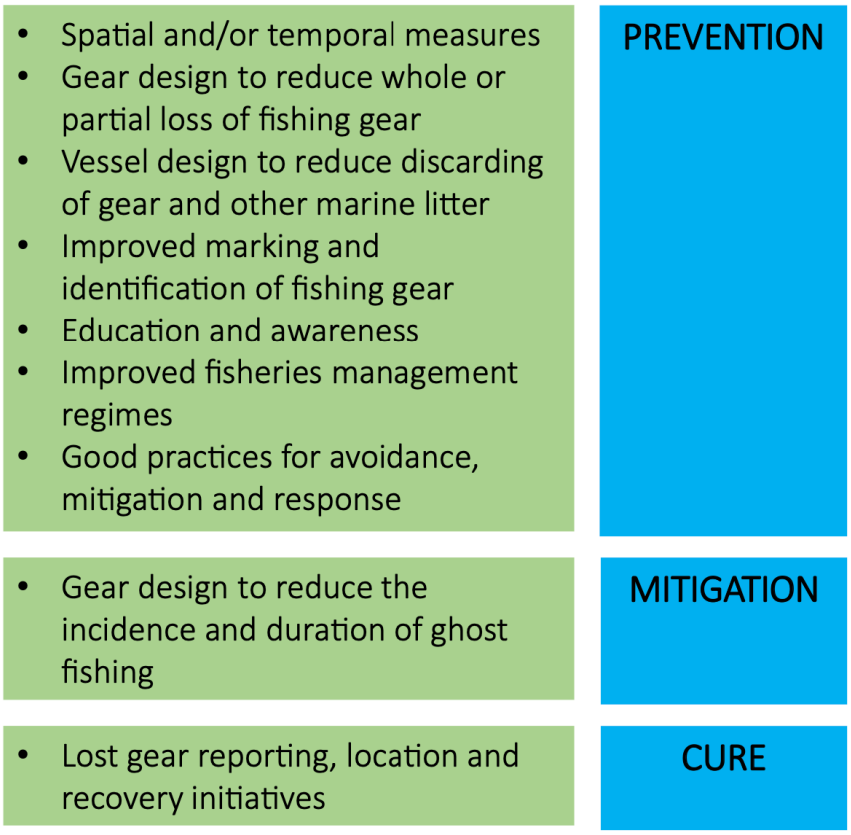


Figure 3: Remediation measures (GESAMP, 2021, pp.62)

### 2.2.2 Circular economy

As a design framework, biodegradable fishing gear is rooted in the principles of circular economy. As defined by the Ellen MacArthur Foundation, a circular economy is "restorative and regenerative by design", aims to "decouple growth from the consumption of finite resources", and is based on three principles: 1) eliminating waste and pollution; 2) circulating products and materials; and 3) regenerating nature (Ellen MacArthur Foundation, n.d.).

Many have recognized the need "to develop a circular economy for fishing gear" (Drakeford et al., 2023, pp.11). In fact, in its *Study on Circular Design of the Fishing Gear for Reduction of Environmental Impacts*, the European Commission clarifies how the concept of circular economy can inform fishing gear design: "circular fishing gear (and its assembling elements) design aims to reduce (or avoid) raw material input and generate less waste while maintaining

and possibly improving gear components functionalities"; it "replaces the idea of a product's 'end-of-life' with 'the end of its period of primary use'" (Feary et al., 2020, pp.45).

### 2.2.3 Biodegradable fishing gear

The core logic behind using biodegradable materials in fishing gear design is that, when the gear is abandoned, lost, or discarded at sea, having a biodegradable construction provides for its decomposition into natural elements that "are non-toxic for the marine environment" (International Seafood Sustainability Foundation, n.d.). Biodegradation occurs when a "material or substance" – in this case fishing gear – "is subject to a chemical process during which microorganisms in the environment" (International Seafood Sustainability Foundation, n.d) – "such as bacteria, fungi and algae" (Standal et al., 2020, pp.5) – "convert materials into natural substances – such as water, carbon dioxide, and decomposed organic matter" International Seafood Sustainability Foundation, n.d.).

While the specific amount of time it takes for biodegradation to occur is dependent on the properties of the material used in the construction of the fishing gear, as well as on the particular environmental conditions interacting with the material, the idea is that biodegradable gear will break down much quicker than their conventional, plastic-based counterparts (current studies mention two years as an approximate baseline) (Wilcox & Hardesty, 2016). Conventional fossil-based plastic, on the other hand, can "fragment to microplastics over timescales of hundreds of years" in the ocean (KIMO International, 2010, pp.8).

In terms of functionality, biodegradable fishing gear is intended to function in the same way as conventional plastic-based gear to catch fish and other seafood for commercial profit. As described above, the two fundamental differences between biodegradable fishing gear and conventional fishing gear are its biodegradable composition and, consequently, its comparatively shorter life span. When biodegradable fishing gear is left at sea, it will break down and "disappear after a specific amount of time" (Standal et al., 2020, pp.2). As such, replacing plastic gear with biodegradable gear can "significantly reduce ghost fishing … caused by non-degradable" plastic gear (Standal et al., 2020, pp.5).

### 2.2.4 Natural materials

Before plastic was introduced to the fishing industry, fishermen used a range of natural materials to develop their gear. See Appendix 4 for further details.

### 2.2.5 Bioplastics

Bioplastic materials represent another alternative for replacing plastic fishing gear. Given their comparable properties and functions to conventional plastic – and thus their potential as a viable replacement – this dissertation focuses on the use of bioplastics as the base material for biodegradable fishing gear, as opposed to natural materials.

Conventional plastics are mostly made from fossil-based resources (Rosenboom et al., 2022, pp.117), and comprise most current fishing gear; in contrast, bioplastics are a type of plastic "made wholly or in part from renewable biomass sources" (Ashter, 2015, pp.251) like plants, starches, and sugars (Zhang, 2022). They are designed to function in similar capacities as are fossil-based plastics, and are commonly used in "packaging, agriculture, and horticulture, composting bags, and hygiene" for example (Ashter, 2015, pp.251).

Conventional plastics are unquestionably harmful to the environment and to human health (Figure 2). Bioplastics, on the other hand, can exhibit a "lower carbon footprint" than fossil-based plastics, given their construction partially or fully from renewable biomass sources (Rosenboom et al., 2022, pp.117). Moreover, types of bioplastics – although not all – are also biodegradable under certain conditions (Rosenboom et al., 2022, pp.117).

As an important caveat, Krieger notes that the term "bioplastics" is often misunderstood, as it is "actually used for two things: **bio-based plastics** (plastics made at least partly from biological matter) and **biodegradable plastics** (plastics that can be completely broken down by microbes in a reasonable timeframe, given specific conditions)" (Krieger, 2019). However, "not all bio-based plastics are biodegradable, and not all biodegradable plastics are bio-based" (Krieger, 2019).

Within this complexity, this dissertation looks specifically at the feasibility of using bio-based and biodegradable plastics in fishing gear design, those that fall in the lower right quadrant of Figure 4. To do otherwise – to use a bioplastic material that is derived from fossil-based resources, or to use a bio-based material that does not biodegrade – would serve to contribute to, rather than mitigate against, the problems associated with ALDFG.

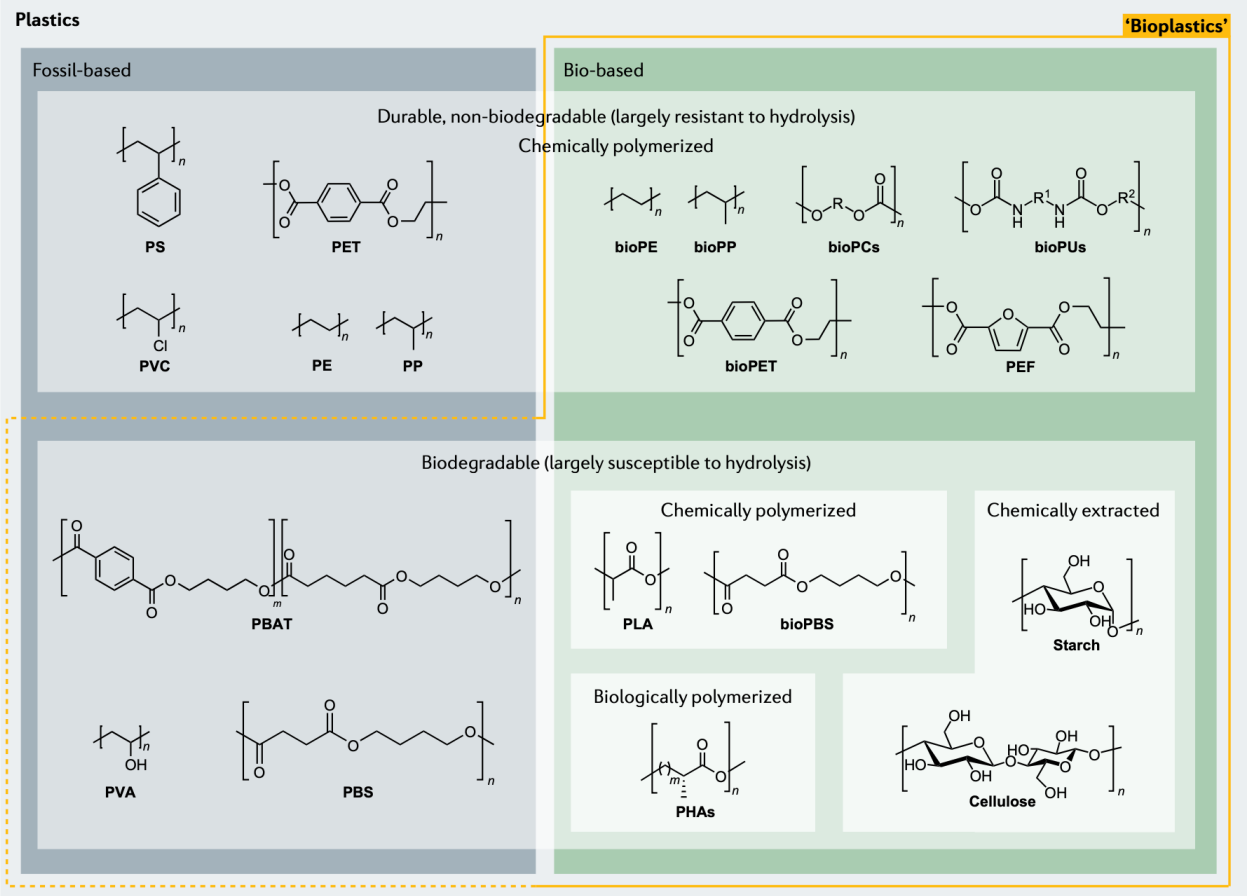


Figure 4: Fossil-based x bio-based x biodegradable (Rosenboom et al., 2022, pp.118)

### 2.2.6 The development of biodegradable fishing gear

Some have attempted to develop biodegradable fishing gear, both from natural-based sources and from bioplastic materials, to reduce the impacts of ghost fishing. These instances, however, are limited (GGGI, 2021, pp.32).

In terms of bioplastic applications, PCL and PHA "were tested in escape rings on crab pots" on the East Coast of the United States "and did not adversely affect catches" (Brakstad et al., 2022, pp.1). Additionally, "the use of biodegradable resin" made from PBS and PBAT, which are fossil-based resources, "for the funnel of the conger eel pot" was "successfully tested in South Korea" (GESAMP, 2021, pp.64).

Kim et al. tested a biodegradable gillnet made from a combination of PBS and PBAT in South Korea's yellow croaker fishery, comparing its physical properties, degradability, and fishing performance to "driftnets made of conventional nylon" (Kim et al., 2016, pp.309). Results revealed that the biodegradable monofilament degraded within two years, and exhibited "slightly inferior physical properties compared to the conventional nylon monofilament"; interestingly, however, these differences did not yield poorer fishing performance - in fact, the biodegradable nets' catch rate was 98.6% as compared to the conventional nets (Kim et al., 2016, pp.316).

Researchers in Norway have also developed and tested a biodegradable gillnet made of biodegradable resin (PBSAT) (Grimaldo et al., 2019, pp.67). In comparing PBSAT gillnets with conventional nylon gillnets, researchers found that the nylon nets "caught 21% more fish … than the biodegradable gillnets" (Grimaldo et al., 2019, pp.67). This attempt, which proved to be less successful than the South Korean case in terms of catch performance, demonstrates the challenge of using the same material in different contexts and fisheries, with varying thermal and physical conditions present at sea.

Aside from these studies, there are several organizations that are actively working on developing bioplastic materials for various types of fishing gear today. SEALIVE, for instance, which is a European innovation project, is in the process of developing "new bio-based plastic solutions

using sustainable biomass sources and efficient processing technologies" for fishing gear, like biodegradable oyster mesh-bags and fishing nets (SEALIVE, n.d.). Further, the Innovative Fishing Gear for Ocean project (INdIGO), which is funded by the EU and kickstarted in 2020, is attempting to "develop the first biodegradable fishing gear with a finite lifespan" (INdIGO, n.d.).

### 2.2.7 The adoption of biodegradable fishing gear

Despite attempts to develop biodegradable fishing gear, its adoption is not common in commercial fisheries today. Drakeford et al. notes that "biodegradable gillnets are currently used in commercial fisheries in China, Norway, Japan, and South Korea and trap type gear in the USA and South Korea" (Drakeford et al., 2023, pp.10). Beyond these noted cases, however, information is limited about the commercial availability and use of biodegradable fishing gear within these countries.

One explanation for this apparent gap could be technical, in that no one has developed biodegradable fishing gear which functions as well as plastic-based alternatives (Drakeford et al., 2023, pp.8). Others cite the high cost of biodegradable fishing gear as a significant hindrance (Standal et al., 2020). Another perspective notes the lack of coordinated governance to incentivize the change as the problem (Standal et al., 2020, pp.7).

Using this secondary research as a baseline, the study's primary research attempts to glean more information explaining why it is that biodegradable fishing gear has not yet been brought to market.

## 2.3 Theories of competitive advantage

As this dissertation focuses on investigating the fishing industry to determine how a social enterprise might fill the gap in the market with biodegradable fishing gear, the concept of competitive advantage is an important theoretical consideration. This dissertation consults the works of Michael Porter and his Five Forces model, as well as Jay Barney, who introduced the Resource Based View (RBV).

### 2.3.1 Porter: Five Forces

According to Porter, an individual firm's performance is necessarily associated with five forces that exist in all industries in different configurations: the threat of new entrants, the bargaining power of buyers, the threat of substitute products or services, the bargaining power of suppliers, and rivalry among existing competitors (Porter, 2008). It is the structure of an industry that "drives competition and profitability, not whether an industry produces a product or service, is emerging or mature, high tech or low tech, regulated or unregulated" (Porter, 2008, pp.80).

As such, to determine its appropriate competitive positioning, a firm must understand its "industry's underlying structure" as it relates to each of the five forces (Porter, 2008, pp.80). In this view, performance is a product of managing an external environment, understanding how a firm can best navigate competitively within an industry's existing constraints and opportunities.

### 2.3.2 Barney: Resource Based View

Barney's Resource Based View, on the other hand, finds that competitive advantage derives from within the firm, from its ability to mobilize its internal capacities and available resources in ways that enable it to outperform others (Knudsen, 1996). Irrespective of the industry in which it operates, RBV holds that a firm can develop a 'sustained competitive advantage' from its "valuable, rare, imperfectly imitable, and non-substitutable resource endowments" (Barney, 1991, pp.117).

Together, these distinctive yet complementary perspectives provide a comprehensive framework for assessing strategy, especially with respect to how to enter the market competitively. As Martin summarizes, the Fives Forces argument provides a 'where-to-play' strategy, whereas RBV tells us 'how-to-win' (Martin, 2015, p.2). Both are important considerations for this dissertation in determining how to fill the gap in the market with biodegradable fishing gear.

## 2.4 Social Business Design

### 2.4.1 The SBMC

As an adaptation from Osterwalder et al.'s original 'business model', the SBMC is a tool for the social entrepreneur seeking to design an enterprise to achieve both social and financial impact. The template used for this study (Figure 5) includes eight 'elements', which, when taken together, demonstrate "the logic of how a company intends to deliver value and make money" (Strategyzer, n.d.).

Given its limitations in scope, this dissertation focuses on designing two of the eight elements – its key activities (2) and VP (4) – both of which are concerned with creating value for the SE's end user.

The design of this SE's key activities is (element #2) is grounded in an evidenced-based Theory of Change (TOC), which was developed using insights from this dissertation's research, and which can be found in Appendix 6.

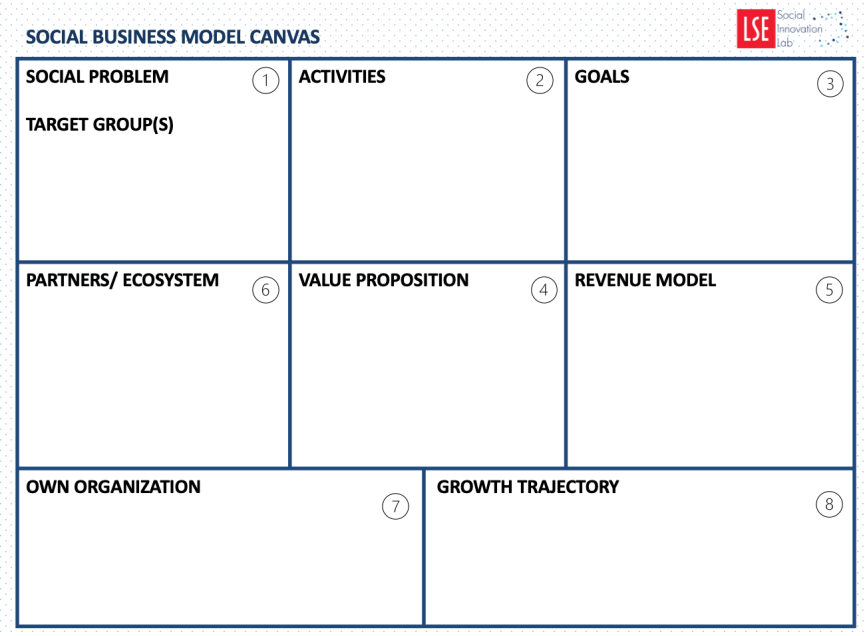


Figure 5: Social Business Model Canvas

### 2.4.2 Value creation

Given this dissertation's focus on designing the SE's key activities and value proposition, the concept of value creation is of particular importance. Taking Haksever et al.'s definition of value to be "the capacity of a good, service, or activity to satisfy a need or provide a benefit to a person or legal entity" (Haksever et al., 2004, pp.292), we can understand value creation in this context to be the SE's ability to configure its offering – which includes its product (biodegradable fishing gear) and its activities – to ensure the needs of its end users are satisfied, or to provide a benefit to them.

The benefit created for the customer through the SE's activities is, effectively, the customer value proposition. As Johnson et al. describe it, the VP is an expression of how an enterprise helps "customers get an important job done" (Johnson et al., 2008). To create value for the fisherman, then, the SE's activities must be designed in a way that supports the fisherman in his quest to do his job, which is sourcing fish from the sea to sell for profit (Borgstrom et al., 2023).

# 3. METHODOLOGY

## 3.1 Research Approach + Epistemology

In considering how one might fill the gap in the existing commercial fishing market with biodegradable gear to address the issues generated by ALDFG, one must seek to understand why such a solution has not already been adopted, despite its seeming potential. As such, this paper appropriately applies an abductive approach to its research methodology, a method introduced by Charles S. Peirce which aims "to find the most logical solution and useful explanation for phenomena" (Thompson, 2022, pp.1411). As it is a method of reasoning that can be most usefully employed "in situations of uncertainty; when we need an understanding or explanation of something that happens or some effect" (Brinkmann, 2013, pp.56), it is thus the most suitable approach for this study.

The accompanying philosophy of abduction holds that "research is never finished, [just] as the human world itself is never finished, but constantly in the making" (Brinkmann, 2013, pp.56). Rather than using abduction to "formulate theories that are universally true", the methodology instead seeks to design "for dialoguing with an evolving reality of persons in conversation" (Brinkmann, 2013, pp.56). This philosophical disposition is applied throughout this paper's research design and approach, welcoming the creativity that it can facilitate (Brinkmann, 2013), and acknowledging its limitations, as well (e.g. incomplete data; lack of certainty).

## 3.2 Interviews

In addition to its secondary research compiled through a diverse set of existing research, this study conducted primary research using qualitative, semi-structured interviews. As defined by Marshall and Rossman, qualitative research is "pragmatic, interpretive, and grounded in the lived experiences of people" in that it "focuses on context", "is emergent and evolving rather than tightly prefigured," and "is fundamentally interpretive" (Marshall & Rossman, 2015, pp.2). Semi-structured interviews are intended to obtain "'descriptions of the life world of the interviewee in order to interpret the meaning of the phenomena'" (Brinkmann, 2013, pp.21).

Together, the application of qualitative methods and semi-structured interviews appropriately aligns to the philosophy of abduction, facilitating iterative, imaginative, and explanatory theory-building through contextualized knowledge gathering from firsthand accounts.

### 3.3 Data sampling

Through 1 phone call and 12 face-to-face video-enabled conversations, this study conducted 13 semi-structured interviews, ranging from 30 minutes to 90 minutes in duration, for a total of 12.5 hours. Additionally, the researcher received 1 in-depth email response from a respondent for a total of 14 interviews.

Interview participants represented 6 different target stakeholder groups, including fishermen and former fishermen (3)[4], alternative materials developers (and potential competitors) (4), national fishing associations (2), marine scientists (2), seafood industry representatives (2), and sustainable fishing advocates (2). Participants represented 6 different countries. A list of the participants is anonymized and featured in Figure 6.

In developing the 6 different target stakeholder groups, the researcher assessed both inclusion and exclusion criteria (Patino & Ferreira, 2018) – see Appendix 1.

[4] 2 of the 3 interviewed were former fishermen, but currently hold other positions in the fishing industry; as such, they were counted under multiple stakeholder groups to represent the full breadth of their perspectives.

| Participant # | Stakeholder group | Interview Duration (min) |
|---|---|---|
| 1 | Alternative materials developer | 60 |
| 2 | National fishing association representative; Former fisherman | 60 |
| 3 | Marine scientist | 90 |
| 4 | Alternative materials developer | 30 |
| 5 | Alternative materials developer | 60 |
| 6 | Fisherman | 90 |
| 7 | Marine scientist | 30 |
| 8 | National fishing association representative | 60 |
| 9 | Sustainable fishing advocate | 45 |
| 10 | Sustainable fishing advocate; Former fisherman | 60 |
| 11 | Alternative materials developer | 45 |
| 12 | Seafood industry | 60 |
| 13 | Sustainable fishing advocate | 60 |
| 14 | Seafood industry | -* |
| Total | | 750 |

**Responses received via email*

Figure 6: Participant list

### 3.4 Data collection

For each group of stakeholders, the researcher developed a relevant set of thematically intentional yet open-ended question guides to allow participants to respond and direct the conversation at will. The intent of this approach was to make use of the "knowledge-producing potentials of dialogues by allowing much more leeway for following up on whatever angles are deemed important by the interviewee" (Brinkmann, 2013, pp.21). An example of an interview question guide can be found in Appendix 9.

The interview guides were organized by stakeholder group according to the research objectives described in Appendix 2.

### 3.5 Data analysis

To analyze the data, the researcher consulted Thompson's *A Guide to Abductive Thematic Analysis*, the purpose of which is to gather "rich understanding from participant narratives, while ensuring findings have theoretical generalizability" (Thompson, 2022, pp.1419).

First, the researcher transcribed each interview using a combination of various software, including Trint, Microsoft Teams, and Apple Voice Memo. After transcription, the researcher conducted an initial round of coding, which involved assigning a "'word or short phrase'" to portions of the transcript to attribute meaning to them, categorizing the text "into codes based on their related characteristics" (Thompson, 2022, pp.1413). From there, the researcher conducted a second and third round of thematic coding analysis, which produced a more consolidated and focused set of coding concepts, illuminating "a deeper level of comprehension for the patterns and relationships in the data (Thompson, 2022, pp.1413). During the iterative process of coding, the researcher consolidated a codebook (see Appendix 7).

In terms of themes, which will be addressed in Findings, the researcher developed them by "looking at relationships between different codes and sorting them based on their ability to collectively explain the story behind the data" (Thompson, 2022, pp.1414). In this step, the "theorizing of data begins by looking back at theoretical knowledge and frameworks and seeing to what extent these could explain the relationship between the themes," (Thompson, 2022, pp.1415). With that said, Thompson notes that "the researcher should also examine instances for which themes cannot be explained by the extant literature", in which cases it is appropriate to be "creative in theorizing different explanations" (Thompson, 2022, pp.1415).

### 3.6 Data quality

Overall data quality and research rigor was achieved through the following strategies:

- The study was approached in a **systematic** way, demonstrating "procedural clarity" (Skovdal & Cornish, 2015).
    - To arrive at the core research question for this study, for instance, the researcher consulted over 40 scholarly sources, and over 10 industry reports.
    - To secure research participants, the researcher reached out to 48 individuals with tailored messages, through a combination of email, LinkedIn, and Instagram.
    - Finally, the coding process required three iterations, yielding close to 300 initial codes.

- The research employed **triangulation** as a tactic for rigor, seeking to "investigate [the] research question from different angles" by recruiting participants from 6 different stakeholder groups (Skovdal & Cornish, 2015, pp.66).

- The researcher ceased data collection once **theoretical saturation** was reached, which, as defined by Glaser and Strauss, occurs when a researcher finds "similar instances over and over again," in the data and can thus become "empirically confident that a category is saturated" (Saunders et al., 2018, pp.1895).

## 4. FINDINGS

The study's key findings are described in the following section. Thematic analysis yielded 288 initial codes, 98 secondary codes, 23 organizing themes, and 6 global themes (GT). The organizing themes and global themes are illustrated in Figure 7.

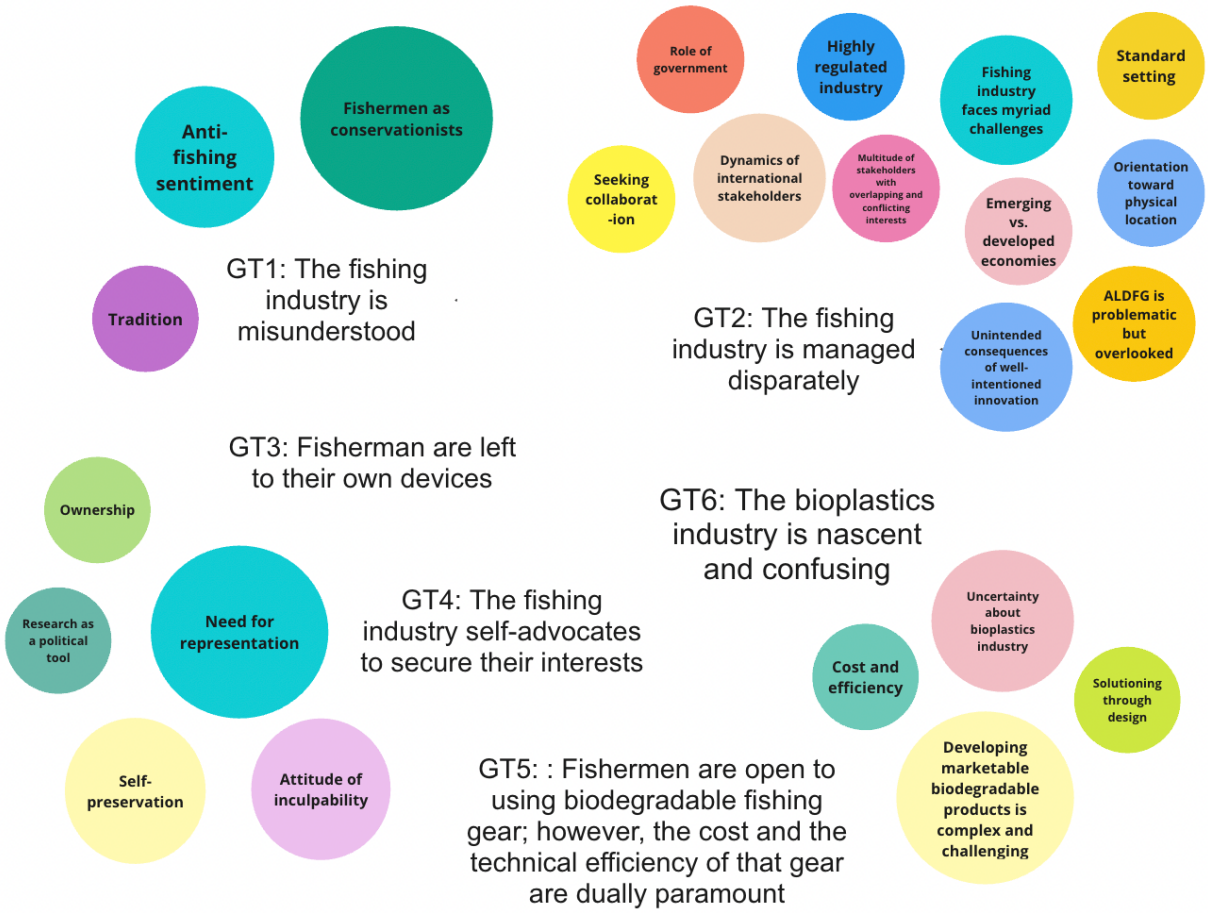


Figure 7: Global themes (GT) + organizing themes

### 4.1 GT1: The fishing industry is misunderstood

Throughout the course of the study, the concept of the 'image of the fisherman' arose consistently, both in terms of how the public perceives the fishing industry, as well as how the fishing industry self-identifies. Insights reveal that, while the public often understands the

activities of fishermen to be the root cause of ALDFG, fishermen consider themselves to be the exact opposite: allies to the ocean and its longevity. In fact, those that understand the work of fishermen, like marine scientists, for instance, consider fishermen to be conservationists. One participant comments: "*fishermen are some of the best conservationists there are in the marine environment because their livelihoods depend on it*".

This depiction, however, stands in contrast to how fishermen are often portrayed in the media. As one interviewee notes, certain documentaries and interest groups have made "*fishermen out to be real pirates, rapists, and pillagers of the ocean*". Participants agree that this "*anti-fishing narrative*" has to do with the fact that the job and activities of the fisherman are wholly misunderstood by those that fall outside of the industry. Thus, when the public finds a news article, for instance, and sees "*a picture of a seal caught in a net at the top, there's a visceral reaction to that*" because "*they don't understand the full context of it*".

Yet, as one interviewee puts it, "*despite what the common narrative is, the fishing industry just wants to ensure economic and sustainable viability into the future*". Fishermen must be concerned with the sustainability of the marine environment and the fish stocks from which they fish to be able to continue providing for themselves and their families. As such, the danger of this misconception of the fisherman, as one respondent puts it, is that it has the propensity to "*burn the industry to the ground*" and threaten the livelihoods of fishermen.

Further, when it comes to the matter of ALDFG, the overwhelming consensus from respondents is that fishermen not only do not want to lose their fishing gear, but in fact will go to great lengths to retrieve their gear when lost. As one interviewee notes, fishing gear "*is 'freakin expensive*", so fishermen will "*try everything in their power to recover their net*", including spending "*a tremendous amount of time looking for that gear*". As another puts it, "*having worked with fishers for every day of my life for over two decades, no fisher ever wants to lose their gear – never, never, never*", as their gear is "*the means by which they harvest seafood to feed their families and to feed the rest of the world*".

### 4.2 GT2: The fishing industry is managed disparately

The fishing industry is managed by different stakeholders according to – but not limited to – a range of determinants: geography, political interests, private interests, types of fisheries, types of environmental challenges. Within each of these determinants exist additional layers of nuance.

For instance, in terms of geography, the United Kingdom regulates its fisheries by their corresponding proximity to shore. As one respondent notes, "*the rules are different depending upon how far away from shore*" the fishery is, with "*shoreline to six miles … [representing] the inshore [regulation], and then out to 12 miles, then it is the economic exclusion zone which is 200 miles out*". As it follows, "*if you're looking at rules and regulations and interest in lost fishing gear and the impacts of ghost fishing, it depends upon how far away from shore you're talking about*".

When managing based on fishery type, an interviewee comments on the dynamic: "*we don't cross into their fishery and they don't cross into ours… anything that's affecting them that doesn't affect us, you know, we keep out of it*". Conflicts can arise, however, when fisheries are managed separately, but physically overlap in the same geographic zone. When scallopers infiltrate an area that also holds crab pots, for instance, the scallopers "*do try to honor where there are pots, but to some of them the value of scallops is worth more than anything else*" and they destroy the crab pots to dredge for scallops.

### 4.3 GT3: Fishermen are left to their own devices

Respondents describe the fishing industry as disadvantaged and left to its own devices to succeed.

**Poor policy**, for instance, is common throughout the fishing industry and often directly and negatively impacts fishermen. The inadequacies of government regulation and the shortcomings of bureaucratic standard setting groups like the Marine Stewardship Council (MSC), for instance,

can cause poor policy. One respondent notes, for instance, that "*the government doesn't have the time, money, or resources*"; another comments that "*the MSC just doesn't go far enough*".

Additionally, the notion of **unfairness** surfaced in the study, as well. Especially with respect to ALDFG, some express concerns about conflating global data on ALDFG rates, arguing that, in doing so, we inaccurately place equal blame on developed nations as we do on emerging states for ghost fishing: "*when you're talking about 20% of the pots going missing in the world, what you're doing is not fair because you're including developing nations in with fisheries [in] the United States, Canada, the United Kingdom*".

The significance placed on **history** also plays a role here. Respondents note, for instance, the generational nature of the fishing industry: "*I spent 20 years in the industry. So did my father, my grandfather, my great grandfather on both my sides, my mom and my dad's long family history of fishery support*". Another makes a connection between history and unfairness: *"from both sides of the divide of the conversation, fishermen were the first people there and they're being moved and moved and moved and moved".*

Finally, insights revealed a commonly held perception that the fisherman **risks more** than the average person. Since fishermen "*get paid for their time based on what they catch*", the risk is higher "*than most people who have a 9 to 5 salaried job*". Trying new fishing gear, for instance, is a huge risk to fishermen because, if it does not work, they "*have to go put food on the table*" regardless. The disproportionate risk that fishermen must take puts them at a disadvantage.

### 4.4 GT4: The fishing industry self-advocates to secure their interests

The study revealed a pattern of self-advocacy and inculpability within the global fishing industry. One interviewee, for instance, warns that fishermen tend to "*game the system to no end and they will tell you what you want to hear*" in hopes of "*a benefit to them further down the line*". Another respondent notes the importance of maintaining exclusive control of his nation's fisheries: "*we have very rich fisheries and we kind of want them for ourselves*".

Self-advocacy is exhibited, as well, by placing blame on others in the face of challenges. A respondent notes that working with fishermen is difficult because it's a "*constant 'not me*'" response.

In terms of ghost fishing, an interviewee comments that their country does not even acknowledge the 'abandoned' and 'discarded' portions of the ALDFG acronym; instead, they "*refer to it as lost gear because it's not intentional*" on the part of **their** nation's fishermen, who have the "*computer navigation systems that can pinpoint the location [of lost gear] down to the meter*". Rather, in their opinion, it is **other** fishermen that are to blame for ALDFG, particularly those from developing countries:

*"... then you start going again to developing nations where it is about catch[ing] as many fish as you can and damn the consequences. And if that means that we lose gear or anything like that, this is where the images start coming up. And this is where those [global] statistics start getting skewed."*

### 4.5 GT5: Fishermen are open to using biodegradable fishing gear; however, the cost and the technical efficiency of that gear are dually paramount

Overwhelmingly, participants agree that if biodegradable fishing gear were to be introduced to the market, it would need to be both price competitive with current plastic-based gear, and it would need to be as technically efficient in terms of catch per unit effort (CPUE). The following excerpts capture this conclusion:

- *"Okay, so if you had a net, I guarantee you if you had a net that could do all those things and if it's lost, we know it disintegrates in eight months, it would be a no-brainer. Yeah, it's just got to work."*
- *"...if you know you can match the effectiveness and the price, no one will have any issue with it."*
- *"...so if there's some biodegradable material that is equally robust, the fishermen will go for it."*

- *"…any substitution of manmade fibres with biodegradable alternatives in fishing gear would require, as a prerequisite, confidence on like-for-like material performance"*
- *"If the biodegradable plastic is of equal robustness to what he's coating the metal of the lobster pot and can be used in the same manner, but you're swapping out plastic for biodegradable plastic, it's a win-win, but it's all it's all about the longevity of the equipment."*

**4.6 GT6: The bioplastics industry is nascent and confusing**

The study finds that bioplastics, the material from which biodegradable fishing gear could be constructed, are not well-understood by the public, nor are they market-ready for this use case. In fact, one respondent even avoids using the term 'bioplastic' to describe her product, even though it is, in fact, an accurate description of her innovation, given the term's controversial association with greenwashing. Another interviewee describes bioplastics as "*an oxymoron*".

Bioplastics are confusing to consumers because they are not yet well-defined, and there are many different iterations of what bioplastics could be. One participant notes, for instance, that "*the definition now is getting clearer … [as] bio-based biodegradable, but some [bioplastics] are bio-based, not biodegradable, and some other ones are not bio-based but biodegradable*." Another interviewee comments on the conditions of biodegradability, which are equally complex: it's "*biodegradable, but under what conditions*?".

Further, the bioplastics industry is burgeoning; as a result, while some forms of bioplastics are existent in the market, specifically bio-based biodegradable products are not yet ready. As one alternative materials developer notes, we will "*continue to develop the ideal [product] that is bio-based biodegradable [plastic], but I think we're still far to be able to reach something in that sense*". As another notes, the concept of a biodegradable fishing net is "*on the [national] agenda, and that's as far as it is*".

# 5. RECOMMENDATIONS

## 5.1 Foundational tenets

These findings were further considered in context of secondary research, which led to the identification of seven tenets upon which the researcher believes a social enterprise must be built to fill the gap in the market with biodegradable fishing gear. These foundational tenets inform the dissertation's objective in designing the SE's 1) key activities and 2) VP.

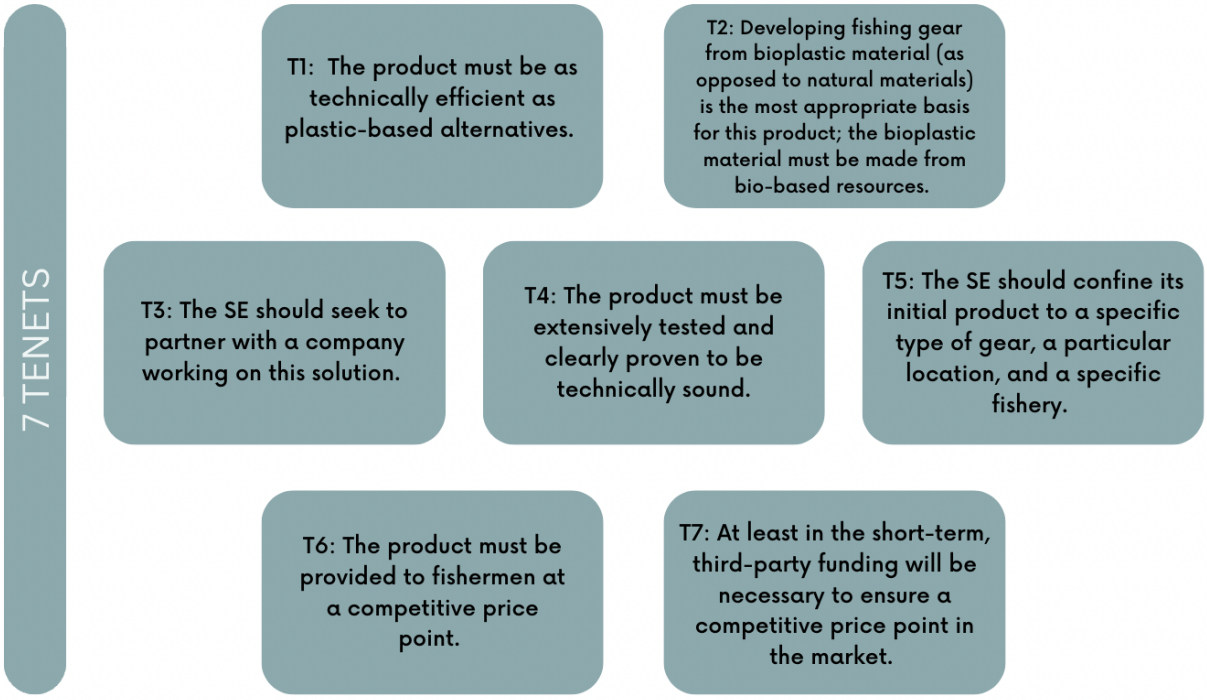


Figure 8: Foundational tenets

### 5.1.1 T1- The product must be as technically efficient as plastic-based alternatives.

The study confirms (GT5) that the durability and performance – the 'technical efficiency' – of fishing gear is paramount to fishermen (along with cost, which will be addressed in T6). This is

due to the fact that the fundamental interest of fishermen is to ensure the economic sustainability of fishing as a viable and continued source of livelihood for the fishing industry (GT1). From an article featured in the Institute for Fisheries Resources, Grader puts it plainly: “if there are no fish, there are no jobs. It's as simple as that.’” (Grader, 1999). Their conservation efforts come, at least in part, from ensuring the ocean is healthy and stocked with fish to catch.

As such, this enterprise should offer the ‘best’ product in this scenario, which, in this context, means fishing gear that works just as well, or better, than conventional fishing gear. In doing so, the SE ensures that fishermen are provided the opportunity to catch fish in the same capacities as they would be able otherwise using conventional fishing gear, without negatively impacting their earning potential.

Delivering the ‘best’ product is a strategy that aligns to the RBV perspective with respect to generating competitive advantage: the idea is that this SE should deliver a product that is valuable, rare, inimitable, and non-substitutable to be able to outperform others (Barney, 1991). Because there is currently no biodegradable fishing gear on the market that works just as well as conventional gear, delivering such a rare product provides for its comparative superiority. The value of the product comes from the perspective of the user, which, according to GT5, is clear: the gear must work.

The alternative strategy here, should the SE not pursue the ‘best’ approach, would be to deliver a product that is not as technically efficient as its conventional counterpart, but that is incentivized in other ways. This is what we see happening in places like South Korea, for instance, where biodegradable gillnets are subsidized by the government to account for lower earnings from less efficient nets (Standal et al., 2020, pp.7). Given the overwhelming consensus from respondents that the technical efficiency of the gear is paramount, however, the SE should not take this alternative approach.

### 5.1.2 T2 - Developing fishing gear from bioplastic material (as opposed to natural materials) is the most appropriate basis for this product; the bioplastic material must be made from bio-based resources.

Using bioplastics as the base material for the composition of the product is appropriate for three reasons:

1) Conventional plastic replaced the natural materials that were once used in fishing gear design because it of its enhanced efficiency (Napper & Thompson, 2020); given this SE's focus on technical efficiency, delivering a product made from natural materials would be counter to its strategy.
2) Bioplastics are designed to function like conventional plastics (Rosenboom et al., 2022) which are highly efficient; bioplastics are, thus, a more appropriate fit for this SE, given that it aims to deliver the most technically efficient biodegradable fishing gear to the market.
3) Bioplastics are a budding but rapidly growing industry; the consumer demand for sustainable products is increasing simultaneously (Rosenboom et al., 2022, pp.130). This presents an opportune backdrop for developing biodegradable fishing gear from bioplastic material; it also reflects Porter's view of competitive advantage in considering 'where-to-play' (Martin, 2015).

It is critical, as well, for this product to be both bio-based and biodegradable to achieve its desired impact of facilitating a healthier and cleaner ocean that is safer and more sustainable for marine life to thrive (see TOC, Appendix 6). In fact, "bioplastics that are 100% bio-based … are considered a part of future circular economies to help achieve some of the United Nations' (UN) Sustainable Development Goals" (Rosenbloom et al., 2022, pp.117-119).

### 5.1.3 T3 - Given that this researcher does not have the expertise to develop a bio-based biodegradable bioplastic material for this purpose, the SE should seek to partner with a company already working on this solution.

It is true that developing bio-based biodegradable fishing gear to function as well as plastic is exceptionally challenging (GT6). However, there are companies in the process of developing a material that is both bio-based and biodegradable, and some are even at the point of testing their materials with fishermen in various locations around the world ("*the fishing nets are being validated in Cyprus and also in Patagonia*").

### 5.1.4 T4 - The product must be extensively tested and clearly proven to be technically sound.

The researcher hypothesizes that the self-advocating disposition and sense of perpetual inculpability projected by the fishing industry (GT4) could be, at least in part, a result of the industry's disparate management (GT2) and its misrepresentation by the media (GT1): the fishing industry has been left to its own devices to fend for itself (GT3). This might create an added psychological barrier for fishermen to the quick adoption of – or even to testing – a new product ("*it is really difficult to convince a fisherman to use this net*"). As such, despite a stated openness to adopt biodegradable fishing gear, as described in GT5, the extensive testing of that gear is not only necessary for developing a superior product (Arifalo, 2023), but the findings of this study also reveal its importance from a credibility standpoint, to induce buy-in from the fishing industry.

To support a shift from using conventional fishing gear to biodegradable fishing gear, the SE should anticipate this potential psychological barrier to adoption by investing in extensive and ongoing testing of its product to build its credibility: people – especially fishermen – "want the assurance that a product is safe to use and that it does what you say it does" (Arifalo, 2023).

### 5.1.5 T5 - The SE should confine its initial product to a specific type of gear, a particular location, and a specific fishery.

To develop a product that functions just as well as conventional fishing gear, the SE should focus its efforts by delivering a specific type of fishing gear that works as a solution for a particular fishery within the context of a defined location. The definition of these elements is outside of the scope of this dissertation and is dependent on the properties of the bioplastic material that will be used.

The logic for this strategy is informed by both primary and secondary findings. Given the complexity of ALDFG and the problems it causes (*"I do wanna take a step back and say like man, this is a complicated issue"*), juxtaposed with the place-based orientation of fisheries management (GT2), there is no 'one-size-fits-all' approach that can be applied to the totality of the industry ("*there's so many factors and this is why we get asked all the time, well, what's the best way to deal with [ALDFG]? And so it depends on where you are and what you're trying to accomplish and what the local circumstances are"*).

As such, the initial product must be tailored to the unique context, conditions, and needs of a particular fishery and physical location.

### 5.1.6 T6 - The product must be provided to fishermen at a competitive price point.

In addition to technical efficiency, the cost of adopting biodegradable fishing gear is just as important to fishermen (GT5). In terms of business design, therefore, affordability is a value that this SE must create in delivering its product to its end users.

### 5.1.7 T7 - At least in the short-term, third-party funding will be necessary to ensure a competitive price point in the market.

The obvious challenge with providing biodegradable fishing gear to the market at a competitive price is that the product will be unquestionably expensive to develop, owing in part to the

nascency of the bioplastics field (GT6). As one respondent puts it, even where these materials are being developed – most notably throughout Europe – "*they have potential*", but "*some of them are really expensive*".

As such, until the equilibrium price point of biodegradable fishing gear lowers, the SE should seek third-party funding to subsidize the cost of producing and delivering this product to the fishing industry. This approach is appropriate when "users contribute to value creation" (Tidhar & Eisenhardt, 2020, p.1256), which is the reality in this case: the fisherman (user) purchases the product (biodegradable fishing gear) to reduce the effects of plastic pollution and ALDFG in the ocean (value creation).

In fact, many respondents noted the importance of employing government to incentivize this change:

- *"Yeah, but that aside, I think that subsidies would probably be necessary to get fisher buy-in in the short term."*
- *"…at least for the short to medium term, subsidies might be necessary… Because I know fishers who cannot make that work. Yeah. To pay more for their gear then they're out of the game."*

Another approach would be to set up outcomes-based funding, as further described in Appendix 11.

## 5.2 SBMC design

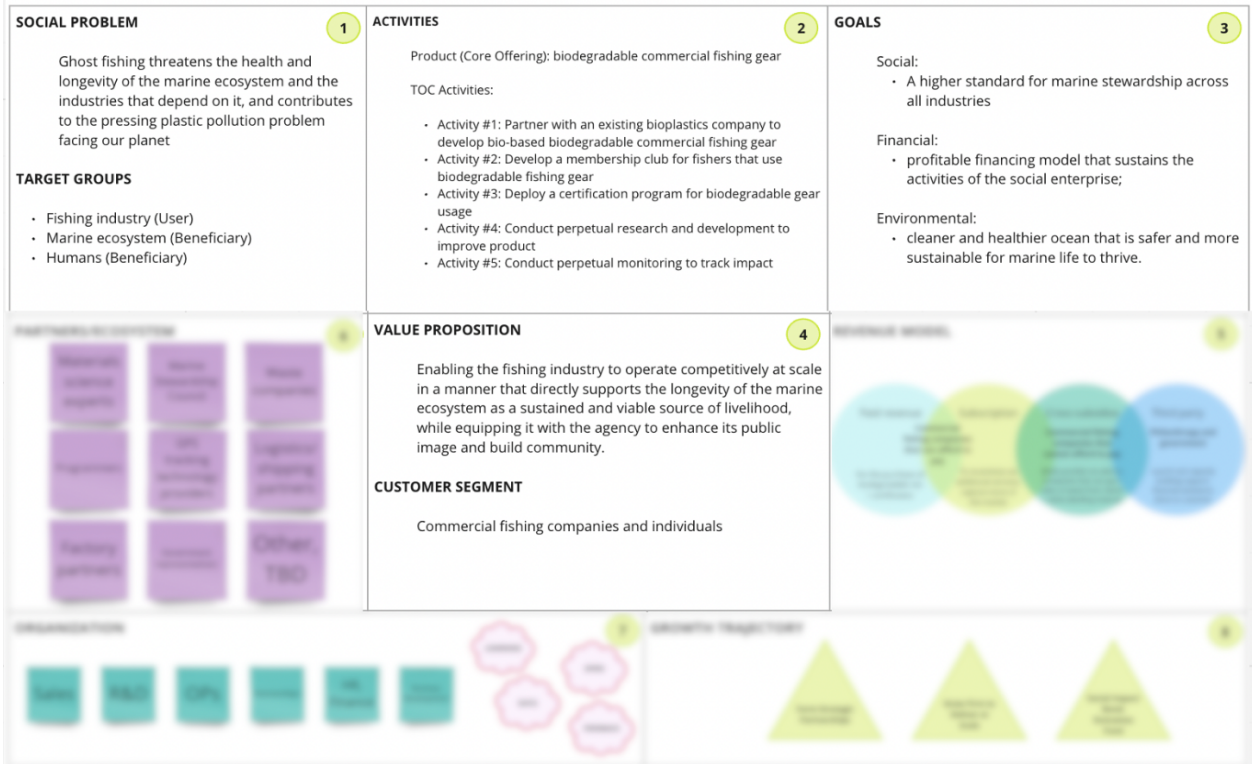


Figure 9: SBMC for this SE; elements #1 and #3 developed from evidenced-based TOC in Appendix 6.

### 5.2.1 Element #2: Activities

Based on the theme of a complementarity business model, "which relies on various ways of bundling or synchronizing offerings (goods or services), activities, or resources" (Climent & Haftor, 2021, pp.355), the following activity framework has been developed to create value for the product's end user (the fishing industry).

- A1: Partner with an existing bioplastics company to develop bio-based biodegradable commercial fishing gear
- A2: Develop a membership club for fishers that use biodegradable fishing gear
- A3: Deploy a certification program for biodegradable gear usage

- A4: Conduct perpetual research and development to improve product
- A5: Conduct perpetual monitoring to track impact

A1 reflects the strategic approach held to be most appropriate in this context for bringing biodegradable fishing gear to market, founded upon T2, T3, and T5.

A2 is intended for building trust and connections with and between fishermen, and is related to T4. In such a disparately managed industry (GT4) in which fishermen often are left to their own devices (GT3), A2 creates value by facilitating a sense of community (McMillan & Chavis, 1986) through the development of a membership club.

The purpose of A3 is to generate agency: to provide an avenue for the fishing industry to enhance its public image and reputation. This is something that, as we learned from GT1, is of value to the fishing industry given its misrepresentation in the media. Additionally, A3 allows fisheries to gain "market acceptance": "certification programmes create market-based incentives for fisheries to achieve ecological and/or social sustainability" provided consumer demand (Robinson et al., 2021, pp.1214).

A4 is important for maintaining a sustained competitive advantage, particularly given the fledgling state of the bioplastics industry and its products. When new actors inevitably enter the market (Five Forces), the SE will need to ensure that its offering is superior (RBV) through the constant technical refinement of its product. This activity relates to T1 through T5. Further, as hypothesized in T4, a potential additional psychological barrier for fishermen to the quick adoption of a new product necessitates trust-building through testing and proven success of its offering (Arifalo, 2023).

Finally, A5 is critical for 1) developing credibility of the product, providing evidence to confirm that it supports the achievement of the SE's social, financial, and environmental goals (as described in its TOC); and 2) working with a third-party to subsidize the cost of production, as noted in T7 and as related to T6. Governments have a vested interest in protecting the marine ecosystem (UNEP, 2021), but need data to incentivize their support.

### 5.2.2 Element #4: Value proposition

The VP has been informed by the primary and secondary insights of this study, and developed using the following concepts and tools:

- The **value proposition canvas** (Figure 11) is an evidenced-based map that plots the challenges fishermen experience in doing their job, as well as the gains they seek through their job, as a strategy to develop a fit between the customer's problems and the SE's solutions (Osterwalder et al., 2014).
- The **value drivers** describe the "different factors that increase the worth of a product or service to consumers" (Cole, 2022).
- The **strategy canvas** is a "visual analytic that depicts the way an organization configures its offering to buyers in relation to those of its competitors" (Blue Ocean Strategy, n.d.), showing how this SE differentiates itself in the market.

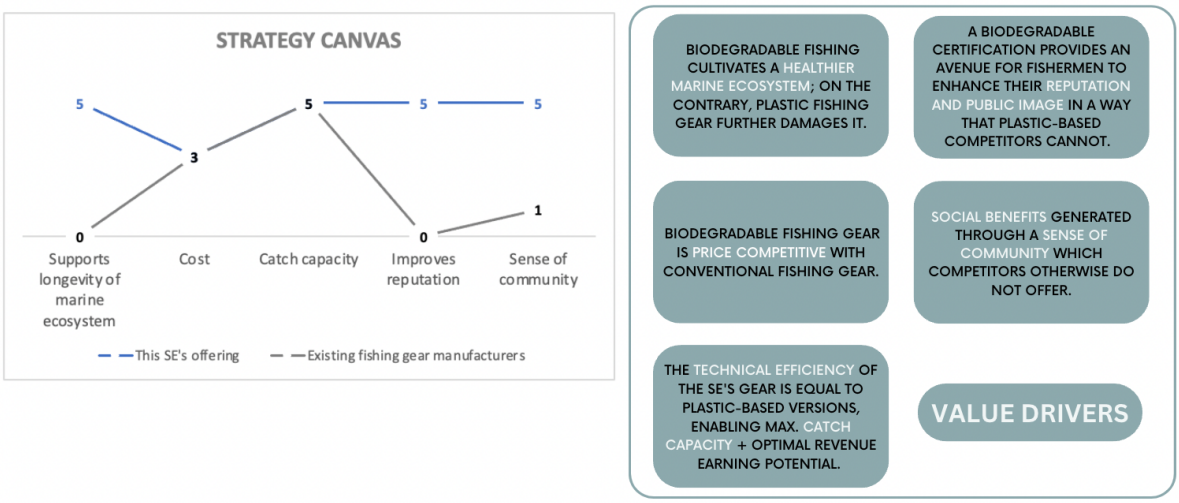


Figure 10: Strategy Canvas + Value Drivers

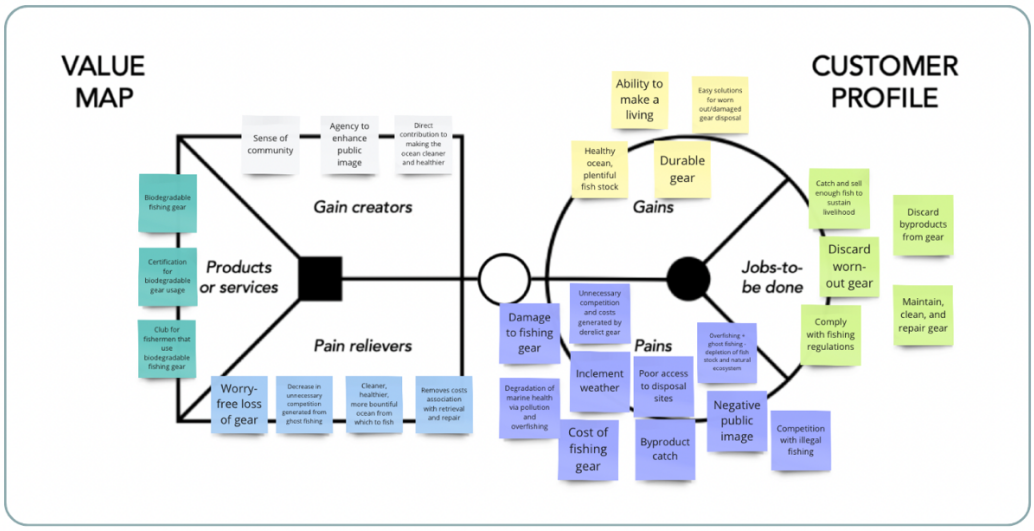


Figure 11: Value Proposition Canvas


Figure 12: Value Proposition

# 6. DISCUSSION

## 6.1 Contributions

Far too often, the public places fishermen in a box: they are stuck in their ways and unwilling to change (Eayrs et al., 2015). This dissertation contributes to an expansion of our understanding of 'the fisherman' as we know him. The study demonstrates that, at least in the case of switching to biodegradable fishing gear, fishermen are open to adapting to novelty (GT5). It also allows us to critically question why the fishing industry might be resistant to change in the first place.

The researcher's hypothesis is that resisting change could be an act of self-preservation (GT4), provided the obstacles with which the fishing industry is faced (GT3), instead of simply a fear of the unknown. In this process of questioning, we knead the rigid image of the fisherman.

As a global community, we need to be able to work collaboratively with the fishing industry to ensure our ocean and the bounty and wonder it provides continues to thrive, particularly given its perilous state. Providing a more nuanced understanding of the fisherman is, thus, important for that objective. Without it, we will continue to see the fishing industry as an obstacle as opposed to a partner.

## 6.2 Risks, Limitations, & Mitigations:

*Risk #1*

The study's social business design necessarily hinges on the supposition that the development of a bio-based biodegradable material that is as technically efficient as plastic for the purpose of commercial fishing is possible. The assumption that this is conceivable derives from the number of initiatives currently working on developing such a solution for such a purpose.

Should this not be the case, the SE should consider pivoting to focusing on solutioning for a different element of the ALDFG problem, provided its vast complexity. Building a product that

does not perform as well as plastic counterparts is likely to be a fruitless act, given the value that fishermen place on technical efficiency.

*Limitation #1*

Given the inherent limitations of this project in terms of timespan, length, and breadth of research, it is possible that the research's sample size is too small to accurately represent stakeholders within the fishing industry, particularly fishermen.

The researcher mitigates this risk by using theory as much as possible to evidence its findings and design, but recognizes that further research is needed for full validation.

**6.3 For future research:**

Further research into the following three areas would serve to enrich this study's findings and social business design:

1. The types of fishing gear that could be most easily and effectively developed in a biodegradable format.

2. The analysis of appropriate strategies for capturing value (the remainder of the social business design).

3. The psychology and mental health of commercial fishermen.

## 7. CONCLUSION

Ghost fishing poses a serious global threat to the health and longevity of the marine ecosystem, upon which livelihoods and industries rely. If adopted, biodegradable fishing gear would significantly lower the risks associated with ALDFG. Unlike plastic, these materials break down naturally in the sea without emitting harmful toxins; further, their controlled lifespan would reduce the indiscriminate killing of target and non-target species.

Given this potential for global impact, some have explored the possibility of using biodegradable fishing gear as a solution for ALDFG. However, biodegradable fishing gear is not commonly available in the commercial fishing industry today. This gap is the subject of this study, giving rise to the study's central research question: *how can a social enterprise fill the gap in the existing commercial fishing gear market with biodegradable fishing gear?*

The dissertation conducted primary and secondary research to answer this question. This research informed the design of two elements of the social business model canvas (key activities; value proposition), the objective of which was to assess the appropriateness of bringing biodegradable fishing gear to market in response to the identified market gap.

The findings of the study suggest that, to fill the gap in the market with biodegradable fishing gear, a social enterprise must be built upon the following foundational tenets:

- From a technical perspective, the product must be as technically efficient as plastic-based alternatives.
- The base material of the product should be a bio-based biodegradable bioplastic.
- The SE should partner with a company already working on this solution.
- The product must be extensively tested and clearly proven to be technically sound.
- The product should be restricted to a specific type of gear, a particular location, and a specific fishery.
- The product must be provided to fishermen at a competitive price point.

- Third-party funding is necessary to ensure a competitive price point in the market, at least in the short-term.

The ensuing design of two elements of the social business model canvas serve to translate these principles into an offering (activities) intended to create an optimal level of value (value proposition) for the SE's end user (fishermen). Through its activities, the SE offers the fishing industry the opportunity to operate competitively at scale in a manner that directly supports the longevity of the marine ecosystem as a sustained and viable source of livelihood; additionally, it equips them with the agency to enhance its public image and build community.

By creating this value for end users, the social enterprise can fill the gap in the market with biodegradable fishing gear. Creating value, however, is but one piece of the business model puzzle – the social enterprise also needs to build a plan for capturing that value in order to sustain itself financially: "the fit between value capture (revenue models) and value creation (activities) [is] at the heart of successful business models" (Tidhar & Eisenhardt, 2020, p.1245). The pursuit of designing value capture is beyond the scope of this dissertation, but should be considered for further research.

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# APPENDIX

## Appendix 1: Inclusion + exclusion criteria

The study's top inclusion criterion includes any adults currently or formerly working in or for any industry that directly or indirectly interacts with the issues related to ALDFG. Two key exclusion criteria include: 1) adults that speak English; 2) adults that can participate between June and July of 2023. Given that the research is focused on the fishing industry, this last exclusion criteria was particularly relevant: for a significant number of fisheries, the fishing season overlapped with the timing of the study, and thus excluded many fishermen.

## Appendix 2: Research objectives

- Alternative materials developers:
    - To understand the challenges, perceptions, and opportunities facing the bioplastics and natural materials industries in bringing products to market.
    - To understand what efforts have been made toward developing biodegradable fishing gear, if any.
    - To understand the feasibility of developing biodegradable fishing gear.
- Fishermen:
    - To understand the lived experiences of fishermen with respect to ALDFG.
    - To understand their perspectives on ALDFG, remediation efforts, and what solutions work best from their perspectives.
    - To map out the landscape of actors involved in commercial fishing.
- National fishing association representatives:
    - To understand the geopolitical landscape of fisheries management and ALDFG on a global scale.
    - To understand how ALDFG is considered in terms of regulation and governance from a national perspective.
    - To map out the landscape of actors involved in commercial fishing.
- Marine scientists:

    - To understand the feasibility of developing biodegradable fishing gear.
    - To test my assumptions and confirm my understandings from a scientific perspective.
    - To map out the landscape of actors involved in commercial fishing.
- Seafood industry representatives:
    - To gain insight into how ALDFG affects the seafood industry and its supply chains.
    - To understand ALDFG from a commercial perspective.
    - To map out the landscape of actors involved in commercial fishing.
- Sustainable fishing advocates:
    - To understand the gravity and breadth of the issues caused by ALDFG.
    - To understand the initiatives already taking place to combat ALDFG.
    - To map out the landscape of actors involved in commercial fishing.

**Appendix 3: Costs, continued**

Generally, costs associated with ALDFG are considered in three categories: 1) lost gear and fishing time costs; 2) at-sea retrieval program costs; 3) costs related to marine litter (Mcfadyen et al., 2009, pp.43-44). Examples of each are noted below, respectively.

1. A study conducted in the Chesapeake Bay found that “USD 831 million in landings could be recuperated annually if less than 10% of the derelict pots from major crustacean fisheries were removed globally” (GESAMP, 2021 pp.23).

2. ALDFG recovery programs have been found to vary widely in cost due to their differences in “scope and duration” (McFayden et al., pp.43). For instance, the “annual Swedish costs associated with a retrieval [program] in the Baltic Sea are estimated at [USD 70,000] while Norway’s annual costs are thought to be in the order of [USD 260,000]” (McFayden et al., 2009, pp.44).

3. Much like retrieval programs, costs associated with marine litter clean-up initiatives are "difficult to quantify and compare" (McFayden et al., 2009, pp.44); further, figures are scarce "on the sources of litter by group … i.e. to what extent can the costs involved be attributed to ALDFG" (McFayden et al., 2009, pp.45). With that said, it was estimated that "in England and Wales, local authorities, industry and coastal communities spend approximately US$30 million a year to clean up coastal marine litter", for instance (McFayden et al., 2009, pp.45).

Aside from these individual examples, an overview of the various economic and social costs of ALDFG is featured in Figure 13, albeit without quantified figures attached, and developed in 2008.

**Economic and social costs of ALDFG**

**Economic costs**

**Direct costs**:

- cost of time spent disentangling vessels whose gear/engine become entangled in ALDFG, which results in less fishing time;
- cost of lost gear/vessels because of entanglement as well as cost of replacement;
- cost of emergency rescue operations because of entanglement of gear/vessels;
- cost of time and fuel searching for and recovering vessels because of gear loss, which results in less fishing time; and
- cost (to fishers or administrations) of retrieval programmes/activities to remove lost/discarded gear, or other management measures, e.g. cost of time required for better communication, cost of better marked gear, cost of monitoring regulations intended to reduce ALDFG.

**Indirect costs:**

- reduced income/value-added resulting from ghost fishing mortality, which means fish are lost from the fishery;
- reduced multiplier effects from reduced fishing income;
- cost of research into reducing ALDFG; and
- potential impact on buying because of consumer fears/concerns about ghost fishing and ALDFG.

**Social costs**

- reduced employment in fishing communities resulting from decreased catch levels associated with unintended fish mortality;
- reduced recreational, tourism and diving benefits from lost gear on beaches and at sea; and
- safety risks for fishers and vessels if vessel maneuverability is compromised by entanglement or navigational hazards.

*Source:* Poseidon, 2008.

Figure 133: Costs of ALDFG (Mcfadyen et al., 2009, pp.43)

**Appendix 4: Natural materials, continued**

Octopus pots, for instance, were once made from ceramic; lobster pots were once constructed from wood (Feary et al., 2020, pp.25). Yet, provided plastic's technical efficiency and relative inexpensiveness (e.g. it is lighter in weight than ceramic; it is more corrosion-resistant than wood), it has become a ubiquitous replacement for many of the natural materials from which fishing gear was once made (Napper & Thompson, 2020).

In response to the current marine litter crisis, some propose increasing the use of natural materials in fishing gear design to replace plastic. In fact, this is one of the recommendations included in the European Commission's 2020 report '*Study on Circular Design of the Fishing Gear for Reduction of Environmental Impacts'*. The report cites, for example, using cow leather instead of conventional dolly ropes, or natural fibers to replace mussel socks (Feary et al., 2020, pp.25). The logic holds that, unlike plastic, these natural materials will eventually biodegrade into natural substances in the marine environment, without causing it undue harm.

Yet, despite its environmental promise, a return to former methods of fishing is not an attractive alternative from an efficiency standpoint: as noted previously, plastic is often lighter, stronger, less expensive, and more durable than its natural-based counterparts (Napper & Thompson, 2020, pp.1).

**Appendix 5: Bioplastics, continued**

*Bio-based + biodegradable*

Polyhydroxyalkanoate (PHA) is "an excellent alternative to traditional fossil fuel-based plastic because it offers a completely compostable solution, biodegradable in all types of natural environments," including the sea (Zhang, 2022). In fact, Sehgal and Gupta cite PHA as being "the most promising solution to" the "major ecological problem of plastic accumulation" because "the properties of PHA make it close to [conventional] plastics", yet it is both "biodegradable and biocompatible" (Sehgal & Gupta, 2020, pp.XX). PHA, in other words, is both bio-based and biodegradable (Rosenboom, 2022, pp.118), and thus "has been found to be one of the only bioplastics that will properly and efficiently break down in the ocean" (Zhang, 2022). The time it takes for PHA to biodegrade is dependent on "the surface area of the product" – plastic straws, for instance, take "six months to disappear" (Zhang, 2022).

Polylactic acid (PLA) is another bio-based, biodegradable plastic that is commonly used today in "single-use products such as straws, bottles, and other packaging materials" (Zhang, 2022). PLA is made of "corn sugar, potato, or sugar cane", and is technically "recyclable, biodegradable, and compostable" (Krieger, 2019). However, "products made of PLA need to be specially treated in industrial composting facilities in order to be properly biodegraded" because the materials need particular conditions to break down: a high temperature that does not exist in nature, and the existence of "special microbes to break the bioplastic down into sugars" (Zhang, 2022). If not treated appropriately, PLA-based products can take "100 to 1000 years to completely degrade" when simply tossed in the trash (Zhang, 2022). For these reasons, although PLA is technically a bio-based bioplastic, PLA is not an optimum candidate for biodegradable fishing gear.

*Fossil-based + biodegradable*

While not an exhaustive list, two other biodegradable plastics of particular note given their application in biodegradable fishing gear development include polybutylene succinate (PBS) and polybutylene adipate-co-terephthalate (PBAT). PBS is "typically fossil-based yet biodegradable

(that is, easily hydrolysable)"; however, although it is typically synthesized from non-renewable feedstocks… its monomers, succinic acid and butanediol, can be obtained from renewable sources", rendering the existence of "bioPBS" (Rosenboom, 2022, pp.122). PBAT is a biodegradable bioplastic derived from fossil-based resources, but that, according to Rosenbloom et al., has the potential to be produced from biomass in the future" (Rosenboom, 2022, pp.125).

Despite these caveats, it is important to emphasize that PBS and PBAT, while they may pose advantageous for some applications in terms of their biodegradable properties, are, in fact, derived from fossil-based resources. As such, they are not suitable as the base material for this social enterprise.

## Appendix 6: Theory of Change

| NEEDS | ACTIVITIES | OUTPUTS | OUTCOMES | IMPACT |
|---|---|---|---|---|
| ALDFG kills marine animals, reduces fish stocks, damages marine habitats, disturbs ecosystems, increases the spread of pathogens<br><br>Ghost fishing creates unnecessary costs, navigational hazards, and competition for fishing industry<br><br>Reduces aesthetic value of recreational areas, costing tourism<br><br>Microplastics reduce human well-being | Partner with bioplastics company to develop a bio-based biodegradable commercial gillnet with a one-year lifespan<br><br>Develop a membership club for fishers that use biodegradable fishing gear<br><br>Deploy certification program for biodegradable net usage<br><br>Conduct perpetual research and development to improve product<br><br>Conduct perpetual monitoring to track impact | Number of nets produced and deployed<br><br>Number of plastic nets replaced<br><br>Number of plastic nets recycled<br><br>Number of members in biodegradable fishers club<br><br>Number of certifications awarded | Decrease in kill rate of marine animals by ghost fishing<br><br>Increase in fish stock of specified fisheries<br><br>Increase in catch % for clients<br><br>Decrease in habitat damage by ghost fishing<br><br>Decrease in plastic pollution in the ocean by ghost fishing, including microplastics<br><br>Decrease in costs for fishing and tourism industries associated with ghost fishing, including repairs, loss of earnings, fuel, etc. | A cleaner and healthier ocean that is safer and more sustainable for marine life to thrive<br><br>A higher standard for marine stewardship<br><br>Increased respect for the ocean and the bounty it provides, both for the marine ecosystems it supports, and for the humans that exploit it |

**Appendix 7: Codebook**

| **Organizing themes --> secondary codes --> initial codes** |
|---|
| **ALDFG is problematic but overlooked** |
| **ALDFG is visible on beaches** |
| Most of waste on beaches from fishing gear |
| **Bycatch is problematic** |
| Bycatch will be a problem regardless |
| **Lack of data globally about ALDFG** |
| Lack of adequate data |
| Do not currently have adequate data about ghost fishing |
| Scale is unknown globally |
| **Lack of education about effects of ALDFG** |
| Education is important for adoption |
| Lack of education is another reason why ALDFG occurs |
| There's a general lack of knowledge and information about the impacts of ALDFG, which is a key component of incentivizing fishermen to manage their gear better |
| **Losing fishing gear is inevitable** |
| Losing fishing gear is inevitable |
| **Marine plastics** |
| Polypropylene |
| **Plastic pollution is a hot topic** |
| Marine litter is a hot topic in Norway |
| Microplastics |
| Plastic is bad |
| Plastic litter is a problem gaining increasing attention |
| **Siloed efforts to address ALDFG** |
| Lack of cohesion globally |
| Small wins |
| Working on same issue in isolation |

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| **Attitude of inculpability** |
| **Perception that the problem is generated from somewhere and someone else** |
| Belief that ghost fishing is unintentional |
| Some are more culpable than others |
| Fishermen's attitudes |
| Global statistics are unfair when taken in a single narrative |
| Illegal fishing |
| Intentional abandonment of fishing gear is more of a problem outside of UK |
| There’s a difference between emerging economies and developed states re: ghost gear |
| **Commercial fishing industry is highly regulated** |
| **Fishing industry is highly regulated** |
| Highly regulated industry |
| Supporting regulation |
| **Highly regulated industry** |
| Highly regulated |
| Highly regulated |
| Highly regulated industry |
| **Regulations exist for marine protection** |
| Regulations to protect marine life |
| **Cost and efficiency are paramount** |
| **Biodegradable fishing gear is a no-brainer if it's price competitive and functions just as well as conventional gear** |
| It’s a no-brainer if you can match effectiveness and price |
| So long as the net functions properly, no reason that fishermen wouldn’t adopt it |
| **Biodegradable fishing gear needs to be as durable as conventional gear** |
| Need for durability of fishing net |
| Plastics and rubber are superior because they are more durable and do not require as much maintenance as other natural-based materials formerly used before the advent of plastic |
| **Biodegradable fishing gear needs to be as effective as conventional gear** |
| Biodegradable fishing gear must be as effective as conventional gear |

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| Biodegradable fishing gear must perform as well as conventional gear |
| **Biodegradable fishing gear needs to be as safe as conventional gear** |
| Biodegradable fishing gear must be as safe as conventional gear |
| New product would fail abruptly if it did not function properly |
| **Biodegradable fishing gear needs to be competitive with conventional gear** |
| Adoption requires net to be better or cheaper or both |
| Bio-based materials are not the same as conventional ones |
| Economic viability |
| If the biodegradable gear is price competitive, no reason that fishermen wouldn't adopt it |
| Price competition |
| **Biodegradable fishing gear needs to make fisherman's job better** |
| Demand for biodegradable net needs to include some sort of benefit for consumer |
| **Cost and efficiency are two biggest factors for fishermen** |
| Cost and efficiency matter most to fishermen |
| Cost and efficiency matters the most to fishermen |
| Cost and efficiency of fishing gear is most important to fishermen |
| **Fishermen are incentivized to maintain their gear** |
| Fishermen are economically incentivized to maintain their gear |
| Accidental loss is much more common than intentional discarding |
| Economic incentive to maintain fishing gear |
| Economic viability/incentive |
| Fishermen are economically incentivized to maintain their gear |
| Fishermen are incentivized to maintain their nets |
| Fishers do not intentionally lose their gear |
| Fishing gear is expensive |
| Fishing gear is expensive to replace |
| There are good and bad actors in all industries |
| **Fishermen are primarily concerned with the economic and sustainable viability of fishing stocks into the future** |
| Concern for continuation of fishing industry |

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| Concern for continuation of fishing industry |
| Economic and sustainable viability |
| **Fishermen don't want to lose their gear** |
| Accidental loss |
| Fishermen do not leave their nets on purpose |
| Fishermen don't want to lose their gear |
| **Profit trumps all** |
| It's all about profit |
| Money directs behavior, to the detriment of others |
| Reliance on base materials because they are cheap |
| **Retrieving lost gear is a common practice among fishermen** |
| High chance of getting lost gear back in this fishery |
| **Developing marketable biodegradable products is complex and challenging** |
| **Complexity of working with natural materials** |
| Complexity of working with natural materials |
| **Conditions for biodegradability vary** |
| Biodegradable prototypes won't necessarily work in different regions with different environmental considerations |
| Design when contradictions exist |
| Different conditions for composting |
| Exposure to elements |
| Heat resistant design |
| If it's biodegradable, it must be made of biomass; it cannot biodegrade into microplastics. |
| Temperature matters for testing |
| Water permeability of material |
| **Many obstacles to bringing products derived from alternative materials to market** |
| A solution for all, not just niche market |
| Challenging industry |
| Choosing an alternative materials is not simple |
| Conventional materials are more effective than biodegradable gear |

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| Expense of biodegradable products |
| Focus on affordability |
| Hard sell to produce something that is less effective and costs more |
| Hard sell to produce something that needs to be replaced more frequently |
| Higher cost of producing biodegradable gear is inevitable |
| If biodegradable material is equally robust to plastic material, fishermen will adopt it |
| Not easy |
| Role of regulation in price competitiveness |
| Scaling challenges |
| **Dynamics of international stakeholders** |
| **Canada is a leader in sustainability** |
| Canada is a leader in fishery sustainability |
| Canada is a leader in sustainability |
| **Industrial ownership structure in US fishing market** |
| More industrial ownership structure in the United States |
| **Influence of Chinese market** |
| Influence of Chinese market |
| **Norway is leader in sustainability and fisheries management** |
| Norway is a leader in fishery sustainability |
| Norway is a leader in sustainability |
| Norway is leader in sustainability, as are other Nordic countries |
| Norway is leader in the sustainability |
| Norway's management is marked by transparency and cooperation |
| **Norway poorly manages fisheries** |
| Canada is bad at fisheries management |
| Norway is bad at fisheries management |
| **Vessels in UK are mostly independently owned** |
| Independent ownership of boats in UK |
| **Emerging vs. developed economies** |
| **ALDFG is greater in emerging economies** |

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| The issue is greater in emerging economies than in developed economies |
| There's a difference between emerging economies and developed states re: ghost gear |
| **Countries have different capacities to properly regulate fishing industry** |
| Difference between emerging economies and developed economies re: fishing sustainably |
| Regulation depends on infrastructure and development of government |
| Regulation tied to wealth of country |
| **Different countries prioritize issues related to ALDFG differently** |
| EU comparatively more progressive than US |
| Korea comparatively more progressive than US |
| **Disproportionate effects on small island and low incomes states** |
| Disproportionate effects on small island and low incomes states |
| **Fishermen as conservationists** |
| **Fishermen as conservationists** |
| Fishermen as conservationists |
| Generally fishermen don't want to hurt the natural environment |
| **Fishing industry faces myriad challenges** |
| **Disposal challenges** |
| Barriers to composting |
| Conditions for composting |
| End of life is an added problem for the ghost fishing problem |
| End of life management is lacking |
| End of life resources are lacking |
| Expense of recycling |
| No proper end of life resources for discarding fishing gear |
| Recycling logistics |
| **Lack of alternatives for fishermen** |
| Lack of alternatives is one reason why ALDFG occurs |
| **Lack of infrastructure** |
| Infrastructure is a major limitation |
| Lack of machinery available to do bio refinery |

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| **Lack of international agreement and cohesion** |
| Lack of international agreement on quota sharing in fisheries |
| **There are many challenges that face the fishing industry** |
| Many crises in fishing industry |
| **Multitude of stakeholders with overlapping and conflicting interests** |
| **Conflicting objectives and interests** |
| Competing interests |
| Conflicting interests create ghost fishing in this region |
| Contradictions in doing the best while also doing the worst re: sustainability |
| Fisheries management can be divisive |
| Lack of sustainability in seafood industry |
| Lowering carbon footprint as a separate and at times conflicting environmental goal |
| Scale predicts intensity of impact |
| Spatial squeeze is a big problem |
| Unforeseen negative consequences of well-intentioned environmental work |
| Use of fish feed is a huge problem |
| **Fisheries are divisive** |
| Fisheries politics are divisive |
| **Fisheries management is extremely complex and multi-layered** |
| Extremely challenging to manage |
| Bridging gap between policymakers and fishermen |
| Coordination across regional, national, international boundaries |
| Exceptionally complex industry |
| Extremely complex issues |
| Concerns span environmental, spatial, biological, sociocultural, economic |
| Fisheries and fishery management is very complex |
| Fisheries range in scale and species |
| Lots of nuance |
| National management by zone |
| Piggybackers |

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| Regulation |
| **Many marine stakeholders with many different interests** |
| Multitude of stakeholders involved in management |
| Overlap of organizations in marine space |
| **Negative effects of bureaucracy** |
| Lots of bureaucracy |
| **Orientation toward physical location** |
| **ALDFG is highly context-specific and place-based** |
| Context really matters |
| Interventions are highly dependent on the context and conditions |
| **Place-based approach to sustainable fishing** |
| Placed-based approach to sustainable fishing |
| **Place-based conflict** |
| Conflict from different parties with different interest operating in same physical location |
| Spatial squeeze |
| **Place-based loyalty** |
| Loyalty to local distributors, even at detriment to cost |
| **Place-based management** |
| Managing fishing industry dependent on geopolitical positioning |
| Regional administration |
| Regionality |
| **Place-based regulations** |
| Rules and regulations differ depending on location |
| **Regionality** |
| Regionality |
| **Ownership** |
| **Gear valued as property** |
| Fishing gear is property |
| Marine litter not considered lost fishing gear |
| **Sense of responsibility to protect own interests** |

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| Ownership of own narrative |
| **Representation of fishing industry** |
| **Aging of fishing industry** |
| Aging as a problem in fishing industry |
| Changing attitudes; readiness for change |
| Different mind gap for older generation |
| Younger generation is more accustomed to the conversation in day-to-day encounters |
| Younger generation of fishermen |
| **Concept of clean versus dirty fishing** |
| Dirty fishing |
| **Fishermen as conservationists** |
| Fishermen are deeply committed to conservation |
| Fishermen as conservationists |
| **Moral obligation to be part of representative body** |
| Culturally appropriate to contribute to membership group |
| Moral obligation to be a member |
| **Representation of fishermen's interests** |
| Committed to representation |
| Expanding membership |
| Membership organization |
| National representation can never represent individual interests |
| Representation of fishermen’s interest |
| Role of independent entities that operate on behalf of the fishing industry |
| Separate from government |
| Use of trusts to support members |
| Vessel size as an indicator |
| **Representation of fishermen's public image** |
| Actively pushing back against negative media |
| Different narratives inside and outside the industry |
| Upholding a public image |

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| **Research as a political tool** |
| **Evidence-based research is paramount** |
| Backed by evidence and research |
| Backed by research |
| Backed by science and research |
| Evidence and research backed |
| **Role of government** |
| **Government is not doing enough** |
| Government isn't doing enough about plastic problem |
| Government more focused on the materials that produce higher amount of waste |
| Inadequacy of government |
| **Government regulation of EPR scheme** |
| EPR |
| **Government regulation of reporting lost gear** |
| Reporting gear scheme in Norway |
| Reporting levels are high because of low risk and simplicity of task |
| **Government regulation to incentivize change** |
| Culture + government regulation are biggest factors |
| Government has sway |
| Massive impacts of small regulatory changes |
| Need for subsidies to cover extra cost of production |
| Regulation |
| Role of government in influencing adoption |
| Subsidies will be critical in short to medium term |
| Subsidization |
| **Seeking collaboration** |
| **ALDFG presents an extremely complex set of challenges** |
| Complexity of industry makes looking at ghost fishing in a single narrative misleading |
| Exceptionally complex industry |
| Extremely complicated issues |

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| **Seeking comradery** |
| Challenging with multiple stakeholders and interests |
| Data sharing |
| Effort to create common ground |
| Everyone has a part to play |
| Finding common ground; finding commonality in a highly disparate atmosphere |
| Need to involve all voices that are involved in this matter |
| Working for the common good |
| **Separate but integrated management** |
| Integrated management |
| **So it's public and free so anyone can use it.** |
| Working for the common good |
| **Working for the common good** |
| Membership increases collective action thinking |
| **Working with the players in the system to create change** |
| Challenging to go outside of the MSC and create own standards |
| Companies actively working on eliminating plastic from their supply chains |
| Have to take the rule-makers and standard-setters into consideration |
| Multi-stakeholder collaboration |
| Solutions need to be partnerships to drive actual change |
| Strategically, need to work with tuna fishers and get them to adopt new gear |
| **Self-preservation** |
| **Change poses risks to fishermen** |
| Hard to convince fishermen to adopt nets for testing |
| Importance of economic efficiency in fishing |
| It’s a bigger risk for fishermen to change their ways |
| Petrol is also another cost needed to be considered |
| Solution needs to work for them now, not next week |
| Will cost too much to have fishermen switch to biodegradable alternatives right now |
| **Fishermen look out for own interests** |

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| Fishermen try to game the system |
| **Ownership of own resources** |
| Fisheries politics are divisive |
| Ownership of nation's fisheries |
| **Sense of responsibility to protect own interests** |
| Industry takes responsibility for advocating for itself |
| Fishing industry taking responsibility for its own longevity |
| Ownership of own narrative |
| Taking responsibility for management when government fails to do so |
| **Solutioning through design** |
| **Carbon neutral model** |
| Carbon neutral model |
| **Circular design** |
| Alignment of lifespan to utility in design |
| Circular economy |
| Cradle to cradle |
| Example of closed loop system |
| Giving value to waste |
| Involvement of local labor |
| **Developing a market to change consumer behavior** |
| "Eat the bait" |
| Creating a market to incentivize different consumption behaviors |
| **Iteration is key** |
| Trial and error |
| **Material properties that imitate nature** |
| Imitating nature |
| **One size fits all does not exist** |
| Different nets for different locations |
| **Purposeful design** |
| Design for behavior of product |

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| **Use of natural materials as alternatives** |
| Use of natural materials as alternatives |
| **Standard setting** |
| **Marine Stewardship Council does not go far enough** |
| MSC doesn't concern itself too much with social issues, like labor rights |
| MSC is a bureaucracy |
| MSC is not nimble enough anymore for the ever-changing world of seafood |
| The MSC doesn't go far enough |
| **Marine Stewardship Council has a lot of influence in industry** |
| Strength of marine stewardship council |
| **The average person cannot understand the technicalities of standards** |
| Need for consumers to understand the certifications |
| The average person cannot understand the technicalities of standards |
| **Tradition** |
| **Fishing has a long history** |
| Knowledge about how gear used to be made |
| Long history |
| Long history of fishing in family |
| Long history of net mending |
| **Long history of using hemp** |
| Hemp is the most marine resistant natural fiber |
| **Long history of using natural materials** |
| Innovation |
| Used to use more natural materials to make pots and traps etc. |
| **Uncertainty about bioplastics industry** |
| **Bioplastics are weak** |
| Bioplastics are weak |
| **Bioplastics fishing gear is not yet commercial-ready** |
| Biodegradable fishing gear Is on the political agenda, but that's it |
| Companies are ready to deploy once material is ready |

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| Fishing crate testing in Ireland |
| Research is the focus in Norway right now; prototypes not ready for market yet |
| Testing nets in France, Cyprus, Patagonia |
| **Bioplastics is a burgeoning industry** |
| European market is advanced comparatively |
| **Dark side of bioplastics industry** |
| “Dirty” bioplastics industry |
| “Dirty” extrusion |
| Avoiding the bad reputation that comes with bioplastics industry |
| Bioplastic is an oxymoron |
| **Lack of clarity about biodegradability and bioplastics industry** |
| Bio-based sources |
| Clarifying nomenclature in bioplastics industry due to confusion |
| Complexity of bioplastic materials |
| Complexity of what it means to be biodegradable |
| Ideal solution is not existent currently |
| PLA |
| Policy for updating biodegradable and compostable standards |
| Standardization gap |
| Timeframe to biodegradation |
| **Unintended consequences of well-intentioned innovation** |
| **Potential negative externalities from biodegradable fishing gear** |
| Avoid incentivizing bad behavior through design of biodegradable nets |
| **Unintentional negative consequences of well-intentioned innovations** |
| Unintended consequences of well-intentioned policy |
| Unintentional negative consequences of well-intentioned innovations |
| Well-meaning change can lead to poor policy |
| **Anti-fishing sentiment from public** |
| **Anti-fishing sentiment from public** |
| Negative image of fishing industry created by media |

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| Anti-fisherman sentiment is caused by lack of understanding for full context of situations |
| Anti-fisherman sentiment is common and hugely detrimental |
| Anti-fishermen narrative |
| Anti-fishing sentiment affects fishermen’s involvement |
| Economic and sustainable viability |
| Fishermen as victims |
| Misconception about fishermen’s objectives |
| Misconceptions of fishing industry |

**Appendix 8: Participant consent form**

Dear Participant,

Thanks for your interest in this project about commercial fishing nets. In this note, I provide information about the project and ask for your consent to participate. If you agree, please complete the form, stating your name and that you agree to the statements in the table below to give your consent. You can send this form back in .doc format as an attachment, or you can copy and paste your consent (including your name and the completed table below) into the body of an email.

**What is the study about?**

Ghost fishing, the unintended or intended abandonment of fishing gear in the ocean, contributes to over 10% of the plastic pollution in the ocean; further, given plastic's 600-year shelf life, ghost nets have the propensity to kill marine animals and degrade natural environments long after their intended use. This study attempts to understand how a biodegradable fishing net might address these challenges.

**What will my involvement be?**

You will be asked to take part in an interview about your experience/knowledge of the fishing industry and/or alternative materials. It should take approximately 30 minutes to 1 hour of your time.

**Do I have to take part?**

Participation is **voluntary.** There are no negative consequences for you if you decide not to take part in this study. If you decide to take part but then later on you change your mind, you can let me know within 2 weeks after the interview takes place to withdraw the information you provided - you will not have to give any explanation why. It is also absolutely fine if you feel that you don't want to answer any specific questions – you can just tell me, and we will move on.

**What will my information be used for?**

Your information will be used for my master's dissertation, through which I will design an enterprise for selling biodegradable fishing gear.

**Will my information be anonymous?**

Your participation will be anonymous - your name will not be used in any reports or publications resulting from the study.

***If you agree to take part in the research, please complete the section below:***

**Your name**:

**Please read these three statements. If you agree with them, put a X in the boxes below:**

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|---|---|
| I have read this message and had the opportunity to ask questions. | |
| I agree to participate in the interview. | |
| I understand that my responses will be kept confidential and anonymous and that my personal information will be kept securely and destroyed at the end of the study. | |

**Once completed please email this form back to me. Thank you!**

Researcher name: XX

Email address: XX

The LSE Research Privacy Policy can be found here: https://info.lse.ac.uk/staff/divisions/Secretarys- Division/Assets/Documents/Information-Records-Management/Privacy-Notice-for-Research-v1.2.pdf

**Appendix 9: Sample question guide**

***Note****: The following question guide has been developed specifically for participants that identify as fishermen, or that work in a fishery management capacity. The researcher created unique guides for each stakeholder group.*

Introduction -

- Background of participant, connection to subject matter
- Mission of organization that they represent

Specific organization -

- Participation in fisheries management
- Participation in setting policies
- Participation in working with government, other key stakeholders

Fishing industry in an ecosystem -

- Description of the ecosystem of fishing-related organizations in participant's context
- Types of fisheries
- Types of gear used
- Types of laws and regulations that guide activities
- Interactions with stakeholders on local, regional, national, global levels

Sustainability/marine protection –

- Sustainability in fisheries management
- Dangers of marine plastic
- Dangers of ALDFG
- Types of innovations, policies, other measures taken to combat these issues

- Thoughts on a biodegradable fishing net/gear as a solution

Looking ahead –

- Any advice on who to talk to, reports/papers to read, directions to pursue, etc.?
- Any questions for me?

**Appendix 10: Excerpt from an interview transcript**

***Note**: A small excerpt of an interview transcript is included here; the researcher opted to refrain from including a lengthier sample size to honor the anonymization of the participants.*

Speaker 1: Well, let's put it this way. In the 1970s is when we started seeing the transition from natural pots made with wooden slats and reeds. You know hemp rope and that type of stuff, they started moving away from that to vinyl coated metal. And then the uh polypropylene netting and mesh and hard plastics and rubber and all of these components are because they just wear better and they don't have to do quite as much maintenance.

Speaker 2: Right.

Speaker 1: There are still a good number of people here in the fishery, at least in ----, that still know how to make a pot from scratch. They know how to do the webbing.
They know how to tie the knots that make a mesh, but most of the time they're only employing that skill in order to mend the pots that they have for most part, though, they buy their pots already made, and then they modify them a little bit. And that's because it's relatively cheap and easy to get these pods.

**Appendix 11: Outcomes-based funding**

As a way to cover the cost of producing biodegradable fishing gear, such that it may be offered in the market at a competitive price point, the SE should consider outcomes-based funding, such as through a social impact bond (SIB), for instance. SIBs typically involve three actors: an outcome funder, a social service provider, and an investor (Cohen, 2020, pp.22).

The outcome funder, which is usually a government entity, but is "sometimes an official aid organization or philanthropic foundation", "commissions a purpose-drive delivery organization" – which, in this case would be the social enterprise bringing the biodegradable fishing gear to market – "to achieve a particular social outcome" (Cohen, 2020, pp.22). An investor – not the outcome funder – then provides the funding for the service delivery (Cohen, 2020, pp.22).

Should the delivery of biodegradable fishing gear to the market not reach its targeted goals, as set forth in an outcome-based contract between these three parties, then the funding provided by the investor is treated like a philanthropic donation, and the investor effectively loses their money (Cohen, 2020, pp.22). However, if "targets are met, the investor receives their investment back, with a return that rises with the extent of the outcomes achieved" (Cohen, 2020, pp.22). The investor receives this return from the outcome funder (Cohen, 2020, pp.22).

The principal idea is that outcome-based funding "reframe[s] social and environmental challenges as investment opportunities" (Cohen, 2020, pp.27), and thus expands the opportunity and the scale of impact that social delivery organizations can achieve.