To Legalise or Not to Legalise: Evaluating the Contribution of Traceability Technology to the Sustainability and Governance of the Peruvian Jumbo Squid and Mahi Mahi Fisheries

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For Isabella and Valentina, may your future be bright and beautiful.

“... if I don't take care of that resource at sea, my business will end... As beautiful as the factory is, it is a useless building. That is why I take care of the resource, because it is profitable for me, it is part of my business” - Industry 6.

Abstract

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Given the worldwide implications of overfishing and its ensuing ecological consequences, the central question this study seeks to address is to what extent are electronic traceability systems, endorsed by organisations like WWF, able to enhance the sustainability and governance of fisheries. In Peru, jumbo squid and mahi mahi fisheries play a pivotal role in the nation's socio-economic landscape, employing tens of thousands of people. Despite their immense importance, significant gaps exist in the sustainability and governance of these fisheries, exacerbated by limited data on annual catches and the number of operational vessels. Addressing these challenges would not only ensure the fisheries' prosperity but would also support sustainable marine resource management. Employing a realist evaluation approach within a case study framework, this research delves into the developmental journey of the Peruvian fisheries' traceability system. It considers various stakeholder perspectives, encompassing artisanal fishers, industry players, governmental officials, and environmental non-governmental organisation (ENGO) representatives, and investigates the role of ENGOs and government institutions in the traceability process. Findings suggest that such systems can significantly strengthen governance arrangements, potentially leading to a marked improvement in sustainability practices. However, technological adaptability challenges emerge as barriers, impacting the uptake of such systems within the fishing community. While electronic traceability systems appear to offer a promising solution for Peru's fisheries, its success is contingent upon addressing various inherent challenges, some being technological, with most others socioeconomic. This study posits that with appropriate adjustments, other global and national fisheries might also derive benefits from similar interventions.

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P.S. No one should try to do a PhD while working full time, it is unhealthy. A message from Kalua as she sits beside me on submission day.

Author's Declaration

I hereby declare that this thesis is my own original work and has not been submitted in substantially the same form for the award of a higher degree elsewhere.

This statement has been confirmed by my supervisor:

- Associate Professor David F. Murphy, University of Cumbria

I confirm that the content of this thesis is a result of my independent work and that I have acknowledged all sources and contributions where applicable.

1 – Introduction

The introduction serves as the foundation of this thesis, providing an overview of the research topic and its significance. This chapter aims to acquaint the reader with the research approach and present the research questions and objectives. It begins by introducing the broader subject area and the specific focus of the study, emphasising the importance of traceability technology in promoting the sustainability and governance in the jumbo squid and mahi mahi fisheries of Peru. The chapter then outlines the structure of the thesis, which includes an overview of the subsequent chapters. It concludes by setting the stage for the subsequent chapters, which delve deeper into the relevant literature, research methodology, findings, discussion, and conclusions. By providing this introduction, the reader gains an understanding of the purpose and structure of the thesis, setting the stage for the subsequent chapters to unfold.

1.1 Research theme

The thematic focus of this thesis is the development and implementation of electronic traceability systems in Peruvian seafood supply chains, with particular attention to the artisanal fisheries of jumbo squid and mahi mahi. The thesis explores the challenges and opportunities of implementing traceability technology in these fisheries, with the aim of contributing to the sustainability and good governance of Peru's marine resources. The research questions addressed in this study include understanding the perceptions of different actors in the fisheries supply chain related to the development of traceability, identifying the challenges and opportunities for implementing traceability, and exploring the potential for traceability to contribute to sustainability transitions in the fisheries sector. By answering these questions, the thesis aims to provide insights and recommendations for improving the implementation of traceability systems in the artisanal fisheries of Peru and offering lessons learned for other regions facing similar challenges.

This research is important for several reasons. First, the seafood industry is a significant contributor to the global economy and plays a critical role in the livelihoods of millions of

people worldwide. However, the sector is facing serious challenges related to its sustainability and governance. Ensuring that seafood is caught and traded legally, while meeting social, economic, and environmental sustainability criteria, is essential for the long-term viability of the industry, as well as for the health of the oceans and the communities that rely on them. Second, while there has been progress in addressing these challenges in some countries, the development of traceability systems for Peruvian fisheries remains largely undocumented.

This research seeks to fill these gaps by examining the state of traceability implementation in Peru's artisanal fisheries and identifying opportunities for improvement. Finally, this research is significant because it takes a multi-stakeholder approach, engaging with actors across the fisheries supply chain, and promoting effective participation of communities as allies of the state in the application of fishing legislation, creating a more collaborative governance approach that can foster sustainability.

Peru is a country with a rich coastal marine ecosystem, which sustains the livelihoods of more than 88,000 artisanal fishers (PRODUCE, 2020). However, the jumbo squid and mahi mahi fisheries, which are the two most important artisanal fisheries in the country, face multiple challenges related to sustainability, governance, and fisheries management. These challenges have led to limited implementation of international sustainability standards, poor governance structures, and inadequate enforcement of existing regulations. The lack of effective management has also led to overfishing, habitat degradation, and negative impacts on the social and economic well-being of the communities that rely on these fisheries (Viatori & Bombiella, 2019). In response to these challenges, there is an increasing need to explore alternative approaches that can strengthen the sustainability and governance of these fisheries.

This thesis aims to explore the potential of traceability as a tool to support sustainability management and good governance of the jumbo squid and mahi mahi artisanal fisheries in Peru. The study focuses on the development and implementation of traceability systems in these fisheries, with the goal of identifying the benefits and challenges of traceability uptake for different stakeholders. This research aims to create a better understanding of how traceability can contribute to the sustainability of fisheries, and what considerations should be had when developing and implementing electronic traceability systems.

1.2 The Inspiration

The World Wide Fund for Nature (also known as World Wildlife Fund - WWF) has been working towards fisheries sustainability in Peru for at least a decade. In the organisation's analysis of the supply chain of the country's three most important fisheries (anchoveta, jumbo squid, and mahi mahi), the need for traceability became evident in 2015 with the new import regulations of the United States. At the time, WWF-US was in the process of developing traceability standards for the global fishing sector (WWF Smart Fishing Initiative, 2015), which served as guidelines for the organisation in Peru.

Having worked in environmental non-governmental organisations (ENGOs) since 2006, I joined WWF International in 2011 as Global Marine Turtle and Cetacean Manager. In 2018, I took on the role of Marine Programme Director for WWF-Peru, overseeing the team working on fisheries sustainability, where we began developing an electronic traceability system for the jumbo squid and mahi mahi fisheries that same year. Although my role has changed to Conservation Director since the end of 2021, I still follow closely the development of this work.

Initially traceability technology was seen as a way towards formalisation of the artisanal fishing sector to avoid illegal, unregulated, and unreported (IUU) fishing, and to gather data about the fisheries to inform and improve management. WWF's development of a traceability system has been centred on the first-mile user, that is the fishers, skippers, and fishing vessel owners. This has enabled the system to be continuously improved based on user feedback, making it more attractive and beneficial to these fishers and their needs.

Today, I am convinced that the development and implementation of electronic traceability systems with a user-centred design can be a game-changer towards sustainability from social, environmental, and economic perspectives in all production supply chains, from fisheries to other food and consumption products, in Peru and beyond, be they marine or otherwise. It is a tool that helps bring people together and solve problems that affect all of us.

As a conservation practitioner, I am deeply involved in the topic of my research. I have seen WWF-Peru's traceability system transform from a stick man drawing proposal to an application that you can download from the Apple or Play store, which is used by hundreds of fishers in Peru today. I participated in the first meetings with government authorities, where they were

not that interested. Yet, after half a decade of work in the field with fishers, by demonstrating adaptability and perseverance, the relationship with government authorities has flourished. Moreover, during this time, government authorities have come to better understand the importance of implementing international standards that facilitate information exchange, that is interoperability, between private and publicly operated traceability systems for fisheries; as well as the value of having a user-centred system that demonstrates benefits to fishers as well as other supply chain users. The implementation of traceability systems in fisheries requires collaboration between supply chain actors that are not necessarily used to working with each other, making trust-building one of the most fundamental requirements for success (Hosch & Blaha, 2017).

My hope is that through this research a contribution can be made to the development and implementation of traceability systems in artisanal fisheries and other supply chains in Peru and beyond. By doing so, there will be a better understanding of the benefits and challenges of traceability uptake for different stakeholders. But most importantly, I hope that as such technologies develop, the needs of first-mile users are prioritised, their roles highlighted, and equity is improved in fisheries supply chains, because the men and women at sea and those who work at fishing docks on land are the ones that do the hardest work for the least remuneration. If traceability systems were incorporated into all global supply chains, with a focus on contributing to social, economic, and environmental sustainability standards, the way society produces and consumes would be better for people and the planet.

1.3 Research approach

To address the research questions and realise the objectives of this thesis, a qualitative research approach was used. Qualitative research is a useful tool for exploring complex phenomena and social processes, allowing for a rich understanding of the perceptions and experiences of individuals and groups (Almeida et al., 2017). This approach allowed for the collection of in-depth data on the development and implementation of traceability in the jumbo squid and mahi mahi artisanal fisheries of Peru. Moreover, it aided in identifying challenges and opportunities for fisheries sustainability and good governance.

The study was designed to be exploratory in nature, as the research area is underdeveloped regarding traceability uptake in the Peruvian fisheries sector. The approach involved the use of semi-structured interviews as the primary data collection method. This technique provided the flexibility required for exploring diverse topics, while also providing a structured framework for data collection. The sample for the study was selected using purposive sampling, which involved the selection of participants based on their knowledge or experience and involvement in traceability efforts in the Peruvian jumbo squid and mahi mahi fisheries. The sample included a range of fisheries stakeholders from the public, private, artisanal, and civil society sectors. Data analysis involved a thematic approach, encompassing a process of familiarisation with the data, followed by a process of coding and categorisation. This led to the identification of key issues and perspectives related to the development and implementation of traceability in the jumbo squid and mahi mahi fisheries.

1.4 The problem and opportunity

The sustainability of fisheries is a complex and multi-faceted global issue that has significant economic, social, and environmental implications. With more than 90 million people employed in the sector worldwide and over 3 billion people relying on seafood as their primary source of protein (FAO, 2020), the importance of fisheries sustainability cannot be overstated.

However, despite international agreements and regulations aimed at promoting sustainable fishing practices, many fisheries are still characterised by overfishing, IUU fishing, and poor governance. These challenges are particularly severe in developing countries, where a lack of resources and weak institutions often hinder effective fisheries management (Widjaja, et al., 2023).

WWF's involvement in traceability within Peru's fisheries stems from its broader commitment to promoting sustainable resource management and combating IUU fishing. Recognising the critical role that transparency and accountability play in achieving sustainability, WWF identified electronic traceability systems as a transformative tool to address governance and environmental challenges in the Peruvian jumbo squid and mahi mahi fisheries. Through collaborative efforts with governmental agencies, industry stakeholders, and local fishing communities, WWF has been instrumental in piloting and scaling traceability initiatives, such

as TrazApp, that aim to ensure compliance with international market requirements while supporting the livelihoods of artisanal fishers.

The key issues addressed by this research are the pressing sustainability and governance challenges faced by the artisanal jumbo squid and mahi mahi fisheries in Peru. These fisheries are vital for the economic well-being and food security of coastal communities. However, they are beset by numerous sustainability challenges, including overfishing, bycatch of non-target species, and a lack of effective fisheries management practices. Additionally, inadequate governance structures, weak regulatory frameworks, and limited enforcement mechanisms contribute to unsustainable fishing practices and hinder the implementation of effective management strategies (Silva & Alfaro, 2021).

Given these challenges, electronic traceability systems hold great potential to address the sustainability and governance issues in the fisheries sector. Traceability systems can provide a robust mechanism for tracking and documenting the entire supply chain of fish products, from the point of catch to the point of consumption. By capturing crucial information such as fishing location, catch methods, and processing practices, traceability technology can enhance transparency and accountability throughout the seafood value chain. This increased transparency enables stakeholders to monitor and verify the sustainability of fishing practices, thereby ensuring compliance with environmental regulations and responsible fishing standards (Leslie & Lugo-Mulligan, 2021).

Furthermore, traceability technology can play a significant role in combating IUU fishing. The jumbo squid and mahi mahi fisheries in Peru face significant challenges related to IUU fishing, which undermine conservation efforts, distort market dynamics, and pose a threat to the livelihoods of legitimate fishers. By implementing traceability systems, it becomes possible to trace the origin of seafood products, detect potential instances of illegal fishing, and prevent the entry of illicit products into the market. This contributes to the conservation and sustainability of fish stocks and supports the economic viability of the fisheries.

Moreover, the adoption of traceability technology can enhance the overall governance of the fisheries sector by improving data collection, information sharing, and decision-making processes. Accurate and reliable traceability data provide valuable insights into the state of the fisheries, facilitating evidence-based decision-making and adaptive management approaches.

It allows policymakers, resource managers, and industry stakeholders to identify trends, evaluate the effectiveness of management measures, and implement timely interventions to ensure the long-term sustainability of the fisheries.

In summary, the sustainability and governance challenges faced by the jumbo squid and mahi mahi fisheries in Peru necessitate the exploration of innovative solutions, such as traceability technology. By promoting transparency, combating IUU fishing, and enhancing governance mechanisms, traceability systems have the potential to contribute significantly to the sustainability and governance of these fisheries. This research, therefore, aims to investigate the adoption, impact, and potential benefits of traceability technology, ultimately informing the development of effective strategies for fisheries management and fostering the well-being of fishers and local communities.

1.5 Research aim and objectives

The aim of this research is to examine how the transition to traceability technology adoption in Peruvian jumbo squid and mahi mahi artisanal fisheries is occurring and its potential contribution to fisheries sustainability and governance. To achieve this aim, the study has the following two objectives:

RO1: Investigate how the transition to electronic traceability systems is occurring in Peruvian jumbo squid and mahi mahi fisheries by:

a. describing the emergence of traceability technology in these fisheries, as well as the drivers and motivations behind its adoption;
b. understanding how and why traceability is gaining momentum in niches and how it can become mainstream; and
c. documenting the reactions of different stakeholders to the changes associated with the implementation of traceability and identifying the barriers and principles for adoption.

RO2: Assess the influence of ENGOs and government structures on the adoption of electronic traceability systems in the jumbo squid and mahi mahi fisheries in Peru by:

a. describing the relationship of ENGOs with government agencies, industry actors, and the artisanal fishing community in the promotion of traceability;
b. identifying situations in which ENGOs are seen as important players driving the adoption of the traceability, when they are not, and why;
c. analysing the influence and impact of government institutions and regulations on the adoption of traceability in the Peruvian jumbo squid and mahi mahi fisheries.

1.5.1 Research questions

The evolution of fisheries management, particularly in the context of Peru's jumbo squid and mahi mahi fisheries, is a complex process influenced by technological advancements, institutional dynamics, and various stakeholders. Traceability technology offers a promising pathway toward improved governance and sustainability of these fisheries. Yet, understanding its adoption process, the role of supply chain stakeholders, and the associated challenges related to its adoption becomes pivotal. With this backdrop, the research is anchored around two primary research questions and six sub-research questions to help respond to the two main questions:

RQ1: How is the transition to electronic traceability systems occurring in the Peruvian jumbo squid and mahi mahi fisheries?

a. How is traceability technology emerging in these Peruvian fisheries? What are the drivers and motivations behind its adoption?
b. How and why is traceability gaining momentum in niches, adapting and growing? How can it become mainstream?
c. How does the fisheries' institutional structure respond to these innovations? What are the perceived barriers and principles for its adoption?

RQ2: What are the contributions of ENGOs and government structures in the transition to electronic traceability systems in the Peruvian jumbo squid and mahi mahi fisheries?

a. How do ENGOs engage with the government, industry and the artisanal fishing community in promoting traceability technology?

b. Under what conditions are ENGOs considered important players driving the adoption of traceability? Under what conditions are their aspirations and objectives marginalised?
c. How do government institutions and regulations influence and impact the adoption of traceability in the jumbo squid and mahi mahi fisheries?

1.6 Influence of literature on research questions

The research questions in this study have been shaped by the influence of existing literature, particularly the Sustainability Transitions Multi-Level Perspective (MLP). The MLP is a multi-dimensional, systems-based approach to understand and analyse large scale, socio-technical transitions. In taking an integrative approach, the MLP aims to transcend the limitations of traditional, single-track enquiries, which might focus on particular social groups, desired outcomes or academic disciplines (Geels, 2011).

For this investigation the MLP has provided a valuable theoretical framework to understand the complex dynamics of sustainability transitions and their implications for traceability technology adoption in Peruvian fisheries. Designed to help understand complex transitions that involve multiple actors and activities, the MLP emphasizes the importance of radical innovations, while taking into account the fact that socio-technical transitions involve multiple social groups (such as companies, consumers, social movements, policymakers, researchers, media and investors), who engage in multiple types of activities (such as exploration, learning, debate, negotiation, power struggle, conflict, investment, coalition-building and goal-setting), in the context of the rules and institutions of society and social groups, including their belief systems and norms (Geels, 2019).

Drawing on the MLP, this research aims to explore the transition processes, considering the interactions between different levels of actors and institutions. Applying the MLP framework enables the different strands of influence and interaction that affect the evolution of an innovation to be teased out. It reveals the potential of that innovation to change not only the socio-technical system or systems in which it develops, but also the broader context shaping the system itself (Dahle, 2007).

The MLP emphasises the importance of understanding the dynamics between niche innovations, existing regimes, and the broader socio-technical landscape (Sovacool, 2017). It has guided the understanding of the various factors that contribute to the emergence and diffusion of traceability technology in Peruvian fisheries, including the roles of ENGOs, government structures, and institutional dynamics.

By employing the MLP, this research seeks to uncover the drivers, motivations, barriers, and principles influencing the adoption of traceability, ultimately contributing to a comprehensive understanding of the sustainability and governance implications of electronic traceability systems uptake in the Peruvian jumbo squid and mahi mahi fisheries.

1.7 Contributions of the research

This research makes contributions to the field of sustainability transitions, particularly related to traceability technology adoption in fisheries contexts. First, the study advances understanding of the potential contribution of electronic traceability systems in improving fisheries sustainability and governance. Drawing on the sustainability transitions MLP framework, this research exposes the complex dynamics and challenges surrounding the uptake of traceability systems in Peruvian jumbo squid and mahi mahi fisheries. The findings shed light on the obstacles, opportunities, and key factors that influence the development and adoption of traceability systems to meet the needs of diverse stakeholders across the fisheries supply chain.

Second, this research contributes to the knowledge of the role played by various stakeholders, with a particular focus on ENGOs, in driving sustainability transitions in the fisheries sector. By examining the engagements and interactions between ENGOs and different actors in the supply chain, this study sheds light on their influence in shaping the transition towards traceability adoption. The research identifies the conditions under which ENGOs are perceived as key drivers in the promotion of traceability systems, as well as the circumstances in which their aspirations and goals may face marginalisation.

Furthermore, this research clarifies the impact of government institutions and regulations on the adoption of traceability in jumbo squid and mahi mahi fisheries. By analysing the role of government institutions and the regulatory framework in facilitating or hindering the adoption

of traceability, the study provides insights into the institutional dynamics and governance structures that shape the transition process. It examines the alignment or misalignment between existing regulations and the needs and aspirations of different stakeholders, including fishers, industry actors, and ENGOs. The findings highlight the worth of supportive policies, adequate resources, and effective coordination among government institutions in driving the successful adoption of traceability systems to improve sustainability practices in these fisheries.

This research makes contributions to the field of sustainability transitions by deepening our understanding of the role of traceability technology in improving fisheries sustainability and governance. It underscores the importance of diverse stakeholders, including ENGOs, in driving sustainability transitions within the Peruvian fisheries sector. The study also identifies and addresses the challenges and opportunities associated with traceability adoption, paving the way for the potential scaling up of sustainability practices and policies in these fisheries.

In the next chapter the context of Peruvian fisheries, including government institutions and regulations will be discussed with a specific emphasis on the jumbo squid and mahi mahi fisheries and the development and uptake of traceability systems.

2 – Context

This chapter provides an overview of the contextual setting of the multifaceted landscape of Peruvian fisheries, exploring its regulations, the artisanal jumbo squid and mahi mahi fisheries contexts, international market requirements, certification schemes, and the evolution of fisheries traceability adoption. The primary focus here is understanding the value of traceability in promoting sustainability and effective governance, as well as the challenges and opportunities entailed in its implementation.

Looking at the role played by ENGOs in the promotion of traceability, their impact on shaping the trajectory of Peruvian fisheries in this regard is introduced. This exploration sets the scene for relationship dynamics between ENGOs, government institutions, artisanal fishers, and industry stakeholders, which shapes the context of this research.

The aim here is to illuminate the complexities surrounding fisheries traceability in Peru, to identify key issues, and to later propose paths to move forward. The structure of the chapter is designed to lead towards a better understanding of the interplay between traceability, sustainability, and governance in the Peruvian jumbo squid and mahi mahi fisheries.

2.1 Peruvian fisheries

Peru has a coastline of 3,000 km and a sea area of 231,000 km², making it home to approximately 250 harvest species (Ruiz et al., 2019). At least 50% of the country's population lives in cities along the coastline, with Lima alone holding one-third of the national population, totalling 10 million inhabitants (Creel, 2003). Local seafood is a crucial part of Peruvian culture, with a per capita consumption of around 14.5 kilos/year (Future of Fish, 2019), and Peru ranks fourth in fish volume caught worldwide (Ruiz et al., 2019). Peru's seafood sector is second only to mining, representing the second-highest source of foreign currency (Future of Fish, 2018). The fisheries industry is also the primary source of employment in the country, with approximately 200,000 people employed directly and 800,000 indirectly. However, many fishers operate with limited or no training, putting lives at risk, since, for example, many of them do not know how to swim (Paredes, 2017).

The governance and management of small-scale artisanal fisheries presents significant challenges for the country. These fisheries have experienced an uncontrolled expansion driven by increasing market demand, open-access policies, deficient or lack of regulation, and limited surveillance and enforcement (Future of Fish, 2018). Existing fishing pressure threatens valuable fishery resources as well as coastal and marine biodiversity. Artisanal fisheries suffer primarily from informality and a lack of data for good governance. For example, even for the nine commercial fisheries that have Fisheries Management Regulations (Reglamentos de Ordenamiento Pesquero or ROPs in Spanish), data is out-of-date and not publicly available.

Additionally, data collection is incomplete as it is mainly focused on gathering information on commercial fishing activities (e.g., landings and fishing GDP), without considering biological data, such as composition of biomass and distribution, and ignoring socio-economic information of artisanal fishers and their families (Intelfin & WWF, 2020). Furthermore, Peru lacks a digital platform to systematise fisheries data in real-time. Such a system would enable timely decision-making on management measures, reducing the possibility of data manipulation and corruption (Intelfin & WWF, 2020). These issues highlight the need for improved governance and management of Peru's fisheries sector to ensure sustainable fishing practices and support the livelihoods of coastal communities.

2.1.1 Informality in Peruvian fisheries

One of the main challenges for fisheries governance in Peru is informality. Illegal, unregulated and unreported (IUU) fishing that does not comply with regulations, includes fishing without proper permits or quotas, operating without proper safety equipment, and using illegal fishing methods can lead to overfishing, the depletion of fish stocks, and environmental degradation. In Peru, as much as 70% of fishing is informal (Gozzer-Wuest et al., 2022). This is a significant problem, as it undermines efforts to manage fisheries sustainably and can have negative social and economic impacts, particularly for small-scale fishing communities.

One of the primary factors contributing to the prevalence of informality within the Peruvian fishing industry is the complex regulatory framework that governs the sector (Gozzer-Wuest et al., 2022). The regulations pertaining to fishing activities encompass a wide range of rules, including licensing requirements, catch quotas, gear restrictions, and environmental conservation measures. The complexity arises from the numerous regulatory bodies involved,

each with its own set of rules and procedures, sometimes overlapping in functions. For instance, fishers must navigate through regulations set by the Ministry of Production (PRODUCE), the Ministry of Environment (MINAM), Regional Production Directorates (DIREPROs), and other relevant agencies.

Moreover, the regulations themselves are not always clear and may be subject to interpretation, leading to confusion among fishers. As a result, fishers may unintentionally violate regulations, facing penalties and fines due to their inability to fully comprehend and navigate the complex regulatory landscape.

Furthermore, the enforcement of regulations is hindered by limited government capacity and resources. Government agencies responsible for monitoring compliance often struggle to allocate sufficient personnel and technology to cover the vast fishing grounds along the coastline. The lack of monitoring and surveillance mechanisms reduces the deterrence factor, as fishers perceive a lower risk of being caught and penalised for non-compliance (Nakandakari et al., 2017). Some fishers choose to operate informally because they do not want to pay taxes or comply with regulations, while others do so because they are not aware of the regulations or find the permit application process too complicated and time-consuming (Defeo, 2020).

Efforts are being made to address the issue of informality in the Peruvian fishing industry. For example, the government has implemented a system of fishing quotas, which aims to reduce overfishing and ensure that the fishing industry operates sustainably. Efforts to strengthen monitoring of fishing activities to improve enforcement have also been implemented, including the use of satellite technology to track fishing vessels (Tveteras et al., 2011).

However, there are still challenges to address informality in the fisheries sector in Peru. According to Paredes (2017:11), “the lack of government oversight, means that fisheries and labour legislation are not enforced, creating a situation that can be characterised as the ‘Wild West’, where anything goes; putting the conservation of marine resources at risk.” This informality leads to less access to formal capital, limited capacity to increase added value to products, and continued precarious living conditions for fishers (Paredes, 2017).

Overall, addressing informality in the fisheries sector is crucial for the long-term sustainability of Peru's fisheries resources and the well-being of those who depend on them. It will also

require the involvement and cooperation of all supply chain stakeholders, including government, industry, and civil society. But the starting point is increasing collaboration between government agencies themselves. In the next section, the regulations governing fisheries in Peru and the government institutions responsible for overseeing the sector are discussed.

2.2 Peruvian fisheries institutions & regulations

Peruvian fisheries face numerous challenges related to IUU fishing, unsustainable fishing practices, and limited fisheries management. Although Peruvian fisheries regulations exist, there are still significant challenges in data gathering, monitoring, and widespread adoption (IMARPE, 2001).

2.2.1 Overview of government institutions

The effective management of fisheries resources in Peru involves multiple government institutions that work together to develop policies, implement regulations, and monitor compliance:

- PRODUCE is one such institution, and is responsible for the design, execution and supervision of national and sectoral policy for Fisheries, Aquaculture, MYPE and Industry (PRODUCE, 2024);
- The National Fisheries Development Fund (FONDEPES) promotes competitiveness and sustainable development in the fishing sector;
- The Marine Research Institute of Peru (IMARPE) conducts scientific studies and provides advice for sustainable fisheries management;
- The National Fisheries and Aquaculture Health Service (SANIPES) ensures safety and quality standards for seafood products;
- The General Directorate of Captaincies and Coastguards (DICAPI) enforces safety and environmental regulations in the fishing industry;

- The Superintendency of Customs and Tax Administration (SUNAT) oversees tax collection and international trade regulations;

- DIREPROs also play a significant role in implementing and enforcing fisheries regulations within their jurisdictions (WWF, 2017).

While these institutions are key players in Peruvian fisheries management, Paredes (2017) highlights significant challenges related to institutional weaknesses and inefficiencies. Inadequate institutions hinder the sustainable, efficient, and equitable exploitation of hydrobiological resources.

Overlapping functions among entities at different levels of government and sectors remain unresolved, leading to contradictions between regional and central government directives, particularly concerning direct human consumption fishing and the artisanal fleet.

Paredes (2017) also notes that corruption may influence judiciary judgments, further interfering with national fisheries management. These observations underscore the need for institutional improvements and effective coordination among stakeholders to promote sustainable practices in Peru's fisheries sector.

To gain an understanding of the opportunities for improvement in the management of fisheries information for government institutions, one must consider the specific information managed by each state institution in the Peruvian fishing sector:

- PRODUCE handles fishing permits, vessel registration, fish processing plant registration, and various certificates related to catch, origin, and landing;

- DICAPI is responsible for vessel and seamen registration, as well as port-related documentation;

- SANIPES oversees technical protocols for sanitary qualifications, registration of importers and distributors, and certification for export and import purposes;

- IMARPE provides scientific fishery information, proposes management guidelines, and analyses fishing data;

- FONDEPES utilises fishing information to construct artisanal fishing infrastructure;
- SUNAT regulates the export processes of fishing products, while the DIREPROs issue certificates of origin and simplified catch certificates (WWF, 2017).

Understanding the specific information needs of each institution is crucial for designing a comprehensive national traceability system. See table 1 for a summary of government roles and challenges.

Table 1. Peruvian government institutions roles and challenges

Government institutions	**Roles**	**Challenges**
Ministry of Production (PRODUCE)	Responsible for sustainable development, resource management, and regulatory compliance.	Limited resources, informality in fisheries, lack of capacity for enforcement.
National Fisheries Development Fund (FONDEPES)	Promotes competitiveness and sustainable development in the fishing sector.	Limited information on the infrastructure and capacity building needs of fishers for traceability adoption.
Marine Research Institute of Peru (IMARPE)	Conducts scientific studies and provides advice for sustainable fisheries management.	Lack of data to provide informed advice for all fisheries.
National Fisheries and Aquaculture Health Service (SANIPES)	Ensures safety and quality standards for seafood products.	Limited information exchange with other government institutions.

General Directorate of Captaincies and Coast Guard of Peru (DICAPI)	Enforces safety and environmental regulations in the fishing industry.	Has an institutional commitment to digitalise processes.
Superintendency of Customs and Tax Administration (SUNAT)	Oversees tax collection and international trade regulations.	Fisheries informality means there is a limited contribution of fishers to legal requirements for tax purposes.
DIREPROs	Play a significant role in implementing and enforcing fisheries regulations within their jurisdictions.	Limited resources, overlap in functions with PRODUCE, and corruption.

Source: J. Castillo, own creation, April 7, 2024.

The subsequent section provides a summary of the most pertinent Peruvian fisheries regulations.

2.2.2 The fisheries regulatory framework

Sustainable fisheries management refers to an approach that ensures fish stocks are harvested at a rate within sustainability limits, where fishing activities do not cause harm to the environment nor the fish stock. This approach prioritizes the long-term health and stability of fish populations, the marine environment, and the communities dependent on fisheries. It encompasses the implementation of scientifically informed policies, practices, and regulations that balance ecological integrity with the socioeconomic needs of communities, ensuring the viability of fisheries for future generations. Key elements include maintaining or restoring populations of target and non-target species to healthy levels, minimizing environmental impacts, ensuring equitable access, benefits for all stakeholders involved, and adapting governance practices in response to scientific findings and socio-economic changes (Shelton & Sinclair, 2008).

Good fisheries governance is underpinned by principles of transparency, inclusivity, and accountability, aiming to achieve ecological sustainability, economic viability, and social equity (Jentoft, 2019). In Peru, the fisheries sector plays a significant role in the country's economy and food security. To achieve sustainable fisheries and good governance, it is essential to have a robust regulatory framework that guides the activities of government institutions, supports compliance with regulations, and addresses the specific challenges faced by different fishing sectors.

2.2.2.1 The General Fisheries Law

Peru's GFL (DS 012-2001-PE) serves as a cornerstone for regulating the fishing industry and promoting its sustained development as a source of food, employment, and income, while ensuring the responsible use of fishing resources and the conservation of marine biodiversity (Ruiz et al., 2019). However, the GFL lacks specificity in its provisions, particularly concerning artisanal fisheries. The law distinguishes between commercial and non-commercial fishing, with artisanal fisheries falling under the non-commercial category. However, the broad definitions in place for artisanal fisheries in Peru include a diverse range of species, techniques, vessel types, and end markets (Future of Fish, 2018). This lack of specificity has resulted in governance and management challenges for small-scale and artisanal fisheries (Viatori & Bombiella, 2019).

The current regulatory framework in Peru is complex and fragmented, consisting of various thematic and sectoral regulations that lack coherence and integration into a comprehensive marine and coastal development policy. One of the major criticisms is the absence of the concept of governance in the GFL (Andia Morales et al., 2019). As a political model, fisheries governance seeks an efficient socio-ecological management system, given by the conjunction between legal, social, economic and political aspects, the establishment of institutions, policies and processes and the interaction of actors from the local to international level (Liscovsky & Parra Vazquez, 2015). The lack of articulation between different participants in the economic activity of artisanal fishing has led to the current situation (Andia Morales et al., 2019). The overlapping of functions between different entities, both at intra and intersectoral levels, as well as between different levels of government, remains unresolved. Additionally,

various judicial judgments, likely influenced by corruption, have interfered with national fisheries management (Paredes, 2017).

Regarding control, enforcement, and sanctions, the GFL emphasises the need for monitoring, control, and surveillance measures (Article 12). The Regulation of Supervision and Sanction of Fishing and Aquaculture Activities (DS 017-2017-PRODUCE) establishes infractions and sanctions applicable to fishing activities. However, supplementary regulations are often difficult to locate, making it challenging for fishers to be aware of the specific regulations they should adhere to. This lack of clarity and awareness creates opportunities for corruption and bribery during inspections, as fishers may be uncertain about the validity of the alleged infractions (Gudynas, 2019).

In addition to the GFL, Peru has several other regulations that aim to ensure the sustainable management of fisheries resources and the protection of marine ecosystems. These regulations cover a range of topics, from fishing quotas and licensing to the protection of endangered species and the conservation of marine habitats. An overview of some of the most important regulations related to Peruvian fisheries management are covered next.

2.2.3 Management rules to protect the stock and ensure sustainable fisheries yield

The GFL, as stipulated under Article 11, requires the Ministry of Fisheries (currently represented by PRODUCE) to establish a management system that promotes the long-term conservation and sustainability of fishery resources. However, despite the existence of over 100 commercially important fisheries in Peru, only 11 marine resources have fisheries management plans (ROPs) (SPDA, 2020).

The ROPs (see Table 2 below) encompass a range of management aspects, including access regimes, fleet and processing capacity limitations, fishing seasons, total allowable catch (TAC), fishing gear restrictions, minimum size requirements, prohibited areas, research obligations, as well as control and surveillance measures. However, the establishment of minimum sizes and closed seasons or temporary access restrictions is still limited in scope. Only 64 marine species have designated minimum sizes, and a mere 27 species have closed seasons or temporary access restrictions. This indicates a gap in the coverage of management measures (RM 209-2011-PE) (SPDA, 2020).

Table 2. Peruvian Fisheries Management Plans (ROPs)

Fisheries	**Supreme Decree**
Anchoveta	DS 005-2017-PRODUCE
Jumbo squid	DS 014-2011-PRODUCE
Mahi mahi	DS 017-2021-PRODUCE
Eel	DS 013-2011-PRODUCE
Mackerel	DS 011-2007-PRODUCE
Tuna	DS 032-2003-PRODUCE
Hake	DS 016-2003-PRODUCE
Cod	DS 236-2001-PE
Benthic species	DS 018-2021-PRODUCE
Macroalgae	DS 019-2009-PRODUCE
Specific to the Tumbes area	DS 020-2011-PRODUCE

Source: Adapted and updated from SPDA (2020).

To illustrate the challenges and complexities of the regulatory framework, the case of mahi mahi fishing in Peru exemplifies the need for improvement. The mahi mahi ROP (DS 017-2021-PRODUCE) stipulates the requirement for establishing fishing quotas before each season. However, in 2021, the fishing season commenced without a published quota, which was only released in March 2022, less than two months before the season's end. Even before the quota was officially announced, the General Office of Impact Assessment and Economic Studies of PRODUCE reported a catch of 43,627 tonnes, which accounted for 99% of the quota (Rovegno, 2022). Therfore, the mahi mahi fishing season continued even after the quota had been met in 2022, highlighting the need for more fisheries data, monitoring, and timely decision-making.

Furthermore, there is a pressing need to update the jumbo squid ROP, as the existing management plan is over a decade old. The ROP for benthic species (DS 018-2021-PRODUCE), on the other hand, stands out as a significant development, as it grants access to organised fishers based on an extraction plan that incorporates management and conservation measures. However, challenges remain in the implementation of this ROP, including the demanding requirements for SANIPES sanitary classification and the need for the development of extraction plans, placing a burden on artisanal fishers that is hard to overcome on their own. The integration of a traceability system could potentially facilitate compliance with such requirements.

The guidelines for monitoring and follow-up of quotas or catch limits established for hydrobiological resources (RM 365–2020-PRODUCE) outline the monitoring procedures for both industrial and artisanal fisheries. While the system works reasonably well for industrial fisheries, which have smaller fleets and specific landing sites, there are significant challenges for artisanal fisheries like jumbo squid and mahi mahi, with thousands of fishing vessels operating along the coast throughout the year, coupled with a limited number of available inspectors.

Another example of the lack of regulatory coherence is that of Legislative Decree Nº 1393 (Gobierno de Peru, 2018), which facilitates the interdiction of illegal activities in fishing, allowing for the intervention, dismantling, and seizure of illegally constructed fishing vessels. However, the practical implementation of this decree faces obstacles, as it is not classified as a crime in the criminal code, a requirement for initiating any interdiction action.

So, although Peru has established the GFL to promote sustainable fishing practices and the conservation of marine biodiversity, the regulatory framework faces significant challenges. Sustainable fishing practices should be based on access rights to fishing zones, with established governance systems, that allow fishers and authorities to assess fish stocks and establish control rules (Silvius et al., 2004). The lack of specificity in the law regarding artisanal fisheries, the complexity and fragmentation of regulations, and the gaps in enforcement and monitoring contribute to hinder good governance and sustainable management of Peru's fisheries sector. Addressing these challenges requires enhanced data collection and monitoring systems,

streamlining compliance procedures, improving control and enforcement mechanisms, and promoting greater transparency and coordination among stakeholders (OECD, 2016).

In the next section the regulations that are relevant to good fisheries governance, particularly with regards to the participation of different sectors in government decision making processes are presented.

2.2.4 Challenges in participatory processes and stakeholder consultation within the fishing sector

The participatory and consultation processes in Peru's fishing sector are limited, with the primary mechanism being the 'pre-publication' method, regulated by Supreme Decree No. 001-2009-JUS (Ministerio de Justicia y Derechos Humanos, 2009). This mechanism was established as part of the obligations acquired by the Peruvian State under the Peru-United States of America Trade Promotion Agreement (APC), specifically in Chapter 19 titled 'Transparency of the APC Peru-USA'. The decree requires public entities to publish draft regulations of a general nature in the Official Gazette ‘El Peruano’, their electronic portals, or through other means, at least 30 days before the scheduled date of their approval, with rare exceptions. Interested parties are allowed to comment on the proposed measures during this period.

However, the regulation does not extend the obligation to pre-publish regulations of a specific nature. Therefore, the authority has discretionary power to determine whether pre-publication is necessary or not based on ‘security concern’s or if it does not consider it of ‘public interest’. Additionally, there is no explicit requirement for public entities to review, evaluate, or consider the comments received. The preparation of a comment matrix incorporating stakeholders' input, is left to the discretion of the officials. The regulation provides broad discretion for the authority to justify why a standard should not be pre-published, which is an evident obstacle for civil society to participate in decisions related to new regulations.

The issuance of approximately a thousand regulations annually, including ministerial resolutions, supreme decrees, and other norms, poses challenges for the understanding and assimilation of these regulations by those affected. While industrial companies usually have

legal departments responsible for processing these norms, artisanal fishers often lack awareness and understanding of the ever-changing rules. It is crucial to consider the development of didactic summaries and training processes, accompanied by consensus-building efforts, to enhance understanding and compliance among artisanal fishers (ILO, 2003).

To address the limitations in participatory processes, there is a need to create spaces for dialogue and consultation involving fishers' organisations, private entities, social institutions, and state agencies focused on artisanal fishing. This would enable stakeholders to be included in decision-making processes and establish mechanisms for collaboration and solution-oriented approaches. By facilitating dialogue and consensus-building, these spaces can contribute to improving the knowledge and assimilation of regulations, enhancing compliance, and promoting a more inclusive and participatory fishing sector (ILO, 2003).

In the next section, the specific regulations relevant to traceability in Peru are discussed.

2.2.5 National legislation relevant to traceability

In the context of Peruvian fisheries, several regulations have been issued by competent authorities to manage information and ensure traceability of fisheries resources and products. These are: the Regulation of the General Fisheries Law (DS 012-2001-PE), the law that establishes the creation of SANIPES (Ley 30063), the Supreme Decree which approves the Regulation of Organization and Functions of the Ministry of Production (DS 002-2017-PRODUCE), the Regulation of Organisation and Functions of the Ministry of Production (Gobierno de Peru, 2013; Gobierno de Peru, 2018; Gobierno de Peru, 2018; Gobierno de Peru), and the General Provisions for the Strengthening of Artisanal Fishing in the Production Chains (DS 006-2016-PRODUCE).

2.2.5.1 Regulation of the General Fisheries Law

The latest version of the GFL Regulations (DS 012-2001-PE), aims to simplify and consolidate the provisions of the GFL. These regulations promote responsible management and sustainable use of hydrobiological resources, emphasising the balance between socio-economic development, conservation, and sustained environmental use. Article 134,

paragraph 3 of the regulation establishes that presenting incorrect information or documentation during inspections or failing to provide documents proving the legal origin and traceability of hydrobiological resources or products is considered an infraction.

2.2.5.2 Law 30063 for the Creation of SANIPES

Under Article 3, numeral 29 (DS 010-2019-PRODUCE), traceability is defined as the ability to discern, identify, find, and follow the trace of a product throughout all stages of production, including planting, extraction, harvesting, processing, storage, distribution, marketing, and veterinary products and feed for aquaculture. Law 30063 (Gobierno de Peru, 2013) assigns SANIPES the function of maintaining the traceability system for fisheries resources and products. Article 14 empowers SANIPES to establish provisions ensuring the traceability of products and verify traceability at all levels of the value chain, including catch, production, processing, storage, distribution, and marketing.

2.2.5.3 Regulation of Organisation and Functions of the Ministry of Production

Article 28 (DS 002-2017-PRODUCE) assigns the General Office for Information Technology (OGTI) of PRODUCE the role of proposing and developing standardised computer tools and information exchange between public and private entities. This provision aims to provide services and procedures to citizens in the fisheries sector.

2.2.5.4 Supreme Decree 006-2016-PRODUCE

Supreme Decree 006-2016-PRODUCE (PRODUCE, 2016) promotes the associativity of shipowners under the modality of fishing cooperatives, with a focus on sustainability, efficiency in the use of hydrobiological resources, and value enhancement of obtained products. Article 5 of this decree outlines general requirements for fishing vessel owners, including having a catch system ensuring traceability connected to PRODUCE, using satellite tracking devices established by PRODUCE, and unloading catches at authorised landing points.

Tables 3-5 below, provided by WWF-Peru, illustrate the different actors involved in the collection of information at various stages of the fishing chain. These tables demonstrate how certain actions require the efforts of multiple institutions, potentially leading to duplicity of

functions. Streamlining data collection and information sharing among institutions could improve efficiency.

Table 3. Actors involved in the collection of information in the first steps of the supply chain

Vessel	PRODUCE	DICAPI	IMARPE	SANIPES	
Place and date of departure	DICAPI	DIREPRO	IMARPE	SANIPES	
Port	PRODUCE	DIREPRO	IMARPE	SANIPES	
Catch	PRODUCE	DIREPRO	IMARPE	SANIPES	
Species	PRODUCE	DIREPRO	IMARPE	SANIPES	FDA
Fishing area	PRODUCE	IMARPE	SANIPES		
Date of operation	PRODUCE	IMARPE	SANIPES		
Place and date of landing	PRODUCE	DIREPRO			
Quantity of product	DIREPRO	SANIPES			
Product	DIREPRO				
Vehicle	DIREPRO				

Source: adapted from WWF-Peru (2021).

Table 4. Actors involved in the collection of information in the second block of the chain

Plant Name	PRODUCE	DIREPRO	SANIPES
Plant Code	PRODUCE	DIREPRO	SANIPES
Weight of Raw Material	PRODUCE	DIREPRO	
Product Type	MINCETUR (Commercial)	SUNAT (Economic)	SANIPES (Safety)
Health Registration of Product	SANIPES		
Plant Traceability Code	SANIPES		

Source: adapted from WWF-Peru (2021).

Table 5. Actors involved in the collection of information in the third block of the chain

Exporter's Business Name	SANIPES (Safety)	SUNAT (Economic)	MINCETUR (Commercial)
Exporter Authorization	SANIPES	SUNAT (Economic)	MINCETUR (Commercial)
FDA Authorization Code	SANIPES		
Product Tariff Code		SUNAT (Economic)	MINCETUR (Commercial)
Export Volume		SUNAT (Economic)	MINCETUR (Commercial)
Importer's Lot	SANIPES		

Shipment Data		SUNAT (Economic)	MINCETUR (Commercial)

Source: adapted from WWF-Peru (2021).

The Regulations of the GFL, Law 30063 for the Creation of SANIPES, Supreme Decree 002-2017-PRODUCE, and Supreme Decree 006-2016-PRODUCE provide a framework for traceability and information management in the fishing sector. These regulations address aspects such as discerning, identifying, finding, and following the trace of products, as well as ensuring correct information and documentation. However, the existence of separate regulations by different institutions related to the fishing sector can lead to duplication of efforts, information, and systems. Effective coordination and data sharing among institutions are essential to ensure efficient management of information and traceability in the fishing sector (Bailey et al., 2016).

By improving the exchange of information and promoting greater transparency and accountability, traceability could help reduce corruption, combat illegal activities, and increase the efficiency and collaboration of government institutions, as well as the implementation of national fisheries regulations (Grant et al., 2021).

The current institutional vulnerabilities, such as low capacity, limited coordination, and gaps in the legal framework, must be addressed to facilitate the implementation of effective traceability systems. To achieve this, it is necessary to address the institutional vulnerabilities, improve the coordination mechanisms between different institutions, and establish platforms to facilitate dialogue and consensus building processes about the use of marine resources (Silva & Alfaro, 2021). In the next section the Peruvian jumbo squid and mahi mahi fisheries are described.

2.3 Overview of the jumbo squid and mahi mahi fisheries in Peru

This section provides a comprehensive overview of the two most important artisanal fisheries in Peru: the jumbo squid and mahi mahi fisheries. Understanding the context and dynamics of these fisheries is crucial for grasping the challenges and opportunities associated with Peru's marine resources. By examining the management, sustainability, supply chain, and traceability

aspects of these fisheries, this section aims to shed light on the current situation and contribute to the broader understanding of Peru's fisheries sector.

The following subsections describe the characteristics of each fishery, starting with the jumbo squid fishery and then moving on to the mahi mahi fishery. For each fishery, factors such as production volumes, fishing practices, market dynamics, management regulations, sustainability concerns, and the need for traceability are explored. By providing a structured analysis of these fisheries, this section equips the reader with a comprehensive understanding of the challenges, potential solutions, and importance of traceability measures in promoting fisheries sustainability and good governance.

2.3.1 The jumbo squid fishery

The jumbo squid (*Dosidicus gigas*) fishery is the world's largest cephalopod fishery, with Peru being the largest producer, accounting for 50% of the world's annual supply, followed by China and Chile (Future of Fish, 2018). The fishery involves over 11,000 fishers and more than 3,000 fishing vessels, making it the second largest fishery in Peru (Peru jumbo flying squid - jig, 2024). Although it accounts for only a small percentage of the total tonnage compared to anchoveta, the jumbo squid fishery in Peru sees annual landings fluctuating between 450,000 and 500,000 tons. This volume is comparable to the combined fisheries landings of countries like Holland or France and is double those of Italy, Portugal, and Germany. This highlights the significant scale and impact of the jumbo squid in regional and global seafood markets (Londoño & Giraldo, 2024).

The maximum sustainable yield (MSY) is, theoretically, the largest yield (catch) that can be taken from a specific fish stock over an indefinite period under constant environmental conditions. It is measured in tonnes caught and removed by fishing (Milusheva, 2020). The MSY for the jumbo squid fishery in Peru, as advised by IMARPE, has been set at approximately 500,000 tons for 2024 (Jiménez, 2024). The fishery is managed through the ROP for jumbo squid (DS 014-2011-PRODUCE), which establishes a total quota for the fishing of jumbo squid in the Peruvian waters. IMARPE’s recommendations are based on available biomass. However, several unknowns about the stock's structure and biology need resolution to ensure, with a sufficient level of certainty, that the models’ assumptions are correct.

Peru exports an average of 265,000 tonnes of jumbo squid per year, with Spain (26%), South Korea (22%), and China (18%) being the most relevant markets for squid products in 2016 (Future of Fish, 2018). In terms of the supply chain, the jumbo squid harvested in Peruvian waters is sent to Asia for secondary processing, often resulting in a loss of data on harvest origin. The value-added nature of squid products contributes to this lack of transparency. Squid is consumed in many forms, including steaks, rings, and strips as well as many preparations (Future of Fish, 2018). Moreover, there is a failing in the current ROP: "The high level of informality, the clandestine construction of vessels and the lack of adequate on-board refrigeration systems are problems that affect the socioeconomic performance of the fishery, all of which has not been adequately addressed in the current ROP" (Andia Morales et al., 2019:34). There are several challenges associated with the fishery, including sustainability concerns, lack of traceability mechanisms, and a high degree of opacity in the supply chain (Silva & Alfaro, 2021).

2.3.2 The mahi mahi fishery

The mahi mahi (*Coryphaena hippurus*) fishery in Peru is the second largest artisanal fishery in the country, with Peru being the top producer of mahi mahi in the Eastern Pacific Ocean (WWF Oceans Program, 2015). The mahi mahi fishery employs over 4,268 fishers, using at least 2,141 boats (INEI-PRODUCE, 2012). However, these figures may not accurately represent the actual number of fishers and boats involved, as crew sizes and boat ownership can vary widely, yet a census of these fisheries have not been carried out since 2012. Trips range from ten to twenty days in the north, and five to seven days in the south, with trip lengths steadily growing over the last five years as mahi mahi have continued to migrate farther offshore (Future of Fish, 2018). In Peru, fishers use mostly longlines to catch these species, using pelagic species, such as sardines, jumbo squid, or flying fish as bait.

Mahi mahi is an important, globally traded species with its primary market in the United States (US). Peru is the largest source of mahi mahi, providing 50% of the global supply between 2000-2013, representing 86% of the catch in the Southeast Pacific. Taiwan, Ecuador, and Indonesia follow, all consisting of about 10% of global production. Peru's annual output has a significant impact on market prices and conditions (Future of Fish, 2018).

Mahi mahi are a highly migratory, widely distributed, fast growing, and rapidly reproducing species. The Ministerial Resolution 245-2014-PRODUCE (PRODUCE, 2014) establishes the fishing season of mahi mahi at the national level, running from October 1st to April 30th. RM 249-2011-PRODUCE (PRODUCE, 2011) sets its minimum catch sizes at 70 cm.

In July 2021, the mahi mahi ROP (DS 017-2021-PRODUCE) was approved to establish regulations for the fisheries management and resource conservation. Among its main provisions are that mahi mahi was declared as fully exploited, establishing a total allowable catch (TAC) for each season. Furthermore, it sets out conditions for both conservation and protection of bycaught species, including on-board scientific observation, and strengthening of its traceability.

The mahi mahi fishery in Peru holds significant economic value but faces various challenges such as long distances from shore, stock dynamics, and migration patterns along the Peruvian coast. Additionally, higher rejection rates by export markets due to quality concerns have impacted the fishery. To address these challenges and ensure the sustainability and competitiveness of the mahi mahi fishery, adopting traceability measures could be very beneficial. Implementing effective traceability systems can enhance transparency, improve product quality assurance, and instil confidence in export markets (Wolff et al., 2023).

2.3.3 The jumbo squid and mahi mahi supply chains

The supply chain is a crucial component of the jumbo squid and mahi mahi fisheries in Peru, and it involves several interrelated economic stakeholders. According to Peruvian Law No. 28846 (Gobierno de Peru), the supply chain encompasses the provision of inputs, production, conservation, transformation, distribution, marketing, and consumption, both domestically and in foreign markets. Seafood is a complex and global commodity, with products undergoing multiple forms of processing and packaging before reaching their destination. The supply chain for jumbo squid and mahi mahi is no exception, with opaque and complex systems often making it difficult to fully trace a product's journey from its origin to its ultimate destination (Greenwood, 2019).

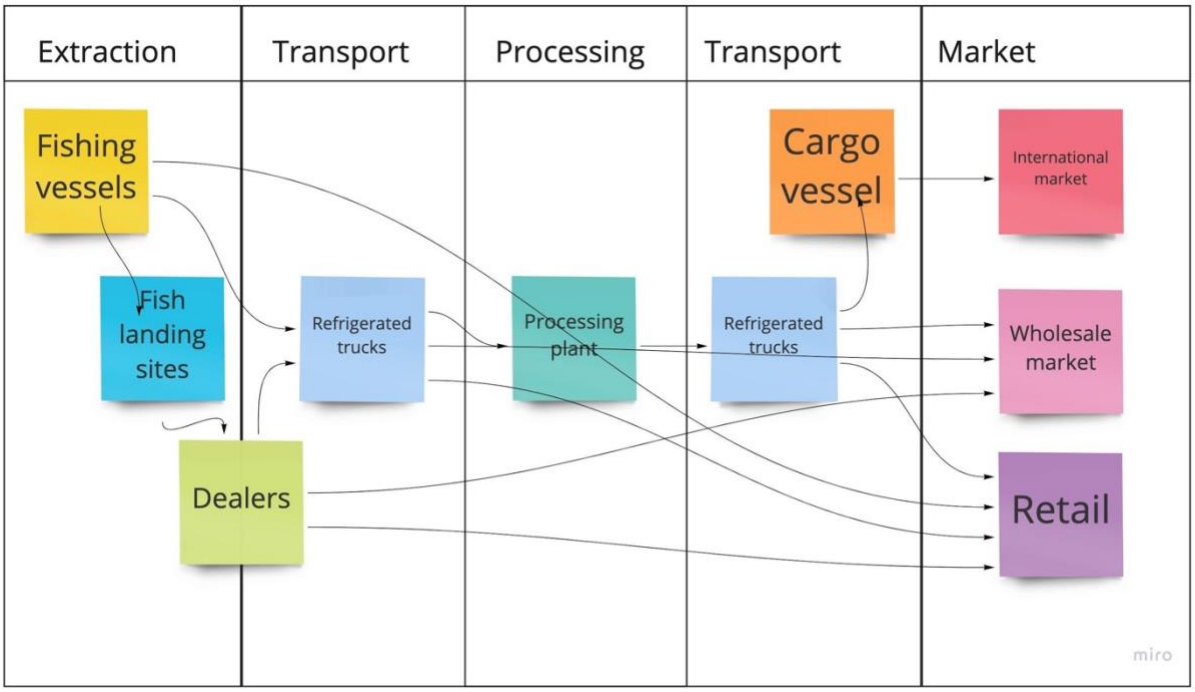
Figure 1 provides a generalised overview of the typical Peruvian jumbo squid and mahi mahi supply chains. While the export markets for these two products differ, many of the in-country

stakeholders are the same: fishers, shipowners, dealers, transporters, processors, and exporters (Future of Fish, 2018).

The mahi mahi and jumbo squid supply chains involve several steps. First, the fishers harvest one or multiple species on a fishing vessel and land the catch at a fish landing site. There, they usually sell the product to a dealer or intermediary. The dealer can perform various tasks, such as buying the catch, financing the fisher, or providing the necessary paperwork to legalise the catch if the fisher lacks such evidence, which is often due to the informality in the sector (described in section 2.1.1). Once the product is sold to the dealer, it is transported to a processing plant or the consumer market. On occasion, the dealer might divide one fisher's catch based on size, species, or quality and send the differently graded products to alternate buyers and markets.

At the processing plant, seafood is transformed, i.e. headed, gutted, and filleted. Some plants with more advanced traceability systems will record the species and weight of the product upon entry and exit. Once the processing is complete, the product is loaded onto a transport vehicle that transfers it to a cargo vehicle for export. The product is then taken to international markets or to the final domestic wholesale or retail market for consumption (Amoros et al., 2017).

Figure 1. Peruvian jumbo squid and mahi mahi supply chains



Source: adapted from Future of Fish (2018) and Amoros et al. (2017).

Most of the data in the seafood industry is recorded on paper, if it is documented at all, making it difficult to track products throughout the supply chain. While some seafood companies are adopting electronic systems to capture and share data, the adoption rate is slow. International pressure for more robust product data, along with internal data systems within primary processing plants, means that there are conditions for full-chain traceability in the jumbo squid and mahi mahi supply chains (Future of Fish, 2018). Traceability systems can enhance quality improvements in two fundamental ways: by increasing efficiencies and coordination at the fleet and primary processing level, and by providing a guarantee of product origin, which is becoming particularly important for export markets. More robust data flow in these two high-value and high-volume artisanal fisheries could provide the basis for data modernisation across Peruvian artisanal fleets, starting with the jumbo squid and mahi mahi fisheries, and then expanding to other species (FAO, 2020).

2.3.4 Jumbo squid and mahi mahi fishing cooperatives

Fishing cooperatives in Peru play a vital role in the management and sustainability of fisheries, as well as in improving the livelihoods of fishers. These cooperatives are legally recognised

entities governed democratically by their members, who share equal voting power. The significance of fishing cooperatives becomes particularly evident in communities like ‘La Tortuga’ and ‘La Islilla’, situated at the border of the Sechura and Paita provinces in the Piura region, which are active participants in the jumbo squid and mahi mahi fisheries. With a combined population exceeding 6,500 people, these communities host a robust fishing fleet, consisting of 270 vessels owned by 70 shipowners in La Tortuga and 370 vessels owned by 207 shipowners in La Islilla (Andia Morales et al., 2019).

In 2014, recognising the potential of fishing cooperatives, PRODUCE proposed the establishment of cooperatives for mahi mahi fishers, drawing inspiration from the successful models adopted in the agricultural sector. Subsequently, the pilot programme was extended to include the jumbo squid fishery, given the overlap in fishers involved in both fisheries. The objective of this government-led initiative was to enhance the sustainability and competitiveness of fishing activities by improving traceability, operational efficiency, and the value of fish products. The shipowners and fishers of La Islilla and La Tortuga actively participated in the pilot programme. The guild of La Islilla officially entered the programme on July 25, 2016, through Ministerial Resolution 279-2016-PRODUCE (PRODUCE, 2016), while the guild of La Tortuga joined on July 27 of the same year. To meet the programme's requirements, both organisations fulfilled the initial condition of forming a shipowners' cooperative. This marked the birth of the fishing cooperative 'Jehovah Rey de Reyes' in La Islilla and the fishing cooperative 'Jehovah es mi Pastor nada me faltará' in La Tortuga, collectively representing a total of 556 fishing vessels.

Fishing cooperatives play a significant role in the jumbo squid and mahi mahi fisheries in Peru. As part of the cooperative framework, they are required to implement catch documentation schemes, which serve as the basis for traceability systems. These schemes ensure that the catch and movement of jumbo squid and mahi mahi are properly documented, enabling the tracking of these fisheries' products throughout the supply chain. By implementing these traceability measures, cooperatives contribute to enhancing transparency, accountability, and the overall sustainability of these Peruvian fisheries. Studies like ‘Community-Based Fisheries Management: A Global Perspective’ (Kar, 2020) support that the impact of the participation of community-based fishing, with the implementation of traceability methods, improve sustainable management practices and good governance of fisheries.

Nevertheless, challenges have emerged in the process of establishing these cooperatives in Peru, primarily stemming from external pressures and varying levels of engagement from community members who may not fully comprehend the necessity of these new requirements (Kar, 2020). Moreover, the cooperatives' structure primarily revolves around vessel owners rather than captains and fishers, which can hinder inclusive decision-making processes.

The jumbo squid and mahi mahi fisheries in Peru are vital for the country's economy and food security. However, sustainability concerns, traceability gaps, and opacity in the supply chain pose significant challenges (Kitts, et al., 2020). The establishment of fishing cooperatives, mandated to implement catch documentation schemes, offers the basis for the development of traceability systems. By improving management practices, enhancing coordination, and implementing effective traceability systems, Peru can promote sustainable fishing practices, protect marine resources, and support the livelihoods of fishers, while meeting global market demands and improving fisheries governance. The following section discusses the international market requirements, both regulatory and voluntary.

2.4 International market requirements

Peru's fishing industry is heavily dependent on international markets for its seafood products. In 2021, Peru exported 9.5 million tons of fishery products, valued at US$3.88 billion (PRODUCE, 2021). The US, China, Spain, South Korea, and Japan are among the main export markets for Peruvian seafood products.

To access these international markets, Peruvian seafood products must comply with various regulations and certifications. The US, for example, requires compliance with safety standards established by the Food and Drug Administration (FDA) and the National Oceanic and Atmospheric Administration (NOAA). Additionally, regulations on labelling, packaging, and traceability must be met. Similarly, the European Union (EU) has its own regulations concerning food safety, labelling, traceability, and conservation of marine resources. Japan and China are also important export markets for Peruvian seafood products. Japan has regulations and certifications, such as the Japan Fisheries Agency's Certification of Compliance for Aquaculture and Marine Products and the Japan Agricultural Standards (JAS) for organic

products. China has implemented its own seafood safety standards, including measures for inspection, quarantine, and supervision of imported and exported fishery products.

These international market requirements have a significant impact on fisheries management in Peru. In response, the Peruvian government has implemented measures to improve the sustainability and traceability of its fisheries. This includes the establishment of a system of fishing permits and quotas, regulations on fishing gear and methods, and a traceability system for seafood products. The traceability system allows for the tracking of products from the point of catch to the point of export, preventing IUU fishing.

However, the implementation of an effective traceability system in Peru faces challenges. Currently, governmental efforts are often isolated and lack interconnectedness, leading to a dearth of information feedback. This weakness can affect national exports and hinder Peru's commitments at the international level, impacting the economic, social, and environmental aspects of the fishing industry (Wolff et al., 2023).

The EU, the US, and Japan have specific regulations on traceability for imported seafood products. The EU's Council Regulation (EC) 1005/2008 (Council of the European Union, 2008) imposes catch certification schemes to ensure compliance with fisheries conservation and management regulations. The US has the Seafood Import Monitoring Programme (SIMP) obliging importers to provide information on the Chain of Custody (CoC) of fishery products. Japan has implemented the Act on Ensuring Quality of Fishery Products and Fishing Boat Operations (Makino, 2011), encompassing requirements for the country of origin, fishing method used, and fishing area.

International market requirements play a crucial role in Peru's fishing industry, necessitating compliance with various regulations and certifications. The implementation of an effective traceability system is essential to meet market requirements and ensure access to international markets. The jumbo squid and mahi mahi fisheries, important export fisheries for Peru, must adhere to traceability regulations to promote sustainable fishing practices and responsible management of marine resources. The regulations imposed by the EU, the US, and Japan on traceability contribute to the sustainability of products destined for these markets. Therefore, it is imperative for the Peruvian government to establish an efficient and interconnected traceability system for fishing and aquaculture activities, ensuring compliance

with market requirements, and preventing illegal fishing practices. Such an approach will benefit the Peruvian economy, society, and environment more broadly (Ruiz et al., 2019).

To meet the evolving demands of international markets, the global fishing industry must comply with various market regulations and requirements that also consider voluntary measures, such as certifications. One important initiative that supports sustainable fishing practices and enhances market access opportunities is the Marine Stewardship Council (MSC) and its Fishery Improvement Projects (FIPs), which are discussed in the following sub-section.

2.5 The MSC and FIPs

The MSC is an internationally recognised non-profit organisation that operates an eco-label and fisheries certification programme for sustainable fisheries. Established in 1996 by World Wildlife Fund (WWF) and Unilever, the MSC certification programme is based on three principles: sustainable fish stocks, minimising environmental impact, and effective fisheries management (Melnychuk, et al., 2022). Certification is open to stakeholders in the fishing sector, including fishers' associations, industries, processors, government authorities, and other interested parties.

FIPs, also created by WWF, represent multi-stakeholder initiatives aimed at promoting sustainability in fisheries and improving market access opportunities through compliance with MSC criteria. FIPs work towards measurable change and the long-term sustainability of a fishery, ultimately leading to MSC certification. Transparent and credible operation is crucial for FIPs, including completing an MSC pre-assessment, developing an improvement action plan, regularly reporting on progress, verifying progress, establishment of clear timelines, and commitment to MSC certification. An efficient and effective FIP includes the development of a traceability system aligned with the MSC Chain of Custody (CoC) certification standard for seafood traceability. The CoC standard provides assurance that all seafood sold with the blue MSC label comes from a fishery that has been certified as sustainable and demonstrates to consumers that your seafood originates from an MSC Fishery or Aquaculture Stewardship Council (ASC) farmed certified source (Marine Stewardship Council, 2019). This ensures that fish identified as coming from the FIP can be verified as part of the FIP (WWF Oceans Program,

2015). Traceability is an essential aspect of FIPs, as it enables the verification of seafood origin and prevents fraudulent mixing of certified and non-certified seafood.

To ensure the authenticity and reliability of MSC-certified seafood, the CoC standard enables the tracing of certified seafood from the point of catch or harvest, through processing and distribution, to the point of sale. The CoC standard includes requirements for record-keeping, product identification and segregation, and management systems to prevent the mixing of certified and non-certified seafood. Traceability plays a critical role in the CoC standard, as it allows for the verification of seafood origin and ensures the integrity of certified products. MSC provides guidance to seafood processors and retailers to develop traceability systems that meet the CoC standard requirements. By incorporating traceability systems aligned with the MSC CoC standard, FIPs enhance the credibility and reliability of their sustainability claims and associated seafood products. This ensures that the progress made by FIPs in promoting sustainability and responsible fishing practices can be verified and recognised by the market.

Overall, the MSC and FIPs contribute to meeting international market requirements for sustainable seafood. Through their focus on traceability and alignment with the MSC CoC standard, these initiatives strengthen the credibility of sustainability claims and promote responsible fisheries management. By supporting the implementation of traceability systems, the MSC plays a vital role in ensuring the integrity of certified seafood products and maintaining access to international markets (Melnychuk, et al., 2022). However, the MSC certification process has faced criticisms regarding its effectiveness and inclusivity. Studies have raised concerns over the formal objections process within MSC certifications, questioning the robustness of the MSC's standards in truly reflecting sustainable practices (Christian, et al., 2013). There are mixed successes and challenges faced by MSC certifications in Latin America and the Caribbean (Pérez-Ramírez et al., 2016), highlighting the complex socio-economic impacts on local fisheries. Moreover, controversies have been raised surrounding voluntary environmental standards like the MSC, pointing to the socio-economic dimensions of sustainability certifications that may not always align with broader environmental goals (Wijen & Chiroleau-Assouline, 2019). These critiques suggest that while MSC certifications are beneficial, they are not without limitations and should be continually assessed to ensure they meet their sustainability objectives effectively.

2.6 Collaborative initiatives promoting sustainable fisheries in Peru

In Peru, multi-stakeholder partnerships and other collaborative initiatives play a crucial role in promoting responsible and sustainable fishing practices, aligning with international market requirements. The Peru Mahi Alliance[1] (PMA), supported by NGOs and international organisations such as WWF and Sustainable Fisheries Partnership (SFP), stands as a notable example. Established in 2016, the alliance brings together Peruvian mahi mahi processors, and exporters with the aim of pursuing MSC certification for the mahi mahi fishery in Peru, while concurrently enhancing sustainability practices within member organisations. Similarly, the Peruvian Chamber of Jumbo Squid[2] (CAPECAL), represent jumbo squid processors and exporters actively striving for MSC certification for the jumbo squid fishery. These collaborative efforts not only demonstrate a commitment to sustainable fishing practices but also align with international market requirements for traceability and certification. By working towards MSC certification and promoting sustainable practices, the PMA and CAPECAL contribute significantly to the advancement of sustainable fishing practices in Peru and the long-term viability of the country's fisheries.

The sustainable management of Peru's jumbo squid and mahi mahi fisheries is essential for the country's fishing industry, which heavily relies on international markets. Meeting international market requirements, such as those established by the EU, the US, and Japan, necessitates the implementation of traceability systems, certifications, and adherence to sustainability principles. The MSC and FIPs provide frameworks for fisheries to work towards sustainability and traceability (Hosch & Blaha, 2017). Collaborative initiatives like the PMA and CAPECAL further support these efforts by promoting responsible fishing practices and working towards MSC certification. Through these collective endeavours, Peru's fishing industry can operate more sustainably, promoting the long-term viability of its marine resources and meeting the demands of international markets (Kitts, et al., 2020).

The next section explores how traceability is developing in Peru's jumbo squid and mahi mahi fisheries. This includes exploring the significance of traceability in seafood supply chains,

[1] https://pma.org.pe/
[2] https://www.capecal.org/

providing an overview of the current state of traceability adoption, and examining the challenges and opportunities for enhancing traceability practices.

2.7 The importance of traceability for seafood supply chains

Traceability plays a crucial role in seafood supply chains, offering numerous benefits for sustainability, transparency, and accountability (Silva & Alfaro, 2021). It involves tracking and documenting the movement of seafood products from their point of origin to the point of consumption, capturing critical information at each stage of the supply chain. This information includes details about the species, fishing or aquaculture methods, catch location, processing facilities, and transportation (Olsen & Borit, 2013).

Traceability in fisheries is vital for ensuring sustainable management of marine resources, as it offers transparency into the entire supply chain from catch to consumer (FAO, 2020). By providing accurate information on the origin, methods, and journey of fish products, traceability combats illegal fishing, promotes ethical labour practices, and empowers consumers to make informed choices that support sustainable fisheries. According to WWF and Future of Fish (Leslie & Lugo-Mulligan, 2021) traceability is also important for:

- **Supporting sustainable fisheries management:** Traceability plays an important role in promoting sustainable fisheries management. By providing detailed information on the origin and fishing practices, it allows for the assessment of environmental impact. This data facilitates the identification of sustainable fishing practices, helps prevent IUU fishing, and supports the conservation of marine resources.

- **Equity and social benefits**: Implementing traceability in seafood supply chains can help ensure equitable distribution of benefits among fishing communities. By tracking product origin and catch locations, it becomes easier to attribute the value of the catch to the specific fishing communities involved. This transparency can lead to more equitable revenue sharing, thereby supporting the economic well-being of local fishers.

- **Working conditions and labour rights**: Traceability systems can help shed light on working conditions in the fishing industry. With information from fishing activities and

processing facilities, stakeholders can monitor labour practices and ensure compliance with labour rights and regulations. Traceability can play a role in addressing issues like forced labour and exploitation, safety at sea, fostering safer and fairer working conditions for fishers.

- **Gender visibility and empowerment:** The adoption of traceability can also contribute to gender visibility in the fishing industry. By capturing data on individuals involved in different stages of the supply chain, such as fishing, processing, or trading, traceability can help recognise and empower women who play crucial roles in the fisheries sector. This data can lead to gender-inclusive policies and initiatives, fostering gender equity in fisheries.

- **Stakeholder engagement and representation:** Traceability systems can enhance stakeholder engagement by involving fishers, processors, and other relevant actors in the decision-making processes. Access to traceability data allows stakeholders to participate in discussions about sustainable practices, fisheries management, and market opportunities, ensuring that diverse voices are heard and represented.

- **Access to formal financing:** Informal fisheries often face challenges in accessing formal finance and government support due to a lack of documentation and transparent records. Formal financial institutions often view fishing as a risky sector due to uncertainties in catch volumes and the potential impact of environmental factors on fishing success. Traceability data can offer a clearer picture of fishing practices, compliance with regulations, and sustainability efforts. By providing evidence of responsible and sustainable fishing practices, traceability mitigates some of the risks associated with lending to fishers, potentially making financial institutions more willing to invest in the sector.

- **Data-driven policy decisions:** Traceability generates a wealth of data on fishing activities, catch volumes, locations, and species composition. This data can be analysed and used to inform evidence-based policy decisions. Governments can gain insights into the health and sustainability of fisheries, identify overexploited areas, and design targeted conservation measures to protect vulnerable marine resources.

- **Targeted enforcement and surveillance:** Traceability data aids in targeting enforcement efforts where they are most needed. Governments can focus surveillance and inspection on high-risk areas or species, optimising their use of limited resources. This targeted approach enhances the efficiency of enforcement actions and contributes to more comprehensive and effective monitoring of fishing activities.

- **Facilitating food safety and compliance:** Traceability systems contribute to food safety by enabling swift and accurate recalls in case of product contamination or disease outbreaks. In the event of a food safety incident, traceability allows for the precise identification of affected products, minimising the scope of recalls and protecting public health. Furthermore, traceability helps seafood producers comply with regulatory requirements and international standards related to food safety, hygiene, and labelling.

- **Enhancing supply chain efficiency and management:** Implementing traceability systems improves supply chain efficiency by streamlining processes, reducing errors, and enabling better inventory management. With accurate and real-time information on the location and status of seafood products, stakeholders can optimise logistics, minimise waste, and ensure timely deliveries. Traceability also enhances trace-back and trace-forward capabilities, facilitating the identification of bottlenecks or issues in the supply chain and enabling prompt corrective actions.

- **Meeting consumer demands and ethical considerations:** Today's consumers are increasingly conscious about the origin and sustainability of the products they consume. Traceability provides consumers with the information they need to make informed choices, supporting their preferences for sustainably sourced seafood and ethical practices. It also allows consumers to verify claims related to fair trade, organic production, or specific certifications, aligning with their values and promoting responsible consumption.

- **Access to premium markets:** Traceability is increasingly valued in global seafood markets, where consumers are demanding sustainably sourced products. By adopting traceability systems, Peruvian fishers can access premium markets that require

verifiable sustainability certifications. Access to such markets can lead to higher prices for seafood products, improving the economic prospects of fishers and incentivising the formalisation of their operations.

- **Transparency in seafood supply chains:** Traceability contributes significantly to transparency by accurately documenting the movement of seafood products from the point of origin to the point of consumption, traceability systems provide stakeholders with an unprecedented level of visibility and access to critical information at each stage of the supply chain. Transparent supply chains enable consumers to make informed choices, ensuring that they have access to accurate and trustworthy information about the seafood they purchase. Furthermore, transparent supply chains facilitate stakeholder engagement, allowing fishers, processors, and other actors to actively participate in discussions about sustainable practices, fisheries management, and market opportunities. As a result, traceability not only enhances accountability and integrity in seafood supply chains but also empowers consumers and stakeholders to advocate for and contribute to the sustainability and responsible management of marine resources.

Traceability in seafood supply chains goes beyond tracking product movement; it holds the key to a more sustainable, equitable, transparent, and responsible fishing industry. The adoption of robust traceability systems not only supports sustainable fisheries management by preventing illegal fishing practices and conserving marine resources but also fosters social benefits and gender visibility. With traceability, fishing communities can expect more equitable revenue sharing and improved working conditions, ensuring fair labour practices (Leslie & Lugo-Mulligan, 2021).

The Fair Work Convention's definition of fair work is work that offers effective voice, opportunity, security, fulfilment, and respect; that balances the rights and responsibilities of employers and workers and that can generate benefits for individuals, organisations, and society (Rogers & Richmond, 2016). It is worth noting that the Fairwork project in Peru seeks to demonstrate the need to improve the working conditions of workers on digital platforms. The results of the project showed that there is a lot to do to improve working conditions on digital platforms in Peru, particularly with regard to fair and decent work (Fairwork, 2023).

Additionally, traceability empowers stakeholders with data-driven insights, allowing them to engage in decision-making processes and participate in market opportunities. Moreover, formal financial institutions find traceability data reassuring, facilitating access to finance for fishers and incentivising the formalisation of the fishing sector. The data-rich environment created by traceability also enables targeted enforcement efforts, optimises resource allocation, and enhances supply chain efficiency (Leslie & Lugo-Mulligan, 2021).

2.8 The challenges and opportunities for increasing traceability uptake in Peruvian fisheries

While the benefits of traceability in seafood supply chains are numerous, there remain several challenges that must be addressed to effectively implement and expand traceability in Peru's fisheries. However, there are also significant opportunities to overcome these challenges and advance towards a more traceable and sustainable fishing industry. The following sections outline and examine the major challenges and subsequent opportunities.

2.8.1 Challenges for increasing traceability uptake in Peru

In the realm of sustainable fishing practices, the introduction of traceability systems has emerged as a critical tool for ensuring the provenance and ethical handling of seafood products. However, the deployment of such systems in Peru's fishing sectors presents distinct challenges that complicate their widespread adoption. These challenges stem from a variety of socio-economic and infrastructural limitations that characterise the fishing communities, particularly in remote areas. This section delves into the primary obstacles faced by these communities, which include limited technological infrastructure, financial constraints, issues with coordination and standardisation, and inherent resistance to change. Each of these factors plays a pivotal role in shaping the feasibility and effectiveness of implementing traceability systems within Peru's diverse and multifaceted fishing industry.

- **Limited technological infrastructure**: Many fishing communities in Peru, especially in remote areas, face limited access to advanced technological infrastructure and internet connectivity. Implementing traceability systems that require digital tracking and real-time data transmission can be challenging in such regions (Defeo & Vasconcellos, 2020).

- **Cost and resource constraints**: For small-scale fishers and local processors, the initial investment required to adopt traceability systems may be prohibitive. The cost of implementing technology, training personnel, and maintaining the system may strain already limited financial resources (Silva & Alfaro, 2021).

- **Coordination and standardisation**: The fishing industry in Peru involves numerous stakeholders, including fishers, processors, exporters, and regulatory authorities. Achieving coordination and standardisation among these diverse actors can be complex, especially when different actors use various data management systems (Viatori & Medina, 2019).

- **Resistance to change**: Introducing new technologies and practices can face resistance from traditional fishing communities or those accustomed to existing practices. Overcoming resistance and building trust in the benefits of traceability is essential for widespread adoption (Siren, 2021).

The implementation of traceability systems in Peru's fisheries is fraught with challenges that are deeply rooted in both technological and socio-economic dimensions. Limited access to technological infrastructure, significant cost and resource constraints, the complexity of achieving coordination and standardisation, and cultural resistance to new practices, collectively hinder the adoption of these systems. Addressing these challenges necessitates an approach that includes enhancing infrastructure, subsidising initial costs, fostering collaboration among stakeholders, and engaging communities through education and demonstration of benefits. Successfully overcoming these barriers is imperative for advancing sustainable fishing practices in Peru, ensuring the long-term viability of its fishing communities and the health of marine ecosystems. In the next section some of the opportunities for traceability uptake will be explored.

2.8.2 Opportunities for increasing traceability uptake in Peru

The enhancement of traceability systems within Peru's fisheries sector is not only a technological endeavour but also a collaborative effort that requires the involvement of multiple stakeholders. Multi-stakeholder partnerships (MSPs) play a pivotal role in this context, bringing together governments, private sector entities, NGOs, and international organisations

to pool expertise and resources (Brouwer et al., 2019). This section explores strategies for the development and implementation of traceability systems in fisheries. These strategies include capacity building and education to foster understanding and acceptance, the provision of incentives and certifications to encourage compliance, phased implementation to manage costs, integration with existing initiatives to streamline processes, support for formalisation to improve regulatory compliance, and empowering local communities to ensure inclusive and sustainable outcomes. Collectively, these approaches align with global best practices and aim to address the complex challenges associated with traceability systems, thereby promoting sustainable fisheries management across Peru.

- **Multi-stakeholder partnerships for traceability systems:** Collaboration among governments, private sector entities, NGOs, and international organisations through MSPs leverages diverse expertise and resources essential for developing and implementing traceability systems. Unlike traditional public-private partnerships, MSPs inclusively bridge technology and funding gaps, ensuring all relevant stakeholders—including civil society and academia—contribute to sustainable fisheries management. This holistic approach aligns with global best practices by fostering comprehensive, democratic, and effective solutions that accommodate the multifaceted challenges of traceability adoption across the fisheries industry (FAO, 2014).

- **Capacity building and education:** Investing in training and education programmes can enhance the understanding and acceptance of traceability systems among fishing communities (Demirel et al., 2023). Capacity building initiatives can empower fishers and processors to actively engage in traceability and recognise its benefits.

- **Incentives and certifications**: Providing incentives, such as financial benefits or preferential market access, to fishers and processors who adopt traceability practices can encourage voluntary compliance. Additionally, certifications like MSC can motivate stakeholders to invest in traceability to access premium markets (Melnychuk, et al., 2022).

- **Phased implementation**: A phased approach to traceability implementation can ease the financial burden on small-scale fishers and processors (Wolff et al., 2023). Starting

with simple and cost-effective systems and gradually expanding them can facilitate escalating adoption.

- **Integration with existing initiatives**: Traceability systems can be integrated with existing government programmes, such as fishing permits and licensing, to streamline data collection and reporting (Silva & Alfaro, 2021). This integration can facilitate compliance and reduce duplication of efforts.

- **Support for formalisation**: Improved traceability can contribute to formalising currently informal fishers in Peru. By providing a transparent record of fishing activities and catch volumes, traceability can assist fishers in meeting formalisation requirements and accessing formal finance and government support (Kitts, et al., 2020).

- **Empowering local communities**: Traceability systems can empower local fishing communities by giving them a voice and representation in decision-making processes (Kar, 2020). Engaging local stakeholders in the design and implementation of traceability initiatives can lead to more inclusive and sustainable outcomes.

While there are challenges to overcome, the opportunities for increasing traceability in Peru's fisheries are many. By addressing the challenges through multi stakeholder partnerships, capacity building, and phased implementation, Peru can unlock the potential of traceability to promote sustainability, transparency, and equity in its fishing industry.

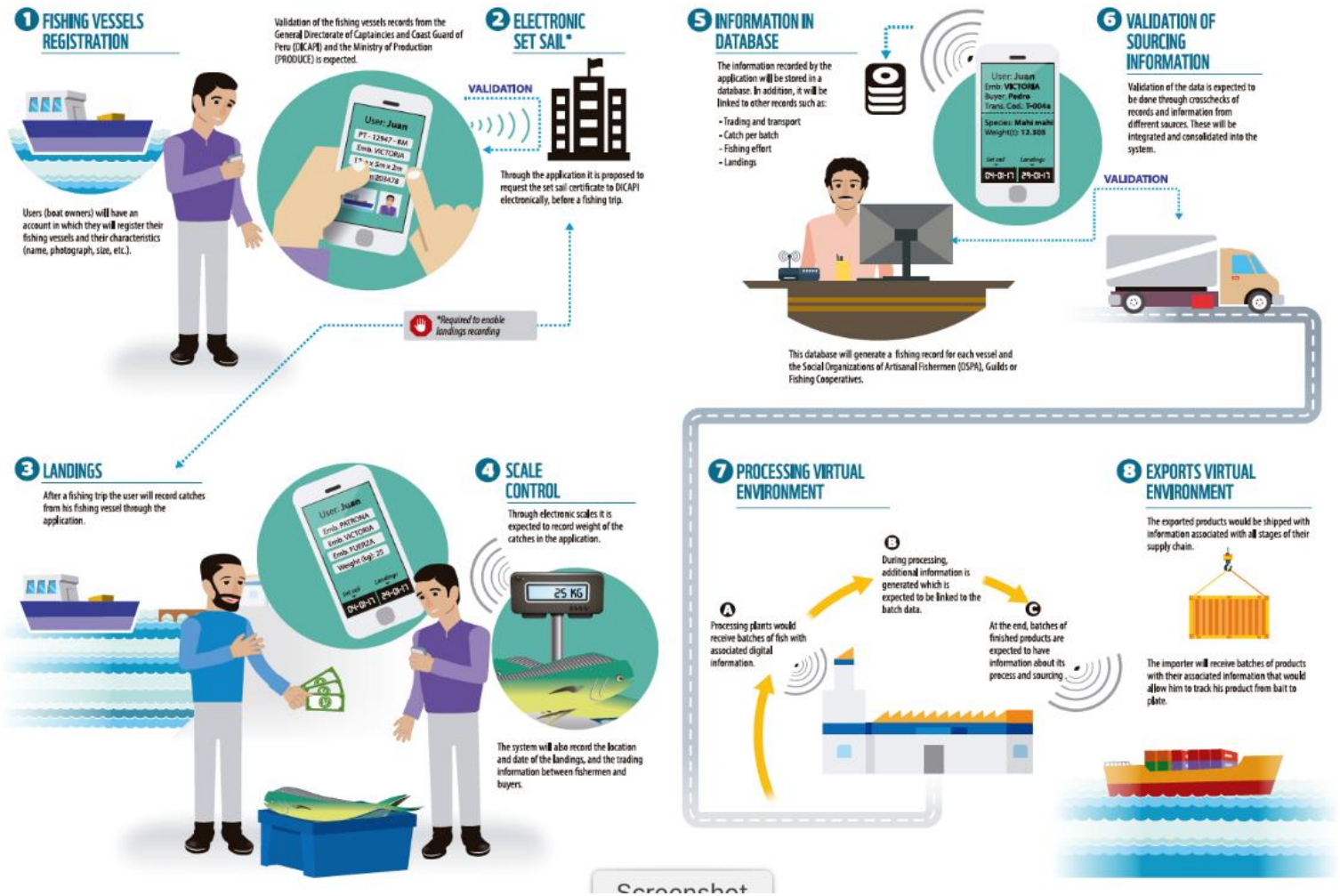
2.9 The evolution of traceability in Peruvian fisheries

The adoption of traceability in Peru's fisheries, particularly in the jumbo squid and mahi mahi sectors, has been evolving with the collaboration of various stakeholders. WWF proposed an electronic traceability system built through the coordination of different state actors to create a robust and efficient system that is compatible and interoperable (WWF, 2017). This system aimed to articulate the required information and enable real-time monitoring and tracking (Figure 2).

One significant initiative in this direction is WWF-Peru's mobile traceability application, TrazApp[3], originally designed for the jumbo squid and mahi mahi fisheries. While still in the early stages of implementation, TrazApp has the potential to benefit various stakeholders in the supply chain, including fishers, processors, exporters, and consumers. Co-designed with supply chain actors, TrazApp provides real-time information about fishing activities, such as fishing trip departure dates, vessel names, crew onboard, catch species and quantity, landing sites, and intermediary buyer details. This application empowers fishers as key players in the production chain and in resource sustainability, improving their decision-making processes and enhancing the overall sustainability of the fishing industry (Grillo et al., 2017).

[3] https://www.trazapp.org/

Figure 2. Catch documentation scheme for artisanal fisheries



Source: WWF (2017).

TrazApp not only supports environmental sustainability but also addresses social and economic aspects. It helps ensure equitable distribution of benefits among fishing communities, as the application enables accurate attribution of catch value to specific fishing communities. This transparency promotes fair revenue sharing and economic well-being among local fishers. Revenue sharing (RS) refers to the distribution of income among stakeholders (e.g., fishers, industry, and government) in a business-to-business environment (Tsao & Lee, 2020). Additionally, the application contributes to gender visibility by capturing data on individuals involved in various stages of the supply chain, with the potential to promote gender equity in the industry. Incentives for fishers include the potential for improved prices and access to high-end markets, rewarding responsible and sustainable fishing practices.

Several public and private initiatives are also contributing to the evolution of traceability in Peru's fisheries. For instance, the Satellite Vessel Monitoring System (SISESAT) monitors the spatial distribution of industrial fishing fleets, aiding in analysing fleet dynamics and resource variability. The Satellite Traceability System (TRASAT) allows users to view the positioning of satellite-monitored fishing vessels (Future of Fish, 2014). According to Future of Fish (2019), the Identification and Monitoring System for Aquatic Traffic (SIMTRAC) transmits satellite positioning data of vessels to the control centre and uses Automatic Identification System (AIS) to determine foreign vessel positions. Furthermore, the Ministry of Production created the fisheries and aquaculture traceability system (SITRAPESCA), which is intended to automate data collection related to landing, transportation, and processing of seafood to prove its legal origin.

However, based on the researcher’s experience, most of these initiatives and systems lack coordination and interoperability, resulting in redundancies and inefficiencies. Collaboration between government, industry, and civil society remains crucial to overcome challenges and capitalise on the opportunities traceability presents (Caldwell, 2019). By supporting technology and infrastructure development, providing training to stakeholders, incentivising traceability adoption, and interoperability between systems, the fishing industry can advance towards improved environmental, social, and economic sustainability.

By adopting electronic traceability systems, Peru's fisheries can develop consumer trust, which in turn can lead to increased demand and value for Peruvian seafood products. This

research aims to explore the contribution of traceability in enhancing fisheries sustainability and governance, emerging adoption, and the influence of ENGOs, such as WWF, in the process. In the next section, the role of ENGOs is discussed.

2.10 The role of environmental NGOs in the promotion of traceability

Environmental non-governmental organisations (ENGOs) exist worldwide, and since the 1980s they have increasingly influenced global environmental politics and environmental discourse (Lemos & Agrawal, 2006). ENGOs are especially prominent in environmental politics, where their expansion has both driven and responded to shifts from state-centred environmental regulation to polycentric governance configurations that include governments, ENGOs, intergovernmental organisations, corporations, and social movements (Partelow, Winkler, & Thaler, 2020).

ENGOs impact people and their environment, through the implementation of projects on the ground and by influencing policy at both national and international levels. ENGOs sometimes fulfil the important role of articulating between governments, industry, and local communities, providing contributions to the advancement of sustainable fisheries management (Fisher, 1997).

Non-governmental organisations (NGOs), including ENGOs, play a role in global development efforts. These organisations, often driven by a strong sense of social responsibility and commitment to positive change, have an impact on shaping the global agenda (Hassan & Forhad, 2013).

By focusing on grassroots engagement, advocacy, capacity building, filling gaps in services, innovation, collaboration, and accountability, ENGOs can make contributions to sustainable development (Hassan & Forhad, 2013). In a world faced with complex and interconnected challenges, ENGOs contribute to progressing the environmental and social agenda (Larsen & Brockington, 2018).

In the context of Peruvian fisheries, where government capacity for oversight is limited, ENGOs have played a pivotal role in bridging the gap by providing critical information to the state and building the capacity of fishing communities to meet legal requirements, for

example providing guidance to fishers on the requirements they need to meet to be able to comply with the mahi mahi ROP requirements (WWF, 2018).

ENGOs now participate throughout the policy cycle, advocating for change, setting standards, generating knowledge, monitoring treaty obligations, and providing social services to communities worldwide (Forman & Segaar, 2006). Their 'soft power' allows them to propose solutions, experiment with innovative approaches, denounce harmful practices, and serve as role models without having decision-making authority. ENGOs have played an essential role in advancing seafood traceability through the publication of informational reports, establishment of guidelines, introduction of traceability technology, and fostering collaborative efforts (Lewis & Boyle, 2017; Bhatt et al., 2016). Notably, survey data demonstrates that many businesses implemented traceability systems in response to constructive feedback and criticism from ENGOs, illustrating the significant impact of the engagement of these organisations in shaping broader industry practices (Sterling, et al., 2015).

Among ENGOs influencing the sustainable fisheries agenda in Peru, WWF-Peru stands out in its active promotion of traceability technology adoption in the country. Recognising that achieving fully traceable fisheries that contribute to sustainability and governance requires collective engagement, WWF-Peru has acted as a facilitator, promoting the implementation of a transparent traceability system for the benefit of different stakeholders along the supply chain. By encouraging the adoption of traceability systems, WWF-Peru aims to position Peruvian fisheries for high-end market access, increase the value of seafood products to improve fisher livelihoods, and reduce pressure on fishing stocks as well as negative environmental impacts (WWF, 2020). Their initiatives, including the development and testing of the mobile traceability application TrazApp, initially developed for jumbo squid and mahi mahi fisheries, have empowered fishers as key actors in the supply chain and champions of resource sustainability (Grillo et al., 2017).

As the transition towards traceability in Peru is examined, this thesis also analyses the dynamic role of ENGOs in promoting sustainable fisheries management. By exploring their interactions with government and industry stakeholders and understanding the conditions under which their aspirations might be marginalised, the collective effort required to achieve traceability for improved sustainability and governance of Peru's fishing sector can be better understood.

Overall, the collaboration between ENGOs, government institutions, and industry stakeholders is critical in achieving comprehensive traceability systems that support transparent and sustainable seafood supply chains. By capitalising on the strengths and expertise of each stakeholder, Peruvian fisheries can further embrace traceability as a transformative tool for environmental protection, social equity, and economic prosperity in the fishing sector (Future of Fish, 2014).

This chapter has laid the foundational context for understanding the dynamics of the Peruvian jumbo squid and mahi mahi fisheries, encompassing insights into regulations, institutions, and market requirements, as well as the efforts towards developing traceability. It has examined the current landscape of Peruvian fisheries, highlighting the interplay between regulatory frameworks and the practical challenges within the sector. The exploration of informality in fisheries and the examination of national legislation relevant to traceability have set the scene for deeper investigation into these complex issues. The role of ENGOs in promoting traceability or other sustainability initiatives has also been examined.

As the thesis transitions into Chapter 3, the focus will shift to the literature review, which aims to deepen the understanding of traceability in fisheries, to explore the sustainability transitions multi-level perspective framework, and to review the literature on the role of ENGOs in the promotion of sustainability and good governance. By bridging the contextual insights from this chapter with the literature analysis forthcoming, Chapter 3 will contribute to the understanding of the critical factors that influence traceability for sustainability and fisheries governance, setting the stage for the research results that follow.

3 - Literature Review

The sustainable management of fisheries should be a major concern for Peru, given the significant contribution of the fishing industry to the country's economy and the vital role it plays in the livelihoods of coastal communities. As highlighted in – Context– Context, there are challenges and opportunities when it comes to the adoption of electronic traceability systems in Peruvian fisheries. The hypothesis that motivates this research is that the adoption of traceability initiatives in fisheries has emerged as a promising technology to enhance sustainability and governance within the seafood supply chain. It is the researcher's belief that addressing issues such as overfishing, illegal fishing practices, and the conservation of marine resources is imperative for the long-term viability of Peru's fishing industry, the sustainability of local livelihoods and more widely planetary health.

At the core of this research is the exploration of fisheries traceability as a potential response to address some of the challenges faced by Peruvian fisheries. This research aims to understand how traceability initiatives can be effectively implemented, how they align with international market requirements and certifications, and the role of ENGOs in promoting traceability practices. The literature review provides a framework to guide this research, enabling the researcher to build upon the knowledge and insights gained from previous studies and related academic inquiry. The primary purpose of this literature review is threefold:

- **Identify existing knowledge**: The first objective of the literature review is to identify and examine the existing knowledge and research related to fisheries traceability. This includes an exploration of academic articles, reports, case studies, and other relevant resources and information that shed light on the concepts of sustainability, sustainable development, governance, traceability, the role of ENGOs, and the theoretical framework of sustainability transitions and the Multi-Level Perspective (MLP).

- **Identify research gaps**: By analysing the literature, gaps and limitations are identified in the current body of knowledge regarding traceability in fisheries. These research gaps highlight areas where further investigation and empirical research are needed to

enhance understanding of traceability systems, challenges, and opportunities in the Peruvian and similar contexts.

- **Highlight key findings:** The third objective of the literature review is to synthesise and present key findings from existing studies. This synthesis will enable the researcher to gain insights into the successes, challenges, and best practices associated with traceability adoption in fisheries.

By achieving these objectives, the literature review provides an understanding of the current state of electronic technology for fisheries traceability. Ultimately, this review will contribute to the development of strategies that aim to promote electronic traceability systems that support sustainable fishing practices and effective governance in Peru. The subsequent sections of this chapter explore the literature on the history and definitions for sustainability and sustainable development, leading to the concept of sustainable fisheries. Then the chapter dives into what is traceability and its application in fisheries, as well as the concept and importance of governance, and the role of ENGOs in driving traceability practices. Finally, the chapter brings it all together under the theoretical framework of sustainability transitions and the MLP, laying the foundation for the research questions that guide the study.

Box 1. Research questions

RQ1: How is the transition to electronic traceability systems occurring in the Peruvian jumbo squid and mahi mahi fisheries?

a. How is traceability technology emerging in these Peruvian fisheries? What are the drivers and motivations behind its adoption?
b. How and why is traceability gaining momentum in niches, adapting, and growing? How can it become mainstream?
c. How does the fisheries' institutional structure respond to these innovations? What are the perceived barriers and principles for its adoption?

RQ2: What are the contributions of ENGOs and government structures in the transition to electronic traceability systems in the Peruvian jumbo squid and mahi mahi fisheries?

a. How do ENGOs engage with the government, industry, and the artisanal fishing community in promoting traceability technology?

b. Under what conditions are ENGOs considered important players driving the adoption of traceability? Under what conditions are their aspirations and objectives marginalised?
c. How do government institutions and regulations influence and impact the adoption of traceability in the jumbo squid and mahi mahi fisheries?

The literature review has identified several themes around the adoption and impact of traceability systems in fisheries, emphasizing technological innovation, regulatory influence, and stakeholder dynamics. These themes will be presented in this chapter to demonstrate their relevance to the research objectives and questions guiding this study on the potential benefits of electronic traceability systems for the sustainability and governance of Peru's jumbo squid and mahi mahi fisheries, but first we will delve into the concepts of sustainability and sustainable development.

3.1 Sustainability and sustainable development

In this section on sustainability and sustainable development, an overview of the historical development of the concept of 'sustainability' and its contemporary interpretation as 'sustainable development' is provided. The various definitions of sustainability, including environmental, social, and economic aspects are discussed. The focus then turns to sustainable fisheries, which have been a key area of application for the concept of sustainability for over half a century. The definition of sustainable fisheries, including the criteria developed by the Marine Stewardship Council is explained. However, the fact that social objectives have not yet been effectively integrated into sustainable fisheries management is also acknowledged. This section sets the stage for the subsequent sections of the literature review chapter, which delve deeper into the specific issues related to sustainability and sustainable development in the fisheries context and the potential applications and benefits of electronic traceability systems.

3.1.1 A brief history of sustainability and sustainable development

From a Western perspective, the contemporary concept of sustainability can be traced back to Hans Carl von Carlowitz (1645–1714). In his book on forest sciences, he argued that timber would be as important as bread and should, therefore, be used with caution to avoid consuming more than is produced. He suggested that supply should be managed through planned reforestation projects (Du Pisani, 2006; Keiner, 2005). These early observations became an important guiding principle of modern forestry.

Thomas Robert Malthus (1766–1834) also contributed to early thinking around sustainable development as the first economist to foresee the limits to growth. Malthus believed that the limited land available for agriculture meant that as the population grew, food supply would be reduced (Du Pisani, 2006; Mebratu, 1998), known as the theory of limits or theory of population.

The latter half of the twentieth century saw considerable development of the concept of sustainability. In 1968, the Club of Rome was formed by a group of industrial leaders who were concerned about what they defined as the ‘problematique’ (or problem in English). They considered that the world’s most pressing issues, such as poverty, war, pollution, crime, and resource depletion, included 66 'Continuous Critical Problems' (Meadows et al., 2007). In 1972, the group launched the seminal publication ‘The Limits to Growth’, where the group used computer simulations to establish that economic growth could not continue indefinitely because of resource depletion, i.e., reductions in the availability of non-renewable resources and the unsustainable use of renewable resources (Meadows & Randers, 2012).

Also in 1972, the United Nations held the Conference on the Human Environment (also known as the Stockholm Conference), which represented “a first taking stock of the global human impact on the environment,” (Handl, 2012:1). The Limits to Growth report had a significant impact on the discussions and debates at the conference, which ultimately resulted in the creation of the United Nations Environment Programme (UNEP) to address global environmental issues. The Limits to Growth report highlighted the urgent need for action to address environmental degradation, and this message was echoed at the Stockholm Conference, where world leaders recognised the need for international cooperation to address environmental problems.

Building on concerns about the rapid depletion of natural resources, Ernest F. Schumacher's 1979 book ‘Small is Beautiful’ criticised over-organised systems and proposed the concept of 'appropriate technology'. Some experts believe that appropriate technology—technology that considers the skill levels of the population and availability of natural resources—was the 1970’s precursor of the sustainable development concept (Mebratu, 1998).

A shift in focus, from 'curing' to 'preventing' environmental degradation, was seen in 1980, when the International Union for the Conservation of Nature (IUCN) and WWF launched the ‘World Conservation Strategy’. The strategy proposed that both development and conservation are key to achieving a sustainable society (McCormick, 1986). In 1983, Barbara Ward and Rene Dubos were the first to articulate the idea of sustainable development in their book ‘Only One Earth’. The concept of sustainable development was explicitly defined for the first time in the 1987 in the report ‘Our Common Future’, also known as the Brundtland report, developed by the World Commission on Environment and Development (WCED). In this report, sustainable development was described as “a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations,” (WCED, 1987:43).

In 1992, the United Nations Conference on Environment and Development, also known as the Rio Conference, led to the production of documents such as the ‘Rio Declaration’ and ‘Agenda 21’, where the global partnership for environment and development was launched. Since then, there have been extensive ongoing efforts at national and international levels to attempt to address the environmental challenges the world faces. Despite many follow-up conferences and the development of new conventions, progress has been considered limited and frustrating (Mebratu, 1998).

In the 2015 United Nations General Assembly (UNGA), the Sustainable Development Goals (SDGs)—17 interlinked objectives designed to serve as a “shared blueprint for peace and prosperity for people and the planet, now and into the future”— were developed (UNGA, 2017). The SDGs consider the interconnected environmental, social, and economic aspects of sustainable development and were adopted in the 2030 Agenda, with established global targets by 2030 or beyond. To date the SDGs have only had limited effects in global, national,

and local governance (Biermann et al., 2022). Ben-Eli argues that attaining all the SDGs under current conditions of conflicting self-interested values, fragmented governance, limitations in technology, and growth-at-all-cost economic goals, “could put us in a deeper sustainability hole, if only by stimulating an ever-expanding, unlimited demand on resources” (Ben-Eli, 2018:1338).

The effectiveness of the SDGs in influencing governance at global, national, and local levels varies significantly, with implications for sustainability governance in Peru. While the country has made notable strides in areas such as poverty reduction and access to education, challenges persist in addressing climate action, biodiversity conservation, and social inequality (Andia Morales, 2019). Without stronger prioritisation and effective integration of the SDGs into national and local governance frameworks, Peru may struggle to balance economic development with environmental and social objectives. This underscores the need for governance mechanisms and policy implementation strategies that explicitly align with the principles of sustainability and the SDGs, fostering a pathway toward equitable and sustainable development while addressing pressing environmental challenges.

3.1.2 Defining sustainable development and sustainability

The sustainable development concept as established by the Brundtland Commission defines limits to society to ensure that the environment has the capacity to meet the needs of current and future generations, giving priority to the needs of the poor. Meeting “the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987:43) is defined as intergenerational and intragenerational equity (Dovers & Handmer, 1993). Brundtland underlined the strong linkages between poverty alleviation, environmental improvement, and social equitability (Du Pisani, 2006; Mebratu, 1998).

Sustainability, on the other hand, is a broadly defined term. Dovers & Handmer (1993:217), define sustainability as “the long-term and difficult goal of reaching an ecologically sustainable state”, which is reached through sustainable development. However, this term has been considered vague, elusive, and an inoperative buzzword that has all but lost its meaning (Mebratu 1998; Goldin & Winters, 1995; Ben-Eli, 2018). Indeed, joining the opposing words sustainable and development amounts to an oxymoron in the view of some (Dovers & Handmer, 1993). While sustainable development is generally understood as a way of balancing economic growth, social development, and environmental protection, the pursuit

of economic growth and development can lead to environmental degradation and social inequality, making it incompatible with the concept of sustainability. This tension highlights the need for careful consideration of trade-offs and the integration of sustainable practices in all aspects of development. It also emphasises the importance of acknowledging and addressing the complexities inherent in balancing economic, social, and environmental priorities in policymaking and governance.

Ben-Eli proposed that sustainability is achieved when "the rate of consumption and regeneration of resources, as well as the rate of production and absorption of by-products, are at equilibrium," (Ben-Eli, 2018:1339). This equilibrium is currently out of balance because of population growth, increase in overall consumption, and intensification of human activities, which have led to biodiversity loss, deforestation, reduced freshwater, climate change, and social strain. Nonetheless, some believe that technology can increase the carrying capacity "by computing total carrying capacity at any given time and for any system boundary and comparing it with cumulative rates of resource consumption and a rate of producing and accumulating waste, a single value could be obtained, representing where we stand," (Ben-Eli, 2018:1343).

Many ENGOs have embraced the concept of sustainable development as a means of promoting both environmental conservation and social justice. WWF is one such organization that has been an active proponent of sustainable development for several decades. The organization promotes sustainable development by advocating for conservation and biodiversity protection, while also supporting economic development that is socially inclusive and environmentally responsible.

Other ENGOs, such as Greenpeace and Friends of the Earth, have historically been more critical of the concept of sustainable development. They argue that it is often used by governments and corporations to justify environmentally destructive policies and practices under the guise of promoting economic growth and development. Instead, these organisations tend to focus on promoting sustainability and conservation, which they see as more closely aligned with their core values and goals.

ENGOs often use a combination of the terms: sustainable development, sustainability, and conservation, depending on the context and audience. Sustainable development is typically used in the context of promoting economic development that is environmentally responsible

and socially just. Sustainability is a broader term that encompasses environmental, social, and economic considerations and is often used in the context of promoting long-term solutions that balance these three factors. Conservation, on the other hand, is typically used in the context of protecting natural resources and biodiversity.

In the next section, how the concept of sustainability has been incorporated into the fisheries context will be explored.

3.2 Sustainable fisheries

Sustainability has been embedded in fisheries literature for about half a century, with a particular emphasis on the idea of maximum sustainable yield (MSY) (Garcia, 1997). Sustainable fisheries can be defined as fishing that can be maintained indefinitely without affecting the viability of the species caught, or negatively affecting other species that form part of the ecosystem or the fishing communities that depend on it (Camara & Santero-Sancez, 2019). Garcia (1997) argued that to assess sustainable fisheries—specifically the environmental resources, economic, and social elements of a fishery—there is a need for accurate information systems, updated in real-time, highlighting the need for traceability technology.

The Marine Stewardship Council (MSC) has defined sustainable fisheries as leaving enough fish in the ocean, respecting habitats and ensuring people who depend on fishing can maintain their livelihoods (Ponte, 2012). Specifically, and according to the three principles of MSC, sustainable fisheries must: (a) be at a level that ensures they can continue indefinitely and that the fish population can remain productive and healthy; (b) be managed carefully so that other species and habitats within the ecosystem remain healthy; (c) comply with relevant laws and be able to adapt to changing environmental circumstances (Kestin, 2017).

In over two decades since the establishment of the MSC, there has been growing recognition that fish populations cannot be considered in isolation from the habitats and larger social and ecological systems that they exist within. Although almost all definitions of fisheries sustainability have dealt with environmental protection (Hilborn, et al., 2015), social objectives have yet to be effectively integrated into sustainable fisheries management (Rindorf, et al., 2017). Indeed, the MSC has been criticised for not covering socio-economic and labour issues in their standards (Ponte, 2012). As such, sustainable fisheries management

needs to consider ocean ecosystem health, habitat management, and include social safeguards for those involved in the industry and ensure equitable and inclusive access (Cummins, 2004).

In the following sections the concepts and potential contributions of traceability in achieving sustainability and sustainable development in fisheries are explored using the emerging research framework of Sustainability Transitions and the Multi-Level Perspective (MLP).

3.3 The concepts of traceability and sustainability transitions

In the modern context of globalised supply chains and sustainability challenges, traceability has emerged as a useful technology that facilitates the tracking and tracing of goods and information through production and distribution processes (Karlsen et al., 2013). Traceability plays a crucial role in ensuring transparency, accountability, and environmental and social responsibility in supply chains (Olsen & Borit, 2013). By providing information on the origin, processing, and distribution of products, traceability can address issues such as environmental degradation, labour exploitation, and food safety risks, while also empowering consumers to make more sustainable and ethical consumption choices (Zhou & Xu, 2022). Consequently, traceability systems have become a powerful tool for facilitating the adoption and implementation of sustainable practices and policies, supporting the transition towards more resilient and sustainable food systems. The increased interest in food traceability was driven by costly food scandals that occurred worldwide in the early 2000s (Olsen & Borit, 2013; Karlsen et al., 2013; Zhou & Xu, 2022). These events led to the development of international regulations focusing on the documentation and traceability of food products, as well as the establishment of standards for food production.

The definition of traceability has evolved over time, influenced by different contexts, stakeholders, and objectives. In the early 1990s, the International Organisation for Standardisation (ISO) introduced the concept of traceability as “the ability to trace the history, application, or location of an entity by means of recorded identifications” (ISO, 1994, as cited in Olsen & Borit 2013:143). This definition was later refined in ISO 9000 as “the ability to trace the history, application, or location of that which is under consideration” (as cited in Olsen & Borit, 2013:143). Subsequently, ISO 22005 provided additional guidance to terms such as “document traceability, computer traceability, or commercial traceability” (as cited in Olsen & Borit, 2013:143). The Codex Alimentarius Commission Procedural Manual defines traceability

as “the ability to follow the movement of a food through specified stage(s) of product, processing, and distribution” (FAO/WHO (1997) as cited in Olsen & Borit, 2013:143). Similarly, the EU General Food Law (2002) defines traceability as “the ability to trace and follow a food, feed, food-producing animal, or substance intended to be or expected to be incorporated into a food or feed, through all stages of production, processing, and distribution" (as cited in Olsen & Borit, 2013:143).

More recent definitions of traceability emphasise the need for a comprehensive and integrated approach that covers all processes in the supply chain, providing a guarantee of the origin and life history of a product (Karlsen et al., 2013, Zhou & Xu, 2022). However, regardless of the specific definition, traceability generally involves the ability to identify and trace the movement of products or materials, from their origin to their final destination, through all relevant stages of production, processing, and distribution. Olsen and Borit (2013) advocate for comprehensive traceability systems that provides access to all food product properties and ingredients, both backward (tracing the product's origin) and forward (tracking its destination). They propose a more integrated and expanded definition of traceability as “the ability to access any or all information relating to that which is under consideration, throughout its entire life cycle, by means of recorded identifications” (Olsen & Borit, 2013:148). This definition is particularly relevant for this research, as it emphasises the importance of traceability across the entire life cycle of the product, from the source of the raw materials to the final consumer. Moreover, this definition also highlights the role of recorded identifications, which are essential for tracking and verifying the information throughout the supply chain. Therefore, this definition provides a useful framework for examining the role of traceability in the sustainability transition of Peruvian jumbo squid and mahi mahi fisheries.

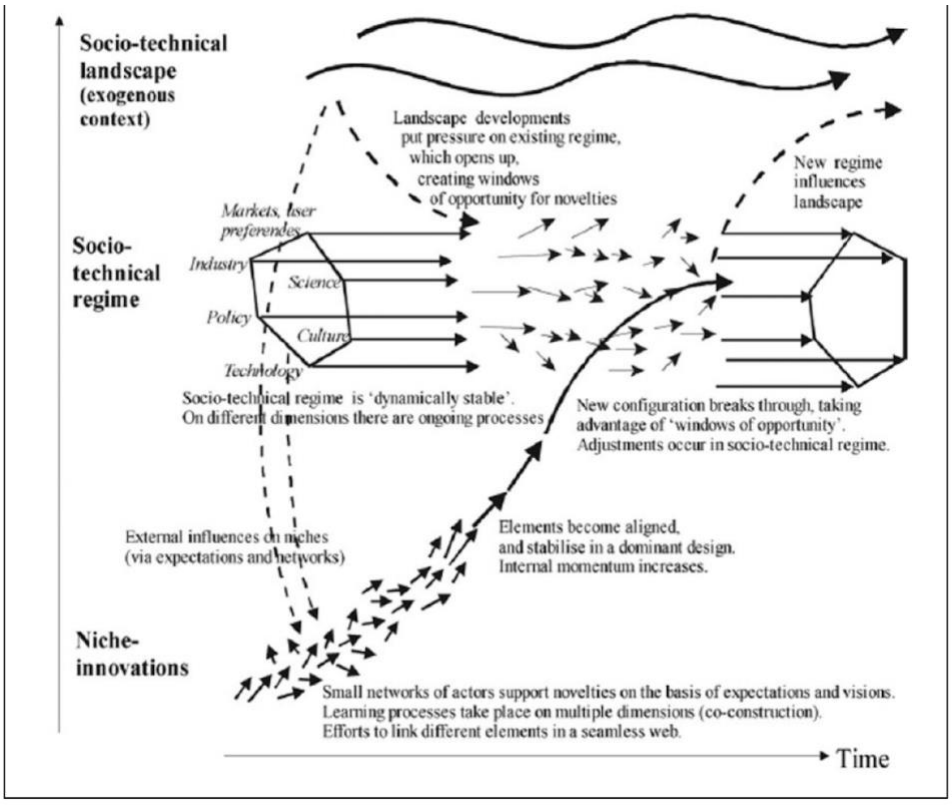
Traceability is a fundamental concept in modern supply chains, and its significance extends beyond mere tracking and monitoring of products. To fully appreciate the role of traceability in the context of sustainability transitions and the achievement of more sustainable and resilient food systems, the theoretical framework of sustainability transitions and the MLP will be used.

Sustainability transitions involve multi-dimensional, long-term changes in socio-technical systems, encompassing various aspects such as technological, material, organisational,

institutional, political, economic, and cultural elements (Brauch, 2013). The MLP serves as a theoretical framework to analyse the emergence and evolution of traceability technology in the context of fisheries. It offers a versatile and widely applicable approach to understanding sustainability transitions in various socio-technical systems (Grin, Rotmans, & Schot, 2010), making it particularly suitable for investigating the adoption and implementation of traceability technology in the Peruvian jumbo squid and mahi mahi fisheries.

The MLP is a process theory that focuses on individual entities, such as people, groups, organisations, and material objects, and examines how their perceptions, interests, and preferences change during transitions. It emphasises the importance of event sequences and trajectories, which are influenced by dynamic processes at three analytical levels: niches, regimes, and landscapes. These analytical levels hold relevance within the context of fisheries, where stakeholder interactions and motivations can significantly influence the sustainability of the sector (Geels, 2011).

Figure 3. Niches, regimes, and landscapes in socio-technical transitions



Source: Geels & Schot (2007).

By integrating traceability within the theoretical framework of sustainability transitions and the MLP, insights can be gained into the dynamics of fisheries transitions. The MLP allows for the exploration of socio-technical system dynamics and interactions, providing a comprehensive framework for understanding how niche innovations, such as the development and traceability technology, can become part of a regime and contribute to sustainability practices. Moreover, it enables the identification of the roles of different stakeholders in shaping such transitions, informing the development of effective policies and interventions to promote sustainability and effective governance in fisheries. The theoretical framework will be further explained later in the chapter.

The subsequent sections contain an examination of the dynamics of traceability technology adoption, its challenges, and the potential pathways for sustainable fisheries management within the Peruvian context, which was described in Chapter 2 – Context. This exploration maintains a focus on the theoretical underpinning of sustainability transitions and the MLP.

3.3.1 Traceability characteristics

Diverse traceability concepts provide insights into the essential elements of an effective traceability system. Here are six elements of traceability (Karlsen et al., 2013):

- Product traceability: Determines the physical location of a product.
- Process traceability: Describes activities that have affected the product.
- Genetic traceability: Determines the genetic constitution.
- Input traceability: Refers to the type and origin of inputs.
- Disease and pest traceability: Traces the epidemiology of pests and biotic hazards.
- Measurement traceability: Relates individual measurement results through an unbroken chain of calibrations to accepted reference standards.

Trade units within supply chains must be uniquely identified, and all transformations must be recorded (Ringsberg, 2014). An effective traceability system needs to incorporate these different elements. The process of identifying a product's origin is known as tracing, while tracking is the forward process used to identify the end users and trading partners

(Óskarsdóttir & Oddsson, 2019). Moreover, many food supply chains exhibit complex multi-step vertical and horizontal branching (Pearson, et al., 2019).

For a traceability system to function, it must have a means to record information, whether in paper-based or digital formats. Systems need to consider the following aspects (Islam & Cullen, 2021):

- TRU (Traceable Resource Unit) identification: Defining the smallest unit of product to trace.
- Recording of data: Encompassing different types of information.
- Data integration: Creating associations and linking recorded data.
- Data accessibility: Requiring interoperability to allow for the exchange of data.

In this context, manual paper-based systems may have errors in the data that are hard to identify, are more prone to information loss, and contribute to bureaucracy and inefficiencies in data processing. Traceability systems require breadth, depth, and precision, where breadth refers to the amount of information recorded, depth is the distance the system can trace, and precision is associated with the degree of assurance with which a particular product's movement or characteristics can be pinpointed (Golan, et al., 2004). McEntire et al. (2010, as cited in Stranieri et al., 2016:3) added access to these characteristics, which refers to the speed with which information can be communicated to supply chain members. Mc Carthy et al. (2018) further emphasised that traceability systems should be scalable and standardised, scalable to meet the needs of global consumers and standardised to ensure that tracked products are not hindered by language or fraud, for example. Additionally, systems that monitor in real or near real-time are much needed.

When it comes to fisheries, specific challenges and complexities unique to this sector must be considered to ensure the successful implementation of traceability systems. In fisheries supply chains, traceability takes on a crucial role, addressing the environmental and social concerns associated with seafood production and distribution (Olsen & Borit, 2013). The characteristics of traceability become even more pertinent in the context of fisheries, where issues like overfishing, illegal fishing, and labour exploitation can have severe consequences for marine ecosystems and coastal communities.

Product traceability in fisheries is not solely about tracking the physical location of fish, it also encompasses the identification of species, catch methods, and harvesting areas (Astill, et al., 2019). Process traceability gains insight into the practices and activities that have affected the fish throughout the supply chain. For sustainable fisheries management, genetic traceability can help identify the origin of fish stocks, ensuring compliance with regulations and the use of sustainable fish sources (Hopkins et al., 2024).

Input traceability becomes crucial when considering the type and origin of inputs used in fisheries. Ensuring that fishing gear and equipment are sustainably sourced contributes to the overall environmental responsibility of the industry (Bailey et al., 2016). Disease and pest traceability are equally important as they enable the tracing of epidemiological factors, ensuring food safety and preventing the spread of diseases in fisheries. Furthermore, measurement traceability plays a vital role in fisheries traceability, especially in recording catch volumes and identifying where and when the catch occurred. These aspects help in monitoring fish stocks, preventing illegal fishing, and contributing to effective fisheries management practices (Fabinyi et al., 2018).

Given the complexities of multi-step vertical and horizontal branching in seafood supply chains, achieving chain-wide traceability can be particularly challenging. The need for harmonising information standards and implementing interoperable technology is crucial in fisheries, where data sharing and accessibility are critical for successful traceability systems (Greenwood, 2019).

The traceability characteristics outlined above are essential in addressing the challenges faced by the fisheries industry, where sustainability practices are of utmost importance (Bailey et al., 2016). As this thesis further explores fisheries traceability in the following sections, these characteristics will provide a foundation for understanding the dynamics, implications, and potential pathways for improving fisheries sustainability and governance in the Peruvian context. Having analysed the necessary characteristics for a successful traceability system, as well as the specificities for its application in fisheries, the next section is about traceability drivers.

3.3.2 Traceability drivers

Traceability drivers can be broadly classified into several categories, including legislation, food safety and quality, supply chain benefits, and sustainability. While different authors have identified various drivers of traceability (Karlsen et al., 2013; Stranieri et al., 2016; Islam & Cullen, 2021), common themes emerge across these classifications. One significant theme is regulatory and market incentives. Many authors highlight the role of legislation in driving the adoption of traceability, with regulations mandating the tracking and monitoring of food products to ensure safety and quality standards are met (GDST, 2022). Similarly, market incentives, such as the need for companies to differentiate their products based on quality or sustainability credentials, can also drive the adoption of traceability (Hopkins et al., 2024).

Another prevalent theme is supply chain efficiency and transparency. Traceability helps companies better manage their supply chains by enabling them to track the movement of goods and identify potential bottlenecks or inefficiencies (Fox et al., 2018). This can lead to reduced costs, improved efficiency, and enhanced overall supply chain performance.

A third theme is the growing importance of sustainability and environmental concerns. Traceability can promote more sustainable and environmentally friendly practices in several ways, such as enabling companies to track the origins of their products and ensure they are produced using sustainable methods (Hosch & Blaha, 2017). Additionally, it allows consumers to make more informed purchasing decisions, based on the environmental impact of the products they buy.

These drivers demonstrate the range of factors that can motivate the adoption of traceability and highlight the need to understand the specific contexts and motivations that drive different industries and stakeholders. In the next section the benefits and beneficiaries of traceability are discussed.

3.3.3 Traceability benefits and beneficiaries

Traceability plays a critical role in managing uncertainty and complexity in global supply chains. In recent years, it has become associated with the need for more transparent, sustainable, and responsible networks that can trace social and environmental breaches (Garcia-Torres et al., 2019). While the implementation of traceability systems can be costly at the outset, numerous benefits can be realised, including supply chain efficiencies, enhanced

market access in an increasingly regulated global environment, and bigger market share (Bailey et al., 2016).

The literature identifies a broad set of benefits resulting from the implementation of traceability systems (Moe, 1998; Karlsen et al., 2013; Asioli et al., 2014; Sterling et al., 2015), which can be categorised as follows (Mai, et al., 2010):

- **Market and customer response**: Correlation of product data leading to improved customer satisfaction and response.
- **Quality and safety management:** Cause-and-effect indicators to satisfy product standards, avoiding mixing of high- and low-quality materials, ease of information retrieval in quality management audits, better quality and process control, and compliance with legal requirements.
- **Enhanced product recall**: Efficient recall procedures, ensuring swift and accurate responses to potential product issues.
- **Improved supply chain operations**: Optimised use of resources, improved process control, and better foundations for implementing information technology solutions in control and management systems.

The business benefits of traceability encompass improvements in production planning and scheduling, minimisation of waste, efficient use of raw materials, improved competitiveness, and increased coordination in supply chains (Karlsen et al., 2013).

Improved supply chain management is particularly emphasised as one of the most important benefits of traceability: "Traceability allows a firm to analyse what goes well, or wrong, and assess the efficiency of the entire supply chain process with data management and analytics, review the likely effect of changes in the business environment, right up to the point of sale, the consumer, and beyond" (Zhou et al., 2022:95).

Sterling and others report that 75% of businesses showed a positive change in opinion before and after implementing traceability, with the benefits surpassing their expectations (Sterling et al., 2015:217).

Islam & Cullen (2021) identify five beneficiary groups for traceability:

- **Public, international standardisation, and non-governmental certification bodies**: These groups can make more informed decisions based on traceability information.
- **Business partners and stakeholders**: Traceability helps them handle recalls more effectively.
- **Consumers and the community**: They can have more confidence in the food system and the products they consume.
- **Food business operators**: Traceability assists in making food production, assembly, and distribution more efficient, and enables product differentiation.
- **The scientific community**: They benefit from access to scientific data for research purposes.

The literature suggests that traceability systems in the food supply chain offer a wide range of benefits that extend beyond mere compliance with legal and regulatory requirements (Golan, et al., 2004). These benefits are enjoyed by various stakeholders, including businesses, consumers, regulators, and civil society actors. While the implementation of traceability systems can be costly, the benefits realised in terms of supply chain efficiencies, improved product quality, enhanced customer trust, and increased competitiveness are significant. Furthermore, traceability systems are increasingly viewed as a means of achieving more transparent, sustainable, and responsible food supply chains (Hobbs, 2004). While the literature demonstrates these advantages across various industries, it is essential to emphasise how these benefits directly relate to sustainability in the context of fisheries (Helyar, et al., 2014).

One of the primary environmental challenges faced by the fishing industry is illegal fishing (Olsen & Borit, 2013). Traceability systems enable the tracking of fish from harvest to consumption, making it easier to identify and prevent the entry of illegally caught or unreported fish into the market. By establishing robust traceability mechanisms, fisheries can combat illegal fishing activities, protect marine biodiversity, and promote sustainable fishing practices (Astill, et al., 2019).

Overfishing is another critical concern for fisheries sustainability. By providing accurate and timely information on fish catch volumes and locations, traceability systems contribute to

improved fisheries management. This, in turn, helps prevent overfishing, maintain fish stocks at sustainable levels, and preserve marine ecosystems. By targeting overfishing, traceability systems serve as a bridge between environmental conservation and fisheries viability (Hosch & Blaha, 2017).

Labour exploitation is a social issue that plagues the fishing industry, particularly in regions where labour rights are not adequately enforced. Traceability systems can address this challenge by providing transparency and accountability throughout the supply chain. Consumers and businesses can use traceability data to ensure that seafood products are ethically sourced and produced without labour exploitation, contributing to improved working conditions and social responsibility in the industry (Jennings, et al., 2016).

Environmental degradation resulting from unsustainable fishing practices poses a threat to marine habitats and coastal communities. Traceability systems that include data on fishing methods and gear used provide insights into the environmental impact of fishing activities. Such information empowers consumers and businesses to make more informed choices, supporting sustainable and environmentally friendly fishing practices (van Zeijl-Rozema et al., 2008).

Furthermore, traceability systems enhance supply chain efficiency and transparency, which are essential elements of sustainability in fisheries. Improved supply chain management through traceability ensures optimised use of resources, minimises waste, and fosters responsible and sustainable fishing practices (Helyar, et al., 2014).

Therefore, it can be said that the benefits of traceability directly align with the goals of fisheries sustainability. By combating illegal fishing, preventing overfishing, addressing labour exploitation, promoting environmental responsibility, and improving supply chain operations, traceability systems play a pivotal role in the pursuit of a more sustainable and responsible fisheries industry (Jennings, et al., 2016).

By connecting the broad benefits of traceability to the unique challenges faced by fisheries, how traceability technology can address issues such as illegal fishing, overfishing, labour exploitation, and environmental degradation is better understood. The following section examines how traceability emerges as a vital tool to promote transparency, accountability,

and responsible practices, aligning with broader sustainability goals and supporting the transition towards more resilient and ethical fisheries supply chains.

3.3.4 Traceability for sustainability

The environmental and social benefits of traceability are the primary focus of this research and are examined in more detail in this section. Sustainability is about both meeting the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). Sustainability information encompasses – among others – human health and safety ('People') and environmental impact ('Planet'), within an economic context ('Prosperity'). Care for sustainability is inevitable in all industries if we want to maintain an environment in which our children and all children after them can live in a healthy environment (Wognum et al., 2011).

Transparency in the supply chain refers to: "the degree of shared understanding of, and access to, product-related information as requested by a supply chain's stakeholders without loss, noise, delay, or distortion. This definition implies that data must be relevant, accurate, factual, reliable, timely, and available in an appropriate quantity," (Wognum et al., 2011:65).

The lack of comprehensive traceability systems across various sectors, from food production to toy manufacturing, has significantly exacerbated crises related to both social and environmental sustainability. Such crises not only undermine ethical labour practices and equitable economic opportunities but also threaten ecological integrity and resource conservation. While existing research at the intersection of traceability and sustainability has predominantly focused on aspects of product health and safety, this narrow scope overlooks the broader implications for social equity and environmental stewardship (Garcia-Torres et al., 2019). Expanding the scope of traceability to encompass these broader sustainability dimensions is crucial for addressing the challenges faced by industries today, ensuring that production processes are transparent, equitable, and environmentally responsible.

The impacts of traceability on sustainability are so significant that the United Nations Global Compact (UNGC) expanded its definition of traceability to include sustainability. It describes traceability as: "[…] the ability to identify and trace the history, distribution, location, and application of products, parts, and materials, to ensure the reliability of sustainability claims

in the areas of human rights, labour (including health and safety), the environment, and anti-corruption" (UNGC, 2014:6).

The UN recognises the role of traceability in achieving the SDGs, particularly those associated with inclusive and sustainable economic growth and decent work (SDG 8); resilient and sustainable infrastructures, industrialisation, and innovation (SDG 9); and sustainable consumption and production patterns (SDG 12) (UN General Assembly, 2015, as cited in Garcia-Torres, 2019:5). This recognition led to the development of TfS, which is defined by Garcia-Torres et al. (2019:5) as: "[…] the ability to combine supply chain information-sharing and visibility in such a way that actors within the chain have access to information that is accurate, trusted, timely, and useful for operational reasons and to ensure the reliability of sustainability claims."

TfS is developed through inter-organisational governance, collaboration, and tracking and tracing routes and processes. TfS can contribute to sustainability goals by fostering: "regenerated competencies and knowledge that enable renewed and more complex strategic planning, inter-organisational control, and monitoring risk and management across the entire supply chain. TfS is, thus, not only about information-sharing, visibility, and accessibility but, rather, about regenerating and managing competencies and knowledge across the whole supply chain through renewed inter-organisational practices and learning processes that are better adapted to complex supply chains so that sustainability goals are met, and their implementation evaluated" (Garcia-Torres et al., 2019:5).

Sterling et al. (2015) argue that consumers value sustainability, and traceability can help demonstrate it, enabling companies that have implemented traceability systems to differentiate their products and potentially capture additional value. According to Zhou and others, "for every industry, every product, at every level, traceability is the driver of a smarter, safer, more efficient, entirely connected global supply chain – an intelligent supply chain, which is the key to a more sustainable world," (Zhou et al., 2022:96).

The literature broadly supports the idea that traceability can significantly contribute to sustainability from social, economic, and environmental perspectives. Nonetheless, the implementation of such systems inevitably faces challenges, which are described in the following section.

3.3.5 Barriers to traceability adoption

Food systems are complex and diverse, and this complexity can create barriers to the adoption of traceability systems. Such barriers to chain-wide traceability may be both technological and organisational. Many actors are involved in supply chains, where material and information flows often cross several organisational and country borders. Wognum and others pointed out that: "Harmonising information standards and the implementation of interoperable technology is difficult in such situations, especially without strong legislative enforcement," (Wognum et al., 2011:73).

Hardt et al. (2017) describe the following barriers to traceability adoption:

- **Lack of awareness and education:** Many actors in the supply chain may not fully understand the need for traceability or be aware of its potential benefits. Educating stakeholders about the importance of traceability and its positive impact on sustainability can be crucial in overcoming this barrier.

- **Knowledge gaps:** There might be gaps in understanding what traceability is and how it works. Proper knowledge dissemination and sharing best practices can help address these gaps.

- **Poorly demonstrated incentives:** If the benefits of adopting traceability systems are not clearly demonstrated or do not outweigh the costs, stakeholders may be hesitant to invest in them. Highlighting successful cases and tangible advantages can incentivise adoption.

- **Resource deficiencies:** Insufficient funding and capacity issues can hinder the implementation of traceability systems, especially for smaller actors in the supply chain. Access to resources and support for technology adoption can alleviate this barrier.

- **Technical issues:** Challenges related to technology and data management, such as data accuracy, privacy, and data sharing, can impede the effective implementation of traceability systems. Ensuring robust and user-friendly technologies can help overcome these issues.

- **Logistical hurdles:** The operation of traceability systems involves coordination among various actors, and the process can encounter logistical challenges. Addressing operational hurdles can streamline the adoption process.

- **Scaling issues:** Promoting broader adoption of traceability systems across entire supply chains may present scalability challenges. Implementing scalable solutions and encouraging collaboration among stakeholders can facilitate wider adoption.

Although there are identified barriers to the adoption of traceability systems in food supply chains, the benefits described in the previous section appear to outweigh these challenges. Nonetheless, there are valuable lessons that can be extracted from the literature for the promotion of traceability, which are analysed below.

3.3.6 Critical factors for successful uptake of traceability systems

The experience acquired in the uptake and adoption of traceability systems in different food supply chains has led to valuable lessons and recommendations. For example, Karlsen et al. (2011) concluded that if a company cannot identify any benefits from implementing traceability, motivation will drop, and motivation influences all other critical criteria for success. In their research, they discovered that motivating factors varied among companies, in some cases stemming from the need to meet regulations, while in others, it was driven by the desire for more information about their products or satisfying customer needs. Generally, when motivation was low, so was the delivery. Companies will not make the investment towards traceability if they cannot identify the benefits to be gained.

Sohal (1997) has identified five critical factors for developing and implementing traceability:

- **Top management support and understanding:** Successful adoption requires support and understanding from top management, as they play a crucial role in driving the initiative forward and allocating necessary resources.

- **Communication of benefits:** Clearly communicating the benefits of traceability to all stakeholders can help overcome any resistance or fear of a new system and encourage buy-in from the entire supply chain.

- **Building relationships:** Strong and collaborative relationships between users and suppliers are essential for smooth integration and operation of traceability systems.

- **Capacity building:** Providing the necessary training and capacity-building efforts can enhance the competence of stakeholders in using traceability systems effectively.

- **Long-term planning:** A well-thought-out long-term plan ensures sustained commitment and support for the traceability initiative.

Central to this framework is the notion that effective traceability transcends technical solutions, requiring a concerted effort that blends leadership-driven commitment, stakeholder engagement, and strategic foresight. Together, these elements foster an organizational culture poised for transparency and efficiency, ensuring that traceability systems not only integrate smoothly into existing operations but also align with broader strategic objectives, ultimately enhancing supply chain resilience and sustainability.

Food traceability systems have several unique characteristics as compared to other types of enterprise systems. They are chain-based systems, complex, and dynamic due to the nature of food products and the requirements for food safety.

Food traceability systems also involve a very wide range of stakeholders from both public and private sectors (Howard et al., 2012; Pizzuti & Mirabelli, 2015). This generates complex interactions at multiple levels that have a bearing on the individual, industry, and society. Refer to Box 2 for recommendations to business, government, and NGOs for traceability uptake derived from the literature.

Box 2. Recommendations for traceability uptake (Sterling, et al., 2015)

Businesses:

• **View traceability from a strategic perspective:** Traceability delivers greater benefits when tightly integrated into value chains, practices, and systems, leading to improved supply chain performance.

- **Establish purpose and objectives before selecting technology:** Clearly define the purpose and objectives of traceability enables informed decision-making when selecting appropriate technology and ensures alignment with business needs.

- **Approach traceability with big vision, small steps:** Implementation of traceability requires a step-by-step approach, emphasising that technology alone cannot solve all issues; it should be accompanied by process improvements and organisational adaptations.

Governments:

- **Enforce legislation that exists:** Governments should apply existing legislation and regulations effectively to address issues related to traceability rather than solely developing new rules.

- **Ensure achievement of intended outcomes:** Governments should ensure that regulations and legislation function as intended by encouraging businesses to adopt traceability for their operational and business purposes.

- **Pursue international consistency and harmonisation:** Governments should work towards harmonising policies and regulations internationally to reduce weaknesses and limitations and lower the costs of traceability for businesses.

NGOs:

- **Engage in constructive dialogue:** NGOs should work collaboratively with industry stakeholders to influence changes in consumer behaviour, which can effectively drive changes in business behaviour and encourage more sustainable practices.

Traceability has been identified as a valuable tool for managing uncertainty and complexity in global supply chains, with numerous benefits to be realised, such as supply chain efficiencies, market access, and increased market share. Furthermore, traceability has been recognised as an important facilitator to achieve and demonstrate sustainability, with the ability to identify and trace the history, distribution, location, and application of products being essential to ensure the reliability of sustainability claims (Asche, et al., 2018). Despite the benefits, the implementation of traceability systems in food supply chains faces several barriers, such as

technological and organisational complexity, a lack of awareness, and resource deficiencies (Hosch & Blaha, 2017). The following section examines traceability in fisheries and identifies specific traceability needs to improve sustainability in fishery supply chains.

3.3.7 The role of traceability in improving fisheries sustainability

Traceability plays a pivotal role in advancing the sustainability of the seafood sector by addressing key challenges that threaten fisheries' long-term viability. By enabling the accurate and real-time assessment of environmental resources, economic factors, and social dimensions of fisheries, traceability technology aligns with the core principles of sustainable fisheries. Through traceability, fishing activities can be monitored and managed more effectively, ensuring that fish populations remain productive and healthy while respecting the integrity of marine habitats (Bailey et al., 2016).

Moreover, traceability's application extends to promoting responsible fishing practices, combating issues such as overfishing and illegal fishing that have detrimental impacts on marine ecosystems. By providing transparency and accountability across the seafood supply chain, traceability contributes to environmental conservation efforts, helping maintain the health and balance of marine ecosystems (Hopkins et al., 2024).

In the context of Peru's fisheries, the application of traceability holds particular significance. As one of the world's leading fishery nations, Peru faces unique challenges in managing its vast fisheries resources. By analysing the role of traceability in Peru's fisheries, valuable insights can be gained into the practical implementation of traceability systems and their impact on sustainability outcomes. The lessons learned from Peru's experience can inform global efforts to improve the sustainability of fisheries through traceability measures. By analysing its applications in specific fisheries contexts, this section seeks to uncover best practices and lessons that can contribute to the broader adoption of traceability as a cornerstone of sustainability in global fisheries.

The role of traceability in achieving fisheries sustainability is explored further using the emerging research framework of Sustainability Transitions and the MLP. This framework offers insights into understanding the complex interplay of factors that influence sustainable development in fisheries and how traceability can act as an enabler for positive change. By examining research studies and academic literature that highlight the relationship between

traceability and sustainability in fisheries, a better understanding of how traceability addresses environmental and social challenges can be gained, paving the way for more informed and impactful decision-making in the seafood sector.

Traceability has emerged as an instrument in promoting sustainability within the fisheries sector, with research studies and academic literature shedding light on its transformative potential. By establishing transparent and accountable supply chains, traceability addresses issues plaguing fisheries worldwide (Jennings, et al., 2016).

The seafood industry has been linked to a range of negative environmental and social impacts, including overfishing, habitat destruction, bycatch, and discards, IUU fishing, labour abuses, unfair distribution of trade benefits, and unsafe working conditions (Bailey et al., 2018). Thus, there is an urgent need to improve the sustainability of fisheries, from social, economic, and environmental perspectives. According to Fox et al. (2018), fraud in seafood products is prevalent because of increasing demand for seafood amid its recognition as a healthy alternative to red meat, coupled with similarities in some seafood species, stock limitations, and price pressures. Species and fisheries substitution, IUU substitution, species adulteration, chain of custody abuse, catch method fraud, modern day slavery, and welfare problems all raise concerns.

The Conservation Alliance for Seafood Solutions has developed a 'Common Vision for Sustainable Seafood' in which they established that “understanding your products and where they come from enables you to assess the sustainability of your products, measure changes, and take action to improve supply over time” (Lewis & Boyle, 2017:A13). Therefore, it can be said that traceability can contribute to the sustainability of the fisheries sector since it provides information to understand seafood products and their origins (Wen, et al., 2016).

There is growing customer demand for food with higher safety and transparency levels, in the context of increasingly globalised fisheries supply chains (Asioli et al., 2014). Today, seafood is the most traded commodity in the world, with the US and Europe as the top global consumers per capita (Leal et al., 2015). Concerns over food provenance, quality and safety, fraud, sustainability, and IUU fishing, have led to an increase in the adoption of traceability systems (Bailey et al., 2016). For example, 95% of seafood consumers surveyed in Europe indicated a desire for more information about product sustainability (Seafood Choices Alliance, 2007, as cited in Sterling et al., 2015:211). Traceability offers a transformative solution by enabling real-

time tracking of catch volumes, ensuring adherence to established fishing quotas and limits (Fabinyi et al., 2018). Through accurate data on catch and movement, traceability empowers fisheries managers to implement evidence-based conservation measures, thus safeguarding fish populations and promoting sustainable harvesting practices (Viatori & Medina, 2019).

There is also a growing awareness of the benefits of traceability by national governments. “Policymakers are recognising that 'bait to plate' seafood traceability is a key tool to achieving sustainable fisheries, combating illegal fishing, and ensuring food security. From both commercial and public policy perspectives, improved seafood traceability has become a top priority. At this time, only a fraction of wild-caught fish products can be sufficiently traced to meet these growing demands for transparency” (Sterling et al., 2015:210).

Besides consumers and policy makers, businesses have also increased their awareness of the benefits of traceability in seafood production. Given that the complexity of seafood value chains is increasing, the ability to access, manage, and share information is critical for mitigating ecological, economic, political, or health-related risks (Bailey et al., 2016). Yet, seafood traceability still faces significant challenges. There is a lack of cost-effective ready-to-use methods that validate origin certifications claimed by fishers, producers, or traders (Leal et al., 2015). Leal and others go on to state: “The perfect tool to trace seafood products should be fast, simple, cheap, and reliable so that it can be widely applied without major financial burdens and logistical restrictions […] Currently, while the ‘perfect tool’ has yet to be developed and validated, the best approach is likely the combined use of multiple tools that complement each other to maximize their accuracy and reliability” (Leal et al., 2015:335).

To be able to use a combination of tools, interoperability between traceability systems is a must. Interoperability is the ability of different information technology systems to communicate with each other for the purposes of exchanging and using data (Bhatt, et al., 2016). Interoperability is essential for the exchange of information between systems, supply chain actors, and ultimately producing countries and the global market. Without interoperability, fisheries information will continue to be siloed, limiting the potential sustainability and other benefits of the implementation of traceability systems.

Effective information sharing is vital for businesses to be able to proactively manage risks, reduce costs, and increase revenue. Data shared between businesses for the purposes of traceability should be accurate and verifiable, which requires effective interoperable

information systems (Howard et al., 2012). To this end, a common blueprint or framework is needed among the systems used by the businesses operating along a value chain (Bhatt et al., 2016:392). For systems to be truly interoperable, they must be able to share data using a common data format (syntactic interoperability) and interpret and understand that shared data (semantic interoperability) (Hardt et al., 2017). Currently, numerous diverse proprietary heterogeneous systems are in use, hindering global interoperable traceability. To address this situation, a series of standards, protocols, specifications, and guidelines are needed to provide information systems with the ability to communicate effectively by sharing standardised data (Bhatt et al., 2016).

Still, the principal challenges regarding the uptake of traceability systems and willingness to share data are less about the technology itself and more about the people and institutions involved, as well as the relationships between them. “The primary challenges to implementing interoperable traceability in seafood are cultural and attitudinal" (Gooch et al., 2017:A45). Resistance to the adoption of new technologies is strongly influenced by prevailing stakeholder relationships. In the seafood industry, these relationships are often adversarial, and businesses may range significantly in size and influence (GDST, 2022). In such situations, individuals may fear that changes will be forced upon them or that the change will harm their business. Acceptance of changes in practice or technologies requires engagement of individuals with the new practice, providing a clear rationale for why they should adopt the proposed changes and forging an emotional connection (Olsen & Borit, 2013).

It can be concluded that interoperability is a fundamental factor to obtain all the benefits of the implementation of traceability systems in fisheries. To achieve interoperability, supply chain actors must first be aware of how interoperable traceability systems will benefit them. In this context, there is one specific standard – the Global Dialogue for Seafood Traceability (GDST) – that has been developed for the seafood sector, which is described in Box 3.

Box 3. Global Dialogue for Seafood Traceability

The GDST is the only recognised global traceability standard for seafood (Leslie & Lugo-Mulligan, 2021). It is an international business-to-business platform for fisheries supply chain actors, both private and of civil society. Its goal is to advance the interoperability of

seafood traceability systems through agreed key data elements, technical specifications, and benchmarks for data validity (Marttila, 2020).

As Leslie and Lugo-Mulligan (2021:27) state: “GDST promotes a unified, interoperable seafood traceability framework to improve the reliability of seafood information, reduce the cost of seafood traceability, reduce supply chain risk, and contribute to securing the long-term social and environmental sustainability of the sector. The Dialogue brings together a broad spectrum of seafood industry stakeholders from across different parts of the supply chain, as well as relevant civil society experts from diverse regions”.

The adoption of GDST standards by governments and traceability systems would allow such tools to communicate between each other to fully benefit from the implementation of traceability in seafood supply chains.

Traceability in fisheries can contribute to the sustainability of the seafood sector by providing information to understand seafood products and their origins. Traceability can also address concerns over food provenance, quality, safety, fraud, sustainability, and IUU fishing (Fox et al., 2018). However, the seafood industry still faces challenges in implementing traceability systems due to a lack of cost-effective ready-to-use methods that validate origin certifications claimed by fishers, producers, or traders. Moreover, to reap the full benefits of the implementation of traceability in seafood supply chains, interoperability is crucial. However, the adoption of GDST standards by governments and traceability systems is still limited, and stakeholders must be aware of the benefits of interoperable traceability systems to achieve full interoperability in the seafood industry (GDST, 2022).

Overall, traceability stands out as an enabler of sustainable fisheries management. Through its ability to combat overfishing, IUU activities, and environmental degradation, traceability offers a pathway to secure the long-term viability of fisheries worldwide. By looking into its applications in fisheries, this section has sought to uncover best practices and lessons that can contribute to the broader adoption of traceability as a cornerstone of sustainability in global fisheries.

Applying this to the Peruvian context, this research explores how these global concepts are integrated into local fisheries practices. This exploration is critical for understanding the specific mechanisms through which electronic traceability systems are emerging in the jumbo squid and mahi mahi fisheries of Peru. As highlighted in previous studies, the adoption is not only a technological shift but also a cultural and regulatory transition, which this research aims to map and understand in depth (see RQ1 in Box 1. Research questions).

In the next section, the importance of governance to fisheries is explored.

3.4 The concept of governance

Considering the changes required to adopt electronic traceability systems to improve fisheries sustainability, all players in the supply chain and the interactions between them must be considered; this is where governance comes in. Governance structures and processes can help steer the process of sustainable development (van Zeijl-Rozema et al., 2008). The overexploitation of common resources, increasing anthropogenic pressures on the environment, and structural inequities in the access, commercialisation, and use of these resources mean that participation, transparency, and equity are fundamental axes for sustainability transitions (Ostrom, 2005). Governance encompasses public as well as private interactions to solve societal problems and create opportunities. It includes developing and applying principles to guide those interactions and the institutions that enable them (Kooiman et al., 2005).

The purpose of governance is to manage social change through democratic interactions. In general, governance is characterised by diversity, uncertainty, societal heterogeneity, and decreased possibilities for long-term change to be induced by the government alone (Loorbach, 2010). Good governance includes openness, participation, accountability, effectiveness, and coherence (Meadowcroft et al., 2005). However, governance in relation to transitions can be a messy process of institutional transformation, where each of the actors involved has a limited view of the whole, which may conflict with the vision of others (Voss et al., 2009; Hulme, 2009). Concerns relating to whose knowledge counts, what changes are necessary and desirable, and even what constitutes the end goal of transformation are all intensely political processes (Patterson, et al., 2017). A key challenge in this regard is how to encourage more effective decision-making and meet legitimacy criteria (Forman & Segaar, 2006).

Formal policy is only one part of governance (Meadowcroft et al., 2005; Loorback, 2010). Policy support for transitions is key, however, and needs to respond to unexpected accelerations and tipping points, risks and losses, as well as distributional effects and power struggles in transitions (Turnheim, et al., 2015). The policy process must include engagement with long-term societal change and introduce new practices to redirect socio-technical systems (Voss et al., 2009).

Engagement with long-term societal change and the introduction of new practices are critical for effective governance because they can redirect socio-technical systems towards sustainability. The benefits of this approach are that it allows for the integration of diverse perspectives and knowledge, facilitates the creation of innovative solutions, and promotes long-term thinking and planning. By involving stakeholders from different sectors, including civil society, industry, government, and academia, governance can become more democratic, transparent, and accountable.

Governance and policy are closely intertwined, but Meadowcroft et al. (2005) argue that specific requirements must be met for governance to be effective in promoting sustainable development. First, governance must involve iterative rounds of envisioning the future, setting goals, designing policies, implementing, and monitoring them. This process allows for continual adaptation and revision of policies based on feedback and outcomes, ensuring that they remain relevant and effective. Second, governance must adopt a long-term focus, as changes towards sustainable development can take several generations to achieve. Third, governance must foster a better understanding of ecological processes and social interactions, as this understanding is necessary to identify and address the root causes of unsustainability. Fourth, governance must integrate different kinds of knowledge into decision-making processes, including natural and social sciences, Indigenous knowledge, western science, layperson knowledge, and expert knowledge. This inclusive approach acknowledges that sustainability challenges are complex and multifaceted and require diverse perspectives and expertise to address. Fifth, governance must structure engagement as a learning process, where lessons are drawn from failures and successes to improve future practices and promote continuous improvement. Finally, governance must prioritise the strengthening of social institutions' resilience, or their capacity to adapt successfully in response to pressures and unexpected changes. This ensures that institutions remain effective in promoting sustainable development even in the face of unexpected challenges or crises.

A key challenge is that sustainability has yet to become a priority for policy at a national level in Peru. Frequently, sustainability goals need to be linked to other more foundational goals, such as human health, economic competitiveness, or security (Turnheim, et al., 2015). Nonetheless, governance and politics are central to understanding, analysing, and shaping transitions towards sustainability, because such transformations are deeply and unavoidably political (Patterson, et al., 2017).

The adoption of a long-term focus and the strengthening of the resilience of social institutions are essential to enable successful adaptation in response to pressures and unexpected changes (Meadowcroft et al., 2005). In Peru, efforts to link sustainability goals with other foundational goals could be a starting point for initiating political action and creating an environment in which governance frameworks can be developed to enable sustainability transitions.

Effective governance of transitions towards sustainability requires acknowledging the complexity, uncertainty, and power dynamics involved in these processes. All societal actors, including governments, businesses, civil society organisations, and individuals, have the potential to shape transitions through their agency and interactions in networks. Therefore, governance should involve a reflexive process of searching, learning, and experimenting (Loorbach, 2010).

Neglecting the influence and perspectives of diverse societal actors can limit the success of sustainability transitions, as public debates and conflicts can emerge around new technologies, generating both advocacy and resistance (Turnheim, et al., 2015). Thus, governance must be designed to foster inclusive and participatory processes that enable the incorporation of diverse perspectives, needs, and values, and promote collaborative problem-solving and learning.

Governance and politics are essential to understanding and shaping transitions towards sustainability as they involve complex, uncertain, and power-laden processes that can have distributional impacts resulting in (actual or perceived) winners and losers (Meadowcroft, 2011). For instance, the development of extractive industries in Peru has led to the displacement of Indigenous communities, environmental degradation, and health problems for local populations, while providing economic benefits to multinational corporations and the government.

Therefore, effective governance of transitions requires a reflexive process of searching, learning, and experimenting that considers the diversity of societal actors and their ability to exert influence on the transition process through agency and interaction. Top-down steering by government and the liberal free market approach are outdated mechanisms to generate sustainable solutions because they often fail to address distributional impacts and may further entrench social and environmental injustices (Loorbach, 2010).

Turnheim et al. (2015) describe three different approaches to governance, which highlight different ways in which societal transitions can be steered. The first approach is 'command and control' public policy, which refers to the use of regulation and information to steer society towards specific political objectives. The second approach is 'public-private governance', which seeks to leverage the dynamics of business and society through research, technology, innovation, and market-regulation policies. The third approach is 'adaptive governance', which responds to the emergent properties of transitions, with an emphasis on visioning and experiments, monitoring, and evaluation, as well as reflexivity.

Adaptive governance is particularly relevant to the context of fisheries sustainability in Peru, as it allows for flexibility and experimentation in responding to the complexity and uncertainty of the fishing industry. Cleaver and Whaley (2018) outline three criteria for adaptive governance: inclusive dialogue, layered institutions, and mixed institutional types and designs that facilitate experimentation, learning, and change. In the case of fisheries sustainability, inclusive dialogue could involve bringing together a range of stakeholders, including government officials, fishing industry representatives, ENGOs, and local communities, to engage in a collaborative process of decision-making. Layered institutions could involve the creation of nested governance structures that allow for local and regional decision-making to be integrated with national policy objectives. Mixed institutional types and designs could involve the use of a range of policy tools, such as market-based instruments, regulations, and voluntary agreements, to support sustainable fishing practices.

For example, adaptive governance has been used in the Peruvian anchoveta fishery, one of the largest fisheries in the world. The Peruvian government, along with industry stakeholders and ENGOs, have implemented a range of adaptive governance measures, including the use of a quota system, catch limits, and spatial management measures to ensure the sustainability of the fishery. In addition, a range of stakeholder engagement mechanisms have been put in

place, such as regular meetings between government officials and industry representatives. These measures have helped to ensure the long-term sustainability of the anchoveta fishery.

The interactive governance approach argues that actors at different levels of society are involved in governance, which is not the same as management or policy making. Policy deals with specific subjects in tight timeframes, while management deals with practical matters, such as implementation. According to Kooiman and others, interactive governance "emphasises solving societal problems and creating societal opportunities through interactions among civil, public, and private actors," (Kooiman et al., 2008:2). While governability provides a "conceptual basis for assessing and improving the interactive governance of natural resource systems," (Kooiman et al., 2008:2).

After exploring the definition and role of governance in sustainability transitions, governance in the context of fisheries will be assessed in more detail in the following section.

3.4.1 Fisheries governance

Governance is the central element of a system that generates social, economic, and ecological benefits, i.e. sustainability (Ostrom, 2005) and is considered the main challenge for Peruvian fisheries (Intelfin & WWF, 2020). Fisheries in Peru have seen uncontrolled expansion, driven primarily by increasing market demand, open-access policies, deficient or non-existent regulation, and inadequate surveillance and enforcement. Existing fishing pressure threatens valuable resources and coastal and marine biodiversity. Artisanal fisheries in Peru suffer from informality and a lack of data for good governance (Andia Morales et al., 2019).

Fisheries governance is meant to establish "the overriding principles and objectives of the sector. It develops the policy and regulatory frameworks. It connects government with civil society, harmonising individual, sectoral, and societal perspectives and maintaining social order and productive socio-ecological systems. It legitimates and balances stakeholders' interaction, enforces decisions and regulations and maintains coherence across jurisdictional, space and time scales. Finally, it conditions the allocation of power, resources, and benefits and maintains the governance system capacity to learn and change," (FAO, 2019, as cited in Jentoft, 2019:188).

In addition, Ostrom (2005) describes an ideal governance system for fisheries, which is resilient and in balance, based on learning and adaptive management, and which allows it to

respond to changes. This ideal governance system includes a set of management rules to protect the stock and ensure sustainable fisheries yield, tools to protect the stock and the associated biodiversity, access/use rules to limit fishing effort and ensure sustained social and economic benefits, and an efficient control, enforcement, and sanction system to ensure compliance with the agreed rules.

At the heart of a good fisheries governance system lies a decision-making process based on collaboration, trust, and the social capital of the resource users and stakeholders. Such a governance system is essential for ensuring the sustainability of fisheries, which in turn is critical for the long-term social, economic, and environmental benefits that these resources provide (May, 2015; Estévez et al., 2020).

The literature underscores the essential role of governance in managing sustainable fisheries practices, with a particular focus on how governance frameworks can either support or hinder the adoption of sustainability transitions like electronic traceability systems. This review has revealed that effective governance is not merely about policy enforcement but also involves the engagement of various stakeholders including government bodies, ENGOs, and the fishing community itself.

In the next section the role of ENGOs in sustainability transitions, such as in the adoption of electronic traceability systems for fisheries sustainability and good governance will be explored.

3.5 The role of ENGOs in sustainability transitions

This section explores the role of ENGOs in driving change towards sustainable development. Sustainable development is more than just about the environment, it should enable a strong, healthy, and just society and economy as well. This means meeting the needs of all people now and into the future, promoting wellbeing, social cohesion, and inclusion, and creating equal access to opportunities (Nhamo, Dube, & Togo, 2021). The analysis of ENGOs serves as a framing for the second research question, which addresses their role in the sustainability transitions process of traceability technology adoption in the Peruvian jumbo squid and mahi mahi fisheries.

ENGOs encompass a diverse array of organisations with varying functions, scopes, structures, goals, and memberships. They can range from charitable groups and research institutes to advocacy organisations focused on environmental or human rights issues. The emergence of ENGOs has been exponential since the mid-1970s, and they encompass different types of non-governmental organisations working on a wide array of issues (Fisher, 1997).

ENGOs play an important role in safeguarding the long-term interests of the citizen against the state and representing those interests in conflicts concerning the activities of multinational corporations for example. Potential ENGO activities that engage with states and multinational corporations are listed and discussed below, with the aim of improving sustainability and governance. For the purposes of this research, ENGOs refer to those non-governmental organisations specifically focusing on environmental concerns, irrespective of their size, location, or funding sources.

ENGOs possess unique characteristics that make them significant actors in sustainability transitions. Unlike governments, they are (mostly) unburdened by large bureaucracies, enabling them to be more flexible and open to innovation, making them more effective and faster at implementing development efforts and responding to grassroots needs (Fisher, 1997). However, it is important to note that some Northern ENGOs have undergone considerable institutionalisation and bureaucratisation, developing organisational structures comparable to business organisations (Princen et al., 1994), and bureaucracies comparable to governments.

These organisations are increasingly involved in international public policy development, participating in advocacy, rulemaking, standard setting, knowledge generation, dissemination, promotion, monitoring, and evaluation of treaty obligations (Forman & Segaar, 2006). Through such engagement, ENGOs can give voice to marginalised groups and promote critical issues that might not receive attention otherwise, contributing to the growth of a robust civil society.

The growth of ENGOs in the public arena is supported by bilateral, multilateral, and private donors frustrated by solely state-led or market-led approaches (Forman & Segaar, 2006). Rejecting top-down government regulation while acknowledging the potential of market failures, these donors enable ENGO involvement in technological innovation, competitive enterprise, and the use of market means to achieve public ends (Forman & Segaar, 2006).

Nonetheless, it is important to recognise that many ENGOs may have asymmetries in power and interests, being accountable only to their donors and boards of directors, and thus, "suffer the paradox of potentially relieving the public sector of its responsibilities" (Forman & Segaar, 2006:222).

Within the context of traceability adoption in seafood supply chains, ENGOs can play an influential role by collaborating with companies on traceability issues and translating consumer attitudes about the environment and sustainability practices into changed consumer behaviour (Sterling, et al., 2015).

External pressures from ENGO campaigns have the potential to generate change in fisheries supply chains. Businesses are compelled to manage their reputational risk by committing to sustainable sourcing, and increasingly, companies' corporate social responsibility (CSR) and related purchasing policies are often developed in partnership with ENGOs that provide expertise on the sustainability of fisheries and guidance on improving less sustainable supply chains (Bailey et al., 2018).

This section directly informs the research questions concerning the contributions of ENGOs in influencing the transition to traceability adoption in Peruvian fisheries, particularly the question that delves into how ENGOs engage with various stakeholders, including government, industry, and the artisanal fishing community, to promote traceability technology. The literature provides valuable insights into the diverse roles of ENGOs in fisheries sustainability.

The literature uncovers factors that influence the effectiveness of ENGOs, such as their level of funding, expertise, and legitimacy in the eyes of stakeholders. It also highlights the importance of collaboration and dialogue between ENGOs and other actors in the fisheries sector (Gray, 2006). It further reveals how power dynamics, political context, and conflicting interests may affect the extent to which ENGOs can drive change and contribute to fisheries sustainability through traceability initiatives (Hopkins et al., 2024); leading to the research question that seeks to understand the conditions under which ENGOs are perceived as significant players in the development of fisheries traceability, as well as situations in which their aspirations and goals may be marginalised.

This section establishes the foundation for understanding the interactions between environmental NGOs, government structures, and the wider fishing industry in the context of traceability adoption.

ENGOs and government play a critical role in driving change towards sustainable development in fisheries (Macusi et al., 2023). The flexibility, innovation, and responsiveness of ENGOs to grassroots needs make them valuable contributors to policy development, advocacy, and service provision. The following section builds upon this foundation to explore the broader theoretical framework of sustainability transitions and the MLP. This framework will guide the understanding of traceability technology adoption in the Peruvian jumbo squid and mahi mahi fisheries, shedding light on the dynamics of niche innovations, drivers of adoption, institutional responses, and barriers to traceability implementation.

3.6 Sustainability Transitions and MLP

The theoretical framework underpinning this research draws from the concept of sustainability transitions, which are transformational processes aimed at establishing new social structures, institutions, cultures, and practices to address sustainability challenges across various industries, including fisheries. Sustainability transitions involve multi-dimensional, long-term changes in socio-technical systems, encompassing technological, material, organisational, institutional, political, economic, and cultural aspects (Markard et al., 2012).

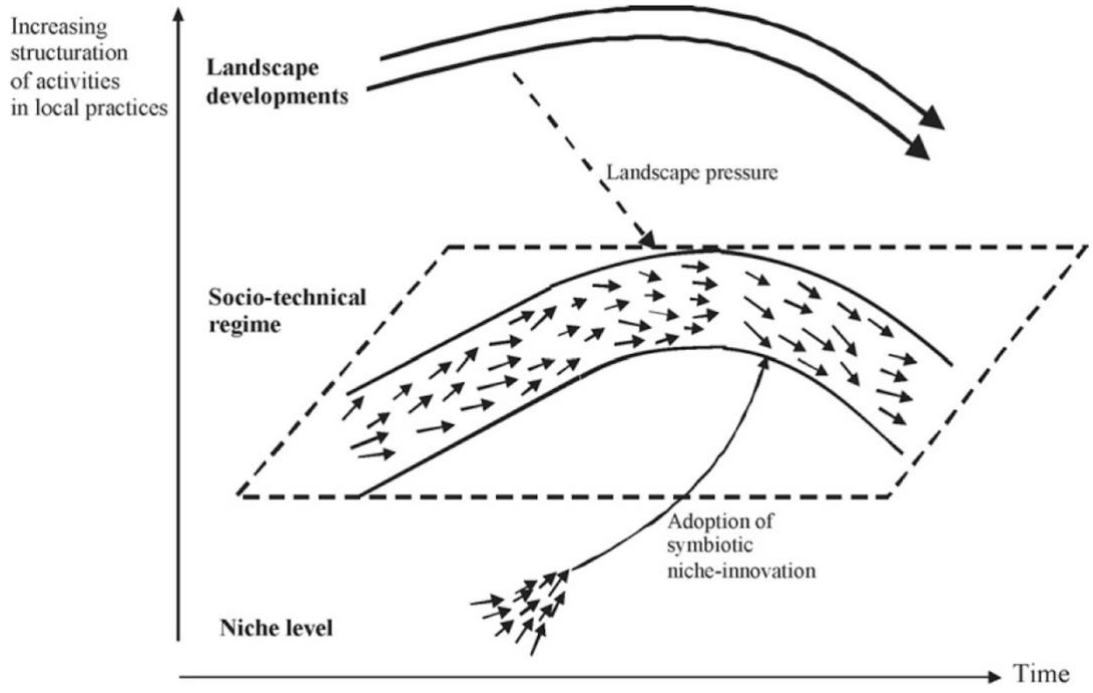
To promote transitions towards more sustainable production and consumption in socio-technical systems like fisheries, various frameworks under the sustainability transitions umbrella have gained prominence. These frameworks include transition management, strategic niche management, technological innovation systems, and the MLP (Vähäkari, et al., 2020). In this research, the MLP serves as the foundational framework to analyse the emergence and evolution of traceability technology in the Peruvian jumbo squid and mahi mahi fisheries and the roles of different stakeholders in its adoption and implementation.

The MLP is a process theory, also known as a narrative explanation, which examines events resulting from the actions and decisions of various actors (Geels, 2019). This framework focuses on individual entities, such as people, groups, organisations, and material objects, and how their perceptions, interests, and preferences change during transitions. Crucial elements

in the MLP include the timing of events and multi-level linkages, which influence the type of transition pathway and outcomes (Grin et al., 2010). The framework involves tracking event sequences and trajectories that arise from dynamic processes at three analytical levels: niches, regimes, and landscapes.

Niches represent protected spaces where innovations are nurtured and developed, while regimes are the dominant sets of rules, norms, and practices shaping a particular socio-technical system. Landscapes encompass the external environment beyond the influence of niches and regimes, often characterised by slow changes. Transitions result from interactions among processes at these three levels. Niche innovations can gain momentum through learning processes, support from powerful groups, and improvements in price and performance. Changes at the landscape level create pressure on regimes, potentially creating windows of opportunity for niche innovations to break through more widely (Geels & Schot, 2007).

Figure 4. Transformation pathway



Source: Geels & Schot (2007).

The MLP is particularly valuable for investigating fisheries sustainability due to its ability to explore socio-technical system dynamics and interactions. It provides a comprehensive framework for understanding how niche innovations can become part of a regime and how

stakeholders' motivations, perceptions, aims, and interests shape transitions. By analysing the context in which innovation occurs and identifying stakeholders, insights can be gained into the dynamics of electronic traceability systems uptake in Peruvian jumbo squid and mahi mahi fisheries.

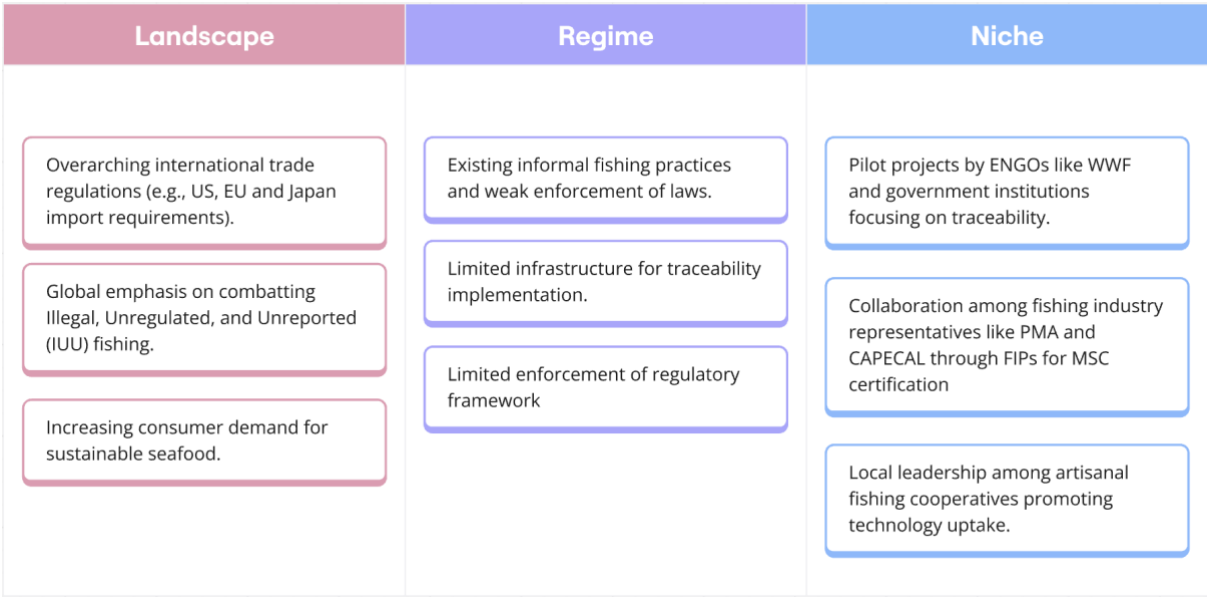
While the MLP offers valuable insights into sustainability transitions, it also has limitations. It can be complex and time-consuming to apply, requiring extensive data and analysis (Dahle, 2007). Identifying and defining the boundaries of niches, regimes, and landscapes, as well as the actors and processes within them, may also pose challenges. The MLP might not fully capture the dynamics of power and politics, which significantly influence fisheries sustainability (Geels, 2019). Additionally, certain cultural, social, or historical factors may not be fully accounted for in the framework. Despite these limitations, the MLP remains a useful tool for understanding the complex processes involved in traceability adoption in fisheries (Geels, 2011).

Given the complexity of the MLP and its emphasis on context and event tracking, case studies offer a suitable research method to explore sustainability transitions. Following the four steps outlined by George and Bennett (2004, as cited in Grin & Schot, 2010), researchers can (a) conduct case studies that provide a detailed narrative, (b) identify patterns and relationships using theoretical mechanisms, (c) develop analytical explanations, and (d) generate general explanations and theoretical arguments based on the findings. Applying case studies within the MLP framework allows for a comprehensive understanding of socio-technical systems in fisheries sustainability, enabling the identification of key drivers of traceability adoption and informing policy and intervention development.

In applying the MLP to analyse the adoption and potential benefits of electronic traceability systems to the sustainability and governance of the Peruvian jumbo squid and mahi mahi fisheries, this study observes the interaction between niche innovations like electronic traceability systems and the existing regimes and landscapes. At the niche level, traceability technologies represent emerging innovations driven by both local needs for sustainable management and global demands for verified sustainable seafood. However, the regime — characterised by established practices, regulations, and infrastructures within Peruvian fisheries — exhibits resistance due to entrenched practices and the vested interests of traditional stakeholders. At the broader landscape level, global environmental concerns,

international market pressures, and socio-economic factors influencing Peru's fisheries sector exert external pressures that necessitate adaptive governance. This MLP framework guides the study by focusing on how these three levels interact to either hinder or facilitate the adoption of traceability systems, providing a comprehensive view of the systemic changes needed for sustainability transitions in fisheries. Please refer to Figure 5 below for a visual representation of the MLP framework's landscape, regime, and niche levels applied to the Peruvian jumbo squid and mahi mahi fisheries.

Figure 5. MLP representation for jumbo squid and mahi mahi fisheries



Source: Own creation.

The research questions (see Box 1. Research questions) pertaining to the transition to traceability technology adoption in the Peruvian jumbo squid and mahi mahi fisheries are linked to the body of literature on sustainability transitions and the MLP. Research question one (RQ1) explores the emergence of traceability technology in Peruvian fisheries and the underlying drivers and motivations behind its adoption. Existing literature on sustainability transitions provides insights into the factors that contribute to the emergence of niche innovations like traceability technology, including growing consumer demand for sustainable products, market access requirements, and the advocacy efforts of ENGOs. Then sub-research question one b (RQ1b) explores how and why electronic traceability systems gain momentum in niches, adapt, and grow to eventually become mainstream. The theoretical framework of the MLP offers a comprehensive understanding of the dynamics involved in niche innovations'

trajectory towards mainstream adoption. By tracking event sequences and multi-level linkages, the MLP elucidates the processes through which niche innovations can break through and transform dominant socio-technical regimes, such as conventional fishing practices. RQ1c explores the response of institutional fisheries structures to traceability innovations and the perceived barriers and principles for traceability adoption.

Drawing upon the MLP's analytical levels of niches, regimes, and landscapes, this research can uncover how institutional arrangements and regulations either facilitate or hinder the integration of traceability technology into existing fisheries governance systems. The theoretical foundation provided by sustainability transitions and the MLP is crucial in guiding the investigation of these research questions and understanding the complexities involved in the transition towards traceability technology adoption in Peruvian fisheries.

In subsequent chapters, the research explores the specific dynamics of traceability technology adoption, its challenges, and the potential contribution of traceability to fisheries sustainability and effective governance within the Peruvian context. This exploration is informed by the theoretical underpinning of sustainability transitions and the MLP.

3.7 Framing the path to fisheries sustainability and governance through traceability adoption

The literature review has delved into varied sources regarding the concept of sustainability, sustainable development, traceability, and governance. It has particularly underscored the transformative potential of traceability technology in mitigating pervasive sustainability challenges. These challenges, as articulated in Chapter 2, centre around the pressing sustainability and governance issues plaguing the artisanal jumbo squid and mahi mahi fisheries in Peru.

These fisheries, crucial for the livelihoods and food security of local communities, are currently entangled in a mire of IUU fishing, overfishing, unsustainable fishing practices, and ineffective management practices. The impact of inadequate governance, weak regulatory frameworks, and limited enforcement further exacerbates these sustainability challenges.

The findings from the literature not only reaffirm the significance of the research problem but also lay a foundation for exploring electronic traceability systems as a promising solution. By

enhancing transparency and accountability, combating IUU fishing, and improving governance through better data collection and decision-making, traceability technology emerges as a critical lever for fisheries sustainability.

This research aims to further dissect the challenges, and potential benefits of traceability uptake in addressing the sustainability and governance challenges faced by Peru's artisanal jumbo squid and mahi mahi fisheries. It seeks to inform the development of strategies for effective traceability uptake, aspiring to secure the ecological integrity of fish stocks and the economic and social well-being of the coastal communities reliant on these resources.

Throughout Chapters 2 (– Context) and 3 (- Literature Review), it becomes evident that fisheries sustainability should be a major concern for Peru, given the economic significance and importance to coastal communities' livelihoods of the jumbo squid and mahi mahi fisheries. The adoption of traceability systems emerges as a tool to enhance sustainability and governance within fisheries supply chains. This review highlights areas where further investigation is needed to improve the understanding of traceability systems, challenges, and potential benefits in the Peruvian fisheries context.

Research question one and its sub-questions (RQ1, RQ1a, RQ1b, and RQ1c[4]) are closely aligned with the theoretical framework of sustainability transitions and the MLP. This theoretical framework offers an understanding of socio-technical system dynamics, stakeholder motivations, and the role of niche innovations in driving sustainability transitions applicable to fisheries. By examining the emergence and evolution of traceability technology in the Peruvian jumbo squid and mahi mahi fisheries, this thesis seeks to contribute to the body of knowledge on the application of sustainability transitions in the context of electronic traceability systems development and adoption in Peruvian jumbo squid and mahi mahi fisheries.

Governance structures, as explored in Section 3.4 (The concept of governance), play a central role in facilitating or hindering the adoption of traceability systems within Peruvian fisheries. This section has highlighted how robust governance can manage the socio-economic and environmental pressures that challenge the sustainability of fisheries. Incorporating the Multi-Level Perspective (MLP), it becomes evident that governance frameworks act as a critical

[4] Refer to Box 1. Research questions.

'regime' component that can either stabilise or shift in response to innovations like traceability systems. Good governance, characterised by transparent policy-making and inclusive stakeholder engagement, is essential for aligning traceability initiatives with sustainable fisheries management. This alignment is crucial for overcoming institutional inertia and integrating niche innovations into mainstream practices. By examining the governance landscape in Peru, this research identifies key leverage points where governance reforms can facilitate the broader adoption of traceability systems, thus addressing the MLP's emphasis on understanding the dynamics at the regime and landscape levels that influence technological transitions.

The literature on the role of ENGOs in sustainability transitions makes evident that these organisations can play an important role in fostering the adoption of traceability technologies in Peruvian fisheries, which is linked to research question two and its sub-questions (RQ2, RQ2a, RQ2b, and RQ2c). This section has underscored how ENGOs, through their position and capabilities, drive change by bridging the gap between grassroots needs and high-level policy making. Their involvement can shape practices that promote sustainability, making them significant stakeholders in the pursuit of sustainable development.

The literature reveals that ENGOs not only advocate for environmental and social standards and economic fairness but can also facilitate the implementation of sustainability transitions by engaging various stakeholders including government, industry, and local communities. Their potential to influence policy and practice, reflects their dual function as both watchdogs and partners in development.

The relevance of the literature review to the current study is twofold. First, it provides an understanding of the concept of sustainability, sustainable development, traceability, and governance, as well as the role of ENGOs in influencing sustainability transitions. Second, the review highlights the complexities and challenges associated with fisheries sustainability, setting the stage for the forthcoming empirical investigation. By examining the drivers and motivations behind traceability adoption, exploring the niches where electronic traceability systems are being developed and implemented, and assessing the institutional responses and perceived barriers, this study will provide an analysis of the factors shaping the sustainability transition to electronic traceability systems in Peru's jumbo squid and mahi mahi fisheries.

While the existing literature provides an understanding of traceability systems' roles in fisheries management globally, there remains a lack of focused studies on the adoption barriers and enabling factors specific to Peruvian fisheries. Particularly, the literature seldom addresses how local governance structures, cultural norms, and economic realities specifically impact the implementation of these systems in Peru. Moreover, there is a gap in understanding the specific roles and influences of various stakeholders within Peru, including ENGOs, government agencies, and the artisanal fishing communities. This research aims to fill these gaps by providing detailed empirical data on the adoption processes of electronic traceability systems in Peru's jumbo squid and mahi mahi fisheries, thereby offering insights into the local adaptation of global sustainability practices.

In subsequent chapters, the specific aspects of traceability development, implementation, challenges, and potential solutions are explored in depth. By integrating the theoretical underpinning of sustainability transitions and the MLP, an analysis of the dynamics at play in the adoption of traceability technology is forthcoming. Using a case study and empirical data, the complexities and nuances of traceability adoption in Peruvian jumbo squid and mahi mahi fisheries shall be explored, providing insights for policy development and intervention strategies.

In conclusion, the literature review has laid the groundwork for this research, providing an understanding of the potential contribution of traceability to fisheries sustainability practices and governance. By bridging theory and practice, this study aims to contribute to the promotion of sustainable fishing practices and effective governance in Peru's fishing industry through the sustainability transition of the adoption of traceability technology.

4 – Methodology

4.1 Introduction and theoretical background

The primary focus of this chapter is to describe the research methodology employed in this study, underscoring its alignment with the overarching aim and objectives. Specifically, the chapter aims to explain how the chosen research methods, grounded in the Multi-Level Perspective (MLP) theoretical framework, have facilitated the exploration of the contribution of traceability technology to the promotion of sustainability and governance within Peru's jumbo squid and mahi mahi fisheries. The chapter begins by establishing the connection between the research questions and the methods used to gather data pertinent to these questions. It then addresses:

- The adopted research philosophy and its relationship to the study's ontological and epistemological stance.
- The rationale for the chosen qualitative design and the case study approach.
- The procedures followed for data collection and analysis methods.
- Considerations regarding the researcher's positionality, reflexivity, and ethics.
- Evaluative criteria focusing on the validity, reliability, and generalisability of the research findings.

Understanding the methodological choices is essential, as it not only makes the research process transparent but also strengthens the study's credibility, ensuring that its findings are both robust and applicable within the context of the Peruvian fisheries sector.

In this study, the chosen theoretical framework is the sustainability transitions MLP. The MLP offers a process theory that is well-suited to exploring how traceability technology can contribute to improving the sustainability and governance of the jumbo squid and mahi mahi fisheries in Peru, as well as the factors that influence the adoption of such innovations. The MLP provides an approach to understanding socio-technical change, by investigating how

different social groups interact with one another and the structures in which they are embedded. This framework is useful in viewing how new practices and technologies emerge in Peruvian fisheries, gain momentum in niches, and can eventually become mainstream. It also provides a means for exploring the role of ENGOs and government institutions in the transition process. By adopting the MLP framework, this study seeks to generate insights into the complex and dynamic nature of socio-technical change in the context of Peruvian artisanal fisheries.

4.2 Research philosophy: Pragmatism

Research philosophical paradigms act as a guiding belief system for an investigation (Guba & Lincoln, 1982). From a conservation practitioner's standpoint, there is urgency to move towards more sustainable production and consumption, safeguarding both human survival and the well-being of other species. In line with this conviction, the pragmatic worldview deeply aligns with the research's aim—to offer practical strategies promoting sustainability transitions in digital-era socio-technical systems. Pragmatism's strength lies in its adaptability, allowing the combination of subjective values and objective facts (Saunders et al., 2019), facilitating a holistic interpretation of research problems.

While pragmatism may be subject to criticism, such as a perceived lack of theoretical grounding or a tendency to prioritise practicality over rigorous exploration, in the context of fisheries, where actionable insights are essential, the utility-driven nature of pragmatism becomes its foremost strength. Far from being superficial, it draws on the essence of theories, hypotheses, and findings, reframing them as actionable instruments with tangible outcomes in specific contexts (Saunders et al., 2015). Pragmatism's flexibility is particularly relevant in the discipline of fisheries, which considers diverse variables like technological advances, institutional setups, stakeholder participation, and regulatory frameworks. Its inclusive approach values diverse stakeholder viewpoints, an important asset when evaluating traceability technology's role in sustainability. Furthermore, contrary to critiques suggesting pragmatism might dilute or prevent deeper inquiry, this research showcases its capability to generate rich insights with real-world applicability. The goal is far from theoretical abstraction—it is geared towards influencing genuine decision-making processes in the fishing sector.

Pragmatism stands out as the appropriate research philosophy for this investigation into how the transition to electronic traceability systems is occurring in Peru and what are its potential benefits for fisheries sustainability and governance. Its focus on actionable solutions, flexibility, and responsiveness to on-the-ground realities unites with the research's ambition to present tangible solutions for fisheries sustainability and effective governance of Peru's jumbo squid and mahi mahi fisheries. Pragmatism aligns well with the aim of offering practical solutions for the sustainability transition of socio-technical production systems in the digital era (Kelly & Cordeiro, 2020). Rooted in pragmatism, this research aspires for lasting, positive transformations for fisheries sustainability and good governance.

4.2.1 Ontology and epistemology

In the context of research philosophy, ontology refers to the researcher's understanding of the nature of reality, while epistemology pertains to the researcher's beliefs about how knowledge can be acquired and validated (Aliyu, Singhry, Adamu, & AbuBakar, 2015). For pragmatism as a research philosophy, its ontology is grounded in a practical and contextual understanding of reality. Pragmatists believe that reality is not fixed or absolute, but rather, it is subject to change and is influenced by various factors and perspectives (Morgan, 2014). This allows the pragmatic researcher to switch between two views of one external reality and the multiple perceptions of this reality and choose between quantitative and qualitative research approaches and methods (Maarouf, 2019). This view acknowledges the dynamic and evolving nature of social phenomena, such as the sustainability and governance of fisheries in the digital era and emphasises the significance of context in shaping research outcomes. At times, the objective is to describe reality using generalisations that can be practically applied. On other occasions, the focus is on exploring social actors' perceptions to gain a better understanding of the given reality. In this approach, researchers have the flexibility to address different sources of knowledge and achieve their research goals.

Epistemologically, I adopt a social constructionist perspective, recognising that knowledge is not discovered in an objective and independent manner, but is actively constructed by researchers and participants through their interactions with the social world (Garrison, 1995). As a research philosophy I adopt pragmatism, where as a researcher I am open to multiple ways of knowing and understanding the research subject, giving value to the contributions of subjective experiences, practical knowledge, and empirical evidence in generating insights

and solutions to real-world problems. By embracing multiple sources of knowledge, including the expertise of industry stakeholders, insights from conservation practitioners, and empirical evidence from the fisheries sector, an understanding of the research problem and effective strategies for achieving sustainability goals can be achieved.

Pragmatism as a research philosophy adopts a practical and contextual ontology, acknowledging the dynamic nature of reality. Epistemologically, I embrace a social constructionist perspective, recognising that knowledge is actively constructed through interactions with the social world. By adopting this pragmatic approach, complex and dynamic issues can be addressed, such as the sustainability and governance challenges in Peruvian jumbo squid and mahi mahi fisheries, to develop actionable solutions, for example electronic traceability systems, that have practical relevance and impact.

4.3 Research design and methodology

It is important to begin by setting the scene for the primary research problem: the pressing sustainability and governance challenges faced by the artisanal jumbo squid and mahi mahi fisheries in Peru and the potential contribution of electronic traceability systems. The two research questions and sub-questions that guide this study are:

RQ1: How is the transition to electronic traceability systems occurring in the Peruvian jumbo squid and mahi mahi fisheries?

a. How is traceability technology emerging in these Peruvian fisheries? What are the drivers and motivations behind its adoption?
b. How and why is traceability gaining momentum in niches, adapting and growing? How can it become mainstream?
c. How does the fisheries' institutional structure respond to these innovations? What are the perceived barriers and principles for its adoption?

RQ2: What are the contributions of ENGOs and government structures in the transition to electronic traceability systems in the Peruvian jumbo squid and mahi mahi fisheries?

a. How do ENGOs engage with the government, industry and the artisanal fishing community in promoting traceability technology?

b. Under what conditions are ENGOs considered important players driving the adoption of traceability? Under what conditions are their aspirations and objectives marginalised?
c. How do government institutions and regulations influence and impact the adoption of traceability in the jumbo squid and mahi mahi fisheries?

To address these questions, a qualitative research approach has been used. The decision to employ a case study design was strategic. It provides an avenue for a detailed examination of the issue within the specific socio-economic, political, and cultural landscape of Peru, bringing to light the nuances of traceability adoption.

Qualitative research is inherently exploratory as it seeks to probe the human dimensions of a problem—behaviours, experiences, and perceptions. This methodology does not merely catalogue numbers but captures rich textual and visual narratives—words, images, observations—that offer an interpretative perspective on the social dynamics at play. The adaptability of this method allows for the integration of unforeseen insights, leading to a richer spectrum of data. Methods such as interviews, participant observations, and document analyses were employed due to their potential to extract profound insights into the perspectives and social contexts of the various stakeholders in the Peruvian fisheries context.

To delineate the alignment, **RQ1** enables the researcher to understand the nature of the transition, by capturing experiences and perceptions of key stakeholders. In-depth interviews and participant observations emerge as the most appropriate methods, facilitating the understanding of the challenges and opportunities inherent in traceability adoption. This approach enables the grassroots-level impact and operational realities to be identified, offering an in-depth view of the adoption process. **RQ2** is about discerning the role of ENGOs and governmental structures, with the examination of policies, collaborations, and interventions. Document analysis, complemented by interviews, proves to be instrumental in determining the underlying motivations and strategies of these entities. This helps in understanding the policy landscape and the influence of external organisations on local practices, which are critical in shaping the sustainability transition to traceability technology adoption.

Subsequent sections will explain further the methodology and methods used, from data collection techniques to analytical processes, enabling other researchers to replicate this

study. The integration of these methods aims to provide a holistic view of the traceability adoption process, aiming for both the micro-level experiences and macro-level influences exploration.

4.4 Research strategy: case study

A case study, as an investigative method, facilitates the ability to examine phenomena within its natural environment. Savin-Baden & Major (2013) explain the versatility of case studies, considering them as both a delimited unit of study and an overarching research approach, resulting in the product of qualitative inquiry. A case study is not just about data collection, but the contextual understanding and analysis of a given scenario or situation.

The theoretical framework, grounded in the exploration of the sustainability transition to traceability technology adoption in Peruvian fisheries, requires understanding of stakeholder behaviours, systemic barriers, and socio-cultural dynamics. These intricacies are often concealed in broad-brush research methodologies but emerge distinctly in case-based investigations.

Several reasons justify the selection of the case study approach for this research:

- **In-depth examination**: Case studies permit a deep dive into real-world, complex phenomena, granting a grasp of situations as they naturally unfold. For this research, understanding traceability technology adoption necessitates this in-depth perspective to capture the nuances. For example, Chhachhar and Omar (2012) highlight the use of information and communication technology by fishers for marketing and weather information, illustrating the practical impacts of technology in fisheries which can be deeply explored through case studies.

- **Theoretical framework alignment**: The core propositions of the theoretical framework revolve around real-life intricacies in socio-technical transitions. The case study aligns with this, offering a window into the operational, behavioural, and decision-making layers of the fisheries sector. Tommasi et al. (2021), for example, use a case study approach to integrate ecosystem models and fisheries management. This supports the theoretical framework alignment by detailing real-life workings in ecosystem management which can parallel technology adoption in fisheries.

- **Methodological flexibility**: Case studies allow for the integration of diverse data collection methods—interviews, observations, and document analyses—thereby providing a multi-faceted view of the phenomenon.

- **Alternative methodologies**: While surveys or broad experimental designs might capture overarching trends, they might overlook the local dynamics, culture, and contextual barriers pivotal to this study. Therefore, their utility in this specific context is limited compared to the chosen method. Jensen (2007), for example, provides an analysis of how information technology improves market performance in the South Indian fisheries sector, a topic well-suited for a case study that captures localized economic impacts and decision-making processes.

Given the research aim of examining the sustainability transition to traceability technology adoption in the Peruvian fisheries context, the case study selected is rooted in a realist evaluation approach. It transcends the superficial query of 'does it work?' and looks into the layered inquiries of 'how, why, where, and for whom?'. Drawing from Marchal et al. (2012), a realist evaluation is inherently theory-driven, reverting to foundational postulations to interrogate programme efficacy.

It is important to establish the case study parameters. The case under study centres on Peruvian artisanal fisheries. Data sources include respondents ranging from fishers, government representatives, and industry, to ENGOs. Each respondent category, detailed further in subsequent sections, plays a role in the wider Peruvian fisheries supply chain, making them instrumental in offering a holistic view of the traceability technology landscape. Their experiences, challenges, and motivations are the cornerstones upon which this research constructs its insights.

4.5 Sampling strategy

Sampling is a critical aspect of research because it determines the selection of participants who can effectively address the research questions and objectives. The chosen sampling strategy, purposive sampling, aligns with the research focus and aims to provide in-depth insights into the adoption of traceability technology in Peruvian jumbo squid and mahi mahi fisheries. Purposive sampling was selected to ensure that participants are specifically chosen based on their relevance to the research questions. As the research aims to explore the

transition to traceability technology adoption and the influence of ENGOs and government structures, participants with expertise and experience in these areas are key in providing comprehensive insights. Furthermore, purposive sampling allows for the selection of participants with extensive knowledge of the jumbo squid and mahi mahi supply chains, fisheries sustainability, governance, and traceability implementation. This approach ensures that the data collected directly contribute to addressing the research questions.

4.5.1 Criteria for participant selection

The criteria for selecting participants in this research were established to align with the research focus and to ensure data adequacy for addressing the research questions. Participants were chosen based on their involvement in the Peruvian jumbo squid and mahi mahi supply chains and their involvement in the adoption and implementation of traceability technology. This criterion ensures that insights from knowledgeable stakeholders directly contribute to the research objectives.

To ensure comprehensive insights:

- **Government officials**: Vital for RQ2c, which includes examination of the impact of government institutions and regulations on traceability adoption.
- **Industry representatives**: Crucial to understanding the commercial drivers and barriers for traceability technology adoption, which aligns with RQ1a and RQ1b.
- **Artisanal fishing community members**: Central to RQ1b and RQ1c, providing grassroots insights into the emergence and reactions to traceability technology.
- **ENGOs**: Directly related to RQ2a and RQ2b, providing insights on the role of ENGOs in promoting traceability and their interactions with other stakeholders.

The selection of participants considered diversity in terms of gender and ethnicity to ensure a representation of different perspectives. The research sought to secure women in the study given their underrepresentation in fisheries, and to reflect the cultural diversity of the Peruvian fishing industry. Therefore, of the 36 interviews carried out, nine were with women, representing 25% of the interviewed population.

4.5.2 Sample size considerations

The sample size for this study was determined based on theoretical saturation and practical considerations. The data collection methods, namely interviews, participant observation, and document analysis, were designed to achieve data richness and adequacy for addressing the research questions. For the semi-structured interviews, initially, 10 interviews were planned, but given the complexity of the research topic, the research was expanded to 36 participants. This decision was based on the need for diverse insights from stakeholders involved in Peruvian fisheries and traceability technology adoption.

Participant observation utilised a snowball sampling approach, with the researcher attending relevant events and stakeholder meetings, to acquire contextual data. The researcher's position as an ENGO practitioner facilitated access to diverse stakeholders, contributing to the data richness. Document analysis was contingent on the availability of relevant policy papers, legislation, and other documents pertaining to fisheries sustainability, governance, and traceability in Peru.

4.5.3 Data adequacy and justification

Ensuring data adequacy is essential for research validity. Here is how the sampling strategy achieves this:

- **Depth and relevance**: By purposefully selecting stakeholders with direct roles in traceability adoption, the data captured is deeply insightful and directly answers the RQs.
- **Diversity**: A mix of stakeholder perspectives, ensuring a well-rounded understanding of the socio-technical dimensions of traceability in Peruvian fisheries.
- **Iterative data collection**: The flexibility to adjust the sample size based on emerging insights ensures thoroughness.

4.6 Data requirements to address the research questions

To address the research questions and realise the study objectives, data requirements were determined from the theoretical framework presented in the literature review. Each research question carries specific areas of inquiry, which are expanded upon below:

RQ1: How is the transition to electronic traceability systems occurring in the Peruvian jumbo squid and mahi mahi fisheries?

Derived from the theoretical framework, the data required to address this question include:

- **Emergence and implementation:** An exploration of the genesis and adoption of traceability technology in Peruvian fisheries, detailing specific technologies in use and their proliferation.
- **Motivational factors:** Insights into the economic, environmental, regulatory, and social catalysts that propel the adoption of traceability technology in the fisheries environment.
- **Institutional dynamics:** Understanding the fisheries' institutional structure, focusing on its receptiveness to innovations like traceability technology. This would involve examining stakeholder roles and participation degrees.
- **Adoption barriers:** An investigation into the impediments facing traceability technology adoption, encompassing technological integration issues, regulatory difficulties, and resource limitations.

RQ2: What are the contributions of ENGOs and government structures in the transition to electronic traceability systems in the Peruvian jumbo squid and mahi mahi fisheries?

To answer this, the data requirements, rooted in the literature review, are:

- **ENGO connections:** Information on ENGOs interactions with government bodies, industry affiliates, and artisanal fishing populations regarding traceability technology advocacy.

- **ENGO's role and influence:** Contextual details on the circumstances under which ENGOs emerge as agents in fisheries traceability development, covering influence magnitude, legitimacy, and collaborative ventures with other entities.

- **Governmental influence:** Data clarifying how governmental structures and policies impact traceability technology uptake in jumbo squid and mahi mahi fisheries. This entails a look at policy infrastructures, incentive schemes, and enforcement strategies.

In pursuit of these data requisites, qualitative methodologies were used, which are explained in the subsequent segment.

4.7 Data collection methods

In this section, the data collection methods used in this study to explore the potential contribution of traceability technology in supporting the sustainability and governance of the jumbo squid and mahi mahi fisheries in Peru are described, aligning each method to a specific research question. The research questions require gathering data from multiple sources and perspectives to understand the dynamics of the Peruvian fishing sector, as well as the attitudes and behaviours of key stakeholders involved in artisanal fisheries. To achieve this, qualitative methods such as interviews, document analysis, and participant observation were used. The data collected through these methods resulted in an understanding of the factors influencing the adoption of traceability technology in the Peruvian fisheries of jumbo squid and mahi mahi, and how different stakeholders interact with each other in this complex system.

4.7.1 Semi-structured interviews

Semi-structured interviews were selected as the primary data collection method for this research project, considering the need for a critical and in-depth examination of the research questions and the context of Peruvian fisheries. This section provides the rationale for the utilisation of semi-structured interviews. This research aimed to explore the transition to traceability technology adoption in the Peruvian jumbo squid and mahi mahi fisheries, as well as the influence of ENGOs and government structures on this process. Given the complex nature of these topics, semi-structured interviews offered a valuable method to investigate the diverse perspectives, motivations, and challenges faced by stakeholders in the fisheries

sector. By using open-ended questions and allowing for follow-up queries, the interviews enabled understanding of the participants' experiences and insights (Rabionet, 2011). Furthermore, semi-structured interviews provided an opportunity to probe deeply into the participants' views, beliefs, and decision-making processes. The research sought to uncover not only what stakeholders are doing but also why and how they are engaging with traceability technology, sustainability, and governance. This approach allowed for a detailed exploration of the participants' subjective experiences, enhancing the richness and depth of the data collected.

Given the evolving nature of the research topic and the need to explore diverse perspectives, semi-structured interviews provided the necessary flexibility and adaptability (Vaughn & Turner, 2016). The interviews started with pre-defined questions, while allowing for the inclusion of new lines of inquiry that may arise during the conversations. This responsiveness ensured that the research remained attuned to emergent themes and allowed for the exploration of unanticipated areas of interest. The research aimed to include a wide range of stakeholders, including fishers, government officials, industry representatives, and ENGOs.

Semi-structured interviews accommodated the participation of diverse stakeholders. The method enabled a representative and inclusive examination of the research topic, ensuring that the voices of relevant actors were heard and considered. Additionally, semi-structured interviews facilitated implementing ethical practices, including informed consent, confidentiality, and participant privacy. By carefully adhering to ethical guidelines, the research maintained a respectful and responsible approach to engaging with participants.

Semi-structured interviews were designed to address:

- RQ1a, RQ1b, and RQ1c by producing in-depth information on the emergence, drivers, motivations, barriers, and responses related to traceability technology adoption from the perspective of key stakeholders in the Peruvian fisheries sector.
- RQ2a, RQ2b and RQ2c by investigating the roles, interactions, and impacts of ENGOs and government structures on traceability adoption.

4.7.1.1 Application of semi-structured interviews

An interview questionnaire was developed to guide the semi-structured interviews to explore the research questions (see Annex 1 – Interview Questionnaire). The questionnaire was designed to progress from broad to specific topics, allowing for a natural flow of conversation while ensuring that all essential areas were covered. The questionnaire also incorporated open-ended questions to encourage participants to share their views, experiences, and insights in their own words. 36 interviews to representatives from the Peruvian fisheries sector, including fishers, government officials, industry representatives, and ENGOs, were carried out. As previously noted, these stakeholders were purposely selected to ensure a representation of the various perspectives and roles within the fisheries context, including a selection of women representatives. In the context of COVID-19, the interviews were conducted virtually, providing practical advantages in terms of accessibility and convenience for the participants. Each interview lasted from 60 to 90 minutes, allowing for in-depth discussions and exploration of the research topics.

4.7.1.2 Critical reflection on the use of semi-structured interviews

While semi-structured interviews offered significant advantages for this research, there are potential limitations that need to be acknowledged. The reliance on participants' self-reports and perspectives might have introduced biases or inaccuracies. However, efforts were made to mitigate this limitation by triangulating data with other sources, such as document analysis and observation, to enhance the reliability and validity of the findings.

Moreover, the virtual format of the interviews could have affected the depth of interpersonal connections and body language cues, potentially impacting the level of rapport and participant engagement. Nevertheless, the researcher sought to establish rapport and create a comfortable environment for open dialogue during the interviews. Overall, the use of semi-structured interviews as a qualitative data collection method is well aligned with the research objectives and the research questions. The approach has facilitated the exploration of the sustainability transition to traceability technology adoption in Peruvian artisanal fisheries under the influence of ENGOs and government structures.

4.7.2 Key document analysis

Document analysis, as a systematic procedure for evaluating written, printed, visual, or digital materials (Bowen, 2009), was chosen as a complementary data collection method to enhance the research findings. This section provides a critical reflection on the use of key document analysis in this study and justifies its application considering the research objectives and the research questions. Document analysis serves as a valuable means of cross-validating data gathered from other sources, such as interviews and observations. By examining diverse documents, including policy papers, legislation, government reports, and ENGO publications, the researcher was able to corroborate findings, ensuring a robust analysis of the institutional framework and decision-making processes related to traceability technology adoption in the Peruvian fisheries sector.

This research aims to understand the evolution of traceability technology adoption in Peruvian fisheries and the broader context that shapes the current situation. Document analysis allowed for the exploration of historical records, policy documents, and institutional reports, providing insights into the sustainability transition of traceability adoption in the jumbo squid and mahi mahi fisheries. Key document analysis enabled the examination of legislation, regulations, and policy frameworks governing fisheries management in Peru. This approach was particularly valuable for understanding the legal and regulatory landscape surrounding traceability adoption and its alignment with international agreements and market requirements.

Document analysis aimed to corroborate findings from interviews, offering secondary data on:

- The historical and institutional context surrounding traceability technology adoption in Peruvian fisheries (RQ1).
- The interactions and influence of ENGOs and government bodies on traceability adoption (RQ2).

Undertaking document analysis prior to primary research allowed for an informed understanding of the existing legislative and institutional framework, which in turn shaped the formulation of interview questions.

4.7.2.1 Application of document analysis

The documents subjected to analysis encompass a range of sources, including legislation and relevant reports from governmental bodies and NGOs. The research questions and theoretical framework guided the analysis, focusing on identifying key themes, patterns, and discrepancies in the documents. The systematic process of skimming, organising, reading, and interpretation allowed for the exploration of the documentary evidence.

4.7.2.2 Critical reflection on the use of document analysis

While document analysis contributed significantly to the research, certain limitations need to be acknowledged. The availability of official documents may be restricted or subject to bias, potentially impacting the completeness and objectivity of the analysis. Additionally, documents may lack certain contextual information or provide an incomplete picture of the decision-making processes related to traceability adoption. To mitigate these limitations, the researcher exercised diligence in accessing a diverse range of documents and utilised triangulation methods to cross-validate findings with data from interviews and observations (Noore, 2008). By combining multiple sources of information, the research ensured a more accurate representation of the institutional framework and decision-making dynamics within the Peruvian fisheries sector.

The use of document analysis as a qualitative data collection method is aligned with the research objectives, providing valuable insights into the institutional context, evolution, and decision-making processes related to traceability technology adoption in Peruvian fisheries. Critical reflection on the method's strengths and limitations has helped to ensure a rigorous and balanced approach to data collection and analysis, enhancing the credibility and reliability of the research findings.

4.7.3 Participant observation

Participant observation offers a unique opportunity to gain in-depth insights into the experiences, beliefs, and practices of the research participants. By actively engaging with stakeholders in real-life settings, the researcher can directly observe their interactions, social dynamics, and decision-making processes within the fisheries context. This method was particularly suitable for capturing aspects of social processes and behaviours that may be challenging to access through traditional interviews or survey methods (Kawulich, 2005).

Understanding the cultural and social context was crucial for understanding the complexities of traceability adoption in Peruvian fisheries. Participant observation allowed the researcher to dip in the activities of stakeholders, providing an understanding of the context in which traceability technology operates. Through close observation and interactions, the researcher can identify cultural norms, values, and social factors that influence the adoption of traceability practices. Moreover, participant observation offered flexibility in data collection, permitting adaptation of the approach and focus based on emerging insights and data. By being present in the natural settings of the jumbo squid and mahi mahi fisheries, the researcher was able to adjust observation strategies and explore unexpected aspects of traceability adoption. This adaptability ensured that the research remained responsive to the dynamic and evolving nature of the fisheries context.

Participant observation targets:

- Understanding the practical challenges and enablers in adopting traceability technology on the ground (RQ1b).
- Observing the real-time interactions between ENGOs, government bodies, and the fishing community in relation to traceability technology promotion and adoption (RQ2a, RQ2b).

4.7.3.1 Application of participant observation

Participant observation was conducted in various settings relevant to the jumbo squid and mahi mahi fisheries, including interactions with government institutions, processing plants, and ENGOs. During these encounters, the researcher observed and recorded field notes, capturing observations, non-verbal cues, and contextual details. Engaging in informal conversations and posing relevant questions, the researcher sought to delve deeper into the perspectives and attitudes of the stakeholders. This method facilitated an immersive understanding of the sociocultural dynamics impacting traceability adoption in a real-world setting, which might not have been fully captured through interviews and document analysis alone.

4.7.3.2 Critical reflection on participant observation

While participant observation yields valuable data, it is essential to acknowledge potential limitations. As an insider observer, the researcher's presence could have influenced participants' behaviour or interactions, leading to observer bias. To address this concern, the researcher exercised reflexivity and maintained a reflexive journal, acknowledging their own role and potential impact on the research context. Additionally, the observational data collected might have been subject to interpretation and subjective impressions, highlighting the importance of data analysis and coding to ensure objectivity. The use of thematic coding in the analysis process, as described in this chapter, has helped to mitigate potential bias and enhance the reliability of the research findings.

4.8 Data analysis methods

4.8.1 Overview of qualitative data analysis

Data analysis entails the systematic examination and interpretation of collected data to extract meaningful insights and conclusions. Qualitative data analysis, distinct from its quantitative counterpart, investigates the subjective experiences, perceptions, and interpretations of research participants. In this research, it was the preferred approach due to the complex social dynamics involved in fisheries sustainability and governance. This method involves several steps:

- **Data preparation:** Organising raw data, transcribing interviews, translating content, and collating documents and observation notes.
- **Data reduction:** Simplifying the data into manageable sets, often through coding.
- **Data display:** Visually organising the data, e.g., using charts, graphs, or matrices.
- **Conclusion drawing:** Interpreting the displayed data to identify themes, patterns, and insights.

4.8.2 Thematic coding

Thematic coding is an approach to qualitative data analysis that identifies, analyses, and reports patterns or themes within the data (Gibbs, 2007). This method requires a review of

the data, with multiple readings to ensure depth (Bowen, 2009). Frequency and prominence of concepts offer cues about their significance (Guest & McLellan, 2003). Given the study's social constructionist epistemology and its alignment with the sustainability transitions MLP theoretical framework, thematic coding proves appropriate. It allows for discerning patterns from the data, resonating with Noor's (2008) recommendations.

Steps in Thematic Coding:

- **Familiarisation:** Immersion in the data by reading and re-reading.
- **Generating initial codes:** Coding the data by particular features.
- **Searching for themes:** Organising codes into themes.
- **Reviewing themes:** Refining the themes to ensure they represent coded extracts and the entire dataset.
- **Defining and naming themes:** Further refining and defining the essence of each theme.
- **Writing the analysis:** Using the validated themes to construct a coherent narrative.

4.8.3 Worked example

"Traceability is important for us. It ensures we maintain quality and provides transparency to our consumers," (Industry 6).

From this extract:

- **Initial code:** Importance of traceability, consumer transparency.
- **Potential theme:** The role of traceability in building consumer trust.
- **Refined theme (after reviewing other data):** Trust-building mechanisms in fisheries.

This process was reiterated across different data sources.

Thematic coding, as employed in this research, offered a robust methodology to unearth the socio-economic dynamics influencing the adoption of traceability in Peruvian artisanal

fisheries. The subsequent narrative shares these themes, offering actionable insights for the enhancement of fisheries sustainability and governance in the Peruvian jumbo squid and mahi mahi fisheries through the adoption of electronic traceability systems.

4.9 Phases of the research

This section and its subsections outline the methodological framework used in this study, systematically structured into phases to explore the dynamics of traceability technology adoption in Peruvian fisheries. Phase I initiates the research by establishing the theoretical framework and conducting the literature review, focusing on traceability, fisheries sustainability, governance, and the sustainability transitions Multi-Level Perspective (MLP) framework. This foundation is vital for understanding the complex interrelationships that influence sustainability practices across various supply chains and setting the stage for the empirical investigation (El Bilali, 2019). Subsequent phases involve purposive sampling to gather diverse perspectives from key stakeholders, the design and implementation of semi-structured interviews to assess traceability impacts, and participant observation to capture real-time data and insights into the practical challenges and successes of traceability implementation. Each phase is designed to build upon the previous, ensuring a comprehensive approach to data collection and analysis, and aligning closely with the theoretical constructs and research objectives aimed at enhancing the understanding and facilitation of sustainability transitions within the artisanal fisheries of jumbo squid and mahi mahi.

4.9.1 Phase I: Establishing the theoretical framework, setting the scene, and carrying out the literature review and key document analysis

The literature review explored concepts such as traceability, fisheries sustainability, governance, and the sustainability transitions Multi-Level Perspective (MLP) framework. A deeper understanding of traceability technology's role in promoting sustainability across different supply chains was obtained, including the drivers, challenges, benefits, and beneficiaries of traceability adoption. Furthermore, the review shed light on the contributions of ENGOs in the promotion and adoption of sustainability transitions in various industries, and how government institutions can help or hinder its implementation.

In this initial phase, the research began by exploring existing literature on interactive fisheries governance, Eleanor Ostrom's governing the commons theory, and the sustainability transitions MLP. The databases used for the search included Google Scholar, JSTOR, ScienceDirect, and the OneSearch online library of the University of Cumbria.

The primary search keywords encompassed terms like "fisheries sustainability", "food traceability", "fisheries governance", and "sustainability transitions". A criterion was set wherein only papers written in the last 15 years were considered to ensure the incorporation of recent advancements and contemporary discussions pertinent to the rapidly evolving field of traceability technologies. A second criterion was to focus on publications in English or Spanish. This linguistic scope enables the inclusion of diverse findings from an array of countries and regions, many of which are at the forefront of implementing traceability in fisheries and thus provide a wealth of relevant data and analysis for this research.

After analysing different options, the sustainability transitions MLP was identified as the most appropriate theoretical framework for this study. Drawing on the MLP, this research aimed to explore the transition process, considering the interactions between the diverse actors and institutions involved. For this investigation the MLP has provided a valuable theoretical framework for understanding the complex dynamics of sustainability transitions and their implications for traceability technology adoption in Peruvian fisheries. By integrating the theoretical underpinning of sustainability transitions and the MLP, the researcher aimed to offer an analysis of the dynamics at play in the adoption of traceability technology (Geels, 2011).

Designed to help understand complex transitions that involve multiple actors and activities, the MLP emphasises the importance of radical innovations, while considering that socio-technical transitions involve multiple social groups, who engage in multiple types of activities in the context of the rules and institutions of society and social groups, including their belief systems and norms (Geels, 2019).

Throughout this phase, a range of sources were consulted, including primary and secondary literature, white papers, internal documents, and grey literature. Potential biases during selection were minimised by considering a balanced representation of perspectives, both supporting and opposing the chosen framework.

4.9.2 Phase II: Purposive sampling

In this phase, purposive sampling was employed, selecting participants based on their experience in Peruvian fisheries spanning over a decade and their respective roles in governance, sustainability, and traceability promotion and adoption**.** Given my extensive engagement as a marine conservation practitioner, I leveraged my connections across fishing communities, seafood processing and exporting plants, governmental bodies, as well as other ENGOs. Each participant was approached via structured email invitations**,** detailing the research objectives and their potential contribution. One limitation of this approach pertained to the potential exclusion of pertinent stakeholders who operate beyond my immediate professional network. While my existing relationships provided a foundation, it is plausible that significant contributors outside of these connections may have been inadvertently excluded, resulting in an incomplete representation of viewpoints. While my existing relationships provided valuable insights, I remained aware of the potential bias. To overcome this, participants were additionally asked to suggest other potential interviewees outside my circle, ensuring a broader representation.

Another consideration revolves around the influence of my established relationships on the participants' responses during interviews. Their knowledge of my involvement in the field and our professional interactions could have introduced an element of bias into their statements, possibly shaping their responses. To address these potential limitations and uphold the study's rigour, careful data collection methodologies were used. The interview protocols were thoughtfully designed to remain open-ended and neutral, thereby encouraging participants to share authentic viewpoints, free from undue influence. Furthermore, conscious efforts were made to encompass a diverse range of perspectives. Snowball sampling, guided by referrals and consultations with field experts, was employed to identify potential participants outside of my immediate circle. By systematically gathering data from a spectrum of participants, the study aimed to construct an understanding of the research subjects, mindful of the potential constraints inherent to the purposive sampling approach. This approach was aligned with the research questions and sought to offer a comprehensive view of the research landscape, while maintaining transparency about the inherent limitations.

4.9.3 Phase III: Semi-structured interview design and implementation

To gain comprehensive insights into the perceptions of diverse stakeholders within the artisanal fisheries of jumbo squid and mahi mahi regarding traceability, semi-structured interviews were chosen as the primary data collection method. These one-on-one conversations presented invaluable opportunities to gain insights into the interviewees' perspectives on traceability, its historical development, perceived benefits, and challenges, as well as the responses of governmental bodies and the influential role played by ENGOs in shaping traceability initiatives.

To ensure a comprehensive exploration of the research questions and alignment with the theoretical framework of sustainable transitions MLP, a set of 17 guiding interview questions was designed in consultation with my PhD supervisors. These questions were organised into five distinct sections: background, traceability, sustainability, governance, ENGOs, and conclusions. By structuring the interviews in this manner, the conversations were steered towards essential aspects of the research, while maintaining the flexibility to delve into unique insights and experiences shared by the interviewees. The semi-structured interview approach was deliberately chosen due to its ability to provide a balance between structure and flexibility. This approach allowed for organic exploration of the interviewees' perspectives, while ensuring that key topics relevant to the research were consistently covered across all interviews. The questions were carefully framed to evoke thoughtful responses, enabling the understanding of the complexities surrounding the adoption and implementation of traceability technology in Peruvian fisheries.

Due to the constraints posed by the COVID-19 pandemic, the interviews, conducted between July 2020 and February 2021, were carried out via video conferencing using the application Zoom, a platform that facilitated meaningful interactions despite physical distances. Each interview session lasted between 60 and 90 minutes, allowing ample time for interviewees to express their thoughts and insights in a comprehensive manner. To maintain accuracy and reliability in data capture, audio recordings were generated during the interviews. Prior to each session, participants were informed of the recording and ensured that their data would be treated with confidentiality. These recordings were later transcribed and translated for analysis. By capturing the richness of the interviewees' responses in their own words, the

transcription process added depth and authenticity to the data, ensuring that the findings were rooted in the genuine perspectives of the participants.

Overall, the semi-structured interview design proved to be an invaluable data collection method, allowing for in-depth exploration of stakeholders' viewpoints, and enriching the study with diverse perspectives on the role of traceability in Peruvian fisheries. The flexibility of this approach, combined with its alignment with the research objectives and theoretical framework, strengthened the reliability and validity of the research outcomes. Table 6 below shows how the interview questions link to the research aims and objectives.

Table 6. Interview questions and links to research aim and objectives

1	Can you briefly tell me about yourself and your activities related to the fishing sector?	Background
2	How do you define fishing traceability and sustainability?	Potential contribution to fisheries sustainability
3	Do you think traceability can contribute towards the sustainability and governance of these fisheries?	Potential contribution to fisheries sustainability and governance
4	What do you think are the benefits of traceability technology?	The drivers and motivations behind its adoption
5	Do you see any downsides to using a traceability system?	Documenting the reactions of different stakeholders
6	4. Can you describe how traceability is emerging in Peru?	Describing the emergence of traceability technology
7	5. Can you provide examples of obstacles or bottlenecks to traceability adoption/support?	Identifying the barriers
8	What is the role of Peruvian government institutions in fisheries?	Analysing the influence and impact of government institutions

9	Can you provide examples of issues in the sector you are aware about and what are the improvements you would suggest?	Analysing the participants view on the research problem
10	Is there consistency in the Peruvian legislation overseeing fisheries? Please provide specific examples.	Analysing the role of regulations
11	Do Peruvian government institutions work in a coordinated way to deliver on these norms? Can you describe some of your main concerns when it comes to coordination between government institutions?	Analysing the influence and impact of government institutions
12	What do you think is the role of ENGOs in influencing sustainability transitions?	Evaluate the influence of ENGOs and government structures on the adoption of traceability
13	Do you think ENGOs are successful in this regard? Why?	Evaluate the influence of ENGOs and government structures on the adoption of traceability
14	How do ENGOs engage with your sector? Please provide examples.	Describing the relationship of ENGOs
15	When are the contributions of NGOs considered and useful, when not and why?	Identifying the situations where ENGOs are considered important players in driving the adoption of traceability, when they are not, and why
16	What recommendations would you make to improve NGOs success rates in promoting sustainability transitions in fisheries?	Identifying the situations where ENGOs are considered important players in driving the adoption of

		traceability, when they are not, and why
17	Anything else you would like to add before we finish this interview or any questions from your end?	Conclusion

A total of 36 interview participants were recruited to ensure representation of stakeholders within the Peruvian artisanal fisheries of jumbo squid and mahi mahi. The participant selection encompassed 11 ENGO representatives, 9 industry representatives, 9 government officials, and 7 members of the artisanal fishing community. Prior to their involvement, all prospective participants received a formal email with a letter of invitation along with a detailed participant information sheet. Through email correspondence, each participant expressed their commitment to contribute to the study. Following the interviews, efforts were made to maintain transparency and validate the accuracy of the collected data. Interview transcriptions were shared with the respective interviewees for their confirmation of consent accompanied by a participant debrief sheet to ensure the accuracy and fidelity of their responses. This approach not only demonstrated respect for the participants' contributions but also fortified the credibility of the findings by fostering a collaborative and transparent research process.

4.9.4 Phase IV: Participant observation and reflexivity journal

Throughout this research, I engaged in participant observation to gain deeper insights into the sustainability transition of traceability adoption in the Peruvian jumbo squid and mahi mahi fisheries. This immersive approach allowed me to witness first-hand the dynamics, interactions, and challenges within these fisheries, providing an understanding that interviews and document analysis alone might not have captured.

Participant observation in government agency meetings: As part of this phase, I participated in meetings with government agencies focused on traceability initiatives. I noted the discussions, decisions, and power dynamics among government officials and other stakeholders. To ensure greater objectivity, I maintained a reflexivity journal. This journal

served as a repository for my immediate post-meeting reflections, capturing both the content of the discussions and my own personal interpretations. This reflective practice ensured that my observations were as accurate as possible.

Engagement in Fishery Improvement Projects (FIPs): My participant observation also extended to active involvement in FIPs, where I engaged in formal workshops, casual discussions, and initiatives related to traceability technology adoption within the industry. By engaging in these industry activities, I was able to gather insights into the perspectives, challenges, and aspirations of industry stakeholders. This first-hand experience enriched my understanding of the complexities surrounding traceability adoption and its integration into existing industry practices.

Interactions with fishing communities for capacity building: Another aspect of my participant observation involved direct interactions with artisanal fishing communities. These interactions occurred through structured training sessions, complemented by informal meetups. These engagements provided an understanding of on-the-ground realities. Engaging with these communities provided me with insights into their practical challenges, concerns, and potential obstacles in adopting traceability practices. These interactions facilitated a better grasp of the realities faced by these communities and their interactions with traceability technology.

Through participant observation, I was able to bridge the gap between theory and practice. This phase allowed me to contextualise data, identify emerging patterns, and gain a deeper understanding of the traceability adoption process within the broader socio-technical production systems of the Peruvian fisheries. The combination of participant observation and the use of a reflexivity journal added depth to the research, ensuring that the findings were rooted in both empirical data and my own reflective interpretations.

4.10 Data analysis process

4.10.1 Transcription and translation process

After conducting the semi-structured interviews, the next step involved the transcription and translation of the interview recordings. The interviews were recorded using Zoom's digital recording option. To facilitate the transcription process, Sonix.ai was utilised, an automated transcription software, to convert the audio recordings into written text. This software

employs advanced speech recognition technology to generate transcriptions. Once the transcripts were generated by Sonix.ai, a thorough review was undertaken to correct any errors or inaccuracies in the transcriptions. This review was vital to ensure the veracity and integrity of the transcribed content. Additionally, to enhance the reliability of the transcriptions, the assistance of three capable colleagues and friends were enlisted, who are fluent in both Spanish and English. They reviewed and translated the transcriptions from Spanish into English. When necessary, the translated transcripts were compared with the original audio recordings to verify their accuracy. This triangulation process, involving both automated and manual efforts, increased the trustworthiness of the transcribed data.

4.10.2 Participant validation and initial thematic analysis

The commitment to rigour extended to the validation of the transcriptions. The finalised transcriptions were shared with the interview participants to allow them to review their responses for accuracy. This participant validation process ensured that the participants' viewpoints were faithfully represented in the transcriptions. Only minor corrections were received from a couple of participants. All adjustments were incorporated into the transcripts and their translations.

Following the translation and validation process, a systematic approach was undertaken to organize and analyse the transcribed interviews. This approach entailed several steps:

a. **Initial data organisation**: The transcribed data were initially segmented and organized chronologically as per the order of interviews conducted. This organization helped in maintaining a clear timeline of the data collection process.

b. **Coding and categorisation**: Each transcript was read multiple times to ensure a deep understanding of the content. Key ideas and concepts emerging from each interview were identified. The first level of coding involved tagging these ideas with descriptive codes that summarized the essence of the participant's statement.

c. **Use of a spreadsheet for structured overview**: The coding was carried out on an Excel spreadsheet, allowing for a structured overview of the responses. Each row of the spreadsheet corresponded to a specific statement or idea, and columns were used to categorize these statements under themes, research questions, and participant identifiers.

d. **Assignment of unique identifiers**: To ensure confidentiality and anonymity, each participant was assigned a unique identifier number. This approach enabled to attribute responses to specific sectors—industry, ENGO, government, or artisanal fishing community—without revealing individual identities.

e. **Keyword highlighting**: Keywords within the transcriptions were highlighted. These keywords acted as links to connect specific statements to broader themes and concepts, such as benefits, barriers, needs, and issues.

f. **Thematic analysis**: After coding and keyword highlighting, came the more interpretative phase of thematic analysis. This involved looking for patterns, similarities, and differences in the data and grouping the codes into potential themes. These themes were then reviewed and refined, ensuring they accurately represented the dataset and aligned with the research questions.

g. **Cross-sectional analysis**: The data was also analysed across different participant sectors to identify sector-specific trends or overarching patterns that cut across different groups.

h. **Iterative review**: The analysis was an iterative process, involving constant comparison between the data, the emerging themes, and the research questions. This iterative nature ensured understanding and interpretation of the data.

The anonymised coding and thematic analysis ensured that the voices of participants were integral to the analysis while maintaining their individual privacy. The systematic and iterative nature of this process facilitated the identification of patterns and trends within the data, offering insights into the complex dynamics of traceability technology adoption in Peruvian fisheries.

4.10.3 Thematic framework development

The next phase involved aggregating and organising the coded and highlighted responses into key themes. This thematic organisation allowed for the understanding of the data, revealing both commonalities and variations in participants' perspectives. The themes were derived directly from the main ideas highlighted during the initial coding process and were further refined as patterns emerged through multiple readings of the data. The Excel spreadsheet

used to code individual participants responses served as a valuable tool for creating an initial thematic framework. It allowed for easy cross-referencing of responses with specific research questions and participant sectors. The framework, developed through this meticulous process, became a foundation for structuring the findings during the write-up phase.

Here is a detailed example of how a response from an industry representative was analysed and coded.

Example transcript (translated from Spanish to English): *"We have seen an improvement in traceability adoption within our processing plants. This technology has streamlined our operations, making it easier to track the origin of our seafood products."*

Step 1: Initial reading and highlighting

I began by thoroughly reading the transcript to grasp the content and context. During this reading, I highlighted the main ideas, as well as specific keywords related to key concepts like "improvement", "traceability", "processing plants", and "origin".

Step 2: Coding and categorisation

After highlighting, I coded the response based on its alignment with the research questions. This response was particularly relevant to RQ1a, which aims to understand how traceability technology is emerging and the drivers behind its adoption. The response was coded as "Improvement in traceability technology adoption in processing plants" under the broader category of "Drivers of traceability adoption".

Step 3: Anonymisation and sector identification

As part of ensuring confidentiality, the industry representative was assigned an identifier number. Additionally, their response was marked with the "Industry" sector label. This allowed for anonymous attribution of the statement to the relevant sector while maintaining privacy.

Step 4: Linking to thematic keywords

Next, I linked the response to thematic keywords such as "improvement", "traceability", and "origin". This step made it easier to locate and connect responses that addressed similar concepts across different interviews.

Step 5: Aggregating responses

This response was further aggregated with other similar responses under the "Drivers of traceability adoption" theme. By grouping responses with commonalities, patterns and trends started to emerge.

Step 6: Refining the thematic framework

As the analysis progressed, the thematic framework was refined to include categories within the broader themes. For instance, the theme "Drivers of traceability adoption" was further divided into "Operational efficiency" and "Supply chain transparency".

The examples provided above demonstrate the detailed process used to analyse the interview data. This systematic approach was consistently applied to each interview, ensuring the reliability and validity of the analysis. The resulting thematic framework served as the basis for organising the findings, which are presented in the following chapters.

4.10.4 Reflexivity

Throughout the data analysis process, reflexivity played a crucial role. Reflexivity involved ongoing self-awareness and consideration of my own perspectives and potential biases. It was important to acknowledge my position as a conservation practitioner in the field, as well as my familiarity with the participants and the topic. Reflexivity helped balance interpretation of the data, enabling a more objective analysis of the findings.

4.10.5 Data management

All data has been securely stored according to the University of Cumbria's guidelines. Quotes have not been attributed to individuals in accordance with the agreement with participants to not cite individuals directly unless authorised by them. No interview data will be shared beyond this thesis without participant agreement.

4.11 Reflection on the research process and discussion of bias or challenges

The research process is inevitably susceptible to unintentional biases that can emerge during data collection and analysis. As a conservation practitioner deeply committed to sustainability and the role of traceability within fisheries supply chains, it was important to critically consider

how my own perspective might influence the interpretation of findings. Given my alignment with the benefits of traceability as a means to improve both sustainability and governance, there could be an inherent bias towards highlighting its advantages over potential drawbacks. This recognition aligns with the concept of positionality, which emphasises that researchers' personal beliefs and experiences can shape the research process and outcomes (Bourke, 2014). Furthermore, my role within WWF, although providing access to participants, may have introduced a certain predisposition in their responses. Despite these potential biases, efforts were made to maintain an objective stance, uphold open-mindedness, and remain receptive to a full spectrum of viewpoints throughout the research journey. Recognising and disclosing these potential biases is important in understanding the findings.

The selection of interview participants represents another potential source of bias. Striving to capture a diverse range of perspectives can be challenging, particularly when engaging with individuals who hold different viewpoints. The difficulty of finding individuals with opposing stances could have influenced the sample composition and potentially skewed the representation of opinions. It is crucial to acknowledge that participants were conscious of my affiliation with the WWF, which might have influenced their responses. While efforts were made to approach participant selection impartially, these underlying biases and challenges need to be considered when interpreting the results.

4.12 Ethical considerations

Ethical considerations constitute an important aspect of any research, and this study was no exception. The following ethical considerations were addressed:

- **Informed consent:** All interview participants were presented with an informed consent form. This document delineated the study's objectives, the nature of their participation, and their rights as participants. Before the interviews commenced, participants were explicitly asked for their verbal consent, underscoring their understanding and willingness to partake in the study (Bhandari, 2021).

- **Confidentiality:** Safeguarding participants' identities was important (Schulte & Sweeney, 1995). To ensure confidentiality, participants' names and contact details were exclusively accessible to the researcher and were stored securely. As part of this effort, any personal

identifying information within the interview transcripts was anonymised and replaced with codes to shield participants' identities.

- **Voluntary participation:** Central to ethical practice, participants were informed that their involvement in the study was entirely voluntary (Mumford, Higgs, & Gujar, 2021). Furthermore, participants retained the right to withdraw from the study at any point without encountering any adverse consequences or repercussions.

- **Debriefing:** Ensuring participants' well-being, a debriefing sheet was provided to each participant post-interview. This sheet offered an understanding of the study's purpose, addressed any inquiries participants may have had, and presented contact details should they require additional support.

- **Researcher reflexivity:** Recognising the potential impact of my own biases and preconceptions, I undertook measures to reduce their influence on the research. Seeking feedback from peers and colleagues fortified the ethical foundation of the study, ensuring its execution was both robust and principled.

The research methodology accounted for ethical risks associated with discussing sensitive topics such as corruption and illegality within the fisheries sector. Recognising the potential risks to participants and the interviewer, ethical protocols ensured confidentiality, voluntary participation, and the safety of all parties involved. Participants were informed of their rights to anonymity and the option to withdraw at any point without repercussions. Interview questions were carefully framed to avoid direct accusations or implications while allowing participants to share their perspectives freely. Additionally, data collection and storage adhered to confidentiality standards, ensuring sensitive information was securely managed.

The research design, methodology, and protocols were submitted for ethical review and were granted clearance by the University of Cumbria's Research Ethics Committee. The approval can be viewed in Annex 2 – Ethics Approval.

By diligently following these considerations and the guidelines set by the University of Cumbria, this research was conducted in a respectful and responsible manner, always prioritising participants' rights and well-being.

4.13 Validity, reliability, and generalisability

Validity, reliability, and generalisability are important concepts in research methodology, although their application in qualitative studies can be debated due to the unique nature of qualitative research. While these concepts have traditionally been associated with quantitative research, they also hold relevance in the context of qualitative studies, although with some differences in how they are approached.

4.13.1 Validity

In quantitative research, validity refers to the accuracy and truthfulness of research findings. In qualitative research, the concept of validity is often replaced with the term 'trustworthiness' or 'credibility'. Trustworthiness in qualitative research is established through various techniques such as member checking, prolonged engagement, and triangulation (Roberts & Priest, 2006).

In this study, strategies were employed to ensure credibility:

- **Member checking**: Participants reviewed their interview transcripts, ensuring that their perspectives were accurately represented.
- **Prolonged engagement**: I spent considerable time in the field in the context of my work, allowing a deeper understanding of the situation, and building trust with participants.
- **Triangulation**: Multiple sources of data, including interviews and secondary documents, were consulted to corroborate findings.

4.13.2 Reliability

Reliability, in quantitative research, refers to the consistency and stability of research findings (Roberts & Priest, 2006). In qualitative research, achieving the same level of consistency can be challenging due to the dynamic and context-dependent nature of qualitative data.

The following steps were taken to foster reliability in this study:

- **Documentation**: Every step of the research process was documented. From participant selection criteria to interview procedures, ensuring that another researcher can understand the process undertaken.

- **Iterative questioning**: During interviews, topics were revisited to check for consistency in participants' responses.

4.13.3 Generalisability

Generalisability refers to the extent to which research findings can be applied to a broader population or context. In qualitative research, the goal is not to achieve statistical generalisability, as in quantitative studies, but rather to achieve 'transferability' or 'applicability' (Leung, 2015). This means that the findings of qualitative research can be applied to similar contexts or situations with similar characteristics. In this study, the findings are presented in a manner that provides insights into the specific context of Peruvian jumbo squid and mahi mahi fisheries.

While it might seem niche, the research design was intentionally chosen for specific reasons:

- **Single cased depth**: By submerging into a single case, rich insights and details emerge that might be overlooked in broader studies.

- **Transferability**: The intention is not for broad generalisation but to provide an understanding that can inform similar contexts. While the direct findings may be specific to the Peruvian context, the methodologies, frameworks, and deeper insights can guide similar studies elsewhere.

- **Potential critiques**: A single case study approach might be critiqued for its limited generalisability. However, the depth and richness of data extracted from such focused studies offer unparalleled insights. It is not about generalising findings to all fisheries but about understanding one context deeply to inform others.

To summarise, qualitative research offers unique perspectives on validity, reliability, and generalisability. In this study, I sought to produce findings that are trustworthy, consistent, and, while specific to one context, can inform and inspire research in similar settings.

4.14 Summary of the methodology

In this chapter, the methodological approach employed to investigate the research questions and objectives of this study have been outlined, which explore the potential benefits of the sustainability transition to electronic traceability systems in the jumbo squid and mahi mahi fisheries of Peru. By selecting an appropriate research philosophy, pragmatism, I positioned myself to adapt to the dynamic and complex nature of the research context, allowing for a flexible approach that accommodates the diverse stakeholders and factors at play. The research design aligns with the theoretical framework of sustainability transitions and the MLP. The three phases of data collection allowed for the understanding of the research topics. Through semi-structured interviews, participant observation, and document analysis, I gathered data from a wide range of stakeholders, capturing multiple perspectives and insights.

The data analysis process involved transcription and translation of interview recordings, followed by systematic coding and thematic analysis. This process enabled the identification of key themes and patterns, linking responses to specific research questions. By utilising an Excel spreadsheet for coding and organisation, I managed to present the findings in a structured manner and ensure consistency in the analysis. Recognising potential sources of bias and ethical considerations, I took measures to minimise their impact on the research. Efforts were made to ensure voluntary participation, maintain confidentiality, and practice researcher reflexivity.

While certain themes like validity, reliability, and generalisability are often discussed in research methodology, their relevance in qualitative studies like this present study is open to debate. Nevertheless, I am aware of these concepts and have designed the study with their principles in mind, emphasising the transparency and rigour of the research process. The methodology chapter has laid the foundation for the exploration of traceability technology adoption in Peruvian fisheries. By adopting a pragmatic approach and utilising a combination of qualitative methods, I have strived to capture the complexities of the research context. The methods employed are aligned with the research questions and objectives, contributing to an understanding of the potential of traceability in enhancing sustainability and governance within these fisheries. This chapter has provided a roadmap for the subsequent phases of the study, where the gathered data will be analysed and interpreted to contribute insights to the field of sustainability transitions and fisheries management.

5 - Findings and Analysis

In this chapter, the conclusion of data collection and analysis is revealed as the study's findings are explored. The purpose of this chapter is to present and interpret the insights obtained from diverse stakeholders across the Peruvian jumbo squid and mahi mahi fisheries supply chains via in-depth interviews, observations, and document analyses. As the narratives, perspectives, and experiences of key actors are uncovered, the complexities of traceability technology adoption and its interaction with various governance structures, ENGOs, the artisanal fishing community, and industry representatives are presented. See Table 7 for the list of interview participants and the institutions they represent.

Table 7. Research interview participants

Coding	Role	Organisation	Gender
ENGO 1	Environmental NGO	Global Fishing Watch	Male
ENGO 2	Environmental NGO	Future of Fish	Female
ENGO 3	Environmental NGO	Oceana	Male
ENGO 4	Environmental NGO	Redes	Male
ENGO 5	Environmental NGO	WWF	Male
ENGO 6	Environmental NGO	WWF	Male
ENGO 7	Environmental NGO	Walton Family Foundation	Male
ENGO 8	Environmental NGO	Sustainable Fisheries Partnership	Male
ENGO 9	Environmental NGO	Environmental Defense Fund	Male
ENGO 10	Environmental NGO	Redes	Female

ENGO 11	International Cooperation Agency	GIZ	Male
Industry 1	Jumbo Squid Industry Group	CALAMASUR	Male
Industry 2	REM & Traceability Tech Developer	Shellcatch	Male
Industry 3	Fisheries Sustainability Certifier	Marine Stewardship Council	Male
Industry 4	Exporters	ADEX	Female
Industry 5	Processing Plant	Perupez	Male
Industry 6	Processing Plant	Coinrefri	Male
Industry 7	Industrial Fisheries Association	National Fisheries Society (SNP)	Male
Industry 8	Traceability Certifier	GS1	Female
Industry 9	Processing Plant	FishOlg	Male
Gov. 1	Regional Government	DIREPRO Piura	Male
Gov. 2	Marine Research Institute	IMARPE	Female
Gov. 3	Captaincies & Coastguard Authority	DICAPI	Male
Gov. 4	Marine Research Institute	IMARPE	Female
Gov. 5	Sanitary Authority	SANIPES	Male

Gov. 6	Fisheries Authority	PRODUCE	Male
Gov. 7	Fisheries Authority	PRODUCE	Female
Gov. 8	Fisheries Authority	PRODUCE	Female
Gov. 9	Forestry Authority	SERFOR	Male
Artisanal 1	Artisanal Fishing Cooperative	La Islilla	Male
Artisanal 2	Artisanal Fishing Association	AAARCUDIPA	Male
Artisanal 3	Intermediary	Individual	Male
Artisanal 4	Artisanal Fishing Association	APAMARPA	Male
Artisanal 5	Fish Landing Site Administrator	DPA Matarani	Male
Artisanal 6	Artisanal Fishing Cooperative	La Tortuga	Male
Artisanal 7	Women's Shipowners Association	Armadoras de Quilca	Female

The findings presented in this chapter contribute to a deeper understanding of the central research questions that guide this study (see Box 1. Research questions). The complexities of the transition to traceability technology adoption are explored, investigating the factors driving its emergence, as well as the institutional responses and barriers influencing its implementation (RQ1). Additionally, the impact of ENGOs and government structures on traceability adoption are analysed, revealing the extent of their engagement, the conditions under which ENGOs influence transitions, and the effects of governmental regulations (RQ2). By structuring the findings around distinct themes, each informed by the research objectives

(see Section 1.5) and guided by the theoretical framework of the sustainable transitions MLP that was presented in Section 3.6, a portrait of the sustainability transition of traceability uptake within the Peruvian artisanal jumbo squid and mahi mahi fisheries is offered. Through this presentation, further analysis is then offered in Chapter 6 – Discussion, on the implications of these findings for fisheries sustainability, effective governance, and future research.

In the next sections, each theme is examined by analysing the subthemes that emerged from the data. The voices of industry representatives, government officials, artisanal fishing community members, and ENGOs provide a description of the web of relationships that play a role in traceability technology adoption of the Peruvian artisanal fisheries. Furthermore, a comparative analysis across stakeholder groups reveals both points of convergence and divergence that shed light on this complex landscape.

In this light, the findings presented here address the research objectives delineated in Section 1.5, and weave in the antecedent contextual, theoretical, and methodological underpinnings of Chapters 2-4, with the forthcoming analytical discussions and implications of the study as will be presented in Chapters 6-7. As the findings are navigated, the emerging narratives are explored and the potential avenues for more sustainable practices and effective governance in Peruvian jumbo squid and mahi mahi fisheries and beyond are uncovered.

5.1 RQ1: How is the transition to electronic traceability systems occurring in the Peruvian jumbo squid and mahi mahi fisheries?

Navigating the landscape of traceability technology adoption in Peruvian fisheries reveals a differing perspectives, motivations, and trajectories related to traceability development, sustainable practices, and effective governance within the sector. The exploration into how traceability is developing in the Peruvian jumbo squid and mahi mahi fisheries reveals the drivers and motivations that play a role in this transition. This is part of **Theme 1: Understanding the transition to electronic traceability systems**, which responds to RQ1 (see Box 1. Research questions). Within this theme, **Subtheme 1.1: Emergence and drivers of traceability adoption** explains the origins and motivations driving this sustainability transition, identifying the socio-economic, ecological, and regulatory factors that influence the adoption of traceability technologies in response to RQ1a. Moving forward, **Subtheme 1.2: Niches where traceability is gaining momentum** explains specific segments within the fisheries

sector where traceability is not just a technological intervention, but is beginning to shape more sustainable fisheries practices, responding to RQ1b. Conversely, the reaction of the established fisheries framework to this transition are covered in **Subtheme 1.3: Regime response to the emergence of traceability**, which describes the perceived potentials, tangible benefits, as well as disadvantages and barriers associated with the adoption of traceability systems, in response to RQ1c. The next sections include the interview narratives that lead to the emergent themes based on the experiences and perceptions of diverse actors engaged in the Peruvian jumbo squid and mahi mahi fisheries landscape.

5.1.1 Theme 1: Understanding the transition to traceability technology (RQ1)

The sustainability transition towards the adoption of traceability technology in the Peruvian jumbo squid and mahi mahi fisheries, has the potential to increase transparency, accountability, sustainability, and governance. Theme 1 analyses this transition, unpacking the interplay of drivers, challenges, and responses that shape the adoption of traceability technology, which links back to RQ1. As the subthemes are explored, the emergence of traceability technology in response to external market pressures, the niches where this technology gains momentum, and the reactions of the regime to this transformative change emerge, responding to RQ1a, RQ1b, and RQ1c. This theme serves as a lens through which it is possible to peer into the landscape of a transition that not only redefines how information flows within the fisheries but also reshapes the relationships and paradigms that govern the fisheries sector.

5.1.1.1 Subtheme 1.1: Emergence and drivers of traceability adoption (RQ1a)

According to interview responses, the adoption and evolution of traceability technology within the Peruvian jumbo squid and mahi mahi fisheries has been significantly influenced by external pressures, particularly from international markets like the United States, Europe, and Japan (see Section 2.4 International market requirements). The Sustainability Transitions MLP as discussed in Chapter 3 (Section 3.4 Sustainability Transitions and MLP), provides a framework to understand how exogenous developments, in this case international markets, drive the diffusion of innovations and shape the trajectory of sustainability transitions. International markets act as a landscape that exerts pressure on the existing regime, creating opportunities for the diffusion of traceability innovations. The essence of this landscape lies in the growing demand of buyers and consumers for information about the origin of seafood

products. As elaborated in Chapter 2 – Context, the requirements set by international markets have significantly evolved, necessitating traceability systems to demonstrate product legal provenance.

The consensus among most interviewees is that the primary driving force behind the development and adoption of traceability technology is the demand from international markets. While local consumers have not expressed a similar level of interest in traceability, the requirements of jumbo squid and mahi mahi export markets have propelled the adoption of electronic traceability systems in these fisheries. The United States, Europe, and Japan, as key importers of Peruvian seafood, have increasingly requested traceability as a prerequisite for market access.

According to interviewee Artisanal 2, the concept of traceability in Peruvian fisheries gained initial traction in 2009, escalating in importance from 2010-2012 due to European import regulations. It gained wider recognition through discussions and forums, culminating in a deeper understanding of its benefits, particularly its role in enhancing control and knowledge within the supply chain. The European market's stringent requirements and regulations necessitates traceability, leading to the first full chain analysis of the jumbo squid and mahi mahi supply chains.

In 2015-2016 came the United States Seafood Import Programme (SIMP) regulations. The potential risk of losing access to the lucrative U.S. market due to inadequate traceability practices prompted stakeholders to recognise the urgent need for the adoption of traceability systems, as noted by Industry 9. It is noteworthy that ENGOs played an important role in disseminating information about the upcoming SIMP regulations to industry actors, as highlighted by ENGO 9. This highlights the symbiotic relationship between market-driven regulations and ENGOs advocacy in promoting traceability adoption. Furthermore, incidents like the U.S. Food and Drug Administration (FDA) rejection of 500 tons of Peruvian mahi mahi fillets due to unsafe histamine levels in 2013 increased the demand for traceability. Industry 8 emphasised that this instance highlighted the critical role of traceability in ensuring product health, quality, and reputation. The ability to trace the origin and identify points of contamination enabled producers to vindicate their product quality, protecting their interests and preserving consumer trust.

The findings resulting from the interviews, demonstrate that pressures coming from international markets have been a catalyst for the development and implementation of traceability technology within Peruvian fisheries. The evolving requirements of these markets have not only driven discussions but also influenced stakeholder mindsets, leading to the recognition of traceability as a valuable tool for market access, quality assurance, and reputation management. Also, governments have a mandate under the Sustainable Development Goals (SDGs), to effectively regulate harvesting, end overfishing, IUU and destructive fishing practices. The subsequent sections explore insights into the niches where traceability has gained momentum, and the various actors involved, showcasing the interplay between market pressures and localised responses in the adoption of traceability technology.

5.1.1.2 Subtheme 1.2: Niches where traceability is gaining momentum (RQ1b)

As noted above, the findings show that the adoption of traceability systems in Peruvian fisheries has primarily been driven by the demands of international markets, especially in Europe. The Peruvian fishing industry recognises that complying with traceability requirements is necessary to access and compete in these lucrative external markets. The government is aware that failing to adopt traceability systems can lead to missed market opportunities in the future. Therefore, both industry and government stakeholders emphasised the importance of implementing traceability measures to meet international standards and maintain market access for Peruvian fisheries.

According to Artisanal 6, traceability is seen as a crucial aspect of modernising fishing practices and aligning with international laws. Given the focus on exports in the fishery, there is a clear understanding that competing in the global market requires high-quality products that are certified and meet traceability standards. Failing to meet these requirements would put the fishery at a disadvantage. ENGO 1 further emphasised the influence of market pressures, stating that ultimately, it is the markets that drive improvements in fisheries, regulations, and traceability. Based on the feedback from the interviewees, it is evident that market demands play a significant role in motivating fishers to enhance their practices, regulations, and traceability systems.

These developments have prompted diverse stakeholders to initiate the adoption or creation of electronic traceability systems within the jumbo squid and mahi mahi fisheries, ranging

from fishing cooperatives to industry alliances such as the Peruvian Mahi Alliance (PMA) and the Peruvian Chamber of the Giant Squid (CAPECAL).

Within the scope of this study, a distinct niche is identified within three fishing cooperatives: La Islilla, La Tortuga, and San Jose (see Section 2.3.4). These cooperatives were mandated to establish a catch documentation system to secure and uphold their fishing permits. In response to this legal obligation, WWF-Peru developed the TrazApp traceability application, a tool that aids fishers in fulfilling this requirement.

The identified niche also encompasses the FIPs for jumbo squid and mahi mahi, spearheaded by PMA and CAPECAL, respectively (see Section 2.6). Market forces dictate that PMA and CAPECAL processing and exporting plants adhere to specific traceability systems, such as 'Trace Register', mandated by international buyers. Industry 4 underscored the implementation of traceability measures, where companies internally adopt techniques and procedures to meet client stipulations. Additionally, government entities like SANIPES and PRODUCE have engaged in deploying their own systems to ensure that fisheries supply chain actors adhere to proper practices. These endeavours are further described below.

With the increasing appreciation of traceability's significance within Peruvian fisheries, its development and adoption have gained momentum. The resultant wealth of information has become valuable for stakeholders across the jumbo squid and mahi mahi supply chains. ENGO 8 chronicles the evolution of traceability information in Peru, tracing its progression from a focus on species-level biological data to recognising the relevance of economic and social units across the various supply chain stages. The appreciation of comprehensive traceability in Peru has undergone gradual incubation and integration, aligning with the country's fisheries sector context.

While some seafood processing and export plants have implemented private traceability systems like 'Trace Register', governmental entities have created their own systems for monitoring and surveillance. In response to market requirements and industry pressure, PRODUCE began developing its traceability system, 'SITRAPESCA.' ENGO 2 mentioned that a national government mandate was taken on by PRODUCE to create a traceability system that could meet market requirements. They created their own traceability system, and electronic database, but the system was not well connected to what was happening at the subnational

level, resulting in the parallel evolution of additional public and private traceability systems in Peru.

In 2020, PRODUCE introduced 'SITRAPESCA' to trace fisheries and aquaculture products, with financial backing from the National Fisheries Society (SNP), which represents the industrial anchoveta fishery industry. This programme emerged from industry advocacy (as highlighted by Industry 7), driven by the necessity for self-regulation in anticipation of market requirements. However, scepticism exists within the jumbo squid and mahi mahi fisheries actors regarding the suitability of SITRAPESCA for artisanal fisheries. ENGO 5 highlighted concerns about the system's focus on anchoveta industrial fisheries, indicating that SITRAPESCA's design was geared towards the anchoveta industry's needs over artisanal fisheries, which have different characteristics. The Peruvian sanitary authority, (SANIPES), developed 'TRAZAMOBI,' a mobile application for the bivalve mollusc fishery. This pilot initiative, shared by Gov. 5, reflects the ongoing automation efforts to streamline previously laborious manual processes. The user-friendly nature of the application has been embraced by its users.

Despite limited resources, government institutions associated with fisheries management identified diverse channels of support for traceability initiatives. PRODUCE secured private funding from the SNP for SITRAPESCA. SANIPES received a grant from the National Programme for Innovation in Fisheries and Aquaculture (PNIPA), facilitated by the World Bank. DICAPI, with support from WWF, streamlined fish sailing departure certificates through digitalisation via the TrazApp system. Gov. 3 further underscored the intent to replicate such digital transformation projects across government institutions. Though promising, an overview of existing traceability systems in Peru and the challenges posed by their lack of interoperability were previously outlined in Chapter 2– Context.

PNIPA contributed partially to the development of WWF's TrazApp system, alongside systems by other ENGOs like ProDelphinus' APPESCAR application. However, PNIPA's failure to mandate coordination and interoperability between supported systems paradoxically impedes widespread adoption, causing redundancy and inefficiency. This disjointedness hinders cross-verification of data, potentially leading to inaccuracies. Consequently, a lack of coordination between public and private efforts curtails the potential for extensive fisheries

data analysis, which could substantially enhance Peru's fisheries management for sustainability and improved governance.

The foundational principles of designing fisheries traceability systems encompass defining goals and ascertaining essential needs. ENGO 2 envisaged an approach that tailors traceability to varying actors' requirements for improved fisheries data management. Simplicity is advocated, encouraging the adoption of the 'Keep it Simple, Stupid' (KISS) principle. This approach suggests initiating with basic features before introducing complexity.

This section has explored the emerging niches that fuel the adoption and development of traceability systems within the Peruvian jumbo squid and mahi mahi fisheries. The dynamics of cooperation between governmental bodies, artisanal and industry players, as well as ENGOs in this domain form a complex and evolving landscape that shapes traceability's implementation and impact. As this chapter progresses, a better understanding of the challenges and opportunities will unfold, allowing for the analysis of the broader traceability context and regime response.

5.1.1.3 Subtheme 1.3: Regime response to the emergence of traceability: potential benefits and perceived disadvantages to traceability adoption (RQ1c)

As previously discussed in Chapter 3 - Literature Review, according to the theoretical framework of the Sustainability Transitions MLP, regimes are the institutional structures (cognitive, regulative, and normative) of the incumbent socio-technical system that the niche potentially affects. In this case study, the regime affected by the incumbent traceability technology encompasses the entire Peruvian fisheries sector. The adoption of electronic traceability systems brings impacts across the entire fisheries supply chain, extending beyond jumbo squid and mahi mahi, and involving a spectrum of public and private actors. To address how the institutional fisheries structure in Peru responds to traceability innovation and the barriers to its adoption, respondents' answers have been categorised by sector into two main themes: perceived traceability benefits and potential disadvantages/barriers to traceability adoption.

Within these categories, government, artisanal fishers, industry, and ENGO representatives were queried about their perceptions regarding the main benefits traceability could offer to

the jumbo squid and mahi mahi supply chains, as well as to Peruvian fisheries in general. The following sections outline the main responses received from each sector.

Traceability benefits perceived by the government

Government representatives articulated a range of traceability benefits:

- **Contribution to sustainability and environmental conservation (5 responses):** Government representatives emphasised that traceability could contribute to sustainable fishing practices. They pointed out that traceability guarantees long-term livelihoods for fishers, reduces environmental impacts like overfishing, juvenile catch, bycatch, and the use of illegal fishing gear.

- **IUU prevention (5 responses):** Government representatives believed that traceability holds strong potential to curtail illegal, unregulated, and unreported (IUU) fishing. They noted that traceability systems can effectively distinguish between legal and illegal products. Additionally, four respondents highlighted that traceability aids in establishing the legal origin of fisheries products.

- **Increased quality and value (4 responses):** Government representatives foresaw increased income for fishers due to the ability to demonstrate product quality through traceability.

Improved monitoring, control, and surveillance (MCS) (4 responses): Government representatives acknowledged that real-time fisheries data collected through traceability technology could enhance the efficiency of MCS efforts. This technological aid is particularly valuable considering the state's limited resources. Gov. 6 highlighted that: "... the use of technological tools makes it possible to optimise the monitoring and control of the responsible use of hydrobiological resources and guarantee their traceability... has a favourable impact on decision-making and the application of corrective measures in the event of alleged cases of illegal activity."

- **Transparency and information sharing (3 responses):** Government representatives emphasised that traceability technology could enhance public access to transparent information about the nation's fisheries resources. Furthermore, it could foster better information sharing between different government institutions.

Please see Table 8 for additional perspectives from government representatives on the benefits of traceability technology for fisheries.

Table 8. Perspectives on traceability benefits from government representatives

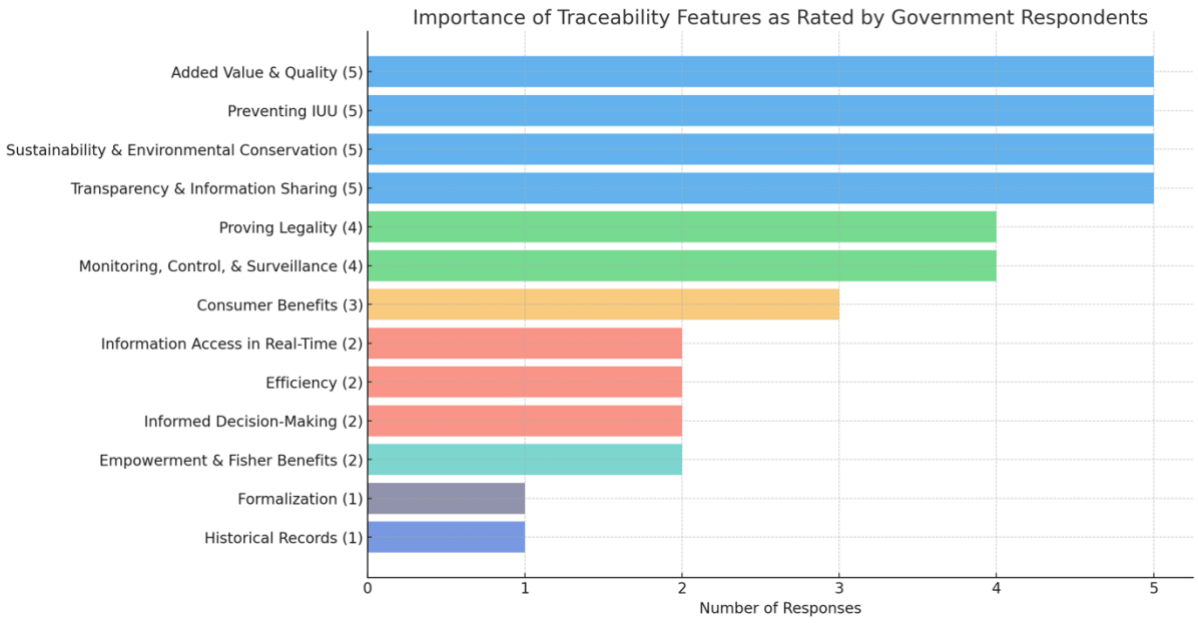
Benefit	**Quote**	**Interviewee**
Sustainability and environmental conservation	*"For protected species it would be a very valuable tool because I think it is the way to force conservation measures to be implemented efficiently. When you have a traceability system, you don't need to demand it from the fisher, but from the buyer."*	Gov. 4
IUU prevention	*"The state is the most interested in this system being the most successful and the most used, because it is not only a matter of tracking what you capture from the sea to the table, but it also prevents the issue of illegal fishing."*	Gov. 7
Increased quality and value	*"There is a value-added benefit for fishers if they can demonstrate that the resource has been captured in a sustainable way. There is also benefit for the state that is protecting the resource, ensuring future work for fishers, and enhancing the country's international image."*	Gov. 3
Information access in real-time	*"It would allow you to know in real time what is happening with the fishery, where they come from, what problems there are, where they are going and what we can propose as policies for the future*."	Gov. 1
Improved monitoring, control, and surveillance	*"The recognition of situations to strengthen the supervision and inspection activities in a manner that is effective, efficient, and timely, which has a favourable impact on decision-making and the*	Gov. 6

	application of corrective measures in the event of alleged cases of illegal activity."	

Source: Own creation.

Figure 6 below summarises all government responses related to the perceived benefits of traceability adoption.

Figure 6. Bar chart of government representatives' responses on the benefits of traceability



Source: Own creation.

Traceability benefits perceived by the artisanal fishing community

Within the artisanal fishing community, fewer benefits were emphasised, and there was a notable absence of repetition across respondents' perceptions of traceability's advantages. Among the highlighted benefits, one recurring theme stood out: safety at sea. This unanticipated advantage resonated with two interviewees, illustrating an unexpected yet crucial dimension brought about by traceability technology. Through registering their fishing trips on the application, fishers can maintain a real-time awareness of their vessel and crew's whereabouts. This information can be shared with family members by granting them access to the user profile on the app. This feature is significant because it addresses the persistent issue of fatalities among fishing crew members during sea expeditions. Having a projected return time and insight into the fishing areas allows concerned parties to promptly raise and

address any alarming circumstances. In practical terms, if a fishing vessel is projected to reach a certain fishing port by a specific date but experiences a delay, both family members and authorities can take swift action due to the baseline data accessible within the traceability system.

The artisanal fishing community recognises the value of heightened oversight and streamlined management of their operational data. This not only empowers them but also enhances their business decision-making processes, potentially leading to increased income. Artisanal 1 captured this sentiment: "...the application confirms with verifiable data, information that fishers used to know empirically. This allows them to share such information with authorities and make decisions based on that data." This consolidation of information offers them a scientific confirmation of their traditional knowledge, transforming it into actionable data for collaboration with authorities and informed decision-making.

Furthermore, the platform fosters improved transparency and communication among fishers, vessel owners, and merchants. For instance, Artisanal 1 elaborated: "... [traceability provides] capacity for fishers, shipowners, and patrons, and in the case of merchants, to know how much that boat caught." This digitised repository verifies historical weather patterns and resource abundance that were previously passed down orally. Consequently, this digitisation facilitates resource management, strategic planning, and even negotiating fair prices with buyers.

See Table 9 for additional perspectives from the artisanal fishing community on the benefits of traceability technology.

Table 9. Perspectives on traceability benefits from interviews with artisanal fishing representatives

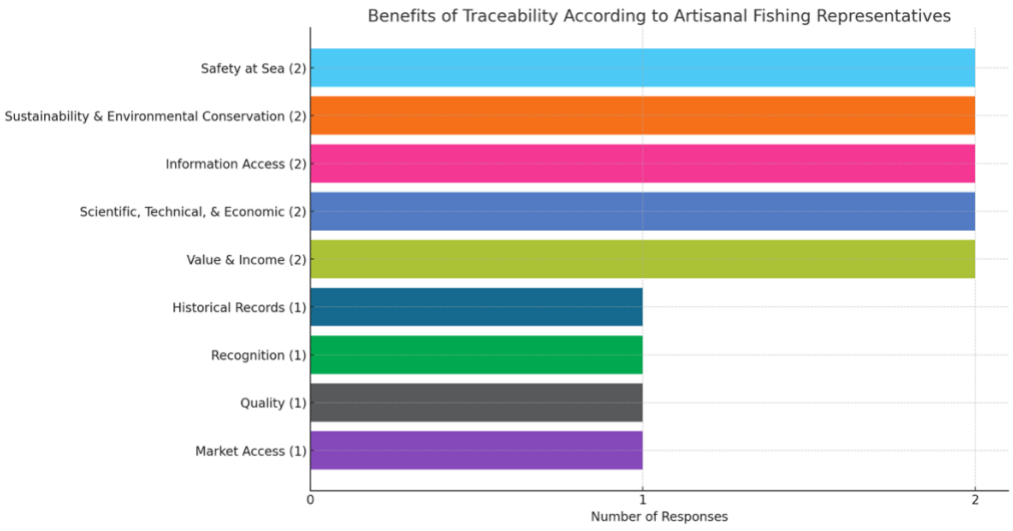
Benefit	**Quote**	**Interviewee**
Safety at sea and capture data	*"They will enter my page on TrazApp and there they can follow me and see when I'm leaving [to fish] and when I'm coming back, as well as how much I capture."*	Artisanal 1

Information in real-time	*"If a fisher wants information like his [capture] weight, we can provide it immediately. One of the main benefits is having the information in real-time."*	Artisanal 5
Historical and financial data management	*"To know how much has been brought and to see what they have earned or produced economically and show it to the crew. And as a historical control to know how he has done in this season and compare with others."*	Artisanal 5
Visibility and recognition	*"Today I fish for a resource, but in the world, no one knows that I caught it. So that product goes as if someone else had caught it and we cannot correct this due to informality. I think the first benefit would be that the product that I fished here in Piura today that is being sold in a month in another country, will say said what boat and what fishers fished it. Then the fisher is going to have recognition."*	Artisanal 6

Source: Own creation.

While Table 9 (above) highlights selected relevant findings, Figure 4 below summarises all fisher responses related to the benefits of traceability systems.

Figure 7. Bar chart of artisanal fishing representatives' views on the benefits of traceability



Source: Own creation.

Traceability benefits perceived by industry

In contrast to the artisanal fishing community, industry representatives demonstrated a heightened awareness of the advantages brought to the fishing sector by traceability technology. This is evident both in the breadth of benefits they identified and the consistency of these benefits across interviews. The most frequently cited benefit among industry interviewees, totalling six mentions, was sustainability and environmental conservation. This unexpected emphasis on sustainability underscores the commitment of industry representatives to ensure the long-term viability of their operations. Industry 5 articulated this perspective: "... if I don't take care of that resource at sea, my business will end... As beautiful as the factory is, it is a useless building. That is why I take care of the resource, because it is profitable for me, it is part of my business." This sentiment reaffirms that a more sustainable resource base is essential for maintaining viable business operations over time.

Economic advantages emerged as the second most frequently mentioned benefit, with five mentions from industry representatives. Industry 8 emphasised that: "... the more certifications you have as a company, the better valued your product will be." This perspective highlights how industry perceives traceability as instrumental for the certification of good practices, ultimately enhancing the economic value of their products. Traceability, in this view, becomes a strategic tool to enhance the market positioning of seafood products.

An intriguing viewpoint on the role of traceability in formalisation was presented by Industry 7: "... before starting the formalisation process, all the information should be collected, because when the formalisation process begins, it does not have the information and begins to collect it, which is where you start to generate disorder..." This industry representative suggests that traceability should have been instituted before the formalisation process, countering the conventional sequence. This perspective adds depth to the relationship between traceability and formalisation, as industry acknowledges the potential benefits of reverse integration (see Chapter 3- Literature Review for more information about the issues around fisheries informality and the formalisation process in Peru).

Export-oriented entities within the industry are cognisant of traceability's significance from a market perspective. Industry 6 articulated their approach as: "... export that information to a traceability system that is tied to the export documents that the client sees..." By intertwining traceability with export documents, these entities enable clients to access comprehensive

information about the product's journey. The desire to convey this narrative underscores the export sector's recognition of traceability's potential to provide added value and align with market expectations.

Table 10 below provides additional perspectives from Peruvian jumbo squid and mahi mahi industry representatives about the benefits of traceability systems.

Table 10. Perspectives on traceability benefits from interviews with industry representatives

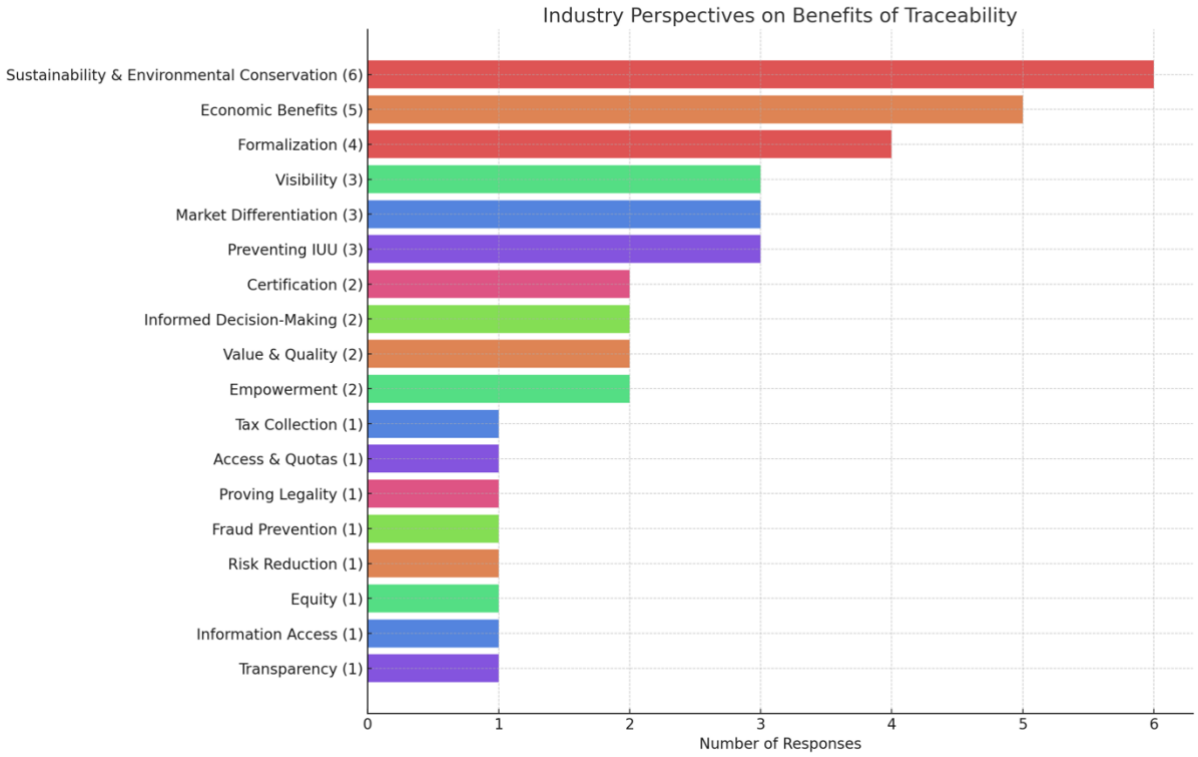
Benefit	**Quote**	**Interviewee**
IUU prevention	*"First, we are going to have a clear idea of the dimension of the activity as well as the need for control, and intervention measures against illegal fishing, and it will allow the state to correct what is not in the right direction."*	Industry 1
Sustainability and environmental conservation	*"Traceability is critical for sustainability and environmental conservation, all this work that has to do with stock assessments, species protection, and dolphin tagging. Traceability allows a proper calculation of fishery products from fishing. So you know if they are meeting the environmental threshold for sustainable fishing."*	Industry 2
Equity improvement	*"Traceability will allow us to identify how the fisher intervenes, how the shipowners intervene, and how the marketers intervene in all this. What value do they add to the product, be it a tangible or intangible value, and how is it that the plants finish completing that valuation of the products; so that each actor gets his slice in a structured way, known from the economic point of view, from the labour point of view, and from the social point of view."*	Industry 9

Formalisation and access to credits	*"Formalisation, which is the birth certificate of traceability, will immediately generate visibility for artisanal fishing, it will generate that the artisanal fisher has a title and has a value. A boat that can be a mortgage guarantee for a loan will have access to credit.*	Industry 1
Reduction of tax evasion	*For the government, there is tax evasion, where millions of dollars, soles and pesos are being lost by this the most fraudulent industry on the planet. Therefore, traceability also improves tax management.*	Industry 2

Source: Own creation.

Table 10 (above) highlights some key quotes related to the main benefits perceived by the industry, while Figure 8 (below) shows all the benefits mentioned by the industry.

Figure 8. Bar chart of industry views on the benefits of traceability



Source: Own creation.

Traceability benefits perceived by ENGOs

ENGOs, as anticipated, emerged as the most vocal proponents of the benefits of traceability, given their role as primary advocates for enhancing fisheries sustainability and governance. Unsurprisingly, the most frequently cited benefit among ENGOs was informed decision-making, voiced a total of thirteen times across the interviewees. A notable example from ENGO 2 articulates this viewpoint: "… [traceability] allows them [the authorities] to make better management decisions because you have the data stream that you actually need... you build that sense of collaboration... to have a real discussion around how to use that data. I believe this is the main potential positive impact of traceability."

The second most prominent benefit was improved monitoring, control, and surveillance. ENGO 5 provided the following insight: "... tools to know where the resource comes from allows them [the authorities] to take proper measures and have an appropriate management... help in making state control more efficient."

Empowerment emerged as a significant benefit, underscored by eight mentions from ENGO representatives. ENGO 6's perspective encapsulated this sentiment: "... traceability empowers the fisher, it empowers the ENGO that is participating, and therefore it empowers everyone tied to the tool. Because, in the end, information is power." This assertion resonates strongly, emphasising the role of traceability in equipping fishers with information to navigate regulations and respond to research. ENGO 1 also highlighted how traceability enhances the visibility of fishers: "... nobody knows you... they talk about numbers, but nobody knows that there is a national fleet... They will not value them as such, if they do not know that they exist." The significance of traceability in elevating fishers' recognition by authorities is highlighted in this assertion. This perspective is substantiated by tangible outcomes, as illustrated by ENGO 1's experience with La Islilla cooperative, where traceability empowered fishers long fishing trips to be recognised and acknowledged by the government, which previously denied that reality.

Table 11 (below) highlights some perspectives from ENGO representatives on the benefits of traceability.

Table 11. Perspectives on traceability benefits from interviews with ENGO representatives

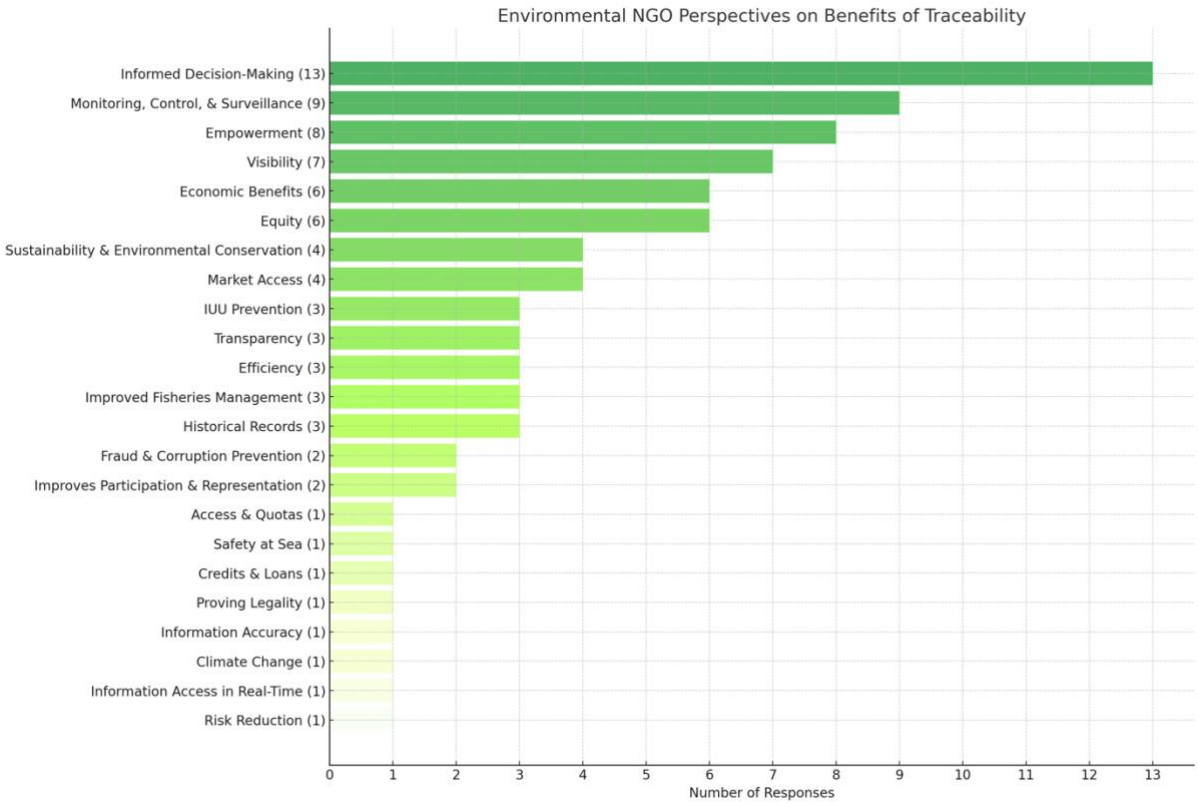
Benefit	Quote	Interviewee
Fisheries sustainability	*"Traceability provides tools to be more aware of what's happening and allows a better management of fisheries from a sustainability standpoint. It allows you to really know what is seasonally produced so that the state has tools to know how much should be captured. Which seasons are not suitable for fishing or take measures about handling species, really knowing what is being produced."*	ENGO 5
Increased collaboration and efficiency	*"It [traceability] can build community, it can build collaboration on things, and it can just help. Traceability can also help streamline needs to make everything easier for the fisher, so that paperwork burden isn't pushed down the line. To just take that lift off them and make it really simple, only collecting what you need. Because now you have SANIPES asking for the same thing as PRODUCE, which DIREPRO is asking for in a different format… And you must send one here and one there and there. [With traceability] you just submit one form, and that data goes to those five different organisations, and it's simple."*	ENGO 2
Improved fleet control	*"Ship owners understood that in that way they could have a bit more control, because that is a fleet in which a ship owner doesn't have only one ship, they have 2, 3, 4; managed generally by one person. And basically, the only communication was the communication by radio with the ship skipper. So, they started themselves to identify the tools for traceability*	ENGO 4

	that could help them have better control of their fleet."	
Fraud reduction	*"By having all that information in order and knowing which fishers are working, which helps eliminate corruption. They are open to objective audits. This system helps you avoid illegal fishing and makes fishing more sustainable. If you have a system that allows you to reduce illegal fishing by preventing the falsification of boat data through a digital system, you have already reduced the stress that fishing can cause through the unrecorded extraction from fishing."*	ENGO 6
Transparency and participation	*"I see transparency as one of the main benefits, in the sense of being able to obtain information. Starting to create a system of traceability in which the fisher is the main producer of the information, or one of the first links in the production of information helps to break the rigid structure that prevents full participation in decision-making or resource management. This is going to help a lot in reducing the number of voluntary or involuntary mistakes in information, which at the same time would contribute to fighting against corruption. So, transparency, participation, corruption [reduction], and better information [are traceability's key benefits]."*	ENGO 9

Source: Own creation.

While Table 10 (above) mentions some key perspectives, Figure 9 (below) compiles all the benefits mentioned by ENGOs.

Figure 9. Bar chart of categorised ENGO representative responses on the benefits of traceability



Source: Own creation.

Similarities and differences of views between sectors on benefits of traceability technology

As the research delved deeper into the perceptions of different stakeholders regarding the adoption of traceability technology in Peruvian fisheries, it became evident that while there were overarching agreements on its benefits, distinct variations in viewpoints also emerged. This section explores these distinctions, revealing the layers of consensus and difference among various sectors – government, artisanal, industry, and ENGOs. This analysis not only highlights the universal appreciation of traceability technology's role in enhancing fisheries management and sustainability but also sheds light on the sector-specific perspectives that shape the overall discourse. The following subsections detail the convergence and divergence of opinions, reflecting on the nature of traceability technology's impact on different stakeholders.

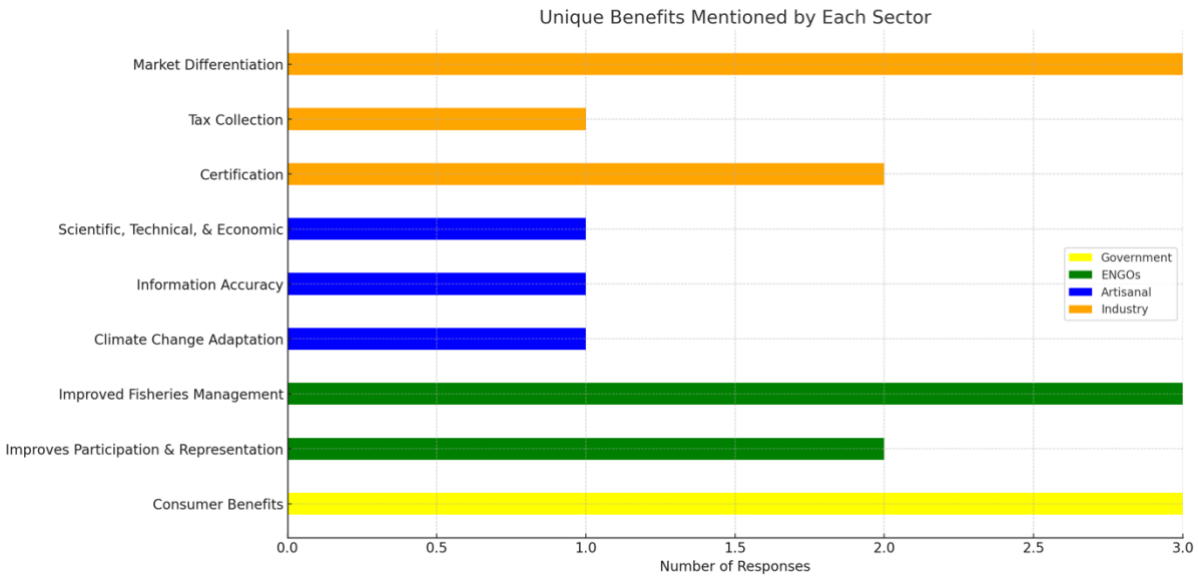
Convergence of opinion: All sectors under study (government, artisanal, industry, and ENGOs) mostly demonstrated agreement on the value of traceability technology in advancing fisheries sustainability and effective governance. This benefit was mentioned by more than four interviewees across all groups, except for the artisanal fishing community, where it was raised once. Similarly, across sectors, the importance of access to real-time information emerged as a shared perception, albeit with no more than two mentions from interviewees in any specific group.

Alignment of perspectives: Convergence extended beyond these fundamental aspects, with notable agreement observed among government representatives, industry stakeholders, and ENGOs regarding traceability's role in curbing IUU fishing, substantiating legality claims, fostering transparency, bolstering empowerment, and enhancing informed decision-making. Furthermore, both fishers and government officials acknowledged the benefits of traceability in augmenting product value and quality. In parallel, ENGOs, industry representatives, and fishers emphasised the importance of increased visibility of fishers facilitated by traceability technology.

Differences of opinion: While there was broad consensus on the advantages of traceability technology, certain differences also surfaced. The limited articulation of specific benefits by the artisanal fishing community may reflect emerging familiarity with such systems for their sector. Nonetheless, across all groups, the recognition of traceability as a tool for fostering sustainability, legality, transparency, and informed decision-making collectively exemplifies the technology's widely shared potential to enhance fisheries governance and elevate stakeholder engagement.

Figure 10 (below) displays the benefits mentioned by only one sector group (government, industry, artisanal fisheries representatives, or ENGOs).

Figure 10. Traceability benefits highlighted by only one fisheries sector group



Source: Own creation.

Summary of the traceability benefits perceived by Peruvian jumbo squid and mahi mahi fisheries actors

In this section, the insights gained from various stakeholder perspectives within the Peruvian jumbo squid and mahi mahi fisheries are synthesised. This overall summary serves to crystallise the understanding of how traceability technology is perceived across different sectors, including government, artisanal fishing communities, the industry, and ENGOs. This section collates the perspectives of these diverse actors, revealing the benefits of traceability as recognised by each group. These insights are key to understand the broader implications of traceability technology for sustainable fisheries management, encompassing environmental, economic, and social dimensions. From government officials' emphasis on sustainability and IUU prevention to the artisanal community's focus on safety and visibility, the industry's commitment to long-term viability, and ENGOs' advocacy for informed decision-making and effective governance, this section offers a view of the diverse yet converging viewpoints on traceability's role in the fisheries sector. The ensuing sections provide an understanding of how each sector perceives and values the various benefits of traceability, highlighting both unanimous agreements and unique sector-specific insights.

Government perspectives: The acknowledgment of traceability technology's benefits resonates within government circles. A minimum of five government representatives

highlighted the following advantages: contribution to sustainability and environmental conservation, IUU prevention, enhanced value and quality, elevated monitoring, control, and surveillance capabilities, increased transparency and information sharing, and access to real-time data. These advantages, as articulated by government officials, underscore a prevailing political intention to endorse and facilitate the adoption of traceability systems within the Peruvian fisheries landscape. These perceived benefits span environmental, societal, and economic dimensions, intrinsically aligned with governmental functions and the pursuit of effective governance.

Sustainability and environmental conservation: This attribute signifies how traceability information fosters optimal resource utilisation, facilitating prudent fishing practices that maximise profitability in the long term, encapsulated in the notion of augmented value and quality. The tethering of IUU prevention to improved MCS, underscores traceability's potential in orchestrating resource-efficient allocation of limited resources, fuelled by real-time data streams.

Artisanal fishing community perspectives: Among the artisanal fishing community, a succinct yet insightful enumeration of benefits emerged, encompassing safety at sea, real-time information access, enhanced data management, and heightened recognition. This articulation implies a growing awareness of how traceability impacts their livelihoods. The overall sentiment towards traceability remains positive, with data's utility perceived both for personal security and informed decision-making.

Visibility and recognition: Of particular significance for artisanal fishers, visibility and recognition address their historical marginalisation. Traceability systems provide newfound prominence for their activities, corroborated by the perspectives shared earlier. Additionally, the assurance of safety at sea and the expeditious access to vital financial data shape the value proposition of traceability for this sector.

Industry perspectives: Industry participants, in their articulate responses, collectively spotlighted sustainability and environmental conservation as paramount. With six mentions, this emphasis reflects industry's commitment to long-term viability. This stems from the industry's understanding that unregulated fishing could jeopardise both resource availability and business continuity. Other traceability benefits underscored by industry encompass IUU prevention, equitable supply chain dynamics, support for formalisation, access to financing,

tax compliance, and risk mitigation. This composite perspective portrays how traceability benefits are recognised not just by the industry but also extend to the government and artisanal fishing community.

Equity improvement and IUU prevention: IUU prevention becomes vital for the industry in terms of stock management and price equilibrium, while equity enhancement resonates through visibility and acknowledgment of various supply chain contributors.

ENGOs perspectives: ENGOs emerged as vocal advocates of traceability, unsurprising given their role in promoting sustainable fisheries management. Foremost among the benefits is informed decision-making, cited thirteen times, wherein traceability data facilitates strategic resource allocation. Improved monitoring, control, and surveillance also found prominence, viewed as tools for effective governance. Empowerment, enhanced collaboration, fraud mitigation, transparency, and broader participation collectively complete the spectrum of benefits underscored by ENGOs.

General agreement: Most interviewees including all stakeholder groups (government, artisanal fishers, industry, and ENGOs) recognised the merits of traceability technology with over four mentions of such merits by each group (with the exception of artisanal fishing community with only one mention) is a testament to its role in improving fisheries sustainability and effective governance. Additionally, across sectors, the recognition of access to real-time information as a benefit reaffirms its integral position, without exceeding two mentions in any particular group. Alignment in viewpoints extends further, as government, industry, and ENGOs are united in recognising traceability's role in IUU prevention, transparency, empowerment, and informed decision-making. This consensus underscores a shared understanding of the present and potential dividends from the integration of traceability systems across all stakeholders.

Perceived disadvantages and barriers to traceability by the government

While there are few perceived disadvantages in adopting traceability systems, a notable exception lies with individuals seeking to persist in illegal activities. Nevertheless, several barriers to the uptake of traceability technologies have been identified, encompassing limited internet access, technology gaps, and challenges in user capacity. Notable misgivings have been articulated within each sector, raising concerns that warrant consideration.

Cost implications: For government entities, cost constitutes a paramount concern. As articulated by Gov. 2, the fiscal considerations loom large: "Receptivity [among fishers] exists, as they recognise the gains from implementing a traceability system. However, resource constraints impede the comprehensive adoption of the necessary measures. It's not just about the fishing domain; investments will be necessitated across various stages of the production chain."

Resistance and illegitimate practices: An inherent concern pertains to the resistance exhibited by those vested in illegitimate practices. Gov. 6 explains: "A potential downside emerges from the reluctance of certain actors who apprehend the exposure of their accustomed illegal conduct. This also extends to individuals rejecting formalisation, driven by various motivations, often rooted in historical patterns of illicit behaviour."

Table 12 (below) highlights government representatives' responses regarding potential challenges and disadvantages in traceability adoption.

Table 12. Perspectives on the potential disadvantages and barriers to traceability adoption shared by government representatives

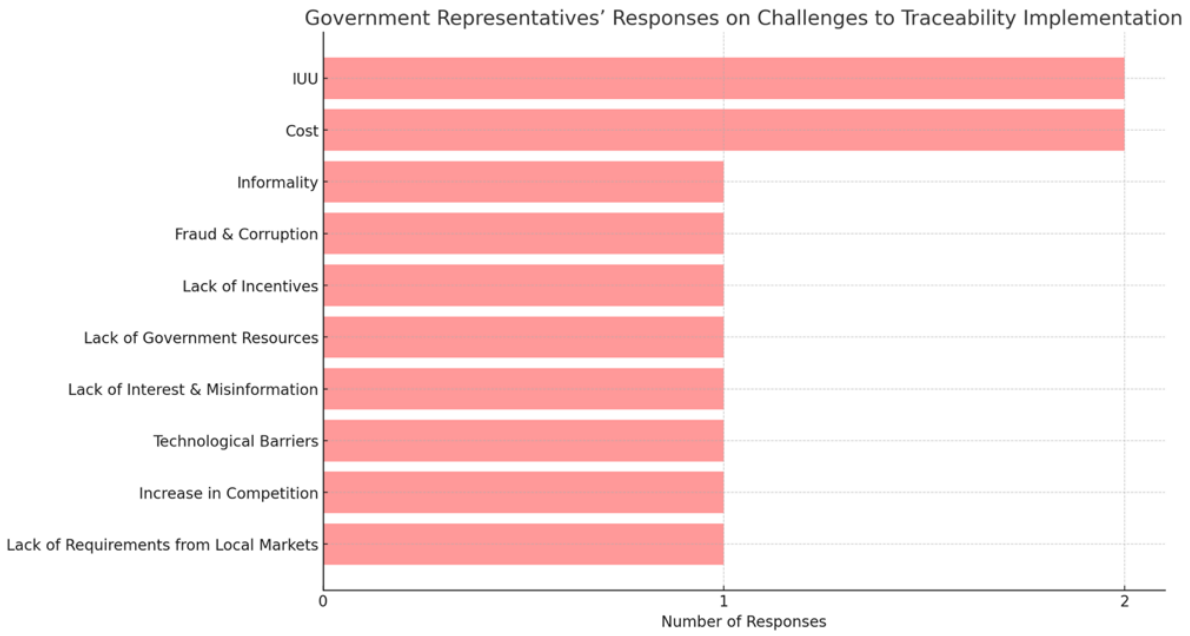
Disadvantage/ Barrier	**Quote**	**Interviewee**
Lack of interest and misinformation	*"There is a lot of misinformation or lack of knowledge, not from everyone, but from many actors in fishing, who think that it is an unfair form of control for fishers. This is because from their point of view, in the 21st century and with years of control or attempted control, they think that the sea is theirs. I always speak of their ancestral fishing traditions, where control for them is not well seen."*	Gov. 3
Increase in competition	*"Something that would worry me about traceability is the fact that this information can be transferred to other vessels, with which it can*	Gov. 8

	increase competition. Because if ten vessels go to an area that is productive, an area or a specific fishing ground and as soon as you know that the resource is traceable, someone starts to look and say: oh, they all come from this area, we are going to put more effort into that area. This could lead to a direct impact on competition for the capture of resources."	
Lack of incentives and technological barriers	*"One of the main barriers is the lack of incentives for traceability. Another point is the technological deficit that many players in the sector have. Many still have a hard time [with technology], so when I tell them: send me a WhatsApp or send me an email, they can't do it. So, we still have a very large gap at the technological level with the users of artisanal fishing, with the fishers, and the shipowners."*	Gov. 8

Source: Own creation.

Figure 11 (below) categorises government responses regarding the challenge or disadvantage to traceability implementation.

Figure 11. Bar chart of government representatives' responses on the disadvantages or challenges to traceability implementation



Source: Own creation.

Perceived disadvantages and barriers to traceability by the artisanal fishing community

From the viewpoint of the artisanal fishing community, several obstacles to the adoption of traceability technology have surfaced. A prevailing impediment is rooted in technology, particularly the challenge of inadequate internet reception, as underscored by two interviewees. Artisanal 1 encapsulated this concern: "Our recurring observation is the hindrance caused by internet limitations. The absence of an antenna supplying instant connectivity renders us unable to utilise the technology. We must seek locations where satellite signals can be captured to facilitate our connection."

Infrastructure deficiencies: Equally consequential is the dearth of port and community infrastructure, as highlighted by an additional two interviewees. Artisanal 6 emphasised this issue: "While the advancements in technology bring about global improvements, it is essential to acknowledge that Peru, in comparison to other nations, grapples with pronounced shortcomings in internet access. If the state contemplates this as a prospective initiative, it becomes pivotal to consider the living conditions specific to each community. Take, for instance, La Tortuga, where basic necessities such as water and roads are lacking, despite the contributions we extend to our nation."

Additional barriers shared by the artisanal fishing community are highlighted in Table 13 (below). It is worth mentioning that no true disadvantages were mentioned when it comes to traceability, only barriers or fears related to its adoption.

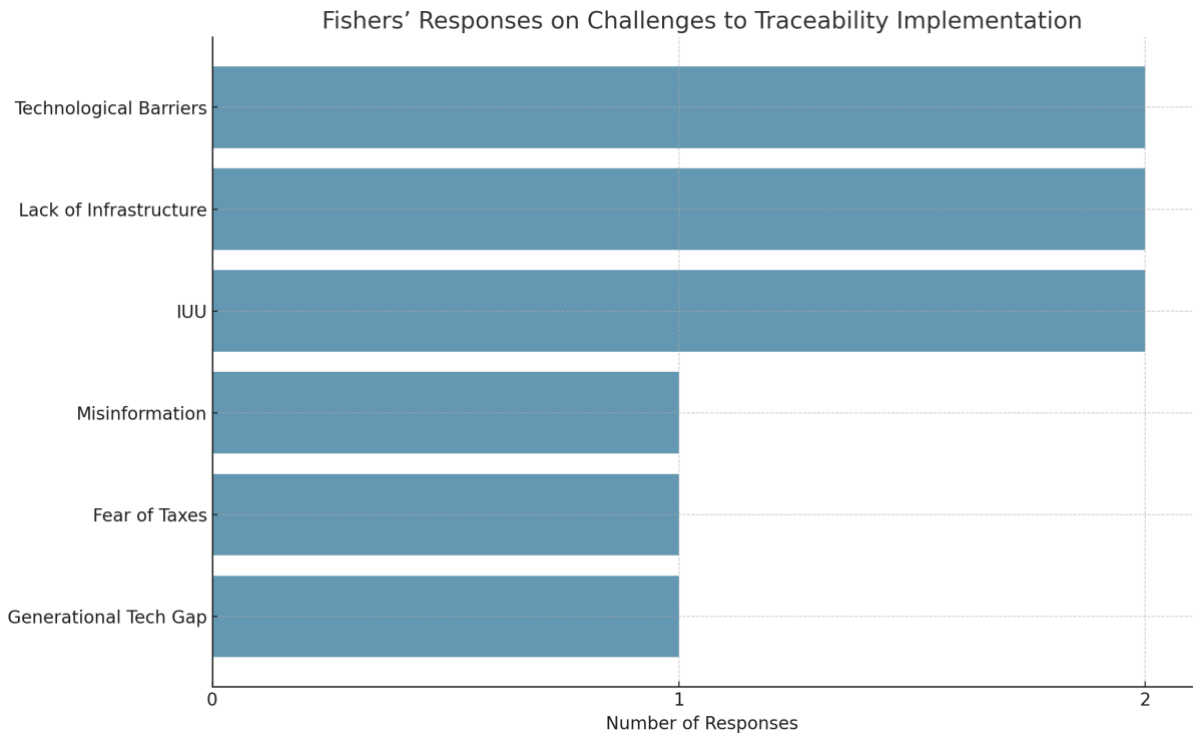
Table 13. Perspectives on challenges to traceability adoption shared by artisanal fishing community representatives

Disadvantage/ Barrier	**Quote**	**Interviewee**
Misinformation and fear of taxes	*"It is not a disadvantage, it is favourable. However, bad leaders tell the fishers not to do traceability because they are deceiving them, that they are going to make them pay more taxes. They want to know how much the fisher earns, so they deceive them. They lie because these bad leaders live off that, they live off lies, they live off slander, and they are not contributors to the system."*	Artisanal 2
IUU	*"For those involved in money laundering, it is not interesting, but for those of us who earn our living honestly, we are interested."*	Artisanal 2
Generational tech gap	*"The issue is that many, because of their age, do not have the training or the knowledge that young people have nowadays, right? So, they say no, this is not for me. I'm with what I've been raised with, with what I've learned."*	Artisanal 5

Source: Own creation.

Figure 12 (below) displays the key disadvantages and barriers highlighted by the artisanal fishing community.

Figure 12. Bar chart of artisanal fishing representatives' responses on the disadvantages or barriers to traceability adoption and implementation



Source: Own creation.

Perceived disadvantages and barriers to traceability by the industry

The standpoint of interviewed industry representatives from the Peruvian jumbo squid and mahi mahi fisheries reflects an absence of perceived disadvantages regarding traceability implementation. Industry 6 offered this view: "Traceability, in my perception, serves as a transparent conduit that faithfully portrays reality and its multifaceted processes. I envision that any negativity within traceability arises from the revelation of detrimental information—be it concerning quality, legality, or informality. Nevertheless, I find no inherent negativity associated with traceability." Similarly, Industry 7 shared this perspective: "I have never regarded the traceability system as a potential source of issues. Traceability inherently encompasses transparency in operational procedures, furnishes comprehensive information to the market, and exercises control over the utilisation of our natural resources. Thus, I discern no attributes within these characteristics that could potentially precipitate difficulties for our operations." Foremost among the industry's discerned disadvantages is the impact on individuals engaged in illicit activities. Industry 1 emphasised this aspect: "The sole drawback pertains to those who are inclined toward unlawful activities or exhibit disinterest in

sustainability. Naturally, for such entities, traceability becomes a substantial impediment, as it nullifies the prospects for unauthorised manipulations."

The perspectives shared by industry representatives regarding the barriers to traceability adoption are encapsulated within Table 14 (below). Further barriers voiced by the industry encompass educational attainment levels, insufficiency of funding for training, the complexity of selecting a technology that accommodates scalability, and a deficiency in governmental capacity for managing an all-encompassing system.

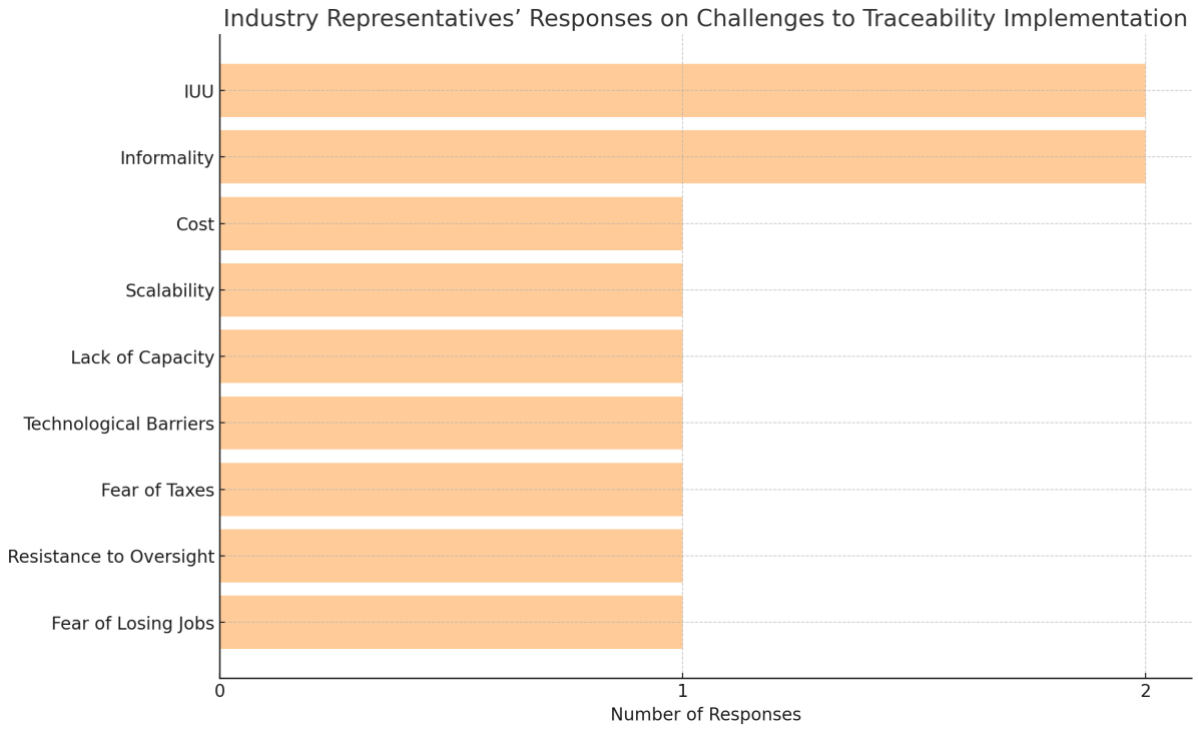
Table 14. Industry perspectives on disadvantages and barriers to traceability adoption

Disadvantage/ Barrier	**Quote**	**Interviewee**
IUU	*"Right now there is a problem, the fishing skippers, the crew, what social benefits do they have? What reality do they have? What is your situation? And there are so many boats that I tell you that they are missing crew members. Then crew members go up without having documents. Then you start to get into another problem of legality. In other words, traceability does not suit them and that means many things."*	Industry 5
Resistance to oversight	*"Unfortunately, there are always actors who do not like order, who seek to evade and sabotage any initiative whose purpose is to find out what they are doing, how they are doing it, and what is the purpose of the activity they are developing. So, when those things come together, it becomes a daunting task to be able to implement an ordering system that allows you to control an activity adequately."*	Industry 7

Source: Own creation.

While Table 14 (above) highlights some industry perspectives on barriers to traceability adoption, Figure 13 (below) provides a summary of the key challenges to traceability mentioned by industry representatives.

Figure 13. Bar chart of industry representative responses on the disadvantages or challenges to traceability implementation



Source: Own creation.

Perceived disadvantages and barriers to traceability by ENGOs

The perspective of ENGOs emphasises certain significant challenges pertaining to the adoption of traceability. According to insights from four interviewees, the primary challenge lies in addressing fishers' apprehensions regarding the utilisation of traceability-derived information. Particularly, two interviewees underscored concerns related to potential fines and taxes. Additionally, two participants accentuated technological barriers as a notable impediment in the process of mainstreaming traceability system adoption.

ENGO 8 offers a distinct viewpoint, highlighting cultural hurdles as the primary obstacles: "Our principal challenge revolves around fear and the reluctance to embrace advancements that

are already being implemented elsewhere—inevitable trends that we cannot avoid, driven by the infeasibility of persistently relying on paper-based methods. The transition to electronic systems is becoming essential. In my view, the obstacles are not of a technical nature; rather, they are predominantly rooted in cultural considerations."

Table 15 (below) summarises the perspectives from ENGOs on perceived disadvantages and barriers to the adoption of traceability.

Table 15. ENGO perspectives on disadvantages and barriers to traceability adoption

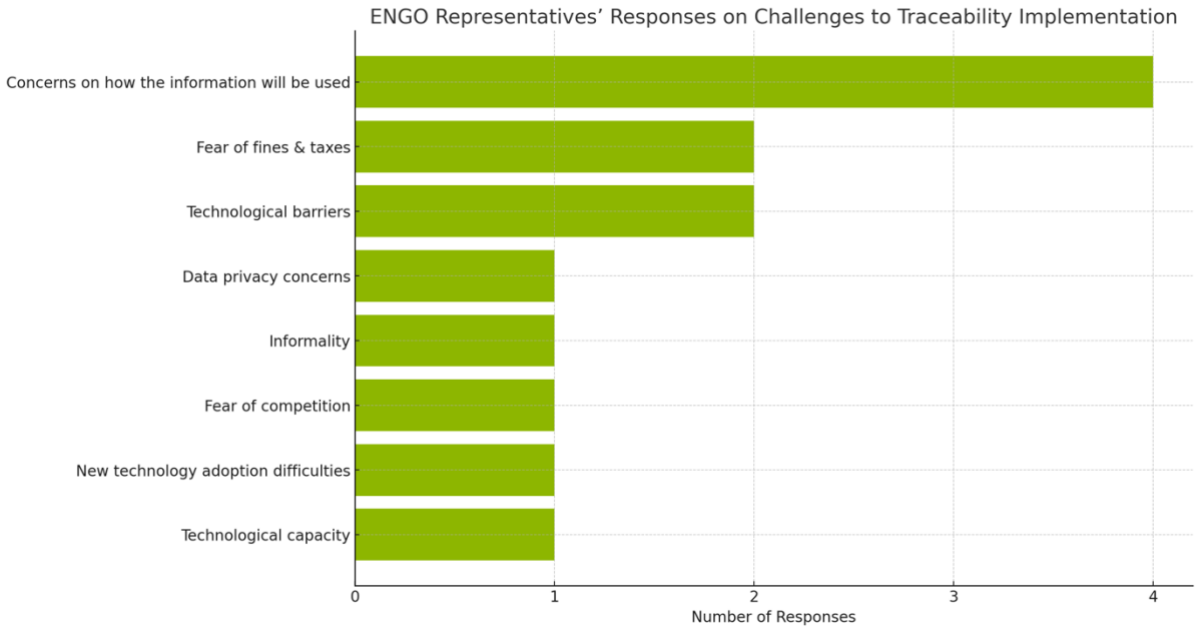
Disadvantage/ Barrier	**Quote**	**Interviewee**
Difficulties in adopting new technology	*"Another thing that I would expect to be challenging is the physical installation of systems on boats and getting people used to that. In my experience, when it comes from a government mandate, and has to happen within a certain period of time, it can cause a lot of confusion; just because people don't know how to use the equipment."*	ENGO 2
Data privacy concerns	*"There are also concerns about things like data privacy and fisher privacy. If you have things like cameras on boats, it's the same issues that folks have had with observers, like, why are you here? What are you doing with this data? What's the purpose of this? So, we've found that if it's not explained well, it can lead to a lot of separation between the groups involved, and some resentment on the part of people who don't know where this data is going."*	ENGO 2
Technological capacity	*"It seems to me that in the Peruvian case, perhaps the topic of access to technologies, not only*	ENGO 10

	access, but also the ability to manage them; and not only the technological capacity, but even being able to analyse the data, see what this type of information can be used for, could be a disadvantage in the case of fishers."	
Fear of fines	*"And that scares them a little, that the government with be able to see the data on what they are producing and who are they buying from, because they don't always buy formal, they also buy informally. There is fear from everyone about providing information, and getting inspected, being subject to more fines, or not knowing if what you do is alright or regulated."*	ENGO 5

Source: Own creation.

Figure 14 (below) summarises the potential disadvantages and barriers mentioned by ENGOs.

Figure 14. Bar chart of ENGO representative responses on the disadvantages or barriers to traceability implementation



Source: Own creation.

Similarities and differences of view between sectors on the disadvantages and barriers to traceability technology adoption

In this section, the examination pivots to the juxtaposition of perspectives among different stakeholder groups regarding the challenges and potential drawbacks tied to the uptake of traceability technology within Peru's jumbo squid and mahi mahi fisheries. The analysis is designed to uncover both the consensus on shared technological barriers, such as the widespread lack of internet connectivity, and the apprehensions that vary by sector. This discourse encompasses the consensus among government representatives, the artisanal fishing community, industry figures, and ENGOs, who collectively acknowledge the technological impediments to traceability. At the same time, it also reveals unique concerns, including the ramifications for actors not in compliance with regulations and the anticipated fiscal implications that might disproportionately impact the artisanal sector. These contrasting views offer an overview of some of the reasons for resistances to traceability.

Common technological barriers: A consensus emerges across all interviewed sectors—government representatives, the artisanal fishing community, industry, and ENGOs—highlighting the presence of significant technological hurdles in the adoption of traceability within Peru's jumbo squid and mahi mahi fisheries. These barriers primarily revolve around the pervasive lack of internet connectivity in numerous locales, coupled with the inherent challenges associated with introducing new technologies to sectors not traditionally accustomed to such demands.

Disadvantage for non-compliant actors: Within the viewpoints of government, artisanal fishing representatives, and industry players, it becomes evident that traceability presents a potential disadvantage solely for those harbouring an inclination toward illicit activities. Participants concur that traceability exposes and curtails activities conducted outside the bounds of legality or sustainability. Industry 1 encapsulated this sentiment, stating that: "… the only disadvantage is for those who want to do illegal activities or for those who are not interested in sustainability. Naturally, for such individuals, it signifies a substantial disadvantage as it terminates avenues for improper conduct."

Apprehensions about taxes: Shared concerns regarding tax implications associated with traceability technology traverse the viewpoints of the artisanal fishing community, industry, and ENGOs. Foremost among these apprehensions is the fear, particularly prevalent in the

artisanal sector, that traceability implementation might trigger increased tax burdens. Artisanal 6, however, voiced an intriguing perspective, expressing their willingness to embrace tax obligations if they yielded reduced corruption: “We do not aim to evade taxes; we are willing to fulfil our tax obligations. However, we seek a streamlined process that entails an annual, comprehensive document that leads us into formalisation and updated compliance, thereby circumventing the impediments currently affecting us.”

In the next section, the potential disadvantages and barriers mentioned by interview participants are analysed.

Summary of the potential disadvantages and barriers to traceability adoption perceived by Peruvian jumbo squid and mahi mahi fisheries actors

As the exploration of traceability technology in Peru's jumbo squid and mahi mahi fisheries progresses, this section analyses the perceived disadvantages and barriers to its adoption, as viewed from the diverse lenses of government, artisanal fishing communities, industry, and ENGOs. This section aims to identify the commonalities and disparities in these perspectives, shedding light on the challenges and apprehensions that accompany the sustainability transition towards electronic traceability systems adoption in these Peruvian fisheries. From technological hurdles like internet connectivity issues to concerns about the potential for increased taxation, this analysis provides an intricate view of the hurdles facing different sectors. The insights gathered here are instrumental in understanding not only the perceived drawbacks of traceability technology but also the underlying fears and resistance that might hinder its effective implementation. This understanding of barriers, including the disadvantages for non-compliant actors and the shared misgivings about tax implications, underscores the complexity of transitioning to more sustainable fisheries practices and effective governance. By analysing these views, we gain a deeper appreciation of the multi-layered challenges encountered by various stakeholders in the adoption of traceability technology.

Government’s perspective: Government representatives identified several barriers and disadvantages to implementing traceability in Peruvian fisheries. These notably include the fiscal burden of adoption across production stages, as well as resistance from those engaged in illegitimate practices who fear exposure. Additional challenges include misinformation and a lack of interest due to perceived threats to traditional practices and hesitations about

regulatory controls, concerns about inadvertently intensifying competition through revealing productive fishing areas, and technological barriers particularly among artisanal fishers. The synthesis of these issues presents a complex array of economic, behavioural, and technological hurdles, demanding a carefully coordinated approach to enable effective traceability adoption.

Industry perspective: Industry representatives predominantly view traceability without significant disadvantages. Instead, they emphasise challenges in the technology's implementation within artisanal jumbo squid and mahi mahi fisheries. Challenges highlighted include informality and IUU fishing, resistance to oversight from those accustomed to operating covertly, limited education levels leading to technology unfamiliarity, scarcity of funds for training, scalability issues in choosing suitable technology, and governmental capacity constraints for comprehensive system management. These barriers collectively impede efficient traceability adoption. Notably, the perceived disadvantages largely reside with those benefiting from secrecy of certain illegal fishing activities—traceability inherently conflicts with such practices.

Artisanal fishing community: In contrast to recognising true disadvantages, the artisanal fishing community identifies several barriers and concerns associated with traceability. Challenges encompass a lack of internet and infrastructure, misconceptions and concerns about taxes, fears of IUU implications, and generational technological disparities. While addressing infrastructure challenges and misinformation is feasible, resolving the apprehension about IUU implications requires robust awareness campaigns and capacity-building efforts. Notably, the artisanal sector's concerns indicate solvable issues rather than insurmountable disadvantages.

ENGOs: ENGOs primarily outline fisher anxieties about traceability information utilisation. The primary misgivings include the possibility of fines and taxes. The presence of technological barriers, notably among older generations unfamiliar with new technologies, also surfaces. Furthermore, data privacy concerns, regarding both information usage and sharing, constitute another obstacle.

Shared themes: Collectively, across all sectors, a singular disadvantage emerges—traceability's inconvenience to those reliant on clandestine practices. Barriers, however, span technological and human realms. These encompass the generational technological gap,

limited internet accessibility, privacy fears, and resistance from individuals accustomed to illegal operations. It is worth noting that these challenges are resolvable through proper infrastructural development, training, awareness campaigns, and technological adaptations.

5.1.2 Summary of findings under theme 1: Understanding the transition to electronic traceability systems (RQ1)

This section synthesizes the key findings related to the adoption of electronic traceability systems within the Peruvian jumbo squid and mahi mahi fisheries, addressing the central research question (RQ1) and its sub-questions. The emergence of traceability technologies, the niches where these innovations are gaining traction, and the broader regime's response to these changes are explored through detailed narratives from diverse stakeholders. These findings are contextualized within the MLP framework, which aids in understanding the complex interplay between technological adoption and systemic shifts in fisheries governance. By examining the drivers, the momentum within specific niches, and the institutional reactions, this section provides a view of the transition toward sustainable fisheries practices and effective governance facilitated by traceability.

5.1.2.1 Subtheme 1.1: Emergence and drivers of traceability adoption (RQ1a)

The data reveal that the emergence and adoption of traceability technology in the Peruvian fisheries are primarily driven by external market pressures, particularly from major import markets like the United States, Europe, and Japan. Stakeholders recognise that adapting to these international requirements is not just about compliance but also about securing a competitive edge in the global market. Interviews with industry representatives highlighted that the evolution of market requirements has necessitated the adoption of traceability to ensure product provenance and quality. Government and ENGO participants also noted the regulatory push as a critical driver, catalysed by international conventions and local policy adaptations aimed at sustainable fisheries management.

5.1.2.2 Subtheme 1.2: Niches where traceability is gaining momentum (RQ1b)

Traceability systems are increasingly being adopted in specific niches within the fisheries sector that are directly linked to export-oriented segments. The adoption is seen as a strategic response to meet international standards that dictate market access. Notably, the segments of the industry involved in exporting to stringent markets have been the quickest to adopt and

adapt to these technological demands. Artisanal cooperatives, under the guidance and collaboration with ENGOs like WWF and local government mandates, have begun to implement traceability to maintain their license to operate, demonstrating a bottom-up approach to adoption.

5.1.2.3 Subtheme 1.3: Regime response to the emergence of traceability (RQ1c)

The regime, consisting of the existing institutional and policy frameworks within the fisheries sector, has shown a varied response to the emergence of traceability technology. On one hand, there is significant support for traceability as a means to enhance monitoring and compliance, particularly from government bodies tasked with enforcing fishing regulations and managing fish stocks sustainably. On the other hand, there are perceived challenges and resistance, primarily from parts of the sector entrenched in traditional practices or those that benefit from less transparency. Concerns about the cost of implementation, the complexity of integrating new systems, and the potential disruption to existing practices were commonly cited by stakeholders across the board.

5.1.2.4 Integration of findings with the MLP framework

The findings under Theme 1 align well with the Multi-Level Perspective (MLP) on sustainability transitions, which frames traceability as a niche innovation impacting the broader regime of fisheries governance. The pressures from international markets and regulatory bodies can be seen as landscape factors that are influencing regime shifts, pushing the fisheries sector towards more sustainable practices through the adoption of traceability. This shift is not just technological but also socio-economic, involving changes in practices, stakeholder relationships, and governance structures.

5.2 RQ2: What are the contributions of ENGOs and government structures in the transition to electronic traceability systems in Peruvian jumbo squid and mahi mahi fisheries?

In the journey towards the adoption of traceability technology in Peruvian fisheries, ENGOs emerge not merely as external observers but actively participating entities, clearly influencing the transition. **Theme 2: Contributions of ENGOs and government structures in the transition to traceability**, steers the exploration towards understanding the roles, contributions, and

interactive dynamics that ENGOs manifest within the complex web of fisheries stakeholders in contribution to RQ2 (see Box 1. Research questions).

Subtheme 2.1: ENGO engagement in traceability uptake, the following subsections aim to clarify the ways in which ENGOs engage, collaborate, and occasionally clash with various stakeholders - government bodies, the artisanal fishing community, and industry players - within the context of traceability technology promotion and adoption. From perspectives of shared goals to instances of ideological and strategic discord, the ensuing narratives lay bare the complex, and at times, contentious relations that percolate through the endeavour of technological advancement for fisheries sustainability and governance in response to RQ2a.

Further unfolding these relationships, **Subtheme 2.2: ENGOs' influence in the sustainability transition to traceability**, endeavours to tease out the tangible impacts that ENGOs imprint on the trajectory of traceability technology adoption, describing their strategic involvements, advocacy, and ground-level interventions, in contribution to RQ2b.

Lastly, navigating into the bureaucratic and institutional labyrinths, **Subtheme 2.3: Government impact on traceability adoption**, sheds light upon the ways governmental structures, policies, and regulatory frameworks shape, facilitate, and occasionally impede the adoption of traceability technology within the fisheries landscape. Engaging with diverse perspectives and varied experiences, this exploration seeks to illuminate the reality wherein ENGOs operate, negotiating with, influencing, and at times, being shaped by, the dynamism inherent within the interplay of technological adoption and sustainability and governance pursuits in the fisheries sector.

5.2.1 Theme 2: Contributions of ENGOs and government structures in the transition to traceability (RQ2)

As traceability technology evolves through the landscape of the Peruvian jumbo squid and mahi mahi fisheries, the role of landscape actors takes centre stage in Theme 2. This theme examines the influence of ENGOs and government structures, spotlighting their contributions to the transition towards traceability adoption. It explores how ENGOs transform from mere stakeholders into active development intermediaries, shaping policies, driving advocacy, and embedding sustainability and good governance within fisheries. It also considers co-operation between government stakeholders and ENGOs, tracing their collaboration, mutual

perceptions, and challenges as they collectively steer the ship of traceability adoption. Amidst these interactions, voices emerge – from artisanal fishing communities to industry players – each contributing to the discourse that is reshaping the foundations of sustainable fisheries management. This theme navigates the corridors of influence, collaboration, and transformation, offering an understanding of the forces that propel the transition towards traceability within Peruvian fisheries.

5.2.1.1 Subtheme 2.1: ENGOs' engagement in traceability uptake (RQ2a)

ENGOs play a pivotal role in advancing fisheries sustainability and effective governance in Peru through diverse strategies, ranging from engagement and promotion of specific fisheries like jumbo squid and mahi mahi, to driving certification via FIPs. They advocate best practices and technologies to mitigate ecological impacts, alongside efforts aimed at refining fisheries regulations with direct implications for fishers, such as the ongoing formalisation process. ENGOs have transitioned from being primarily 'honest brokers,' to 'development intermediaries' (F. Lugo-Mulligan, personal communication, May 21, 2022), signifying a shift in their organisational identity. In the context of traceability adoption, ENGOs hold a crucial position in disseminating international experiences, raising awareness about market prerequisites, elucidating traceability's benefits, and formulating policy recommendations. Their involvement extends to the creation, enhancement, and implementation of traceability systems, combined with capacity building efforts and developing interoperability agreements with existing public and private systems.

Government perceptions on ENGO roles

Government stakeholders acknowledge the substantive influence of ENGOs in traceability promotion and adoption within fisheries. According to Gov. 5, ENGOs have assumed a leading role by providing expert guidance, disseminating international practices, and proposing viable strategies. Gov. 5's affirmation underscored a progressive attitude towards ENGO contributions in shaping and facilitating electronic traceability systems implementation. Gov. 6 emphasised the vital role of civil society organisations, highlighting their support in the formalisation process. This recognition resonates with the sentiment that ENGOs aid in behavioural transformation among fishers, fostering sustainable hydrobiological resource management. The cooperative interaction between PRODUCE and ENGOs reflects a shared

goal of developing more effective traceability and sustainable fisheries management practices.

Artisanal fishing community perspective on ENGOs

ENGOs have made significant strides in raising awareness about traceability's advantages among the artisanal fishing community. By delivering capacity building initiatives on electronic traceability system usage and incorporating feedback for system enhancement, ENGOs have empowered fishers to embrace quality improvements in their fishing practices. Artisanal 6's testimony expressed gratitude for ENGO support, acknowledging their transformative impact on both individuals and communities.

Industry's view on ENGO relations

Historically, interactions between ENGOs and the private sector have been characterised by apprehension stemming from differing interests. Industry stakeholders have, at times, displayed reluctance to engage due to perceived criticism from certain ENGOs. However, over time, viewpoints have evolved, fostering greater collaboration between the two sectors. Industry 1 underscored the catalytic role of ENGOs in addressing implementation challenges and bolstering traceability management. This transformation from scepticism to collaboration underlines the importance of building mutual trust. This has been achieved by identifying areas of collaboration based on mutual interests and getting to know the individuals behind the organisations or sectors.

A clear example of where this trust has been strengthened is the Marine Stewardship Council (MSC) certification programme that has been established between ENGOs and the fishing industry in Peru (see Section 2.5 The MSC and FIPs of Chapter 2).

ENGOs' perspective on their relationships

ENGOs are recognised by all sectors—industry, government, and artisanal fishing communities—for their pivotal role in traceability advancement. ENGOs serve as catalysts for change and intermediaries, channelling distinct voices into the decision-making arena. ENGO 8's characterises the different ENGO roles within the spectrum of government and private sector, emphasising that diverse ENGOs contribute complementary strengths. ENGO 6 underscores the significance of personal relationships with government authorities to

expedite progress, highlighting that meaningful change often emerges behind closed doors. In the context of fishers, the importance of cultivating trust through personal connections is reiterated. ENGO 2 accentuates the role of ENGOs as amplifiers of voices, thereby ensuring inclusivity and democratic representation within decision-making processes. This emphasis on inclusion aligns with ENGOs' intrinsic mission to provide a platform for unheard perspectives.

ENGOs emerge as drivers of traceability promotion and adoption in Peruvian fisheries, celebrated for their role in building awareness, sharing international experiences, and advocating for necessary capacities. Across the spectrum of stakeholders, ENGOs are valued for their assistance in meeting legal requirements, imparting knowledge, and capacities, as well as advocating for artisanal fishers' voices. This recognition underscores the critical role of ENGOs as catalysts for positive change in the fisheries sector.

5.2.1.2 Subtheme 2.2: ENGOs' influence in the sustainability transition to traceability (RQ2b)

The aim of this section is to consider scenarios where ENGOs can significantly influence the transition to traceability adoption in Peruvian jumbo squid and mahi mahi fisheries.

Government's perception of ENGOs' role and influence

Regarding funding, Gov. 1 highlighted that "[E]NGOs play a pivotal role due to their access to funds. These financial resources are vital for project execution, either from international cooperation or obtained through the National Programme for Innovation in Fisheries and Aquaculture [PNIPA]." Evidently, the financial capacity of ENGOs shapes their perceived influence. In shedding light on ENGOs' role in awareness, Gov. 4 noted that "ENGOs have been actively promoting measures proposed by the United States' protection act. Their active role in advocating these measures and the subsequent implications for our nation surpasses that of the government." Clearly, ENGOs' contributions to creating awareness are valued. Gov. 4 also pointed out the challenge of aligning international conservation agendas with the local context: "ENGOs often bring global conservation agendas that might not fit our reality. Adapting these global schemes to our context is key for their effectiveness." Gov. 1 emphasised that at times, ENGOs' positions may lead to disagreements: "ENGOs occasionally take sides on certain matters, resulting in conflicts." This illustrates that ENGOs' stances can indeed hold sway.

Artisanal fishers' perspective on ENGOs' role and influence

While Artisanal 2 stressed the advisory role of ENGOs, he also underlined the boundary of their influence: "ENGOs should be mindful of their non-governmental status, indicating that they can provide suggestions and assistance, but not impose decisions." However, Artisanal 4 articulated the need for ENGOs to advocate more strongly: "ENGOs must move beyond simply warning to demanding action. This shift is crucial to determine the actual impact of their efforts." On the funding aspect, Artisanal 1 offered a strategic suggestion: "ENGOs should allocate a substantial portion of project funds to benefit the fishing community. This approach not only strengthens the community but also solidifies the community's trust in the [environmental] NGO's initiatives."

Industry's view of ENGOs' role and influence

Industry 1 praised ENGOs as sources of knowledge and catalysts for mindset shifts: "ENGOs serve as vehicles for knowledge transfer, inducing a change in perspectives and a realisation of the fundamental need for traceability. Their role is instrumental in fostering consciousness across the production chain." Industry 4 stressed the need for solutions-oriented guidance: "ENGOs must not only critique but also provide actionable solutions. Practical suggestions that draw from international experiences are paramount in encouraging industry improvements." Industry 5 highlighted ENGOs' potential in drafting regulations: "ENGOs could contribute significantly by aiding in the formulation of laws and administrative structures. Their impartial stance garners credibility, making them valuable in regulatory matters." Encouraging empathy, Industry 1 emphasised the significance of effective communication: "Empathy is paramount for ENGO officials. Effective communicators who exude professionalism, confidence, and empathy can dispel misconceptions and doubts regarding the NGO's intentions."

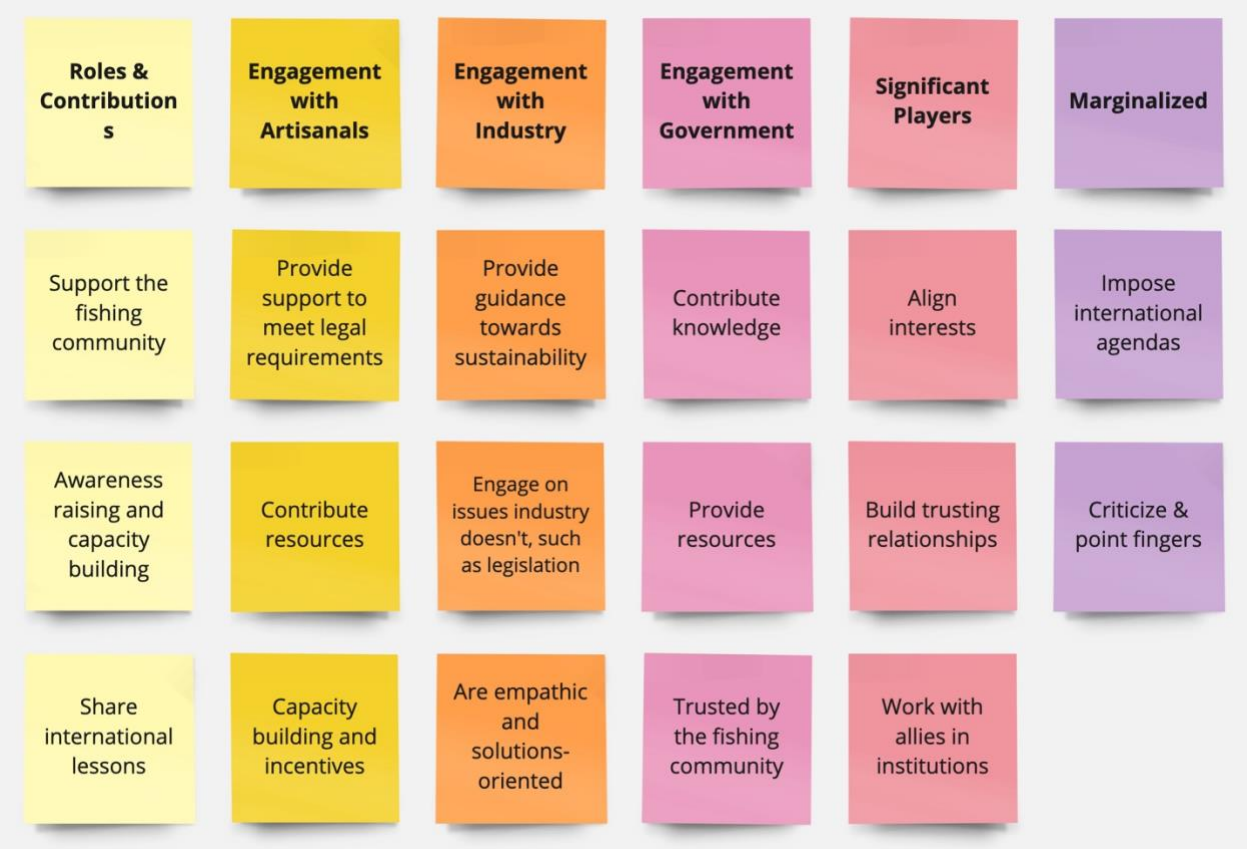
ENGOs' perspective on collaboration with government

ENGO 1 underscored the necessity of aligning with government priorities: "ENGOs should identify government priorities and tailor their initiatives accordingly. Collaborating on issues aligned with the government's interests can enhance impact." Emphasising the role of funding, ENGO 2 explained: "ENGOs can offer their expertise when the government lacks

specific skills or resources. Sometimes, the government's need for external support can lead to effective collaboration." ENGO 5 highlighted the importance of offering solutions in line with government needs: "ENGOs should present ideas that resonate with the government's agenda. This approach ensures that proposed solutions align with government priorities."

Please see Figure 15 (below) for further information on the roles and contributions of ENGOs as perceived by the different sectors that were interviewed.

Figure 15. Roles and contributions of ENGOs according to interview participants



Source: Own creation.

The research reveals that ENGOs thrive when they align their efforts with local needs, build trust through relationships, and adapt international agendas to the local context. Gaining government consent, securing financial resources, and leveraging valuable insights are all actions that enhance ENGOs' influence. However, the ability of ENGOs to exert a meaningful impact does not solely rest on their alignment with governmental perspectives. Indeed, there is a significant role for ENGOs to challenge and offer relevant critique, serving as a check on

power and advocating for environmental integrity when governmental policies do not align with sustainability practices.

It is this balance between cooperation and constructive critique that underpins the effectiveness of ENGOs. Their capacity to engage in open dialogue and present evidence-based alternatives is crucial for catalysing change and ensuring accountability. Conversely, when ENGOs' positions are opposed to government interests or are perceived as overly critical without proposing viable solutions, their influence may be marginalised. Therefore, a strong, solutions-focused stance, coupled with the willingness to offer rigorous critique, when necessary, is pivotal for ENGOs to wield meaningful impact and foster sustainable outcomes.

5.2.1.3 Subtheme 2.3: Government impact on traceability adoption (RQ2c)

The landscape of fisheries governance in Peru involves numerous government bodies, including PRODUCE, SANIPES, DICAPI, IMARPE, and DIREPROs, among others. These institutions often face challenges due to a lack of internal and inter-institutional coordination, compounded by frequent changes in personnel. The result is a range of issues regarding fisheries governance, such as conflicting regulations, duplication of efforts, absence of clear vision, and even regulations being disregarded due to changing personnel as highlighted by the research participants.

Government's perspective on regulations

Gov. 4 highlighted the shortcomings of fisheries regulations: "In Peru, rules are often issued without a clear implementation plan. Lack of monitoring and accountability further hampers progress. Although conservation agreements exist, their execution lacks clarity and oversight, hindering their effectiveness." In a similar vein, Gov. 3 acknowledged the limitations in executing regulations: "The gap between written regulations and actual enforcement is substantial. While regulations exist, capacity constraints impede proper execution." The case of contradictory regulations was exemplified by Gov. 1, who pointed out the complications arising from differences between central and regional government regulations: "Conflicting norms between central and regional governments created challenges during formalisation. These contradictions hindered the smooth implementation of regulations, causing confusion among stakeholders."

Artisanal fishing community's view of regulations

Artisanal 1 offered insights into the struggles of the fishing community in adhering to regulations, particularly in the formalisation process: "The formalisation process imposes significant costs and efforts on us, the fishers. Despite substantial progress, we encounter issues like unnecessary tilt tests, illustrating the complexities faced by fishers." Artisanal 4 linked traceability to formalisation and fleet organisation: "For us, traceability is crucial for formalisation and subsequently, organising fishing fleets. Although regulations exist, their implementation remains questionable, especially in cases like vessel licenses."

Industry's perspective on regulations

Industry 5 addressed the issue of regulations: "The inconsistency between regulations and actual control is evident. Regulatory intentions rarely align with real-world practices, contributing to a state of disorder."

ENGOs' perspective on regulations

ENGOs also noted the impact of conflicting regulations on traceability efforts. NGO 1 highlighted the consequences of non-compatible regulations: "Incompatible regulations across institutions impede effective processes like traceability. The lack of clarity within each institution's regulations is a major impediment."

Challenges in government capacity, coordination, and corruption

The lack of coordination between central and regional governments has been flagged by research participants as a significant hurdle. Gov. 1 emphasised the need for clarity in roles and responsibilities: "The ambiguity between central and regional government roles often results in last-minute validations. Ensuring consistent participation of all stakeholders is pivotal." Institutional weaknesses were noted by Industry 1, particularly in regional governments: "Institutional fragility, especially in regional governments, is apparent. Insufficient training and corruption plague these institutions, impeding effective governance." Artisanal 4 echoed concerns about corruption: "Regional government bodies like DIREPRO often remain ineffective and ornamental. Corruption and lack of fieldwork exacerbate the problems."

In essence, the government's role in fisheries regulation is marred by challenges like conflicting regulations, inadequate implementation, and limited capacity. These issues hinder effective governance and contribute to the alarming rise of the informal fishing sector.

5.2.1.4 Summary of findings under theme 2: contributions of ENGOs and government structures in the transition to traceability (RQ2)

This section provides a summary of the findings associated with Theme 2, which addresses RQ2: "What are the contributions of environmental non-governmental organisations (ENGOs) and government structures in the transition towards electronic traceability in the Peruvian artisanal jumbo squid and mahi mahi fisheries?" Exploring the roles and impacts of these stakeholders, the discussion is structured into three subthemes: ENGOs' engagement in traceability uptake (RQ2a), their influence on sustainability transitions towards traceability uptake (RQ2b), and the impact of government structures on the adoption of traceability systems (RQ2c). Through these subthemes, the analysis highlights how ENGOs leverage their resources and networks to foster sustainable practices and robust governance, while it also scrutinises the complexities and challenges posed by government actions in regulating and facilitating traceability initiatives. This inquiry not only sheds light on the roles played by these actors but also uncovers the dynamics between their global ambitions and local implementations, contributing to the understanding of governance in the fisheries sector.

Subtheme 2.1: ENGOs' engagement in traceability uptake (RQ2a)

ENGOs have emerged as facilitators in the transition to traceability by leveraging their expertise and international networks to promote sustainable practices and effective governance in the fisheries sector. They play roles, from advocacy and policy influence to directly participating in the development and implementation of traceability systems. Their efforts are particularly focused on enhancing regulatory frameworks and fostering collaboration across sectors, ensuring that traceability systems are not only adopted but also effectively integrated into the fisheries management practices. Government representatives appreciate ENGOs for their technical guidance and strategic insights, which have been crucial in shaping the adoption and implementation strategies of traceability systems. Artisanal fishers acknowledge ENGOs for their capacity building initiatives, which have significantly improved local understanding and operation of these systems.

Subtheme 2.2: ENGOs' influence in the sustainability transition to traceability (RQ2b)

ENGOs influence the sustainability transition by actively participating in the policy-making process, facilitating the adoption of best practices, and ensuring that traceability systems align with international standards. Their ability to bring financial resources to the table enhances their influence, allowing them to pilot projects and drive innovation within the sector. However, their influence is sometimes seen as double-edged; while they are pivotal in driving change, there are challenges in aligning their global conservation agendas with local realities, occasionally leading to conflicts with governmental and industry stakeholders. Despite these challenges, their role is largely seen as positive, with their efforts leading to advancements in regulatory frameworks and operational practices in the fisheries sector.

Subtheme 2.3: Government impact on traceability adoption (RQ2c)

Government structures play a crucial role in the regulatory oversight and facilitation of traceability systems. However, findings indicate a fragmented approach to governance, with frequent misalignments between different government bodies and levels of administration, which complicates the regulatory landscape. This often leads to redundancies and inefficiencies that can complicate the adoption and effective implementation of traceability systems. The lack of coordination and capacity within government institutions, coupled with challenges in corruption and resource allocation, further complicates the effective governance of traceability adoption. Nevertheless, when government actions are well-coordinated and clearly communicated, they significantly enhance the effectiveness and acceptance of traceability systems within the fisheries sector.

These findings directly respond to RQ2 and its sub-questions by illustrating the dynamic roles and interactions between ENGOs, government structures, and other stakeholders in the adoption of traceability systems. ENGOs are shown to be crucial in bridging gaps between international standards and local practices, while government actions and policies are pivotal in creating an enabling environment for the adoption of these systems. The complexity of these interactions highlights the need for continued collaboration and dialogue among all stakeholders to ensure the successful integration of traceability systems into Peru’s fisheries management practices.

5.2.2 Comparative Analysis of Niche, Regime, and Landscape Factors in the Jumbo Squid and Mahi Mahi Fisheries

The findings of the research demonstrate that the adoption of electronic traceability systems in Peru's jumbo squid and mahi mahi fisheries is shaped by distinct and overlapping factors at the niche, regime, and landscape levels. This section summarises these factors, highlighting the similarities and differences between the two fisheries. By doing so, it provides insights into how these dynamics influence traceability adoption using the sustainability transitions MLP framework. See Table 16 below for further details on how the MLP applies to these fisheries.

Table 16. Niche, regime, and landscape factors affecting the jumbo squid and mahi mahi fisheries

MLP Level	Jumbo Squid	Mahi Mahi	Similarities/Differences
Niche	Pilot projects supported by ENGOs (e.g., TrazApp); focus on addressing informality and IUU fishing	Pilot projects also led by ENGOs; focus on enhancing export market access and certifications	Both rely on ENGO support for pilot projects led by FIPs and artisanal fishing cooperatives
Regime	Predominantly informal sector; significant issues with IUU fishing and outdated regulations	Significant bycatch concerns, but regulations have been recently updated	Sustainability and governance issues affect both fisheries, but mahi mahi benefits from a recently updated ROP
Landscape	Driven by international market pressures for sustainability, including the EU and Japan market regulations	Heavily influenced by export market requirements, particularly the U.S. SIMP	Both fisheries face similar landscape pressures, but mahi mahi has increased pressure due to US border rejections

Source: Own creation.

The comparison reveals some distinctions and many commonalities between the two fisheries. Both fisheries operate under significant international market pressures that drive

the need for traceability, with the U.S. SIMP playing an important role in shaping adoption efforts in the mahi mahi fishery. While the jumbo squid fishery, characterised by an outdated ROP and pervasive IUU fishing, faces greater challenges in achieving compliance.

This comparative analysis underscores the need for context-specific strategies that account for the structural and institutional differences between fisheries. By addressing these nuances, stakeholders can more effectively promote the adoption of electronic traceability systems and advance sustainability in Peru's fisheries sector.

5.3 Synthesis of insights: Tracing the pathways to traceability adoption to improve fisheries sustainability and governance of the Peruvian jumbo squid and mahi mahi fisheries

In this chapter, the complex scenario of the transition to traceability technology within the Peruvian jumbo squid and mahi mahi fisheries was explored. Through the examination of stakeholder perspectives, insights into the challenges, benefits, and dynamics that shape the adoption of traceability systems have been gained. The viewpoints of government authorities, artisanal fishing communities, industry representatives, and ENGOs have clarified the complex web of considerations that surround this transition.

These findings underscore the shared recognition across stakeholder groups of the potential benefits of electronic traceability systems. The alignment on the significance of improved fisheries sustainability and governance highlights a commitment towards fostering positive change within the sector. However, as with any significant transition, challenges have emerged, ranging from technological barriers and capacity limitations to concerns about the misuse of information and resistance to oversight.

The transition from findings and analysis now moves to the discussion, where the focus is on synthesising the insights gleaned from this exploration. The next chapter (6 – Discussion) dives into the implications of these findings, engaging with the broader themes and overarching questions of this research. It is here that the intricacies of how the perceptions and interactions of stakeholders, the roles of ENGOs, and the structures of governance intersect to shape the sustainability transition to traceability adoption in Peruvian jumbo squid and mahi mahi fisheries.

In the next chapter, the specific aspects of traceability implementation, challenges, and potential solutions are explored in depth. By integrating the theoretical underpinning of sustainability transitions and the MLP, an analysis of the dynamics at play in the adoption of traceability technology is offered.

6 – Discussion

The preceding chapter - Findings and Analysis has illuminated a range of insights garnered from an examination of the perspectives and dynamics surrounding the adoption of electronic traceability systems within the Peruvian jumbo squid and mahi mahi fisheries. As these findings are discussed in this chapter, the goal is to contextualise them within the broader theoretical framework of sustainability transitions MLP. This framework, as reviewed in the earlier chapters (see Section 3.4 Sustainability Transitions and MLP), offers a lens through which the introduction, integration, and uptake of innovations within sociotechnical systems can be understood.

This framework encompasses three analytical levels: the landscape, regime, and niche. At the landscape level, the macro-level trends and external factors that shape transitions are examined. The regime level delves into the established structures, rules, and norms governing a specific sector, while the niche level focuses on the innovative practices and initiatives developed at the margins of the sociotechnical system.

In line with the purpose of this chapter, the key findings from Chapter 5 are summarised and form the basis for the analysis. The findings encompass diverse stakeholder perspectives, including government representatives, the artisanal fishing community, industry stakeholders, and ENGOs. These perspectives not only offer insights into the perceptions about traceability technology but also highlight the interplay between the actors involved.

By applying this theoretical lens to the findings, the aim is to uncover how the perceptions and challenges surrounding traceability technology in the Peruvian context intersect with the broader transition dynamics within the sector to improve sustainability and governance of Peruvian artisanal fisheries.

The overarching objectives of this study were divided into two:

RO1: Investigate how the transition to electronic traceability systems is occurring in Peruvian jumbo squid and mahi mahi fisheries by:

a. describing the emergence of traceability technology in these fisheries, as well as the drivers and motivations behind its adoption;

b. understanding how and why traceability is gaining momentum in niches and how it can become mainstream; and
c. documenting the reactions of different stakeholders to the changes associated with the implementation of traceability and identifying the barriers and principles for adoption.

RO2: Assess the influence of ENGOs and government structures on the adoption of electronic traceability systems in the jumbo squid and mahi mahi fisheries in Peru by:

a. describing the relationship of ENGOs with government agencies, industry actors, and the artisanal fishing community in the promotion of traceability;
b. identifying situations in which ENGOs are seen as important players driving the adoption of the traceability, when they are not, and why;
c. analysing the influence and impact of government institutions and regulations on the adoption of traceability in the Peruvian jumbo squid and mahi mahi fisheries.

To accomplish these objectives, the study sought to answer the following research questions:

RQ1: How is the transition to electronic traceability systems occurring in the Peruvian jumbo squid and mahi mahi fisheries?

a. How is traceability technology emerging in these Peruvian fisheries? What are the drivers and motivations behind its adoption?
b. How and why is traceability gaining momentum in niches, adapting and growing? How can it become mainstream?
c. How does the fisheries' institutional structure respond to these innovations? What are the perceived barriers and principles for its adoption?

RQ2: What are the contributions of ENGOs and government structures in the transition to electronic traceability systems in the Peruvian jumbo squid and mahi mahi fisheries?

a. How do ENGOs engage with the government, industry and the artisanal fishing community in promoting traceability technology?
b. Under what conditions are ENGOs considered important players driving the adoption of traceability? Under what conditions are their aspirations and objectives marginalised?

c. How do government institutions and regulations influence and impact the adoption of traceability in the jumbo squid and mahi mahi fisheries?

Chapter 6 seeks to link the findings from the previous chapter with the literature and theoretical constructs explored in Chapter 3. Sections 6.1 and 6.2 unpack the findings vis-a-vis each research question, establishing a dialogue between empirical insights and scholarly discourses. Following this, Section 6.3 delineates the implications and contributions of this study. Section 6.4 provides an examination on the limitations of the study and moves the discussion towards future research avenues. By integrating the findings with theory and practice, this study contributes to sustainability transitions within the global fisheries context, shedding light on the factors that facilitate or hinder the adoption of electronic traceability systems and the potential contributions of such technology to sustainability and governance of the Peruvian jumbo squid and mahi mahi fisheries.

6.1 Summary of key findings in response to the research questions

Chapter 5 explored the perspectives, barriers, and dynamics associated with the adoption of traceability technology within the Peruvian jumbo squid and mahi mahi fisheries. The findings, organised into themes and subthemes that address the research questions, offer an understanding of the landscape surrounding this transition.

6.1.1 RQ1: How is the transition to traceability technology adoption occurring in the Peruvian jumbo squid and mahi mahi fisheries?

In exploring the transition to traceability technology within Peruvian jumbo squid and mahi mahi fisheries, **Theme 1: Understanding the transition to traceability technology** responds to RQ1 by looking into the underlying processes and dynamics. **Subtheme 1.1: Emergence and drivers of traceability adoption** responds to RQ1a by looking at the development and motivating factors that are leading to the adoption of traceability within the fisheries context. **Subtheme 1.2: Niches where traceability is gaining momentum** responds to RQ1b by analysing the niches within the fisheries wherein traceability technology starts to gain influence, highlighting the arenas that are early adopters or focal points of implementation. Lastly, **Subtheme 1.3: Regime response to the emergence of traceability: potential benefits and perceived disadvantages** responds to RQ1c by examining the interplay between existing regimes and traceability mechanisms, analysing the advantages and apprehensions brought

forth by this emerging technology. This exploration thereby aims to build an understanding on how the uptake of traceability technology is developing, from its inception to its integration with established regimes within the targeted fisheries.

6.1.1.1 Theme 1: Understanding the transition to electronic traceability systems (RQ1)

To address RQ1 **How is the transition to electronic traceability systems occurring in the Peruvian jumbo squid and mahi mahi fisheries?** the Sustainability Transitions MLP theoretical framework, as posited by Geels (2012) is used. Geels identifies three analytical levels (a) niches, (b) socio-technical regimes, and (c) exogenous socio-technical landscape, which collectively provide a lens through which the complex dynamics of sustainability transitions, like that of traceability adoption, can be analysed. These three levels are analysed separately in response to each sub question in the sections later in this chapter.

Furthermore, integrating technology readiness assessments as explored by Nakamura et al. (2013) in the aviation sector with the MLP framework could provide additional depth by understanding the maturity of traceability technologies within the existing socio-technical regime and landscape, aiding in identifying technological adoption timelines and challenges.

Addressing identified challenges while scaling benefits will require a strategy for the technological intervention that considers infrastructural needs, educational campaigns, and regulatory adjustments, all tailored to the unique needs of each stakeholder. Consequently, while the transition is broadly conceived as beneficial, its complexity demands an organised, multi-stakeholder approach to effectively harness the potentials of traceability within these fisheries, informed by the MLP framework, ensuring the interactions between varied levels and entities are adequately addressed and synergised.

Consequently, Subtheme 1.1 delves into the 'Emergence and drivers of traceability adoption', investigating the factors that are propelling the shift towards incorporating traceability technologies in the Peruvian jumbo squid and mahi mahi fisheries. The ensuing discussion seeks to reveal the motivations and influences that have fostered the gradual acceptance of traceability technology, particularly examining the pressures, incentives, and circumstances that have shaped its adoption across diverse stakeholder groups.

Subtheme 1.1: Emergence and drivers of traceability adoption (RQ1a)

Subtheme 1.1 reveals a complex interplay between international market pressures, regulatory frameworks, and adaptation within local industries. The research proposes an inquiry into the dynamics and evolution of fisheries in response to increasing demands for traceability and sustainability, primarily from major international markets. These demands have fostered the urgency for traceability adoption, improvement in fishing practices and regulatory adherence within Peruvian fisheries. This section highlights key findings regarding international market pressures, advocacy from ENGOs, and the critical role of traceability in ensuring sustainability and governance within the context of the Peruvian jumbo squid and mahi mahi fisheries.

Traceability technology is emerging in the Peruvian jumbo squid and mahi mahi fisheries in response to multiple pressures and opportunities:

- **International market requirements**: Programs like the U.S. Seafood Import Monitoring Program (SIMP) are significant drivers, requiring traceability to ensure legal sourcing and sustainable practices for market access.
- **Environmental and sustainability concerns**: The fisheries face challenges like IUU fishing and overexploitation, motivating stakeholders to adopt traceability as a tool to promote sustainable resource management.
- **ENGO advocacy**: Environmental NGOs play a key role by raising awareness, providing technical expertise, and advocating for traceability as a means to improve governance and compliance.
- **Economic incentives**: Industry stakeholders see traceability as a way to enhance product value, achieve certifications, and access premium markets, motivating broader adoption.

In the next section the influence of international markets will be further explored.

International market pressures catalyse traceability adoption

The findings and analysis of this study evidence that international market pressures, principally from the United States, Europe, and Japan, have been pivotal in driving the development and adoption of traceability technology within the Peruvian jumbo squid and

mahi mahi fisheries. This aligns with the literature on sustainability transitions, which highlights the critical role of external pressures, such as market demands and regulatory changes, in shaping technological and systemic innovations (Geels, 2002; Kalfagianni & Pattberg, 2013).

Regulations, notably those enforced by the European Union between 2010 and 2012 and the United States SIMP between 2015 and 2016, materialised not merely as compliance challenges but as critical turning points, leading to the uptake of traceability within many fisheries (NOAA, 2022).

This focus on traceability reflects broader shifts in consumer behaviour and regulatory landscapes, as discussed in Arner et al.'s (2015) study on fintech evolution, where external socio-economic and regulatory pressures drove industries through distinct phases of transformation. In Peru, this focus on traceability stems largely from a shift in consumer behaviour and regulatory requirements in these markets, with a demand for detailed information concerning the origin, harvest methods, and sustainability metrics of seafood products. Such findings resonate with theories of niche creation and strategic niche management (Kemp et al., 1998), emphasizing that external pressures often create a protective space for innovative systems like traceability to emerge and gain traction.

Drawing parallels with Arner et al.'s (2015) study on fintech evolution, where external pressures, whether they be regulatory or technology-driven, have led the industry through distinct evolutionary phases. Similar to fintech’s transition from an analogue to a digitally intensive industry due to varied socio-economic and regulatory factors, the Peruvian fisheries experienced an enhanced emphasis on traceability, moving from initial dialogues surrounding its need and merits to its adoption, compelled by regulatory alterations in international markets (APEC Ocean and Fisheries Working Group, 2024).

The complex relationship between regulatory compliance and actual operational transition within the fisheries may necessitate a deeper exploration, analysing to what degree these transitions were genuine reflections of an evolving attitude towards sustainability and effective governance, as opposed to a reluctant adherence to compliance for market retention. Thus, the sustainability transition of the Peruvian fisheries considering these international pressures requires a critical examination into the various ways industries navigate, resist, and ultimately assimilate global sustainability and governance demands,

adapting their practices in alignment with a constantly evolving international landscape (Gustafson, 2022).

The efficacy of ENGOs in promoting traceability

The effectiveness of ENGOs in enhancing traceability adoption within Peruvian fisheries is an interplay of advocacy, information dissemination, and facilitation. ENGOs play an important role in advocating for sustainable practices and influencing policy through direct involvement and collaboration with government bodies and other stakeholders. Studies have shown that ENGOs can significantly shape fisheries management and contribute to sustainability by leveraging their expertise, stakeholder engagement, and policy influence (Dunn, 2005).

In comparison with fintech ecosystems, as shown by Palmié et al. (2020), provides a lens from which the roles and influences of ENGOs can be analysed. Similar to how innovations within fintech often emerge from a collaborative ecosystem encompassing various stakeholders, ENGOs have similarly sewn themselves into the fabric of the fisheries' ecosystem, acting not merely as broadcasters of information but as nodes that connect governmental bodies, industry stakeholders, and artisanal fishing communities. Their role, however, extends beyond that of facilitation. Informing and promoting the requirements of international market regulations and embedding themselves within the narrative of traceability, ENGOs have not only championed the dissemination of critical information but have also made the connection between market-driven regulations and advocative actions. Their intermediary function has further articulated the insights shared by Palmié et al. (2020), but tailored to the fisheries' context, illuminating how ENGOs, far from being passive bearers of information, have mobilised technological and regulatory changes in response to international obligations.

However, whilst the important role of ENGOs is underscored, it raises questions about how sustainable and reliable it is to depend heavily on these organisations for spreading information and advocacy. Such reliance invites reflections on the necessity of formulating formal channels that could guide, fortify, and sustain transitions within the fisheries sector, especially in the realm of traceability, thereby ensuring that the confluence between regulatory compliance, technological adoption, sustainability and governance is not only maintained but aligned with the demands of international markets.

Traceability as a mechanism for quality assurance and reputation management

Traceability technology, within the context of Peruvian jumbo squid and mahi mahi fisheries, has become established, particularly for quality assurance and reputation management. One instance that spotlighted the need for traceability in these fisheries was the 2013 incident where the FDA rejected Peruvian mahi mahi due to elevated histamine levels (DeBeer et al., 2021). This incident underscored the importance of traceability in ensuring product quality, identifying contamination sources, and maintaining the integrity of international reputation. It aligns with literature emphasizing that external shocks, such as market rejections, often act as catalysts for technological adoption (Kalfagianni & Pattberg, 2013).

Placing this within a broader framework, like Palmié et al. (2020) and Arner et al. (2015), traceability in fisheries reflects parallel dynamics observed in fintech innovation, where regulatory pressures and reputational risks drive adoption. Unlike fintech, which prioritizes efficiency and automation, traceability adoption in fisheries is often reactive, driven by crises like the 2013 event. However, this reactive approach underscores the need for pre-emptive mechanisms, aligning with governance theories advocating proactive risk management to ensure long-term resilience and sustainability (Geels, 2002; Kemp et al., 1998).

While the 2013 incident served as a catalyst for amplifying traceability adoption, it urged the industry towards an examination of the mechanisms in place and demonstrating the need for the establishment of pre-emptive, rather than purely reactive, mechanisms for quality assurance. This ensures that the deployment and utilisation of technologies such as traceability are aligned with both immediate and future-oriented objectives and demands of the sector.

6.1.1.2 Subtheme 1.2: Niches where traceability is gaining momentum (RQ1b)

When investigating the landscape of traceability within the Peruvian fishing industry, Subtheme 1.2 delves into the niches that have become arenas for the evolution and expansion of electronic traceability systems. Amidst the ebbs and flows of regulatory and market pressures, certain sectors within the jumbo squid and mahi mahi fisheries have witnessed the nurturing of traceability innovations, carving out specialised niches where adherence to and development of traceability is not merely an obligatory compliance but rather a strategized adoption to meet sustainability claims and maintain international competitiveness. The

integration of technologies like 'TrazApp' and 'Trace Register' within these niches underscores a diligent effort to harmonise technological advancements with regulatory compliance while meeting the discerning demands of international markets. This subtheme ventures into the dynamics and interactions within these niches, exploring the relationship between technological innovations and their regulatory and market environments, thereby illuminating how traceability is progressively permeating the Peruvian fisheries sector.

Synchronisation of government and industry objectives

In the context of the Peruvian fishing sector, the synchronisation between governmental objectives and industry practices becomes vital. The narrative revolves around traceability, essential for maintaining and enhancing access to international markets, particularly in Europe. The alignment of industry and government objectives reveals an acknowledgment of the role traceability plays in ensuring compliance with international market demands and the modernisation of fishing practices (Hosch & Blaha, 2017). Exploring academic literature, parallels appear between the adoption of technology in the financial and agriculture sectors.

In various national contexts, such as the United Kingdom and Argentina, fintech is driven by a combination of regulatory compliance, market demands, and technological innovation (iProUp, 2021). In these scenarios, technological adoption, although disruptive, becomes crucial for adhering to regulatory frameworks and exploiting market opportunities, reflecting a similar situation in the Peruvian fisheries.

In the case of agriculture, there are already more than 10 Argentine companies implementing blockchain in various areas of agriculture, from traceability to financial solutions and reduction of environmental impact (Krakov & Fusoni, 2022). Despite the growth of these technologies, there are significant barriers such as the lack of a clear regulatory framework and the cultural and technological gap between producers and digital solutions. These technologies not only guarantee the quality and safety of food but also open the door to more demanding market niches, where quality and sustainability are rewarded with higher prices.

The synergy between the Peruvian fishing industry and governmental objectives underscores a collective commitment to traceability. This collaboration signals a united effort that could potentially streamline regulatory and market-oriented compliance, thereby strengthening Peru’s position in international markets.

6.1.1.3 Subtheme 1.3: Regime response to the emergence of traceability: potential benefits and perceived disadvantages (RQ1c)

Subtheme 1.3 investigates regime responses to the emergence of traceability, revealing a contrast of acknowledgment and apprehension among stakeholders in Peruvian fisheries. The universally recognised merits of traceability, such as enhancing sustainability and mitigating IUU fishing, position it as a key tool to foster transparent and accountable practices within the sector. However, distinct perceptions and emphasis of each stakeholder present appreciation with scepticism and concern. This subtheme explores the expectations, perceived benefits, and apprehensions regarding electronic traceability adoption.

Universal acknowledgment of traceability benefits

There is a recognition of the merits of traceability across all stakeholder groups in the Peruvian fishing sector, wherein the universal acknowledgment underscores its role in sustainability, IUU fishing prevention, and enhanced governance. Government institutions, such as PRODUCE, acknowledge traceability as an essential mechanism for improving fisheries monitoring, enforcement, and compliance with international standards. Traceability is also seen as a driver for market differentiation, enabling industry actors to achieve certifications and enhance their competitiveness in global markets. These perspectives align with literature on governance and sustainability, which identifies traceability as a means to ensure accountability and transparency in supply chains (Hosch & Blaha, 2017; Jennings et al., 2016). Existing literature that has underlined the centrality of traceability in sustainable fishing practices globally. Particularly, other sectors and country contexts, such as the European meat industry, have also observed that robust traceability frameworks fortify not only sustainability but also market trust and compliance with regulatory frameworks (Charlebois et al., 2014).

However, these findings slightly contrast with instances in some sectors or regions where traceability is viewed with scepticism or resistance, often due to fears of operational inconveniences or financial burdens (Karlsen et al., 2013). There is the case of a study that examined traceability systems that have emerged in the wheat to bread supply chain in the United Kingdom. The study revealed that ethical concerns are ever changing and contested. In the case of the supply chains studied, a significant concern with safety was followed by a greater focus on the provenance of wheat and flour and the environmental impacts of more

industrialised supply chains (Barling et al., 2009). The study of traceability schemes and the views of the stakeholders demonstrate restricted 'fields of ethical vision'.

Though the acknowledgment of traceability's benefits is broad in some sectors, one might interrogate the depth of its understanding and application among the artisanal fishing communities. The apparent uniformity of perception could potentially mask apprehensions or misconceptions, especially given the heterogeneous nature of stakeholder groups.

Divergent perceptions and prioritisations of traceability

While there is alignment in recognising traceability's merits, divergences exist in how different stakeholders prioritise various benefits of traceability, reflecting distinctive challenges and priorities. This perspective is echoed in frameworks such as the Technology Acceptance Model (TAM), which stipulates that perceived usefulness is a core determinant of technology adoption (Davis, 1989). In the Peruvian context, stakeholders identify and prioritise divergent utility aspects of traceability, reflecting their operational and strategic imperatives. Notably, these findings contrast with sectors where stakeholder alignment on technological benefits leads to uniform adoption and prioritisation, which might be due to the fisheries sector's inherent diversity and complexity.

The diversity in benefit perception may potentially hinder the establishment of a unified and comprehensive traceability framework. Further studies might probe whether these divergences could potentially result in implementation incongruences or misalignments in strategic traceability objectives across stakeholder groups.

Challenges and barriers towards traceability adoption

- Stakeholders expressed some challenges and barriers towards traceability adoption, primarily centred on implementation, technology, and perceived operational and financial impacts, despite no solid disadvantages being pinpointed. Existing studies in diverse sectors underline that technological adoption, especially in contexts where traditional practices are deeply rooted, is often plagued by tangible and psychological barriers (Joachim et al., 2018). These apprehensions, often centred around practicality, costs, and capability, are notably visible across different stakeholder perspectives in the Peruvian fisheries context.

It is important to note that the absence of highlighted 'disadvantages' contradicts findings from other industries, where stakeholders openly pinpoint and document perceived negatives of technology adoption, such as privacy concerns in digital health record adoption in healthcare settings (Keshta & Odeh, 2021).

Underlined resolvability of challenges

There exists an underlying theme across stakeholders that, while challenges and barriers to traceability adoption are recognised, they are perceived to be surmountable through various strategies. This is notably reflective of the 'Socio-Technical System' theory, which posits that technological implementation in organisational contexts is influenced by a confluence of social and technical factors (Bostrom & Heinen, 1977). In the Peruvian fisheries sector, stakeholders echo this by recognising that socio-technical interventions like infrastructural enhancements, training, and awareness campaigns can potentially mitigate adoption barriers.

This differs from industries or contexts where challenges, especially those related to technology and operational practices, are often perceived as insurmountable or requiring fundamental shifts in practices and frameworks. The belief in resolvability should be further analysed for its realism in practical contexts. How viable are the proposed solutions in the light of financial, infrastructural, and socio-cultural contexts in Peruvian fisheries, and to what extent might this positivity bias mask potential pitfalls in traceability implementation?

6.2 RQ2: What are the contributions of ENGOs and government structures in shaping the transition towards adopting traceability in Peruvian fisheries?

Theme 2: Influence of ENGOs and government structures responds to RQ2 by looking into the roles and influences of key stakeholders within the sector. The importance of collaboration and stakeholder engagement aligns with the principles of adaptive governance and participatory processes, as discussed by Turnheim et al. (2015). **Subtheme 2.1: ENGOs' engagement and collaboration** responds to RQ2a by analysing the cooperative dynamics and strategic partnerships formed by ENGOs, clarifying the alliances and shared initiatives that mark the course towards traceability. These partnerships align with the literature on network governance (Kooiman et al., 2008), where multi-stakeholder engagement is seen as critical for addressing complex challenges like traceability adoption. By fostering trust, sharing expertise,

and bridging gaps between stakeholders, ENGOs create an enabling environment for innovation.

Subtheme 2.2: ENGOs' role and impact on traceability adoption responds to RQ2b by showing the influence exerted by ENGOs in the traceability adoption process through advocacy, policy push, and capacity-building efforts. NGOs act as mediators, bringing international best practices into local contexts, advocating for regulatory alignment, and empowering stakeholders with technical skills and knowledge. Furthermore, **Subtheme 2.3: Government influence on traceability adoption** responds to RQ2c by examining the regulatory and role of governmental structures, probing into the policies, incentives, and frameworks that promote or hinder traceability technology adoption within these fisheries. However, as noted by Jennings et al. (2016), inconsistent or fragmented regulations can undermine efforts, a challenge that resonates with the Peruvian fisheries' regulatory environment.

This thematic exploration is aimed at synthesising the understanding of how ENGOs and government structures shape, direct, and sustain the move towards implementing traceability technologies, providing insights into the collaborative, influential, and regulatory mechanisms at play in the Peruvian context.

6.2.1 Theme 2: Influence of ENGOs and government structures (RQ2)

In a time where sustainable practices emerge as pivotal for the longevity and health of fisheries, the sustainability transition towards traceability in the Peruvian fisheries sector requires agreement and collaboration by various actors. This section is centred around RQ2, analysing the contributions and influences of ENGOs and governmental structures in the transition to traceability technology in the Peruvian jumbo squid and mahi mahi fisheries. This theme draws on the literature's emphasis on governance and stakeholder dynamics in socio-technical transitions (Geels, 2002; Kemp et al., 1998) to provide a nuanced understanding of how collaboration, advocacy, and regulatory frameworks facilitate or hinder technological uptake. Theme 2 clarifies the roles and impacts of ENGOs, exploring the symbiosis, and occasionally, the tension between regulatory frameworks and advocacy, as they promote the incorporation of traceability systems within the sector. Subtheme 2.1: ENGOs' engagement and collaboration (RQ2a).

In explaining the role of ENGOs in helping Peruvian fisheries adopt traceability, it becomes clear that ENGOs have shifted from being just advisors to actively participating in development and policymaking. The MLP framework, hinging upon actors' interactions and decisions throughout transition phases, provides a constructive lens to analyse these evolving roles and strategies employed by ENGOs within the fisheries sector (La Riviere et al., 1996). The cooperative dynamics and strategic partnerships formed by ENGOs align with the literature on governance (Kooiman et al., 2008), where multi-stakeholder engagement is seen as critical for addressing complex challenges like traceability adoption. By fostering trust, sharing expertise, and bridging gaps between stakeholders, ENGOs create an enabling environment for innovation. ENGOs support sustainability transitions through initiatives such as Fisheries Improvement Projects (FIPs), capacity-building programs, and policy advocacy, all of which contribute to the adoption of traceability. These organisations not only support sustainability through strategies like FIPs and regulatory improvements but also play a significant role in traceability adoption, engaging with the social and technical aspects of the fisheries industry.

This aligns with the MLP's identification of niche innovations as instrumental in effectuating transitions within regimes. ENGOs develop and support these niche innovations, helping them grow and eventually become standard practices in the fisheries sector. Geels and Schot (2007) suggest that landscape pressures can instigate a cascade of modifications within prevailing regimes, potentially creating opportunities for niche innovations. Such landscape pressures may emanate from international market requirements and sustainable fishing practice advocacy, areas where ENGOs are notably active.

A divergence from past relational dynamics is evident between ENGOs and various stakeholders, signalling a shift towards collaboration and collective engagement in enhancing traceability. This transition from antagonism to cooperation, especially with the industry sector, substantiates the conceptualisation of ENGOs not only as 'honest brokers' but as 'development intermediaries' (Future of Fish, 2019). This evolution aligns with the MLP's characterisation of transition pathways, where multi-level interactions contribute to the materialisation of innovative practices within dominant regimes. The transformation within these relationships potentially signifies a subtle, yet impactful, shift within the underlying norms and practices that characterise the fisheries' socio-technical system.

Furthermore, the ENGOs' initiative to raise awareness and build capacity within the artisanal fishing community underscores their instrumental role in embedding traceability within localised practices (Christensen et al., 2014). This grassroots involvement reflects the interaction with the broader regulatory landscape, fostering a bottom-up influence on policymaking and system optimisation, thereby resonating with the MLP's emphasis on multi-level interactions and event sequencing in effectuating transitions. In addressing sustainability within fisheries, a contextual application of the MLP, as highlighted by Grin and Schot (2010), necessitates considering the interplay among the niche, regime, and landscape levels, which seems to permeate the ENGOs' strategies and interactions across governmental, industrial, and community sectors.

In synthesising these analyses, it becomes important to acknowledge the MLP's limitations, particularly in contextualising power dynamics, which could be crucial in the ENGOs' ability to influence policy and practice within the fisheries sector. While ENGOs have evidently sculpted a multi-faceted role within the transition towards enhanced traceability and sustainability in Peruvian fisheries, their efficacy and influence are potentially contingent upon the interplay of power dynamics, governmental policies, and global market pressures. Future research might delve deeper into the micro-dynamics of these interactions, offering a granular insight into the influences and strategies employed by ENGOs and other stakeholders in navigating sustainability transitions within fisheries.

6.2.1.1 Subtheme 2.2: ENGOs' role and impact on traceability adoption (RQ2b)

As the role of ENGOs comes into focus in the context of traceability adoption within Peruvian jumbo squid and mahi mahi fisheries, **Subtheme 2.2: ENGOs' role and impact on traceability adoption** provides an exploration of their influence. In the next subsection **The financial role of ENGOs,** the attention is turned towards understanding how ENGO's financial involvement influences traceability initiatives. In the ensuing section, **The advisory vs. action tug-of-war in ENGOs' role** seeks to understand how ENGOs balance between policy advisement and tangible actions within the fisheries. Moreover, **ENGOs as knowledge conduits and regulatory influencers** offers a view into how these organisations serve as channels for knowledge dissemination and regulatory influence, linking theoretical know-how to on-the-ground practices and policymaking. Finally, **Alignment and collaboration between ENGOs and government** analyses the interface where ENGOs and governmental structures collide and

collaborate. This exploration seeks to portray ENGOs not merely as peripheral but as central, influential actors that shape the sustainability transition to traceability adoption within the fisheries.

The financial role of ENGOs

ENGOs in the Peruvian fisheries sector exert substantial financial influence, mobilising resources that drive key sustainability projects and traceability adoption initiatives. Serving as financial conduits, ENGOs facilitate international and national funding flows directly impacting project execution in the fisheries sector, giving them more freedom and capacities than the government in many cases. Nonetheless, the impact of ENGOs' financial contributions, particularly in developing nations, often depends on the alignment between donor objectives and local needs, marking a challenging balance to strike.

The advisory vs. action tug-of-war in ENGOs' role

A contradiction exists in the perception of ENGOs within the artisanal fishing community, which fluctuates between viewing them as gentle advisors and aspiring for them to emerge as more assertive change agents. This duality echoes global discussions in ENGO involvement where, as asserted by Raakjaer et al. (2014), ENGOs often navigate the challenging terrain between offering passive advice and taking active leadership in fisheries management, especially in small-scale settings. The equilibrium between respecting local autonomy and exerting necessary pressure to foster change exposes a delicate balance that requires careful navigation.

ENGOs as knowledge conduits and regulatory influencers

ENGOs play a key role as knowledge transmitters and regulatory shapers, by providing guidance and practical input in policy design. ENGOs not only impart information that fosters industry advancements but also influence regulatory frameworks by being credible partners in legislative processes. Consistent with studies like Gulbrandsen (2009), ENGOs frequently negotiate the path between offering knowledge and shaping regulations in global fisheries. Nevertheless, the fusion of these roles, particularly in contexts like Peru, underscores an expanded potential for ENGOs to facilitate international-local knowledge translation, while ensuring regulations are crafted with a blend of international best practices and local relevance. By aligning knowledge-sharing and regulatory influence, ENGOs have the potential

to create a narrative for traceability adoption that is both globally informed and locally applicable.

Alignment and collaboration between ENGOs and government

The relationship between ENGOs and the government is key to advancing traceability through collaboration and alignment. When ENGO initiatives align with government priorities, they become more viable and foster a mutually beneficial partnership that addresses resource and expertise gaps. This ENGO-government synergy, while similar to some global contexts (Betsill & Corell, 2001), presents unique challenges and opportunities in Peru.

ENGOs have emerged as important actors in shaping the transition toward traceability adoption in Peruvian jumbo squid and mahi mahi fisheries. Their roles as financial enablers, knowledge conduits, and advocates for regulatory improvements position them at the intersection of international demands and local realities. By raising awareness, providing capacity building, and adapting traceability systems based on stakeholder feedback, ENGOs have strengthened their relationships with artisanal fishers, government, and industry actors, gradually transforming skepticism into trust and collaboration. Their ability to amplify fishers' voices and facilitate alignment between diverse actors within the supply chain underscores their credibility as connectors and agents of change.

However, the duality of their role—as both gentle advisors and assertive change agents—reflects the complexities of balancing local autonomy with the urgency of sustainability transitions. Moving forward, the collaborative synergy between ENGOs, government bodies, and industry actors will remain a critical factor in ensuring that traceability initiatives are globally aligned yet locally relevant, advancing both sustainability and governance within Peruvian fisheries.

Subtheme 2.3: Government influence on traceability adoption

Shifting the focus towards an investigation into the governmental sphere within the adoption of traceability in Peruvian fisheries, **Subtheme 2.3: Government influence on traceability adoption** brings to light the problems created by bureaucracy and its impact on sustainability transitions. The subsection **Regulatory discrepancies and weak enforcement** examines the contrasts between established regulations and their on-the-ground enforcement, looking at the differences that may exist between policy intent and practice within the fisheries. Shifting

the perspective slightly, **Inter-institutional discord and inconsistencies** examines institutional interactions and collaborations, exploring how divergences and alignments between governmental bodies shape the regulatory landscape. In **Struggles of the artisanal fishing community with formalisation and regulation**, the narrative reflects on how local, smaller-scale fishing communities navigate, and are often trapped by, the complex web of formalisation and regulatory frameworks. Finally, **Institutional fragility, corruption, and capacity challenges**, addresses issues related to structural stability, ethical dilemmas, and capability to enforce and uphold regulatory mandates. Through this examination, this subtheme aims to explain the sometimes-contradictory roles and impacts of governmental structures on the pathways and obstacles associated with traceability adoption in the fisheries sector.

Regulatory discrepancies and weak enforcement

The Peruvian fisheries sector faces significant challenges in implementing and enforcing regulations. Despite existing frameworks, there is a clear disconnect between policy and practice, a common issue observed in fisheries globally (Jentoft et al., 2017). This gap is intensified by ineffective monitoring and accountability mechanisms, limiting the impact of these regulations. To achieve real progress in fisheries management and traceability, it's crucial to close the gap between regulation design and enforcement, ensuring policies are effectively put into practice.

Inter-institutional discord and inconsistencies

The involvement of multiple government entities in Peru's fisheries governance creates conflicts and inconsistencies. These institutions struggle with internal issues and inter-institutional discord, leading to a disjointed regulatory environment. Similar challenges are seen globally (Bavinck, et al., 2005), but in Peru, the situation is exacerbated by the complex web of entities, each with distinct mandates and frequently changing personnel, resulting in a convoluted governance structure. To improve efficiency, a clear restructuring and delineation of mandates among these governing bodies is crucial for more coherent and effective fisheries governance (Kooiman et al., 2005).

Struggles of the artisanal fishing community with formalisation and regulation

Artisanal fishers in Peru face significant barriers in navigating formalisation requirements and regulatory adherence. Fishers not only confront financial and complexity hurdles but must also steer through dubious regulatory enforcement. Globally, small-scale fisheries often wrestle with the dual challenge of regulatory adherence and maintaining financial stability (Rashid, 2020). In Peru, fishers' struggles are further exacerbated by a lack of support and a disconnect between regulatory intent and actual on-ground controls. Helpful systems and flexible, fisher-focused rules are crucial to support artisanal fishing communities and help them follow the law.

Institutional fragility, corruption, and capacity challenges

Institutional fragility and a concerning undercurrent of corruption critically undermine the governance capacity within the fisheries sector in Peru (Paredes, 2017). Through weak structural frameworks and pervasive corruption, particularly within regional governmental bodies, the governance mechanism teeters on instability, diminishing its efficacy and stakeholder trust. Corruption and institutional fragility within fisheries governance are global issues, often diluting policy efficacy and disrupting management efforts (Pomeroy, 1995). In Peru, these issues are further complicated by localised challenges such as sporadic training and inactive fieldwork, which not only exacerbate existing governance issues but also significantly frustrate attempts towards building a reliable and robust governance structure. Strengthening of institutional structures along with anti-corruption mechanisms, emerge as critical precursors to resuscitating the integrity and functionality of fisheries governance in Peru.

6.3 Implications and contributions

This section explores the wider implications of the findings, examining how this research contributes to existing literature by illuminating areas where the findings align, counter, or deepen current understanding.

6.3.1 Interplay of niche, regime, and landscape factors in Peruvian fisheries: insights and implications for the MLP framework

This research reveals the complex dynamics of the adoption of traceability technology, specifically within the Peruvian jumbo squid and mahi mahi fisheries. It enhances understanding of sustainability transitions by undercovering the motivations, barriers, and interplays among diverse stakeholders, presenting a narrative of how transitions evolve within a complex network of actors, institutions, and societal contexts. The findings underscore the multifaceted character of sustainability transitions (Geels & Schot, 2007), from technological and regulatory frameworks to stakeholder perceptions and collaborative endeavours. This section explores how the levels of niche, regime, and landscape factors interact, influencing and reinforcing one another, and suggests ways in which governance and power dynamics can be more explicitly integrated into the MLP framework.

The findings demonstrate that niche-level initiatives, such as pilot projects supported by ENGOs, act as incubators for innovation, creating spaces for experimentation and adaptation of traceability technologies. However, their success is contingent on regime-level factors such as governance structures, institutional capacity, and stakeholder trust. In both fisheries, landscape pressures, particularly international market requirements catalyse these dynamics by setting the overarching context within which regime and niche factors operate.

These dynamics highlight the bidirectional influence between levels: while regime factors shape the feasibility and scalability of niche innovations, the success of niche initiatives can create momentum for regime-level changes, such as improved governance or stakeholder collaboration.

A notable finding is the feedback loop between governance and traceability systems. Good governance is a prerequisite for the successful adoption of traceability, as it provides the regulatory frameworks, enforcement mechanisms, and stakeholder trust needed to support implementation. At the same time, traceability systems generate data that enhance governance by increasing transparency, accountability, and compliance monitoring. This cyclical relationship underscores the interdependence of governance and traceability, suggesting that interventions targeting one can have ripple effects on the other.

The findings from this research suggest several ways in which the MLP framework can be adapted to better reflect the complexities of fisheries sustainability transitions:

- **Integration of power dynamics**: Power asymmetries between actors, such as artisanal fishers, industry stakeholders, and government entities, significantly influence the adoption of traceability systems. For instance, artisanal fishers often lack the resources and political leverage to influence regime-level decisions, while ENGOs and industry actors wield greater influence in shaping both niche and regime dynamics. Incorporating power relations into the MLP framework would provide a better understanding of how transitions are shaped by stakeholder dynamics.

- **Governance as a cross-cutting factor**: Governance operates across all levels of the MLP framework, influencing niche experimentation, regime stability, and responses to landscape pressures. The feedback loop between governance and traceability highlights the need for a more integrated approach that considers governance as both a driver and outcome of sustainability transitions.

By examining the interplay of niche, regime, and landscape factors, this study highlights the dynamic and context-dependent nature of sustainability transitions in fisheries. Integrating power dynamics and governance feedback loops into the MLP framework can enhance its applicability to complex socio-technical systems like fisheries. These adaptations provide a foundation for more targeted interventions that address the unique challenges and opportunities of transitioning toward sustainable fisheries management.

6.3.2 Synthesising research and practice

The study serves as a bridge between research and practical application. By pinpointing challenges, surfacing opportunities, and cataloguing stakeholder perspectives, it offers actionable insights that can shape the design and execution of traceability initiatives in fisheries management. Furthermore, the research emphasises the importance of cooperation and knowledge exchange among ENGOs, governmental entities, and industry participants, potentially forging effective partnerships in the quest for sustainable fisheries.

6.3.3 Enriching governance and adoption discourse

The research broadens the conversation concerning governance structures and technology adoption within sustainability transitions. By examining the interactions among government entities, ENGOs, industry, and artisanal fishing communities, it reveals the linkages between regulatory alignment, capacity building, and stakeholder engagement. These findings contribute to the dialogue about how governance mechanisms and collaborative ventures either facilitate or obstruct the incorporation of innovative technologies within sustainability transitions. Moreover, the research emphasises the necessity of adopting context-sensitive approaches, which contemplate local realities and stakeholder perceptions, an important insight for policymakers in the application of traceability systems.

6.3.4 Embedding sustainability transitions within emerging economies

A distinct contribution of this research resides in its exploration of how electronic traceability systems are developing in an emerging economy, providing a perspective on their unique challenges. While the prevailing literature often focuses on experiences in high income nations, this study provides a valuable contextualisation of sustainability transitions within Peru's socio-economic, technological, and regulatory landscapes. This angle enhances comprehension of sustainability transitions across varied settings and highlights the necessity of customising strategies to the distinct scenarios encountered in developing nations.

Finally, the research unveils implications both within the specific domain of traceability adoption in Peruvian fisheries and the governance of sustainability transitions. Through advancing understanding, joining research and practice, understanding the influence of governance structures, and contextualising transitions in emerging economies, this study contributes to knowledge and presents tangible insights to the adoption of traceability to improve the sustainability and governance of Peru’s jumbo squid and mahi mahi fisheries.

6.4 Limitations and future research

This section critically examines the limitations of the study and identifies opportunities for future research to deepen the understanding of traceability adoption and sustainability transitions in fisheries. By addressing challenges related to sample composition,

methodological considerations, and broader research implications, this section highlights areas where further exploration can refine the insights gained from this research.

6.4.1 Sample composition and generalisability

This study is limited to the Peruvian jumbo squid and mahi mahi fisheries. Given the particularities of these fisheries and their local contexts, there exists a constraint regarding the generalisability of findings to other fisheries and regions, with different socio-economic, cultural, and ecological contexts. Future research could broaden its focus to a wider array of fisheries in both developing and developed nations, thereby offering a more holistic understanding of the alignment and interplay between traceability adoption and sustainability transitions.

6.4.2 Methodological considerations

While qualitative research provides in-depth insights, it carries a susceptibility to interpretational bias and subjectivity during data analysis. Thus, the findings and discussion could be influenced by researchers' biases in interpreting and categorising qualitative data (Liscovsky & Parra Vazquez, 2015). Future studies employing a more mixed-method approach could fortify the robustness of findings while minimising potential biases.

6.4.3 Future research directions

This section outlines future research directions to expand upon the current understanding of traceability adoption's sustainability and governance implications. Future studies are encouraged to examine the socio-economic impacts more thoroughly, offering an analysis of costs and benefits to stakeholders, and to undertake longitudinal research to trace the long-term effects of sustainability transitions, revealing how these evolve over time. Comparative analyses across different regions would serve to understand the influence of local factors on traceability system efficacy, and explorations into emerging technologies, such as blockchain and artificial intelligence, could provide insights into how innovation shapes the adoption and efficacy of traceability in the context of sustainable fisheries management.

6.4.3.1 Socio-economic impacts of traceability adoption

While the current study shares various stakeholder perspectives regarding traceability adoption, a broader exploration into the socio-economic ramifications for different stakeholders could provide a deeper understanding and validate alignment or divergence with existing literature. Future research could analyse the economic implications, costs and benefits for actors embedded in the traceability system, further narrowing the divide between research and pragmatic application.

6.4.3.2 Long-term sustainability transitions

This research essentially encapsulates a snapshot of the current status of traceability adoption and its alignment with prevailing literature. An investigation into the long-term impacts of traceability adoption on sustainability transitions, examining ecological outcomes, regulatory changes, and stakeholder responses, could provide insights into the temporal evolution of sustainability transitions. Employing long-term studies that track traceability initiatives could clarify the paths of such sustainability transitions.

6.4.3.3 Comparative analyses across regions

To enhance the understanding of contextual factors that dictate alignment or divergence, ensuing research could initiate a comparative analysis of findings amongst varied regions or countries. Such comparative studies could pinpoint whether certain elements, such as regulatory structures, cultural norms, or economic climates, consistently build the alignment of traceability adoption with the existing literature across diverse contexts.

6.4.3.4 Technological innovations and adaptation

In the context of rapid technological advancements, a closer inspection of how nascent technologies influence the alignment of traceability adoption with sustainability transitions is warranted. Subsequent research might explore the assimilation of innovative technologies, such as blockchain or artificial intelligence, assessing their impact on traceability adoption and sustainable fisheries management, following the research of Cruz & Rosado (2020) using blockchain to implement traceability on a fishery value chain. While this study has provided insights into traceability adoption and sustainability transitions, certain limitations affect the breadth and depth of the findings. Future research that addresses these limitations can

enhance our understanding of how traceability initiatives intertwine with broader sustainability agendas, offering insights for policy and practice.

6.5 Discussion summary

This chapter has offered a discussion which bridges the gap between key findings and the literature. The main points analyse the interplay between stakeholders, regulatory frameworks, and contextual dynamics, as well as the influence of the landscape, the development of traceability in niches, and the responses of the regime to the development of this sustainability transition.

These findings have wide-ranging impacts, with areas of agreement strengthening existing knowledge and confirming the importance of established sustainability transition concepts and the benefits of electronic traceability system uptake for fisheries sustainability and governance. As emphasized by Markard, Raven, and Truffer (2012), advancing our understanding of sustainability transitions requires a robust knowledge base that is continuously developed through empirical research and theoretical refinement.

This study contributes to the existing literature, offering a new perspective on the alignment between traceability adoption and the sustainability transitions MLP. This research underscores the significance of considering the factors influencing the interaction between technology adoption and sustainability transitions, inclusive of stakeholder dynamics, regulatory hurdles, and contextual subtleties.

Chapter 7 will combine these findings, discussions, and implications into a set of conclusions drawn from the study. This concluding chapter will encapsulate the key takeaways from this research, offering insights into the complex relationship between traceability adoption and sustainability transitions in Peruvian jumbo squid and mahi mahi fisheries. As this study progresses towards its culmination, it is recognised that these findings pave the way for a deeper understanding of the challenges and opportunities inherent in the pursuit of sustainable fisheries and good governance through traceability technology adoption in the Peruvian context.

7 - Conclusions

At the outset of this study, the research questions and objectives (see Box 1. Research questions) were formulated to guide research on the potential contribution of traceability technology to the sustainability and governance of jumbo squid and mahi mahi fisheries in Peru.

Chapter 7 reviews the results of the study in relation to the original objectives of the research. It also reminds the reader of the main themes covered in the previous chapters. The chapter also offers reflections on the implications of this research, recommendations for practitioners, as well as noting limitations and potential future research directions.

7.1 Summary of key findings

Overall, the key findings of this study contribute to a better understanding of the role of traceability technology in promoting the sustainability and governance of fisheries in Peru. The findings have important implications for policymakers, industry stakeholders, and environmental ENGOs involved in fisheries management and traceability implementation.

The main findings of each chapter are summarised below, highlighting the most significant results that address the research question(s) and objectives.

7.1.1 Chapter 1: Introduction

The – Introduction provides an overview of the research topic, focusing on the potential contribution of traceability technology to the sustainability and governance of the artisanal jumbo squid and mahi mahi fisheries in Peru. The chapter describes the objectives of the research, the research questions, and the contribution the study intends to make. It also identifies how this research contributes to existing knowledge.

7.1.2 Chapter 2: Context

The – Context provides the background on the Peruvian jumbo squid and mahi mahi fisheries, detailing their economic and social significance while addressing critical sustainability challenges such as illegal fishing and governance shortfalls. It discusses the transformative potential of traceability technology in enhancing fisheries management and aligning actual

practices with regulatory frameworks. The chapter underscores the complex socio-political dynamics within the fisheries sector, emphasising the role of ENGOs in fostering a collaborative approach to implement traceability systems effectively. Moreover, it highlights a global dilemma where ineffective monitoring and accountability mechanisms often hinder the operational impact of policies, advocating for traceability technology as a key tool to ensure that regulatory designs are effectively translated into tangible, ground-level actions in fisheries management.

7.1.3 Chapter 3: Literature Review

The - Literature Review conducts a review of the literature surrounding the development of the concepts of sustainability and sustainable development, to then move on to fisheries sustainability, the development of traceability technology and its link to sustainability, as well as the importance of good governance, integrating the theoretical framework of the Sustainable Transitions and Multi-Level Perspective (MLP), to then turn to the literature that portrays the role of ENGOs in influencing change. Recognising existing research gaps, the chapter calls for more focused studies on specific fisheries like jumbo squid and mahi mahi in Peru to enhance understanding and improve sustainability and governance practices in artisanal fisheries.

7.1.4 Chapter 4: Methodology

The – Methodology sets out the research methodology employed in the study, focusing on a qualitative approach to explore the adoption of traceability technology within Peruvian fisheries. The methodology involved data collection through interviews and document analysis, engaging with a diverse set of stakeholders including government officials, industry representatives, artisanal fishers, and ENGOs. A thematic analysis was conducted to extract recurring themes and patterns from the qualitative data, enabling an understanding of the dynamics at play in fisheries management. This chapter explains how the chosen methodologies align with the research questions and objectives, effectively capturing the complexities of implementing traceability systems and their impact on sustainability and governance in the fisheries sector.

7.1.5 Chapter 5: Findings and Analysis

The - Findings and Analysis presents the core findings from the study on the adoption of traceability technology in the jumbo squid and mahi mahi fisheries in Peru. It highlights how traceability impacts fisheries sustainability and governance, underscores the roles played by ENGOs and government institutions in promoting or hindering traceability, and explores the emergence of traceability technology within the sector. The chapter details the challenges of transitioning from policy to practice, emphasising the need to bridge the gap between regulation design and actual implementation to ensure that policies effectively influence ground-level operations. It also discusses the niches where traceability is becoming increasingly prevalent and examines stakeholder responses, including perceived benefits and barriers related to implementation and technological adaptation. The chapter concludes by synthesising these findings and presenting their broader implications for fisheries sustainability, governance, and the advancement of traceability technology.

7.1.6 Chapter 6: Discussion

The – Discussion analyses and interprets the findings related to the adoption of traceability technology in Peruvian fisheries, linking them to the study's research questions and situating them within the broader academic discourse. It reviews the integration of technologies like 'TrazApp' and 'Trace Register' to illustrate how Peruvian fisheries are aligning technological advancements with regulatory demands and international market requirements. The discussion highlights the study's contributions to the existing body of knowledge, addressing gaps in the literature and advancing understanding of traceability's impact on fisheries sustainability and governance. Implications and significance of the findings

This section summarises the implications of the research findings for theory, practice, and policy in the context of fisheries sustainability and governance. It also reaffirms the importance of the findings and their contribution to the existing body of knowledge in the field.

7.1.7 Implications for theory

The findings of this study have several implications for theoretical perspectives on fisheries sustainability and governance. The research suggests the need for a more explicit delineation

of mandates among government institutions to resolve the lack of clarity regarding the assignment of functions and responsibilities to improve fisheries governance in Peru.

The dilemma of institutional discord and regulatory overlap, which resonates with the global challenges of fisheries governance, is exacerbated in the Peruvian context by the complex network of entities involved, each with its distinct mandates and frequently changing staff, leading to a labyrinthian governance structure that hinders more streamlined management.

By examining the impact of traceability technology on fisheries governance, the study contributes to theories of governance, highlighting the importance of transparency, accountability, and stakeholder engagement in achieving sustainable fisheries management.

The research also sheds light on the role of government institutions and environmental ENGOs in driving the adoption of traceability, providing insights into the dynamics of multi-level governance and the interactions between state and non-state actors in the fisheries sector.

The implications of the research findings on the socio-political dynamics within the Peruvian fisheries sector underscore the fundamental, multifaceted roles of ENGOs. ENGOs play a role in advancing fisheries sustainability in Peru through various strategies, ranging from engaging with and promoting traceability adoption in specific fisheries such as jumbo squid and mahi mahi, to boosting certification through Fishery Improvement Projects (FIPs).

ENGOs have moved from being primarily 'honest brokers' to 'development brokers', which signifies a change in their organisational function and identity. Their involvement extends to the creation, improvement, and implementation of traceability systems, combined with capacity building and promoting interoperability with existing public and private systems.

7.1.8 Implications for practice

The practical implications of this research have significant relevance for key stakeholders involved in fisheries management, including policymakers, industry actors, and ENGOs. The findings provide valuable insights that can inform decision-making, improve governance practices, and support the implementation of effective traceability systems in the following ways:

- **Policymakers:** The research highlights the importance of clear regulatory frameworks and coherent enforcement mechanisms to facilitate the adoption of traceability systems. Policymakers can use these findings to strengthen existing legislation or develop new policies that promote sustainability and strengthen governance in the fisheries sector. In addition, the research emphasises the need for enhanced stakeholder engagement and the inclusion of fishers' perspectives in decision-making processes, suggesting that policymakers should create platforms for better dialogue and collaboration to ensure the effectiveness of governance initiatives. These platforms should facilitate and promote political and legal reforms, that create a space for discussion on the diverse perspectives of the fishing sector and that allows for the development of stronger relationships between stakeholders.

- **Industry players:** The study reveals the benefits of traceability systems for industry players, including improved market access, enhanced reputation, and increased consumer trust. A key concept for the organisation and internal process management of a company is traceability. It is based on an organisation’s ability to detail the history, function, applicability or even the location of a particular product using previously established information – which, for some industries, may become a legal requirement. One of the most important benefits of traceability is the possibility of improving the transparency and quality controls of all company activities, allowing for the early identification of risks and their quick correction. The findings underscore the importance of industry-led initiatives and multi-stakeholder collaboration to drive the adoption of traceability across the supply chain.

Transparency in industry governance promotes a cooperative and interactive governance approach that can foster sustainability, which is essential for the long-term viability of the fishing industry, as well as for the health of the oceans and the communities that depend upon them.

Industry players can use the knowledge generated in this thesis to advocate for the implementation of traceability systems within their own operations and support the development of industry-wide standards and best practices. The research also highlights the need for capacity building programmes to facilitate the integration of traceability technology into existing business practices. Traceability systems can also help shed light on working

conditions in the seafood industry and contribute to gender visibility in the sector by capturing data on the people involved at different stages of the supply chain.

- **Environmental NGOs:** The research recognises the critical role of environmental ENGOs in promoting the adoption of traceability and supporting stakeholders in the fisheries sector. The findings demonstrate the value of their expertise, guidance, and capacity-building efforts in driving sustainability and shaping governance practices.

ENGOs can build on these findings to strengthen their advocacy strategies, establish partnerships with government agencies and industry stakeholders, and continue their important work of raising awareness of the benefits of traceability systems, the need for sustainable fisheries management and their wider advocacy on sustainable development. In the context of traceability, ENGOs play an important role in disseminating international experiences, raising awareness of market prerequisites, elucidating the benefits of traceability and formulating policy recommendations.

The practical implications of this research provide all fisheries management stakeholders with valuable information about the benefits and challenges associated with the adoption of traceability. Governments can use these findings to develop or refine regulations; industry players can leverage them to drive industry-wide traceability initiatives; and environmental ENGOs can strengthen their efforts to promote sustainability and support the contributions of other stakeholders.

It can be concluded that interoperability is a fundamental factor to obtain all the benefits of the implementation of traceability systems in fisheries. To achieve interoperability, supply chain actors must first be aware of how interoperable traceability systems will benefit them. By embracing the practical outputs of this research, all relevant stakeholders can work towards more effective and collaborative governance practices and sustainable fisheries management.

7.1.9 Policy implications

The results of the research have significant implications for policy development and decision-making in the fisheries sector. The adoption of traceability technology can contribute to more informed policy decision-making, enabling better monitoring and control of fishing activities and supporting sustainable fisheries management. The results highlight the importance of integrating traceability requirements into fisheries regulations, establishing clear guidelines

for data collection, sharing, and ensuring effective coordination between government institutions. Policymakers can use this knowledge to develop policies that promote the adoption of traceability, combat illegal fishing, and improve the sustainability of fisheries.

7.1.9.1 Policy Recommendations

- **Strengthen regulatory frameworks:** Improve existing legislation and regulations to explicitly mandate traceability systems for all fished species. This can be achieved by requiring the use of standardised data collection and reporting protocols, ensuring comprehensive coverage throughout the entire supply chain, and establishing clear guidelines for traceability implementation and compliance.

- **Improve enforcement mechanisms:** Increase monitoring, control, and surveillance (MCS) capacity to ensure effective enforcement of traceability regulations. This includes allocating resources for regular inspections, audits, and verification of traceability data, as well as implementing appropriate sanctions and penalties for non-compliance. This also requires strengthened collaboration between government agencies, industry associations, and ENGOs to improve compliance efforts.

- **Foster multi-stakeholder collaboration:** To effectively implement traceability in Peru's fisheries, a concerted effort that brings together government agencies, industry representatives, fishers, and ENGOs is essential. This collaborative approach should focus on establishing best practices and standardising traceability protocols. Key initiatives would include:

    - **Formation of a multi-stakeholder traceability working group**: Establish a dedicated traceability working group, composed of government representatives (e.g., PRODUCE, SANIPES), industry leaders, artisanal fishing community leaders, and ENGOs. This group could be convened and mediated by an independent body, such as a national fisheries commission or a specialised working group within PRODUCE.

    - **Stakeholder forums and workshops**: Organize regular forums and workshops that would enable stakeholders to share experiences, discuss challenges and propose

solutions. These sessions could be facilitated by industry associations such as the National Fisheries Society (SNP), providing a platform for dialogue**.**

- **Pilot projects**: Initiate joint pilot projects involving key stakeholders to test and refine traceability systems in different fisheries contexts (artisanal and industrial). These projects can also serve as models and provide valuable information for wider implementation.

- **Shared online platforms:** Develop online platforms for stakeholders to share real-time information, best practices, and updates on traceability technology. This could include a centralised database accessible to all stakeholders, offering transparency and promoting trust between different parties.

- **Policy co-creation workshops:** Conduct workshops that bring together policymakers, fishers, industry experts, and ENGOs to co-create policies and regulations governing traceability. This collaborative policy development can ensure that regulations are practical, equitable, and widely accepted.

- **Capacity building programmes:** Implement specific training and capacity building programmes, especially for small-scale fishers, to improve their understanding of and commitment to traceability systems. These measures could be facilitated by ENGOs with expertise in fisheries management and technology.

- **Formal collaborative fisheries governance arrangements:** There is a need for a more formalised collaborative governance agreement in Peru to ensure the effective adoption of traceability systems and fisheries management in general. This could take the form of a legally established fisheries governance council or a similar entity, tasked with overseeing the implementation of traceability across the fisheries sector. Such a body would ensure that the responsibilities and contributions of each stakeholder group are clearly defined and that there is accountability and transparency in the process.

- **Allocate resources to provide training and technical assistance programmes:** Aimed at improving the knowledge and skills of fishers, industry personnel, and government officials in the effective implementation and utilization of traceability systems. These

capacity-building initiatives should cover areas such as data collection, data management, use of technology and compliance with traceability requirements.

- **Promote market incentives:** Collaborate with international partners and market stakeholders to develop market-based incentives that reward the adoption of traceability and sustainability practices. Explore preferential market access and certification programmes to incentivise industry players and fishers to invest in traceability systems and sustainable fishing practices.

- **Improve collaboration with ENGOs:** To drive the adoption of traceability for the improvement of sustainability and governance in Peruvian fisheries, it is crucial to strengthen partnerships between government entities and ENGOs. ENGOs act as knowledge conduits and regulatory influencers, offering a point of view on how they serve as channels for knowledge dissemination and regulatory influence, linking theoretical knowledge with field practices and policymaking.

These collaborations can draw on the expertise, resources, and networks of ENGOs, integrating their contributions into fisheries policy and practical management. Practical steps for collaboration include:

  - **Designation of a convening body**: A respected and neutral organisation should play the role of convener to facilitate collaboration. Potential candidates include prominent local or international ENGOs, a university with a strong marine science or environmental policy department, a fisheries research institute, or even a United Nations agency such as FAO. The selected coordinator must have the ability to bridge gaps between government and ENGOs, ensuring balanced representation and participation.

  - **Establish joint working committees**: Create new committees composed of representatives from government institutions (e.g., PRODUCE, SANIPES), ENGOS, academic institutions, and industry stakeholders. These committees would focus on specific areas such as policy development, technology integration, and capacity building.

  - **Regular stakeholder dialogues**: Organise frequent opportunities for stakeholder dialogue and workshops, facilitated by the joint working committees, to discuss

progress, challenges, and plans related to fisheries traceability and management. Such dialogues would help to foster transparency and mutual understanding among all parties.

- **Collaborative research projects**: Encourage joint research initiatives and projects involving government agencies, ENGOs, and academic institutions. By aligning knowledge sharing and regulatory influence, ENGOs in Peru have the potential to weave a coherent narrative into the adoption of traceability that is both globally informed and locally applicable. These research projects could explore new traceability technologies, assess their impact on the sustainability of fisheries, and identify best practices for their implementation.

- **Knowledge exchange**: Develop formal knowledge-sharing programmes, where experts from ENGOs and academia can share ideas and innovations with government and industry representatives. These could take the form of workshops, training sessions, or collaborative research.

- **Policy advisory panels**: Include ENGOs in advisory groups that help shape fisheries policies and regulations. Their inputs can provide a broader perspective, ensuring that policies are comprehensive, effective, and can maintain sustainability across relevant spatial scales.

- **Funding and resource sharing mechanisms**: Establish funding instruments to support joint initiatives. This could involve the creation of a dedicated fund, pooling resources from various stakeholders, or seeking external funding (e.g. grants from international organisations). The impact of ENGOs' financial contributions, particularly in developing countries, often depends on alignment between donor objectives and local needs, making this a difficult balance to achieve. By acting as financial conduits, ENGOs facilitate national and international funding flows that directly impact the implementation of projects in the fisheries sector. It is equally important to strategically apply these funds to ensure they catalyse substantial and sustainable improvements in traceability.

- **The role of government**: While a neutral convener is ideal for facilitating collaboration, government should support and actively participate in these initiatives. A clear

delineation of mandates among the governing bodies are essential to resolve the prevailing chaos, offering a more agile path towards coherent and effective fisheries governance in Peru. Consequently, the involvement of the government is crucial to ensure that collaborative efforts are aligned with national policies and objectives, and to provide the necessary policy and logistical support.

- **Continuous monitoring and evaluation:** Establish a robust system for monitoring and evaluating the effectiveness of traceability systems in achieving the intended objectives. Regularly evaluate the performance of traceability programs, gather feedback from stakeholders, and use the information to inform policy adjustments and improvements. Emphasise the importance of adaptive management in addressing emerging challenges and capitalising on opportunities for further improvement.

By implementing these policy recommendations, the Peruvian government has the potential to create an enabling environment for the adoption of traceability technology, strengthening fisheries governance, and promoting sustainability. These measures will contribute to increasing transparency, accountability, and responsible practices throughout the seafood supply chain, ultimately leading to a more sustainable and resilient fisheries in Peru.

7.1.10 Social and economic impacts

The adoption of traceability in the fisheries sector has important social and economic implications for the various stakeholders. The implementation of traceability systems can bring both positive and negative effects, which should be carefully considered.

7.1.10.1 Positive Impacts

- **Improved livelihoods:** Traceability systems have the potential to improve the livelihoods of fishers by promoting fair trade practices and access to premium markets. By ensuring the traceability of their products, fishers can demonstrate compliance with sustainability standards, which can lead to better market opportunities and increased revenues.

- **Strengthening community participation:** Traceability systems can empower local fishing communities by giving them a voice in decision-making processes and improving their representation in fisheries management. Through active participation,

fishers can contribute to the formulation of policies more in line with their needs and aspirations.

- **Market competitiveness:** The adoption of traceability systems allows fishers and seafood processors to access international markets that have strict traceability requirements. By meeting these requirements, Peruvian seafood can gain a competitive advantage, enhance its reputation, and command higher prices in the global marketplace.

7.1.10.2 Negative impacts

- **Costs and technological barriers:** Implementing traceability systems can involve upfront costs and technological challenges, particularly for small-scale fishers and resource-limited stakeholders. The adoption of new technologies and the need to improve infrastructure may pose financial burdens and require appropriate support mechanisms to ensure more equitable participation.

- **Exclusion from the market:** In cases where traceability systems are not implemented effectively or do not meet market standards, there is a risk of exclusion from the market. Fishers and seafood processors who are unable to meet traceability requirements may struggle to access premium markets, which can impact their economic viability and competitiveness.

It is crucial to carefully manage and mitigate the potential negative impacts associated with the adoption of traceability. As noted earlier, this can be achieved through targeted support programmes, capacity-building initiatives, and financial considerations to ensure that fishers and other relevant stakeholders can overcome barriers and actively participate in traceability processes.

In addition, there are many criteria and methodologies for evaluating and optimising the performance of a traceability system. In fact, impact assessments should be carried out to monitor and assess the social and economic consequences of the adoption of traceability. These assessments should consider the diverse characteristics of fishers and fishing communities, such as gender dynamics, cultural differences, and socio-economic conditions, to ensure that the benefits of traceability are more inclusive and sustainable.

While there is agreement in recognising the merits of traceability, there are divergences in how different stakeholders prioritise the distinct benefits of traceability, reflecting unique challenges and priorities.

In the Peruvian context, stakeholders identify and prioritise divergent utility aspects of traceability, reflecting their operational and strategic imperatives. These findings contrast with sectors where stakeholder alignment on technological benefits leads to more uniform prioritisation and adoption, which could be due to the diversity and complexity of the fisheries sector in Peru.

By considering and addressing the social and economic impacts of the adoption of traceability, policymakers, industry actors, and other relevant stakeholders can develop strategies that maximise positive outcomes and mitigate potential challenges, thereby creating a more equitable and sustainable fisheries sector in Peru.

7.1.11 Stakeholder engagement

Traceability systems can improve stakeholder engagement by involving fishers, processors, and other relevant actors in decision-making processes. The perspectives and inputs of all relevant stakeholders, including government institutions, industry players, and ENGOs, have been invaluable in shaping the results of this study. Reflecting on their commitment, it is important to recognise the value of fostering multi-stakeholder collaboration and promoting inclusive decision-making processes for the development of more sustainable fisheries management practices.

7.1.11.1 Collaboration for sustainable fisheries management

- **Government institutions:** The active participation of government institutions is crucial for the successful implementation of traceability systems and the overall governance of the fisheries sector. Close collaboration between different government agencies can ensure coordination and alignment of efforts, resulting in consistent policies and regulations. Involving the artisanal fishing community and industry representatives in decision-making processes where appropriate and leveraging their expertise can promote effective governance practices and policy reforms that support sustainability.

- **Industry actors:** Collaboration with industry stakeholders, including fishers, seafood processors, and supply chain actors, is essential in addressing the practical challenges of traceability adoption. By actively involving industry players in the design and implementation of traceability systems, their perspectives, needs, and concerns can be addressed, fostering a sense of ownership and shared responsibility. Industry-driven initiatives, such as fisheries improvement projects, can further contribute to sustainability practices by promoting traceability, supporting resource conservation, and improving the economic viability of the sector.

- **Artisanal fishers:** are a vital stakeholder group whose inclusion in traceability initiatives is essential for fostering sustainability and good governance in fisheries management. Despite facing challenges such as bureaucratic hurdles, resource limitations, and informality, actively engaging artisanal fishers in the design and implementation of traceability systems ensures that their needs and realities are addressed. This participatory approach builds trust, enhances their capacity to navigate formal systems, and empowers them through tailored solutions, capacity-building initiatives, and simplified regulatory frameworks. Traceability systems improve artisanal fishers' visibility within supply chains, enable fair compensation, and strengthen their compliance with regulations, thereby enhancing their livelihoods and market position.

- **ENGOs:** play a key role in promoting more sustainable fishing practices and the adoption of traceability systems. Their experience, research capabilities, and engagement with diverse stakeholders help bridge the gap between policymakers, industry players, and local communities. By facilitating dialogue, knowledge sharing, and capacity building, ENGOs contribute to more informed decision-making processes and the development of more robust sustainability initiatives.

7.1.12 Impact and contribution to knowledge

The value of this research lies in its contribution to the existing body of knowledge in the field of fisheries traceability technology, with the theoretical underpinning of the Sustainability Transitions MLP. By examining the specific context of jumbo squid and mahi mahi fisheries in Peru, this study provides empirical evidence of the impact of electronic traceability systems on fisheries sustainability and governance outcomes. The research contributes to a deeper

understanding of the roles and interactions of different stakeholders, including government institutions, artisanal fishers, industry players, and ENGOs, in driving the adoption of traceability, as well as its perceived benefits and barriers. The study fills gaps in the literature by exploring the complexities of the application of traceability in the context of developing countries and highlighting the challenges and opportunities of enabling more sustainable fisheries management.

The findings of this study contribute to the ongoing debate on traceability technology and its potential to improve the sustainability and governance of fisheries. As the research delved deeper into the perceptions of different stakeholders regarding the adoption of traceability technology in Peruvian fisheries, it became apparent that there was general agreement on its benefits. Almost all individuals surveyed from the different sectors studied (government, artisanal fishing communities, industry, and ENGOs) demonstrated agreement on traceability as a transformative tool to foster sustainability, legality, transparency, and informed decision-making, collectively exemplifying the widely shared potential of technology to improve fisheries governance and elevate stakeholder engagement.

The research offers considerable insights for researchers, policymakers, and practitioners seeking to improve traceability systems, strengthen stakeholder participation, and promote the sustainability and good governance of fisheries globally.

7.2 Evaluation of research objectives

This section assesses the extent to which the research objectives have been achieved based on the results of the study. It discusses how each research objective has been addressed and supported with the results and the strengths and limitations of the research design and methodology used.

RO1: Investigate how the transition to electronic traceability systems is occurring in Peruvian jumbo squid and mahi mahi fisheries: The study effectively explored the emergence of traceability technology in Peruvian jumbo squid and mahi mahi fisheries, uncovering the drivers behind its adoption. The results detailed the important role of international market pressures and regulatory requirements in initiating the transition to traceability. Information on stakeholder motivations revealed multidimensional perspectives emphasising

sustainability, legal compliance, and market access as primary catalysts for the adoption of traceability technology.

The research further explored the traceability of fisheries and their characteristics and has provided a basis for understanding the dynamics, implications, and potential pathways for sustainable fisheries management in the Peruvian context. This research evaluated the drivers, principles, benefits, and beneficiaries of traceability technology.

Stakeholder reactions and barriers: The study documented diverse stakeholder perspectives about the implementation of traceability. The study identified key barriers such as technological challenges, resistance from certain industry actors, and the need for capacity building, especially within government institutions and the artisanal fishing community.

RO2: Assess the influence of ENGOs and government structures on the adoption of electronic traceability systems in the jumbo squid and mahi mahi fisheries in Peru: The research explored the dynamic relationships of ENGOs with government agencies, industry actors, and artisanal fishers. Furthermore, the study highlighted the critical role of ENGOs in promoting, raising awareness, and facilitating knowledge transfer, contributing significantly to the promotion of traceability.

Influence of ENGOs on the adoption of traceability: The research results described situations in which ENGOs significantly influenced the adoption of traceability and cases in which their impact was limited. The study looked into the factors that increased or hindered their effectiveness, offering an understanding of the role of ENGOs in the fisheries sector.

Government influence on adoption: The influence and impact of government institutions and regulations on the adoption of traceability was also analysed. The research shed light on the critical role of governance and regulatory frameworks, government capacity, and inter-agency coordination in facilitating or impeding the adoption of traceability systems.

By improving information sharing and promoting greater transparency and accountability, traceability has the potential to help reduce corruption, combat illegal activities, and increase the efficiency of government institutions and the implementation of national fisheries regulations.

7.2.1 Reflections on research design and methodology

The research design facilitated an in-depth exploration of the complex dynamics surrounding the adoption of traceability in Peruvian fisheries. However, limitations such as geographic focus and stakeholder representation may influence the generalisability of the findings.

The methodological approaches allowed for the understanding of the sustainability transition to traceability technology adoption, highlighting the interaction between various stakeholders and the multifaceted nature of associated transitions in the context of developing countries.

Ultimately, the study effectively addressed and supported the research objectives, offering meaningful insights into the transition to traceability technology in Peruvian fisheries and the roles of diverse stakeholders, particularly ENGOs and governmental actors, in this process.

7.3 Contribution to the fields

This study makes contributions to the fields of fisheries management and traceability technology. In addition, it fills gaps in the existing literature and advances knowledge in the subject area of sustainability transitions.

7.3.1 Originality and significance of the research

This research is one of the first academic studies to examine the adoption and impact of traceability technology in Peru's jumbo squid and mahi mahi fisheries. It provides an in-depth analysis of the complex interactions between stakeholders, including government institutions, ENGOs, industry actors, and the artisanal fishing community. By focusing on these specific fisheries, the study offers a detailed understanding of the challenges and opportunities associated with adopting traceability in a unique geographical, sectoral and cultural context.

The originality of this research lies in its exploration of the relationships and dynamics between stakeholders, shedding light on the role of traceability in improving sustainability and governance in fisheries. The qualitative approach of the study allowed to obtain insight into the experiences, perspectives and decision-making processes of the different actors involved in the adoption of traceability. This understanding contributes to the broader discourse on fisheries management and traceability technology, providing a valuable basis for future research and practical applications.

7.3.2 Filling gaps in the existing literature

This study fills gaps in the existing literature on traceability technology and fisheries management. While previous studies have examined the adoption of traceability in various contexts, this appears to be one of the first studies to focus on jumbo squid and mahi mahi fisheries in Peru. By addressing this gap, the research expands our knowledge of traceability practices in specific fisheries and provides information that can inform other specific interventions and contribute to policy recommendations.

In addition, the study goes beyond examining the technical aspects of traceability and delves into the institutional and governance dimensions. It explores the role of government institutions and ENGOs, shedding light on their interactions and contributions with regards to the adoption of traceability.

This research also offers an exploration of fisheries sustainability management and governance, incorporating diverse stakeholder perspectives. This approach enriches the study by providing a view of the complexities of fisheries management, particularly in the way different stakeholders perceive, react, and influence the adoption and implementation of traceability technology. This facet of the research highlights the importance of considering diverse viewpoints and experiences in fisheries governance, thus contributing to a more inclusive understanding of sustainability management in this sector.

This study provides a basis for future research, policy development, and practical applications aimed at improving sustainability and governance in fisheries through the adoption of electronic traceability systems around the world.

7.4 Reflection on the research process

This section reflects on the research process itself, including consideration of some of its limitations and challenges that were encountered during the study. By acknowledging these limitations and challenges, it demonstrates the researcher's awareness of potential sources of bias and improves the credibility of the research.

7.4.1 Limitations

During this research, several limitations were identified that are worthy of noting. First, the study focused specifically on the jumbo squid and mahi mahi fisheries in Peru, which may limit the generalisability of the findings to other fisheries contexts. While efforts were made to select these fisheries as representative examples, caution should be exercised when extrapolating the results to different regions or species.

Another limitation relates to the qualitative nature of the research. While qualitative methods allowed for in-depth exploration and understanding of stakeholder perspectives and experiences, they may be subject to biases and interpretations by researchers. To mitigate this, rigorous data analysis techniques, including triangulation and interviewee verification, were employed to ensure the reliability and validity of the findings. However, it is important to recognise that subjective interpretations can influence analysis to some extent.

In addition, the research was conducted within a specific period, in the context of the COVID pandemic, which may have limited the depth and breadth of the study. Although efforts were made to include diverse stakeholders and data, there may be aspects of traceability adoption and its impacts that have not been fully captured. Future studies with larger sample sizes and longer timeframes could further explore these issues and provide additional insights, particularly in the context of fast developing technologies.

7.4.2 Challenges

During the research process, several challenges were encountered that influenced the execution and findings of the study. A notable challenge was the access to and participation of certain stakeholders, particularly government officials and industry representatives. Securing their participation and including their perspectives proved to be difficult due to time constraints, bureaucratic processes, and competing priorities, particularly in the context of the COVID-19 pandemic. Nonetheless, every effort was made to maximise stakeholder participation and bring together a wide range of perspectives.

Another challenge was navigating the complex political and institutional landscape surrounding fisheries governance in Peru. Conflicting regulations, inconsistent enforcement, and frequent policy changes added complexity to the research process.

7.4.3 Mitigation strategies

To mitigate the limitations and challenges faced during the research, several strategies were employed. These include utilising rigorous data analysis techniques, engaging in reflective practices, maintaining detailed field notes, and verifying interview transcripts to ensure the accuracy and credibility of findings. In addition, establishing trusting relationships with relevant stakeholders through ongoing engagement and transparent communication contributed to the quality and depth of the data collected.

In addition, regular consultations and feedback from the research advisory committee and peer investigators helped improve the research design and analysis, ensuring a robust and well-informed study. Their guidance and expertise provided valuable perspectives that enriched the overall research process.

7.5 Recommendations for future research

This section offers suggestions for future research based on the limitations of the current study and the gaps identified in the literature. These recommendations are intended to guide further research that can build on the results of this study and advance knowledge in the field of fisheries management and traceability technology.

7.5.1 Expansion to different fishing contexts

While this study focused on jumbo squid and mahi mahi fisheries in Peru, there is a need for research exploring the adoption of traceability and its impacts in other fisheries contexts. Future studies could examine the effectiveness of traceability systems across different regions or species, considering variations in governance structures, market dynamics and socio-economic conditions. Comparative studies across several countries or regions could also provide valuable information on the transferability and adaptability of traceability systems.

7.5.2 Longitudinal studies

Given the dynamic nature of fisheries governance and the adoption of traceability, longitudinal studies would be beneficial. Longitudinal research designs would allow for the tracking of changes and developments over time, capturing the long-term impacts of traceability technology on fisheries governance and sustainability. Such studies would

improve our understanding of the evolution of traceability systems, the challenges faced during implementation, and the effectiveness of governance interventions over extended periods. Ultimately, collecting data for a longitudinal study can help identify cause-and-effect relationships that may not otherwise be perceived.

In addition, longitudinal research could evaluate the effectiveness of traceability technology in achieving sustainability and governance goals. This objective would focus on assessing the actual environmental, social, and economic impacts of traceability implementation in the Peruvian or other fisheries context. By examining outcomes such as reductions in IUU fishing, improvements in resource management, and enhanced livelihoods for artisanal fishers, as well as government transparency and accountability, these studies could provide valuable insights into the extent to which traceability contributes to sustainability and governance objectives. Such evidence-based evaluations would not only inform policy and practice but also guide the refinement of traceability systems to better align with sustainability and governance goals.

7.5.3 Evaluation of governance interventions

To make further progress in the field of fisheries governance and traceability, research is needed to assess the effectiveness of targeted governance interventions aimed at promoting sustainability practices. This could involve assessing the impacts of policy reforms, capacity-building initiatives, and collaborative governance models on the adoption of traceability, compliance with regulations, and the achievement of sustainability goals. By evaluating these interventions, valuable insights can be gained on the most effective approaches to improve fisheries sustainability governance and traceability implementation.

7.5.4 Integration of technological advances

As traceability technology continues to evolve, future research should explore the potential integration of emerging technologies, such as blockchain, artificial intelligence, and the Internet of Things (IoT) into traceability systems. Research into the perceived benefits and challenges associated with these new technologies could inform the design of more efficient, secure, and interoperable traceability solutions. In addition, studies focusing on the usability and user experience of traceability technologies would contribute to their effective adoption and acceptance by a wider range of stakeholders.

7.5.5 Socio-economic impacts of traceability

While this study focused primarily on the sustainability and governance aspects of traceability, future research should also examine the socio-economic impacts of traceability systems on different stakeholders, in particular small-scale fishers, and fishing communities. Understanding the socio-economic implications, including livelihood dynamics, power relations, and social equity, can help guide policymaking and decision-making processes to ensure that traceability initiatives are not only environmentally and economically sustainable, but also socially just and inclusive. With the development of new technologies and systems, the capability for end-to-end traceability is becoming an increasingly attainable reality.

7.6 Closing remarks

At the conclusion of this thesis, key insights into the adoption and impact of traceability technology to Peru's jumbo squid and mahi mahi fisheries have been revealed using the Sustainability Transitions MLP theoretical framework. This study has brought together diverse perspectives of fisheries stakeholders, the role of government and ENGOs, and the interplay of sustainability and governance within fisheries management.

The research objectives set at the beginning of this study have been met, and the results enrich the understanding of the sustainability and governance of fisheries in the context of the adoption of traceability technology. Despite focusing on specific fisheries in Peru, the insights gained offer valuable considerations for broader applications and highlight potential challenges of implementing traceability systems in various fishery contexts.

While this research provides a contribution to the fields of fisheries sustainability and governance, inherent limitations are recognised. The specificity of the context and the problems encountered in data collection underscore the need for cautious extrapolation of the results. Consequently, this opens avenues for future research, suggesting the exploration of diverse fisheries contexts, longitudinal studies, and integration of emerging technologies to deepen understanding of the role of traceability in sustainable fisheries.

Embarking on a journey through the lived experiences of traceability adoption in Peruvian fisheries, this research creates a narrative that reveals both conformity and divergences from existing theoretical frameworks on sustainability transitions. External pressures, especially

from prominent international markets, emerge as undeniable catalysts, igniting transformative actions and innovative efforts within fisheries.

The research reveals important implications both within the specific scope of traceability adoption in Peruvian fisheries and in the broader space of sustainability transitions. By promoting understanding, linking research and practice, enriching governance discourses, and contextualising transitions in developing countries, this study presents tangible ideas to guide the future trajectory towards sustainable fisheries management through the adoption of traceability.

As the thesis concludes, the study underlines the contribution of traceability to improve the sustainability and governance of fisheries. Collaborative efforts by various stakeholders, coupled with effective policy interventions, are crucial to the successful implementation of traceability systems. This research offers pragmatic insights for stakeholders interested in navigating the complexities of integrating traceability into sustainable fisheries management.

In essence, this thesis contributes to shaping a future in which fisheries are managed more sustainably, ensuring that marine resources are conserved and protected for generations to come, thus echoing the global call for more responsible and sustainable practices in our interactions with the world's oceans.

Annex 1 – Interview Questionnaire

Interview Questionnaire

Title of Study: To Legalize or Not to Legalize: Evaluating the Contribution of Technology to the governance and sustainability of the Peruvian Mahi mahi and Jumbo Squid Fisheries

Personal Information

Name:

Briefing and Consent

- *Provide participant with information sheet and respond to any questions*
- *Confirm participant consent*

Background Fisheries Information

1. Can you briefly tell me about yourself and your activities related to the fishing sector?
2. What is your relation to the mahi mahi and jumbo squid fisheries?

Traceability

3. Can you tell me how much you know about or have been exposed to traceability?
4. What do you think are the benefits of traceability technology? Do you see any downsides to using a traceability system?

5. Do you think traceability contributes to fisheries sustainability? If so, how so? If not, why not?

6. Do you think traceability can contribute to fisheries governance in Peru? If so, how so? If not, why not?

7. Can you describe how is traceability emerging in Peru?

8. Are fishing practices being impacted by this technology? How do you think they will be impacted in the future?

9. How have you seen the adoption of traceability in Peru evolve over time?

10. What do you think is needed so traceability becomes mainstream in Peru?

11. Which institutions are supporting the adoption of traceability in Peru and which are not?

12. What has been the response of the sector to the development of this technology and changes in their practices?

Peruvian Institutions

13. What is the role of Peruvian government institutions in fisheries governance?

14. How well do these institutions deliver on their mandate and why?

15. Can you provide examples of issues you are aware about and what are the improvements you would suggest?

16. Is there consistency in the Peruvian legislation overseeing fisheries? Please provide specific examples.

17. Do Peruvian government institutions work in a coordinated way to deliver on these norms? Can you describe some of your main concerns when it comes to coordination between government institutions?

18. Do fishers receive the information and support they need to be able to implement the regulations pertaining to their sector? Can you provide examples of issues and mention the improvements would you recommend in this area?

19. What mechanisms are in place for fishers to be able to participate in policy decision-making processes related to their sector? Which mechanisms do you think are lacking?

20. Do you think fishers' rights and concerns are considered in governmental decision-making processes?

21. Are women's rights in the fishing sector considered? Can you provide specific examples and suggest areas for improvement?

22. Who do you think are the winners and losers of the current status quo?

Environmental NGOs

23. What do you think is the role of environmental NGOs in influencing sustainable transitions?

24. Do you think NGOs are successful in this regard? Why?

25. How do NGOs engage with government? Please provide examples.

26. How do NGOs engage with industry? Please provide examples.

27. What are the factors that determine if an NGO is successful in its pursuit?

28. What are the factors that cause the opinions of NGOs to be marginalized under certain conditions?

29. What recommendations would you make to improve NGOs success rates in promoting sustainability in fisheries?

Conclusion

30. Anything else you would like to add before we finish this interview or any questions from your end?

- *Thank participant and provide debrief sheet.*

Annex 2 – Ethics Approval

Aimee Leslie Bogantes
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5 May 2020

Request for Ethical Clearance – Our Ref: 19/49
Project: To legalise or not to legalise: Evaluating the contribution of Techonogy to the governance and sustainablility of the Peruvian Mahi mahi and Jumbo Squid Fisheries

Dear Aimee

Thank you for your revised documentation.

Approval has been granted with no further changes or amendments.

Kind regards

Professor Diane Cox
Chair
Research Ethics Panel

Acronyms

AIS - Automatic Identification System

APC - Peru-United States of America Trade Promotion Agreement

APEC – Asia Pacific Economic Cooperation

ASC - Aquaculture Stewardship Council

CALAMASUR - Committee for the Sustainable Management of Giant Squid

CAPECAL - Peruvian Chamber of Jumbo Squid

CASS - Conservation Alliance for Seafood Solutions

CITES - Convention on International Trade in Endangered Species of Wild Fauna and Flora

CoC – Chain of Custody

CSR – Corporate social responsibility

DER - Declaration of extraction or collection

DHC - Direct human consumption

DICAPI - General Directorate of Captaincies and Coastguards

DGPCHDI - Directorate of Fishing for Direct and Indirect Human Consumption of PRODUCE

DGSFS - General Directorate of Supervision, Inspection, and Sanctions of PRODUCE

DIREPROs - Regional Production Directorates

DPA - Fish landing site according to the Spanish acronym

DSA - Data Sharing Agreement

EC – European Union Council Regulation

ECDT - Electronic Catch Documentation and Traceability

ENGO – Environmental non-governmental organisation

EU – European Union

FAO - Food and Agriculture Organisation of the United Nations

FDA - U.S. Food and Drug Administration

FIP - Fishery Improvement Project

FONDEPES - National Fisheries Development Fund of Peru

FPAS - Forum for Sustainable Fisheries and Aquaculture

GDP - Gross Domestic Product

GDST - Global Dialogue on Seafood Traceability

GFL - General Fisheries Law of Peru

GFW - Global Fishing Watch

IATTC - Inter-American Tropical Tuna Commission

IIED - International Institute for Environment and Development

ILO – International Labour Organisation

IMARPE - Marine Research Institute of Peru

IMARSIS - Fisheries Information System of IMARPE

IMO - International Maritime Organization

IUCN - International Union for the Conservation of Nature

IUU – Illegal, unregulated, and unreported

ISO - International Standardisation Organisation

JAS – Japan Agriculture Standards

KISS – Keep it Simple, Stupid

MCS - Monitoring, Control, and Surveillance

MINAM – Ministry of Environment

MLP - Multi-Level Perspective

MSC - Marine Stewardship Council

MSP - Multi-stakeholder partnerships

MSY - Maximum Sustainable Yield

MARE - Centre for Maritime Studies of the University of Amsterdam and Wageningen

NDF - CITES Non-Detrimental Finding Report

NGO – Non-governmental organisation

NOAA- National Oceanic and Atmospheric Administration

OGTI - General Office for Information Technology of PRODUCE

PMA - Peru Mahi Alliance

PNIPA - National Program for Innovation in Fisheries and Aquaculture

PRODUCE - Ministry of Production of Peru

RENIEC - National Registry of Identification and Marital Status of Peru

RFMO - Regional Fisheries Management Organisation

RO – Research objective

ROP - Fisheries Management Plan

RQ – Research question

RS – Revenue sharing

SANIPES - National Fisheries and Aquaculture Health Service of Peru

SDG - Sustainable Development Goal

SERFOR – National Forestry and Wildlife Service of Peru

SFP - Sustainable Fisheries Partnership

SIMP - U.S. Seafood Import Monitoring Programme

SIMTRAC - Aquatic Traffic Identification and Monitoring System of PRODUCE

SISESAT - Vessel Satellite Tracking System of PRODUCE

SITRAPESCA - Fisheries and Aquaculture Traceability System of PRODUCE

SNI - National Society of Industries

SNM - Strategic Niche Management

SNP - National Fisheries Society

SSF - Small-scale fisheries

SUNAT - Superintendency of Customs and Tax Administration of Peru

TAC – Total Allowable Catch

TfS - Traceability for Sustainability

TM - Transition Management

TRASAT - Satellite Traceability System of PRODUCE

TRAZAMOBI - Traceability System for Molluscs and Bivalves of SANIPES

TRU - Traceable Resource Unit

UNEP - United Nations Environment Programme

UNGA – United Nations General Assembly

UNGC - United Nations Global Compact

US – United States of America

WCED – World Commission on Environment and Development

WTO - World Trade Organisation

WWF - World Wide Fund for Nature (also known as World Wildlife Fund)

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