Exploring traceability in small-scale fisheries: from harvest to landing

By

Camille Marie Clémentine Mancion

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Pour Frédéric Mancion et Papé (Jean-Michel Mancion) ;
Nous sommes liés a jamais par notre amour pour l'océan

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Abstract

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As consumers and governments demand to know the origins of seafood products, there is a push for transparency across the seafood supply chain. However, for many small-scale fisheries (SSF), this growing demand for transparency is also serving as a barrier to markets and additional financial burdens as they are increasingly required to demonstrate traceability in their operations at sea. Through a literature review, this study outlines global traceability requirements from point of harvest to landing, including legal and recommended key data elements from large seafood importing markets. Overall, reporting requirements varied between countries at different stages along the supply chain. The study identifies some of the challenges faced by SSF in adopting traceability systems including cost, data sharing and privacy concerns, infrastructure limitations, poor governance and lack of incentives. With this information, an evaluation framework was developed as a tool for SSF to identify traceability systems appropriate for data collection and reporting at sea. Through a case study on Indonesian small-scale tuna fisheries, the framework evaluates three traceability tools. Well-implemented, traceability systems provide an opportunity for SSF to demonstrate their sustainability commitments and obtain a higher market price for their products. Highlighting the benefits of electronic traceability systems and developing appropriate incentives is key to increasing the adoption of traceability tools in SSF globally.

Keywords: traceability, small-scale fisheries, Indonesia, traceability technologies, reporting requirements, IUU fishing

Abbreviations

CCAMLR	Convention for the Conservation of Antarctic Marine Living Resources
CCP	Catch Certification Program
CCS	Catch Certification Scheme
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CDS	Catch Documentation Scheme
CTE	Critical Tracking Event
eLogbook	Electronic Logbook
EU	European Union
FAME	Futuristic Aviation and Maritime Enterprise
FAO	Food and Agriculture Organization
GDST	Global Dialogue on Seafood Traceability
GPS	Global Positioning System
GT	Gross Tons
ICCAT	International Commission for the Conservation of Atlantic Tunas
IMO	International Maritime Organization
IPNLF	International Pole and Line Foundation
IUU	Illegal Unregulated Unreported
KDE	Key Data Element
MMAF	Ministry of Marine Affairs and Fisheries
MDPI	Yayasan Masyarak dan Perikanan Indonesia
NFC	Near-field Communication
NGO	Non-governmental Organization
NOAA	National Oceanic and Atmospheric Administration
ODK	Open Data Kit
RFMO	Regional Fisheries Management Organization
SIMP	Seafood Import Monitoring Program
SSF	Small-scale Fisheries
US	United States
UVI	Unique Vessel Identifier
VMS	Vessel Monitoring Systems

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Chapter 1: Introduction

Globally, there is an expanding demand for transparency in the seafood industry as consumers and governments are requiring a full disclosure of the origins of their products. In the past, seafood traceability was mainly aimed at addressing food safety concerns (Bailey et al., 2016). Today, traceability in the seafood industry can be linked to rapidly expanding trends to increase transparency in fishing activities at a national and international scale. With challenges ranging from overfishing to labour abuse at sea, traceability can provide a framework for transparency and an opportunity for fisheries to demonstrate their sustainability commitments. Governments and regional fisheries management organizations are taking innovative steps to coordinate catch documentation, prevent illegal fishing practices and encourage responsibly-caught fish (Bush et al., 2017; Iles, 2007). In recent years, several global traceability initiatives have emerged including the Global Dialogue on Seafood Traceability (GDST), The Seafood Alliance for Legality and Traceability (SALT) and The Seafood Ethics Action Alliance (SEA Alliance) (FAO, 2018). These industry-led initiatives are collaborating with stakeholders worldwide to advance traceability and provide guidance to fisheries and seafood industries. Moreover, non-governmental organizations (NGOs) including World Wildlife Fund for Nature (WWF), Oceana, Future of Fish and FishWise are collaborating to advance traceability across seafood supply chains on a global scale. Additionally, industry and NGOs are transitioning towards transparency in seafood supply chains through the development of fishery improvement projects (FIPs) (Wakamatsu & Wakamatsu, 2017). This trend of traceability is increasingly providing opportunities for fisheries to differentiate their catch as originating from practices that are socially and environmentally responsible, and can help connect with lucrative sustainable seafood markets (Iles, 2007).

Fishery products are a highly traded food commodity, with international trade increasing rapidly in recent decades as seafood markets expand from a regional to global scale (FAO, 2020d). In parallel, the increasing demand for traceability is forcing large seafood importing nations, including the United States (US) and European Union (EU), to in turn demand key information from importers regarding the traceability of seafood products from “boat-to-plate” (FishWise, 2018; Sylvia et al., 2020). For instance, the EU requires seafood imports to be accompanied by a catch certificate, including records of the product's harvest area, catch vessel, transport vessel and Flag State (The Council of the European Union, 2008). This measure was implemented to deter illegal, unreported and unregulated (IUU) fishing, and to ensure compliance with conservation measures (USAID, 2020). In 2018, the Seafood Import Monitoring Program (SIMP) was established by the US to enhance traceability and reporting of imported seafood products to prevent IUU caught fish and misrepresented seafood from being traded on the US market (NOAA Fisheries, 2019a). These forms of regulatory traceability can aid in validating the origin of seafood products for both importing and exporting countries (Bailey et al., 2016).

Traceability is defined 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" (FAO, 2020a). For seafood, this implies tracing the final seafood product up the supply chain to the point of harvest. Traceability includes the products' origin, processes or transformations and distribution (Expert Panel on Legal and Traceable Wild Fish Products, 2015). In this way, traceability is a framework for transparency (FAO, 2020a). Transparency is broadly defined as the disclosure of information (Mol, 2015), and with respect to global value chains, there is an increasing trend in voluntary and mandatory transparency to the sustainability of products and production processes (Mol, 2015). Strengthening traceability in seafood supply chains can bring several benefits to fisheries including improvements in operational efficiency and reduced spoilage (Mai et al., 2010). In addition to improving brand image, robust traceability systems can enhance consumer loyalty and help seafood producers gain access to more profitable markets (Bush et al., 2017). These advantages are particularly beneficial for small-scale fisheries to promote their engagement in sustainable practices and differentiate themselves in the global market.

Small-scale fisheries (SSF) play a significant role in the socio-economic well-being of many coastal communities by sustaining local livelihoods and food security. In many countries, SSF are embedded within local culture and traditions, supporting social cohesion (FAO, 2015). SSF contribute to over half of the world's fish catches and employ over 90% of the world's capture fishers (FAO, 2020c). They play a vital role in poverty alleviation and social safety nets in many developing countries (The World Bank, 2012). The Food and Agriculture Organization (FAO) Guidelines on Securing Small-Scale Fisheries describes SSF as "diverse and dynamic, as well as generally anchored in local communities and having historic links to adjacent fishery resources, traditions and values" (FAO, 2017, p. 6). The definition of SSF varies across countries as there is no universally agreed-upon definition. They are broadly characterized according to fishing gear type, vessel characteristics (e.g. length or tonnage) or socio-cultural factors (Smith & Basurto, 2019). This study uses the broad definition outlined above to describe small-scale fisheries. The case study explored later in the text will use the countries' definitions of SSF as this is context-dependent.

Though SSF are often associated with local markets and subsistence fishing, many are linked with international markets as seafood landed is distributed globally (Crona et al., 2015; Smith & Basurto, 2019). In comparison with industrial fisheries, SSF are known to generate less waste in terms of unwanted catch discarded and are generally less energy intensive (The World Bank, 2012). Despite this, SSF usually face challenges in being upgraded to sustainable seafood markets. As Wakamatsu & Wakamatsu (2017) explain, SSF face difficulties in realizing market benefits and price premiums for their products. Though market-based certifications like Marine Stewardship Council (MSC) bring a wide range of benefits to fishers, it is often criticized for being inaccessible to SSF (Wakamatsu & Wakamatsu, 2017). In many cases, MSC traceability requirements, operationalized through their chain of custody certification, originate in the Global North and are designed for large-scale fisheries, creating several barriers for SSF, particularly in developing countries (Duggan & Kochen, 2016). Lack of financial resources is a significant challenge faced by many SSF that are keen on being certified, as MSC certifications are associated with high investment costs for assessment and maintenance (Bailey et al., 2016). Additionally, it remains unclear who is to pay to for these traceability systems (Bush et al., 2017). These obstacles hinder small-scale fisheries' ability to obtain a premium price for their products as they are left out of upgrading to a sustainable market. As Purcell et al. (2017) suggest, small-scale fishers are perceived to receive a small percentage of economic value from the fish traded. Furthermore, access to sustainable seafood initiatives is heavily based on transparency and traceability across the seafood supply chain. Since many SSF are data poor (Jacquet & Pauly, 2008), they are face challenges in meeting the standards of market-based seafood certifications.

In general, data collected from fishing operations at sea is comprised of information on landing sites, structure of the fleet, catches, species composition and fishing effort (Graaf et al., 2011). However, many SSF globally face difficulties in collecting and reporting data due to gaps in national fisheries monitoring and management systems. Underreporting or misreporting is a common issue faced by many SSF (Pauly & Zeller, 2016), causing poor data collection. In developing countries, inefficient data collection can be linked with misidentification of species, failure in filling a logbook and consumption of fish by crew members (Yuniarta et al., 2017). This can also be tied to limited training and lack of incentives to collect data. In some cases, SSF operate in areas where reporting requirements are not enforced by fishery authorities, thereby reducing the incentive for documenting fishing activity. This is particularly true in tropical coastal nations where state-based fishery information systems are poor, resulting in weak data management and limited transparency in fishing operations (Bush et al., 2017). For instance, in Indonesia small fishing vessels below 5 gross tons (GT) are not required to document and report catch data (Yuniarta et al., 2017). This illustrates how weak governance systems and poor law enforcement can hinder the implementation of legal and traceable fish products (WWF, 2015). Moreover, lack of information on SSF operations also hinders evaluation of fisheries policy and resource management (Graaf et al., 2011).

Another significant obstacle in achieving traceable and legal fish products is the lack of agreement on the information and level of detail required to demonstrate the traceability of wild-caught fish, particularly with key data elements (KDEs) (Expert Panel on Legal and Traceable Wild Fish Products, 2015; FishWise, 2018). Stakeholders in the seafood industry have expressed the need for standardization of KDEs globally (FishWise, 2017). For this, it is necessary to gain a better understanding on traceability reporting requirements for international seafood markets as well as voluntary guidelines recommended by industry groups or other relevant organizations. FishWise (2017) recommends that fisheries collect KDEs in compliance with government import requirements (including U.S SIMP and EU IUU Regulation) and any additional KDEs necessary to fulfill industry best practices. Despite the various data collection systems available to collect KDEs, SSF face difficulties in implementing appropriate traceability systems. Many face challenges in identifying traceability technologies suitable to small vessels with limited infrastructure, capacity and financial resources. Traceability technologies can range from cameras installed on the vessels' deck to mobile applications that enable data collection. To support SSF as they improve traceability, it is necessary to understand the key requirements for traceability and barriers in adopting traceability systems.

1.1 Research objectives

This research aims to gain a better understanding of traceability in small-scale fisheries, including the challenges they face in demonstrating this. To ensure end-to-end traceability in the seafood supply chain, tracing wild-caught products back to the vessel is essential (FishWise, 2017). The scope of this study is to explore traceability in one segment of the supply chain: from the point of harvest to the point of landing. Point of harvest refers to the moment where the wild-capture fish is brought onboard the fishing vessel. Landing is the process whereby wild-capture fish is unloaded from the fishing vessel, usually at port. The study seeks to explore the following questions:

1. What are the legal and voluntary reporting requirements for small-scale fisheries to demonstrate their traceability and access international seafood markets?
2. What are potential barriers faced by small-scale fisheries in adopting traceability systems?
3. How can small-scale fisheries identify suitable traceability technologies that meet their needs and international market requirements?

Chapter 2: Context

This chapter outlines global traceability requirements and recommendations, and describes critical tracking events and key data elements; two critical components underlying seafood traceability in the supply chain. Furthermore, electronic traceability systems are presented, including some of the advantages of adopting them.

2.1 Traceability requirements

Large seafood importing markets, such as the United States (US) and European Union (EU), are increasingly implementing control mechanisms to regulate the legality and origins of seafood that enters their markets; while in other countries, their traceability requirements are associated with safety, origin and quality of seafood products (Borit & Olsen, 2012). As the demand for transparency in the seafood industry rises, traceability requirements are expected to become more stringent in the coming years with more market states implementing their own import controls (Oceana et al., 2020). To illustrate the depth and breadth of traceability approaches, this section outlines the current traceability requirements for the two largest seafood importing nations (US and EU), as well as for regional fisheries management organizations (RFMOs).

2.1.1 European Union

The EU is a significant importer of seafood, with much of that volume originating in developing countries (Swartz et al., 2010). To prevent illegally-caught seafood from entering the European market, the EU IUU Regulation (Regulation (EC) No 1005/2008) was implemented in January 2010 (European Commission, n.d.). The EU catch certification scheme (CCS) was implemented as a part of the IUU Regulation to ensure that imported seafood products comply with national and international fishing laws. Under this scheme, all processed and unprocessed marine wild capture fish imported from non-EU countries must be presented with a catch certificate at the point of import (Oceana et al., 2020). To ensure that SSF meet the requirements to trade products within the EU, the European Commission implemented a simplified catch certificate for small-scale vessels. This applies to: (1) vessels below 12 meters without towed gear, (2) vessels below eight meters with towed gear, (3) vessels with no superstructure, or (4) vessels below 20 GT (European Commission, 2010). In May 2019, the European Commission announced the launch of a digitized catch certification program known as ‘CATCH’ (European Commission, n.d.). The system is designed to record catch certification, processing statements and other import documentation into a single database to ensure consistency across EU Member States (Oceana et al., 2020).

2.1.2 United States

The US is the second-largest importer of seafood, with much of its imports being made up of substantial quantities from East Asian countries (FAO, 2020d; Oceana et al., 2020). The Seafood Import Monitoring Program (SIMP) was implemented in 2018 to regulate the legality of specific seafood products most vulnerable to IUU fishing and fraud (NOAA Fisheries, 2019a). Currently, there are 17 species listed under the SIMP including several species of tuna (albacore, bigeye, skipjack, yellowfin, bluefin), sharks, shrimp, swordfish, grouper, Atlantic cod, sea cucumber, Pacific cod, king crab, blue crab, red snapper, abalone and mahi mahi (NOAA Fisheries, 2020). Catch and landing documentation for these species is reported on a data portal (i.e. International Trade Data System) that records imports and exports (Oceana et al., 2020). The National Oceanic and Atmospheric Administration (NOAA) uses the International Trade Data System to verify and trace the listed species to their point of harvest using specific information (NOAA Fisheries, 2020).

It is worth noting here the difference between the EU and the US systems. The EU system works on a country to country basis, and is irrespective of species or product form. The US system, on the other hand, is a business-to-business program, meaning the importing business is responsible for ensuring the legality of its products through its relationships with exporting businesses.

2.1.3 Regional fisheries management organizations

Regional fisheries management organizations lay the foundation for managing and conserving highly migratory fish stocks. Through international agreements and treaties, RFMOs regulate fishing for a group of species or a species including tuna (Rosello, 2017). In total, three RFMOs including the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR), the International Commission for the Conservation of Atlantic Tunas (ICCAT), and the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) have implemented catch documentation schemes (CDS) to combat IUU fishing and verify the legality of catches (International Seafood Sustainability Foundation, 2016). The CCAMLR implemented a CDS covering Patagonian and Antarctic toothfish; the CCSBT introduced a CDS applicable to Southern bluefin tuna; and the ICCAT implemented a CDS for Atlantic bluefin tuna (FAO, n.d.). The catch documentation schemes implemented by these RFMOs collect information relating to harvest, export and import operations through paper-based records or electronic systems. Moreover, they record international transactions and trace seafood products at landing and export, but do not record transactions at a national scale. As Hosch & Blaha (2017) suggest this can be described as a pitfall of the CDS since it does not enable traceability within national supply chains.

2.2 Critical tracking events and key data elements

Key data elements and critical tracking events lay the foundation for seafood traceability within the supply chain and are essential components in establishing a harmonized system for electronic fisheries information platforms globally (Sylvia et al., 2020). Critical tracking events (CTEs) are points along the supply chain where data is captured to record product movement (Zhang & Bhatt, 2014). CTEs in the seafood supply chain include actions such as harvesting, landing, transportation and processing (Figure 1) (Hosch & Blaha, 2017). Within each CTE, data must be captured to ensure traceability within the value chain (Sylvia et al., 2020). The data that are recorded at each CTE are known as key data elements (KDEs). KDEs enable us to trace products across the supply chain, and tell us the who, what, when, where and how of a product (Romdhane, 2020). In this way, KDEs can shed light on various facets of the seafood industry including social aspects and human welfare (USAID, 2017c). Key data elements may be physically attached to the fish using a barcode or a tag (Expert Panel on Legal and Traceable Wild Fish Products, 2015). They can also be recorded manually in a logbook or electronically through various platforms including e-logbooks or electronic catch documentation and traceability (eCDT) systems.

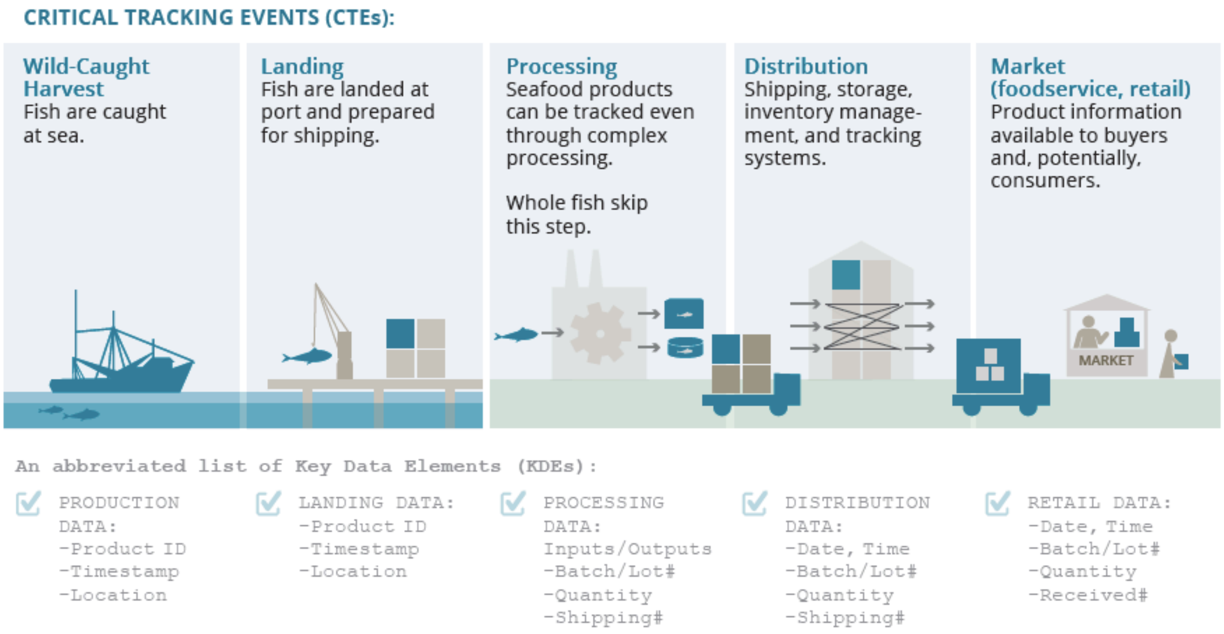

Figure 1. Critical tracking events and associated key data elements along the seafood supply chain (Expert Panel on Legal and Traceable Wild Fish Products, 2015).

Though it is well understood that KDEs are crucial for seafood traceability; industry, markets and governments face difficulties in standardizing and aligning KDEs. In many cases, the information collected for KDEs is dependent on the geographic area and market requirements. Overall, there is lack of agreement on the level of detail and information required for certain KDEs (Blaha & Katafono, 2020). This creates an inefficient traceability system as it is unclear what KDEs must be recorded and what they must be comprised of for fisheries to demonstrate traceability. As Pickerell (2020) suggests, there is a growing need to standardize KDEs to enable fisheries and other actors along the supply chain to meet market and regulatory requirements, and demonstrate product traceability effectively.

2.3 Electronic-based traceability systems

With an increasing demand for certified and traceable seafood products, fisheries worldwide are strengthening traceability systems through enhanced data collection and reporting. The FAO (2020a) defines traceability systems as “constructions that enable traceability; they can be paper-based, they can be computer-based, or they can be a combination of the two” (p. 5). To that end, a variety of tools are in use including video-recording and camera devices, electronic logbooks, block chain technology and more. The use of vessel monitoring systems (VMS) and automatic identification systems (AIS) on fishing vessels is increasingly becoming a requirement by several governments to monitor vessel activity and behavior. In some regions, video-recording and camera devices are being installed on fishing vessels in place of onboard observers to document fishing activity. Paper-based systems are increasingly being replaced by electronic traceability systems that use computerized databases, barcodes or other software tools to track traceability information (FISHWISE, 2018). For instance, traditional paper logbooks are being replaced by electronic logbooks to reduce errors and the laborious nature of paper logbooks.

Overall, there are several advantages in using electronic-based traceability systems in place of manual data collection systems. Manual forms of data collection can produce human errors as data are recorded at multiple levels across the supply chain by several individuals (Future of Fish, 2014). Moreover, paper-based systems like catch certificates can result in fraud and falsification more easily (Bailey et al., 2016). Through automated systems, electronic-based traceability tools can prevent some of these issues through reduced transaction errors, improved data accuracy and enhanced trust amongst stakeholders (Chryssochoidis et al., 2009; Probst, 2019). Technological initiatives provide digital information and standardized data formats that integrate traceability across value chains, and facilitate trade as data and processes are harmonized (FAO, 2018). Additionally, traceability technologies can bring a wide range of benefits to fisheries, including increasing production efficiency, improving planning, and reducing labour and operating costs (Mai et al., 2010).

Chapter 3: Developing an evaluation framework

Following from the discussion above, it is clear that electronic-based traceability tools may bring multiple socioeconomic and ecological benefits for small-scale fisheries. However, there are important questions related to the current capacity of such fisheries to adopt these tools. This chapter answers the research questions outlined in Figure 2 through a literature review. To bridge the knowledge gap on global traceability requirements, this chapter identifies the key data elements required for SSF to demonstrate traceability and examines some of the challenges they face while adopting traceability systems. Additionally, the key attributes of electronic-based traceability systems are outlined. Based on these findings, an evaluation framework was developed as a tool for SSF to evaluate different traceability technologies.

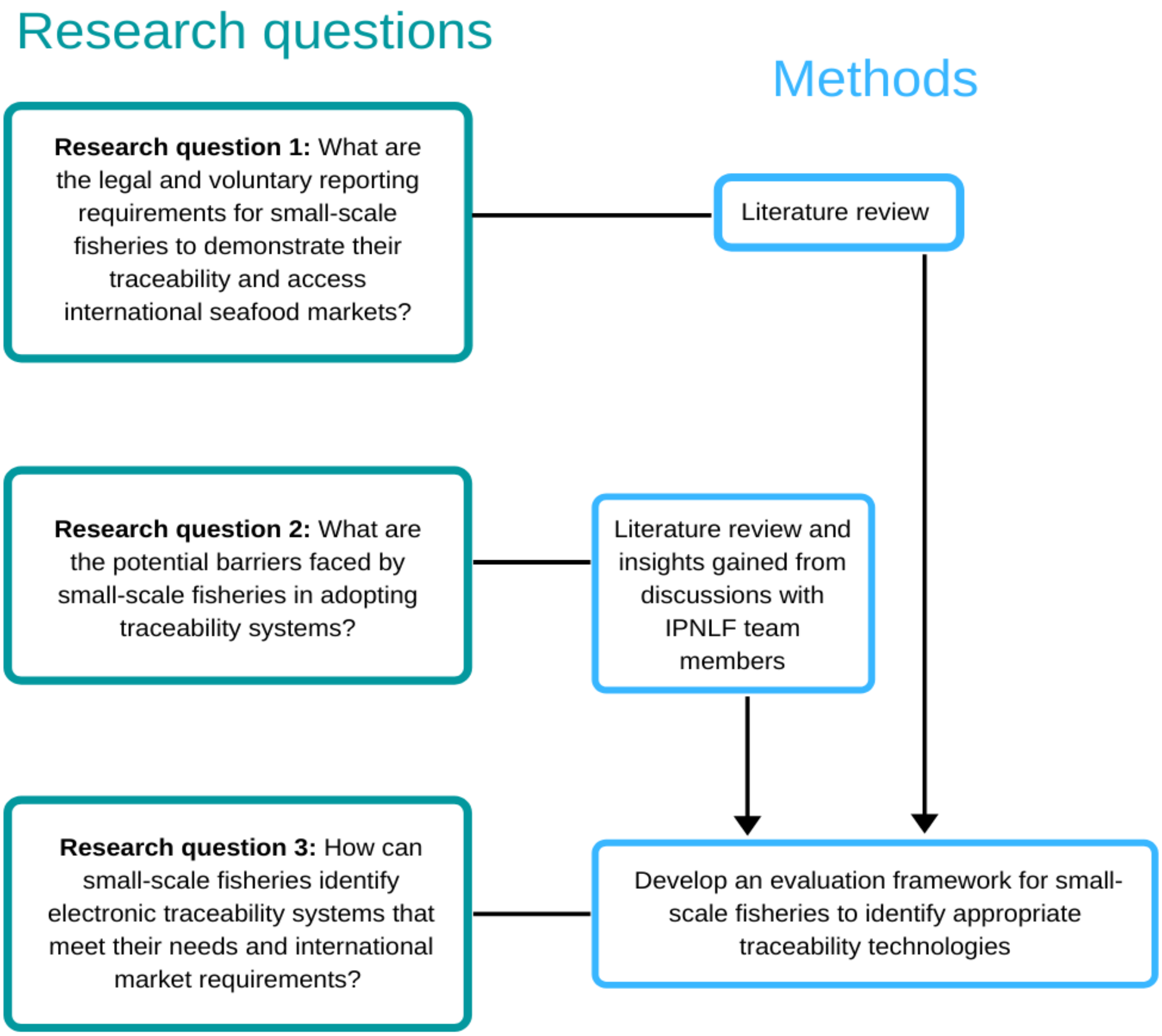

Figure 2. Research questions and methods used in this study.

3.1 Key data elements required for traceability

This section outlines major voluntary and legal KDE requirements for traceability from the KDE master list from point of harvest to landing (Appendix I). As illustrated in Figure 3, each critical tracking event was further divided into several categories and sub-categories. The KDEs for point of harvest, transshipment and landing were organized into six CTE subcategories: species harvested, bycatch data, catch data, vessel data, transshipment data and landing data.

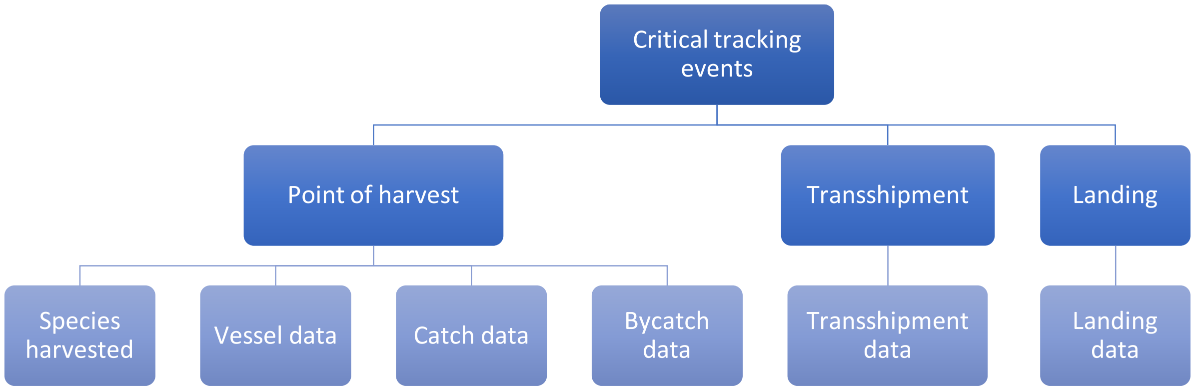

Figure 3. Critical tracking event categories used in this study.

Similar to the FAO (2020a) study, this section analyzes global traceability norms by identifying KDEs required by regulatory standards, international market requirements and voluntary guidelines (non-regulatory) from industry and NGOs. This comprised of evaluating government import regulations from large seafood importing nations including the US (SIMP) and EU (catch certification scheme and simplified catch certificate). Though the EU simplified catch certificate is designed for SSF specifically, the requirements from the IUU Regulation were used in the analysis since the European Commissions' definition of SSF may not apply to all small-scale fisheries globally as the definition varies from country to country. Moreover, despite the fact that Japan is also a large seafood importing state (Swartz et al. 2010), it does not yet have specific market requirements for importing seafood (Blaha, 2019). For this reason, they were not included in the analysis of traceability requirements.

Requirements from three RFMOs including ICCAT, CCAMLR and CCSBT were analyzed, as were Association of Southeast Asian Nations Catch Documentation Scheme (ACDS) requirements. It is important to note that RFMO requirements are species specific and apply to four species: Atlantic bluefin tuna, Southern Bluefin tuna, Patagonia toothfish and Antarctic toothfish (FAO, n.d.). Though the requirements are species-specific, they were incorporated in the analysis for a comprehensive overview as species like tuna are a highly traded commodity. In addition, voluntary guideline recommendations from the FAO, WWF and Global Dialogue on Seafood Traceability (GDST) were evaluated. The data from these sources were then compiled into a KDE master list (Appendix I) using information from: European Commission (2010); European Commission (2009); NOAA Fisheries (2019a); NOAA Fisheries (2019b); Global Dialogue on Seafood Traceability (2020a); Global Dialogue on Seafood Traceability (2020b); Oceana et al. (2020); Yuniarta et al. (2017); Salas et al. (2007); Graaf et al. (2011); FAO (2011); USAID (2017c); ASEAN (2017); CCAMLR (2017); ICCAT (2018); ICCAT (2010); CCSBT (n.d.).

3.1.1 Species harvested

Species name is a KDE required by most authorities including the US SIMP, EU catch certification scheme, EU simplified catch certificate, CCAMLR and ACDS. This KDE is also recommended by WWF and FAO. *Species name* is the Latin (scientific) name of the species which can be represented with the FAO ASFIS 3-alpha code (NOAA Fisheries, 2019b). The ASFIS 3-alpha code is a unique code that is used to exchange data among fishery agencies globally (FAO, 2020b). As NOAA Fisheries (2019b) suggests, the species name and ASFIS code is "needed to determine whether the inbound shipment is comprised of species subject to additional data collection at entry into commerce" (p. 5). In addition to *species name*, the *common market name* is also a requirement by the US SIMP. Moreover, *estimated weight is a* KDE required by the EU CCS, ACDS, ICCAT, CCSBT and CCAMLR. The EU CCS also requires *weight to be landed* at this stage. Finally, the *catch description* is required by the EU CCS, ICCAT and CCSBT. The two RFMOs require the number of fish to be listed under *catch description* (Appendix I).

3.1.2 Bycatch data

From the literature review, KDEs on bycatch did not appear to be a legal requirement by any of the regulatory bodies described in the methods. However, they were included in the KDE master list (Appendix I) as they were recommended by an NGO serving the small-scale sector (i.e. the International Pole and Line Foundation). For bycatch, they recommend recording information on *species name, location, date(s)* and *catch certificate or license*.

3.1.3 Catch data

The *location of catch* (Global Positioning System coordinates) is a KDE required by several authorities including the US SIMP, ACDS, CCAMLR, ICCAT, and is recommended by WWF and FAO. The results demonstrate that it is not a requirement for the EU CCS. The *location of catch* or catch area is an important KDE as it provides information on where the catch occurred to identify the relevant regulations that apply to fishing activity in that region (NOAA Fisheries, 2019b). Additionally, the EU CCS requires the following KDE: *type of processing authorized onboard*. Processing can include heading, gutting, scaling or storing fish after harvest (USAID, 2017a). This KDE was not required by other jurisdictions. Moreover, the US SIMP, ICCAT, CCSBT and ACDS all require a KDE on *date(s) of capture.* This was also recommended by the EU CCS and WWF. The *date(s) of capture* or harvest date is necessary to cross-reference the fish harvest with the certificate or license issued by the relevant authorities to establish whether regulations were respected by the fishing vessel (NOAA Fisheries, 2019b). In addition, *vessel trip date(s)* is required by the CCAMLR. Finally, the GDST (2020b) lists the name of the *fishery improvement project* (FIP) as a KDE that must recorded, when applicable (Appendix I).

3.1.4 Vessel data

Type of gear or capture method is a KDE required by the US SIMP, EU CCS, ICCAT, CCSMT, and recommended by WWF. This information is necessary to examine whether seafood was harvested during an authorized period and using appropriate gear as certain gear types are prohibited or restricted in some areas or during certain periods of the year (NOAA Fisheries, 2019a). Additionally, *vessel flag state, vessel name, vessel registration number* and *authorization to fish* (fishing license, permit or registration number) are required by several authorities including the EU CCS, ACDS, US SIMP and several RFMOs. Moreover, the EU simplified catch certificate requires the *vessel name, vessel registration number* and *vessel flag state* as KDEs for fishing vessels. The *vessel flag state* is required to determine the national regulations concerning the fishing vessel at the time of harvest (NOAA Fisheries, 2019b). The *vessel name* can be used to confirm if the vessel was authorized by relevant authorities (NOAA Fisheries, 2019b). Similarly, the *authorization to fish* can be used to confirm that a relevant authority has released an appropriate license or permit to the fishing vessel (NOAA Fisheries, 2019b).

As NOAA Fisheries (2019b) suggests the *Unique Vessel Identifier (UVI)* is " needed to positively identify the vessel and link the vessel to the fishing authorization issued by the competent authority" (p. 2). The *UVI* is listed as an optional KDE by the US SIMP since this is not something all vessels have. Similarly, the EU CCS has *International Maritime Organization (IMO)/Lloyds number* and *VMS number* as optional KDEs for the same reasons. Moreover, the CCAMLR requires the vessels' *VMS number* to be listed. The EU CCS is the only authority to demand the following KDEs on vessel data: *fishing vessel owner name* and *vessel type or tonnage*. Additionally, the *name of the captain or master* is a required by the EU CCS, and ACDS. The EU CCS and US SIMP also require information on *address & contacts*. Moreover, the US SIMP is the only authority to require information on the *company name.* From the literature review, two KDEs on human welfare were identified as potential KDEs: *existence of human welfare policy* and *human welfare standards*. However, these were listed by the GDST and were not associated with any legal requirements from seafood importing nations or RFMO requirements.

3.1.5 Transshipment data

Vessel name is required by the EU CCS, US SIMP, ICCAT, CCSBT, CCAMLR and recommended by the FAO. The EU CCS also requires information on the vessel flag state; this KDE is also a FAO recommendation. In addition, the KDEs on transshipment *date* and the transshipment vessels' *UVI* are requirements for the US SIMP and CCAMLR. *Date(s) and time* of transshipment are a recommendation by the FAO, and required by the US SIMP as well as ICCAT and CCSBT. Next, transshipment *location* and *vessel registration* are both recommended by FAO. The latter is also a requirement for the US SIMP. Additionally, *location* of transshipment is required under catch documentation schemes for the CCAMLR and ICCAT. Under transshipment, ICCAT and CCSBT also list *transshipment authorization* (unloading code or authorization) as a

KDE requirement. Moreover, ICCAT requires *estimated weight (kg)* to be listed during transshipment. Finally, the GDST (2020a) lists *Observer ID* as necessary KDE in this stage (Appendix I).

3.1.6 Landing data

The KDE *verified weight landed* is required by several authorities including the US SIMP, EU CCS, EU simplified catch certificate, ACDS, CCAMLR, and is recommended by WWF. This KDE is necessary to regulate IUU fishing and identify the volume of seafood originally landed and reported to authorities (NOAA Fisheries, 2019b). Additionally, landing *date(s)* and *landing recipient* are both requirements under the US SIMP. Information on the landing recipient (e.g. landing ticket) is necessary to record the first transaction as seafood is transferred from the vessel to the dealer, buyer or processor (NOAA Fisheries, 2019b). NOAA (2019b) describes this as necessary to "support the "one up – one back" approach to auditing the supply chain" (p. 4). In addition, *date(s)* landed are also required by the CCAMLR and CCSBT. The *landing location* or landing port is required by the CCAMLR and US SIMP to cross-reference the harvest event with any documentation released by the component authorities (NOAA Fisheries, 2019b). Additionally, the *product form* at landing is required by the US SIMP, CCAMLR and CCSBT. This KDE is necessary to determine whether the fish harvested was processed onboard prior to offloading. This information can then be used to regulate IUU-caught fish (NOAA Fisheries, 2019b). Finally, the *species name and composition* is required by US SIMP, and is recommended by FAO and WWF. Though a catch certificate is not a KDE within itself, it is important to note that it is mandatory at landing in the EU CCS (European Commission, 2009). Additionally, a *landing authorization* can be an important KDE to list during landing. Overall, 47 KDEs were identified from point of harvest to landing; these are summarized in Table 1 below.

Table 1. Key data elements and their corresponding critical tracking event sub-categories.

Critical tracking event	Sub- category	Definition	Key data elements
Point of harvest	Species harvested	Information on the marine species captured	Species name, common market name, estimated weight (kg), estimated weight to be landed (kg), catch description
	Bycatch data	Information on the harvest of non-target species by the fishing vessel	Species name, location, date(s), catch certificate/ license
	Catch data	Information on the fishing operations itself	Location of catch, time of catch, type of processing authorized onboard, vessel trip date(s), fishery improvement project, date(s) of capture
	Vessel data	Administrative information and relevant paperwork on the fishing vessel	Type of gear or capture method, name of captain or master, company name, fishing vessel owner name, address and contacts, vessel name, vessel registration number, vessel type/tonnage, Unique Vessel Identification (UVI) (if applicable), VMS number (if applicable), IMO/Lloyds number (if applicable), authorization to fish, vessel flag state, existence of human welfare policy, human welfare policy standards
Transshipment	Transshipment data	Information on the transshipment vessel and operations	Vessel name, vessel flag state, Unique Vessel Identifier (UVI), vessel registration, location, date(s) and time, transshipment authorization, observer ID, estimated weight (kg)
Landing	Landing data	Information on the landing process as marine capture is unloaded from the vessel	Species composition and volume, product form, date(s), location, company name of landing recipient processor or buying entity, vessel ID and license, verified weight landed (kg), landing authorization

3.2 Barriers to uptake electronic-based traceability systems

Given the rapid development and increasing adoption of traceability technologies in fisheries worldwide, this section explores the potential implementation of electronic traceability systems in SSF. Small-scale fisheries face several challenges in implementing traceability technologies and transitioning from traditional methods like paper-based systems towards electronic-based systems. This section describes some of the barriers SSF face in adopting electronic-based traceability systems, based on review of the literature.

3.2.1 Data sharing and privacy concerns

Privacy concerns are a significant barrier to the implementation of whole-chain traceability within the seafood industry, for both large-scale and small-scale fisheries. The competitive nature of the seafood industry generates a lack of trust, making companies and stakeholders reluctant to share data and information beyond government requirements (Future of Fish, 2014). Many are resistant to share data over fears of the release of proprietary and confidential business information, which may result in a loss of competitive advantage and threaten their establishment (Future of Fish, 2014). In addition, fishers can be reluctant to collect data if they do not have access to the information collected through traceability systems (Doddema et al., 2020).

Popper (2007) argues that workers' privacy is often ignored in discussions around traceability. In traceability, food is traced across the supply chain, however, it is important to recognize that humans are an integral part of this process (Popper, 2007). Privacy of the crew is a significant challenge associated with electronic monitoring (Michelin et al., 2020), and can be viewed as an invasion of privacy by fishers (Probst, 2019). In addition, electronic recording devices have the potential to disclose proprietary information including data on fishing locations and activities (Fujita et al., 2018). Moreover, some fishers do not want to be held accountable for their actions and compliance to regulations (Fujita et al., 2018). Another significant issue relates to the use of data for purposes outside fishery monitoring objectives once data leaves the workplace (Michelin et al., 2020). For example, some fishers are reluctant to disclose information on catch volumes as it can make them liable to pay taxes.

3.2.2 Cost

Though electronic traceability systems can lead to more efficient data collection and improved reporting in fisheries, many technologies come with a high price. The expensive nature of traceability technologies is a significant factor that hinders their implementation as they are perceived as a significant investment, particularly for small-scale fisheries (Fujita et al., 2018). The widespread assumption that the costs for adopting traceability tools are higher than benefits generated (Future of Fish, 2014), combined with little evidence for fisheries to prove economic returns on their investment are significant barriers to uptake. Moreover, it is unclear who is responsible for these costs and for how long arrangements between stakeholders may last (Fujita et al., 2018). Duggan & Kochen (2016) suggest that there is often a "mismatch between costs and benefits of establishing such systems. Those making the financial contribution to set up and maintain the system are not necessarily those receiving the rewards" (p. 35). This can create barriers for both uptake of traceability systems as well as incentives to participate in the data collection process.

3.2.3 Lack of governance

Poor governance can be an important barrier in the implementation of traceability systems in SSF. Some of the challenges include lack of funding to implement traceability systems in fisheries, lack of resources and infrastructure to maintain permit registries, and inadequate resources to process and analyze fishing data (Fujita et al., 2018). In some cases, governments do not require small-scale vessels to produce catch documentation (Song et al., 2020), thereby reducing the incentive to adopt traceability systems. Moreover, distrust in the government or authorities is another considerable barrier. For instance, some fisheries are apprehensive to share data as they worry it may compromise their operations or ability to remain in the fishery (Fujita et al., 2018).

3.2.4 Infrastructure limitations

In SSF, vessel infrastructure ranges in shapes and sizes; from artisanal wooden canoes to larger motorized vessels. Differences in vessel size and capacity entails that some SSF have limited choices when it comes to identifying an appropriate technology for their vessel. For instance, small-scale fishers in developing countries often operate from small open-deck vessels and have limited options to safely place electronic devices on their boat. Additionally, limited access to cellular coverage, internet reception and electricity creates barriers for implementing electronic traceability systems in some fisheries (Duggan & Kochen, 2016; Fujita et al., 2018). For example, some vessels may not have the capacity to implement cameras that require a constant power source (i.e. powered by the vessels' battery) and require an external power source such as solar power.

3.2.5 Lack of incentives

The lack of incentives for small-scale fishers to collect data and improve transparency on fishing vessels is another barrier to implementing traceability systems (Graaf et al., 2011). This is especially true when the advantages of adopting traceability tools are unclear to fishers. In Indonesia, some small-scale fishing vessels are incentivized by the regional government to collect data with electronic logbooks (eLogbooks) through fuel subsidies. However, many Indonesian small-scale fishers remain unmotivated to collect data as it is perceived as an additional task with little purpose, since many are doubtful that the data collected is processed and verified by authorities. In a pilot project conducted by Yayasan Masyarak dan Perikanan Indonesia (MPDI) and Fair Trade USA, Indonesian fishers refused to collect data through logbooks as they claim it disrupted post-harvest activity and they saw no value added from the data collected itself (Doddema et al., 2020). The distrust in government and limited understanding of the advantages of traceability systems, results in Indonesian small-scale fishers to opt for markets with no traceability requirements as many are reluctant to change their practices.

3.3 Key attributes of electronic-based traceability systems

To ensure successful implementation of traceability technologies in small-scale fisheries, several key attributes must be considered while evaluating tools and technologies, as they will affect adoption rates and implementation success. The key attributes illustrated in Table 2 were developed from the barriers identified in the previous section and through discussions with members from the International Pole and Line Foundation (IPNLF). IPNLF is a charitable organization that supports the development of one-by-one fisheries including handline and pole-and-line fishing in several countries (The International Pole & Line Foundation, 2020).

Table 2. Key attributes to consider while evaluating electronic-based traceability systems.

Key attributes	Description
Scaling	Scaling from a pilot project to full-scale implementation within a fishery can be a significant barrier to success (Blondin, 2018). Therefore, how easily the tool or technology can be scaled-up must be considered at an early stage. Battista et al. (2017) suggest that an intentional scaling strategy must be implemented in the early stages of innovation design for scaling to be successful. Successful scaling is also dependent on other factors including transparency, having a clear goal, proper infrastructure, cost-benefit analysis, industry buy-in, flexibility and timeline (Blondin, 2018).
Data validation	Mechanisms should be in place to ensure that the vessel collecting electronic data is compliant at all points along the supply chain (USAID, 2020). Data validation also consists of evaluating whether the traceability technology has systems in place to verify that the data collected is accurate and true (USAID, 2020).
Privacy	An efficient traceability system should include data privacy and security measures to protect crew members and data collected (USAID, 2020).
Accuracy	The accuracy of the data collected through the traceability systems must meet the fisheries' traceability standards and minimum data requirements.
Costs	Cost is a significant barrier for many SSF with limited financial capacity. For some fisheries, several sources of financing may be required to implement electronic traceability systems. This can be difficult to achieve as they must be consistent in the long-term to be viable. The financing mechanism adopted is influenced by social, administrative, political, legal and environmental factors. SSF must also be cautious not to become overly dependent on external sources of funding as it can affect their long-run sustainability (USAID, 2020).
Infrastructure	Infrastructure requirements and limitations of the traceability tool and fishery should be identified early on, as a "one-size-fits-all" approach cannot be applied. For instance, certain technologies may require a continuous power supply or cellular coverage to operate and transmit data, which may not be possible for vessels operating in remote areas.
Data ownership	Proprietary rights and ownership over the data collected must be evaluated against fishery requirements and local regulations at an early stage, as some technology providers may have ownership over data collected. This can create barriers with local authorities and governments.
Interoperability	Interoperability is a key component of electronic traceability systems to ensure efficient data transfer and scalability (USAID, 2020). FAO (2020a) define interoperability as "the ability of different information technology systems or software programs to communicate seamlessly for the purpose of exchanging and using data" (p. 4). As USAID (2020) suggests this can be achieved through "a shared database, file transfer, and messaging to transfer of data between applications." (p. 48).

3.4 An evaluation framework as a tool for SSF

Based on the findings obtained from the first part of this chapter, an evaluation framework was developed as a tool for SSF to evaluate different traceability systems. The framework is comprised of KDEs required at different critical tracking events: point of harvest, transshipment and landing (Appendix II). These CTEs were chosen to identify traceability requirements from harvest to landing. The framework can be used to evaluate how efficiently a traceability technology captures a specific KDE. Figure 4 below is a sample of the evaluation framework used to assess KDEs captured for catch data. By using information obtained on the traceability tool and a scoring system, SSF can use this framework to assess how efficiently a traceability system captures KDEs at different points along the seafood supply chain.

Name of traceability system	Category: Catch data						**Score**	**Percentage (%) fulfilled**
	Location of catch	**Time of catch**	**Type of processing**	**Vessel trip date(s)**	**Fishery improvement project**	**Date(s) of capture**		

Figure 4. Evaluation matrix used to assess KDEs on catch data.

As illustrated in Table 3, the scoring system is made up of four fulfillment categories (Yes, Likely, No, Information not available) with an associated score to assess whether the traceability system can capture a specific KDE. Once the traceability system is evaluated against individual KDEs, a final score is obtained as well as the total percentage fulfilled (Figure 4).

Table 3. Scoring system used to evaluate different traceability tools.

Fulfillment category	**Score**
Yes	1
Likely	0.5
No	0
Information not available	0

Chapter 4: Case study

This chapter uses the framework developed in Chapter 3 to evaluate traceability systems that can be adopted by small-scale tuna fisheries in Indonesia. Insights gained from discussions with members from the International Pole and Line Foundation (IPNLF) helped shape this case study. The reporting requirements and KDEs applicable to SSF were extracted from the KDE master list (Appendix I) through discussions with team members from IPNLF Indonesia. Next, the traceability systems were identified through a desktop research and compilation of over 50 traceability technologies. They were shortlisted through (1) discussions with IPNLF team members or (2) by evaluating whether the system was developed for a SSF, particularly in developing countries. The shortlisted traceability systems were then analyzed using the evaluation framework described in the previous section.

4.1 Context

Indonesia's tropical waters are home to rich marine biodiversity and support several species of tuna including skipjack, yellowfin, bigeye, bluefin and Eastern little tuna (Sunoko & Huang, 2014). Prepared tuna is the most significant export commodity as Indonesia exports 17-22 % of global tuna production (California Environmental Associates, 2018). Wild capture fisheries play a crucial role in national food security and livelihoods as many coastal communities engage in fishing for primary or secondary employment. Most Indonesian fishers partake in small-scale fisheries and operate from vessels with limited capital and technology (Yuerlita & Perret, 2010). The definition of small-scale fisheries and fishers in Indonesia has been evolving since the mid-90s (Halim et al., 2019). Fisheries Law 45/2009 defines small-scale fishers as "any person whose livelihood is undertaken to meet his daily needs" (USAID, 2017b, p. 36). This definition was revised in 2016 to include fishers fishing with or without fishing vessels less than 10GT in size (USAID, 2017b). Under the legal context, small-scale fisheries hold the same definition. IPNLF applies the definition of small-scale fisheries to one-by-one fisheries more broadly by including vessels that range from 5-30GT.

For many years, artisanal fishing methods including one-by-one fishing dominated the countries' tuna fisheries (California Environmental Associates, 2018). One-by-one fishing practices including handline and pole-and-line, catch one fish at a time using live-baitfish (Gillett, 2016). These artisanal methods are one of the most sustainable forms of tuna fishing, with little to no bycatch (The International Pole & Line Foundation, 2017). Additionally, one-by-one fisheries generate various social benefits across coastal communities including local ownership, community engagement and favorable working conditions (The International Pole & Line Foundation, 2020).

Though most one-by-one fisheries are socially and environmentally responsible, many face difficulties in demonstrating the sustainability of their fishing practices due to unreported catches and limited data collection. Unreported fishing and catch underestimation may be driven by challenges in data collection (Yuniarta et al., 2017). Poor data collection can be tied to misidentification of species, failure in filling a logbook, logbooks being filled by an individual who did not partake in the fishing trip, and onboard consumption of fish or fish taken for home consumption (Yuniarta et al., 2017). Poor reporting and limited transparency in fishing operations creates barriers for Indonesian small-scale fishers to obtain premium prices for their products and differentiate themselves in the competitive globalized seafood market.

4.2 Reporting requirements

A significant proportion of tuna harvested through SSF is exported to several international markets including the US and EU. Therefore, many small-scale fishers and seafood producers must meet the reporting requirements of the US (Seafood Import Monitoring Program) and EU (catch certification scheme and simplified catch certificate). Being a member of several RFMOs, Indonesian tuna harvesters also need to abide by RFMO reporting requirements including the catch documentation scheme.

Indonesian fisheries must comply with regulations implemented by the nation’s federal (the Ministry of Marine Affairs and Fisheries) and provincial governments. In 2015, the Ministry of Marine Affairs and Fisheries (MMAF) implemented a regulation to target 5% onboard observer coverage on capture vessels within five years. In support of the EU catch certification program, the Indonesian government implemented a Fish Catch Certificate (*Sertifikat Hasil Tangkapan Ikan* or SHTI) system in 2012. Under the catch documentation program, all vessels above 5GT are required to submit a catch logbook following a fishing trip (Marine Change, 2020). Electronic logbooks or eLogbooks were introduced and made mandatory by the MMAF for all vessels above 30GT (Marine Change, 2020). As illustrated in Table 4, most reporting requirements implemented by the Indonesian government apply to large-scale vessels (above 30GT). Since many small-scale fishers are not required to report catch data, many SSF lack the incentive to adopt data collection and traceability systems on fishing vessels.

Table 4. MMAF reporting requirements by vessel size.

Vessel size (gross tons)	Manual logbook	Electronic logbook (eLogbook)	Vessel Monitoring System (VMS)
> 5 GT	✓		
> 30 GT		✓	✓

4.3 Traceability systems used in Indonesia

In the last few years, several traceability initiatives and pilot projects have been trialed in Indonesia’s small-scale fisheries. Table 5 provides an overview of the traceability tools that have been used in the past, including their strengths and weaknesses.

Table 5. Overview of traceability tools used in Indonesia.

Tool	Description	Strengths	Weaknesses
Manual logbooks	• Catch and vessel activity can be entered manually in paper-based logbooks • Under the catch documentation program, all vessels above 5GT are required to submit a catch logbook following a fishing trip (Marine Change, 2020)	• Relatively simple to use • Cheap cost • Most fishers are familiar with this tool i.e. limited training required	• May result in transcription errors, particularly as data is transcribed onto an electronic software • Errors can occur in recording data if multiple individuals fill the logbook • The logbook system is criticized for being weak (Banks, 2015)
MMAF eLogbooks	• eLogbooks are required for all vessels above 30GT (Marine Change, 2020)	• Data can be easily transferred onto a database for analysis	• Vessels below 30GT are not required to collect data through eLogbooks • Lack of incentives for small-scale fishers to adopt eLogbooks results in low adoption rates
Vessel registering system	• The vessel registry system was developed by IPNLF for Asosiasi Perikanan Pole & Line dan Handline Indonesia (AP2HI). The system uses mobile-enabled web application so that vessels can be audited at port or at sea • The system can also verify vessel details and supporting documents against AP2HI's database (Purves, 2017)	• Useful traceability tool that can help meet the requirements for MSC certification (Purves, 2017) • Relatively cheap cost as most fishers have smartphones	• This system can be time-consuming; reducing fisher's incentive to use it • Fishers need to be trained to learn how to use the tool • Fishers may be reluctant to use the tool as they may not want to take their smartphones at sea (at risk of damaging smartphones)
Port sampling	• This requires onshore observers to collect data from fishing vessels when they return to port	• Provides accurate and rigorous data (Mangi et al., 2015) • Can provide data on species that may not have been sampled at sea (Mangi et al., 2015)	• Can be hard for observers to access remote locations, making it hard to implement across the archipelago • Observers are relatively expensive
Onboard observers	• Observers on fishing vessels can record information on fish catch, quantities retained and discarded species • In 2015, the MMAF implemented a regulation to target 5% onboard observer	• Data collected is accurate and robust • Establishes a relationship between scientists/observers and fishers (Mangi et al., 2015)	• Having an observer onboard can modify fishers' behavior and practices (Mangi et al., 2015) • This practice is not possible on all vessels due to size and space constraints (Mangi et al., 2015)

Tool	**Description**	**Strengths**	**Weaknesses**
	coverage on capture vessels within five years (Marine change, 2020)		• Onboard observers are relatively expensive. Average cost per observer per day on handline vessels is approximately US$13-16 (Marine change, 2020)
Smartphone based systems	• Smartphone monitoring systems can work in real time or data can be saved on the phone until network is obtained • Can record information on fishing trip and catch through logbooks on smartphones • Examples: Blue Ventures Open Data Kit, OurFish	• Some systems provide added advantages including weather data, messaging options and safety features for fishers • Relatively low cost as most fishers have smartphones • Some smartphone systems can operate offline, in remote areas	• Certain monitoring systems may not work in remote areas due to poor network coverage • Some fishers do not want to bring their smartphones on fishing trips as they fear it may be damaged or lost • Technical glitches are always a risk. This was an issue with the OurFish mobile application (Doddema et al., 2018)
Satellite tracking systems	• The MMAF requires vessels above 30GT to have an onboard vessel monitoring system that transmits hourly position data (Marine Change, 2020) • Examples: Pointrek, Inmarsat fleet one, Spot trace, Pelagic data systems	• Certain satellite tracking devices cannot be turned off, hence, data cannot be falsified • Data can be easily transferred to other platforms for analysis (e.g. iFish database)	• High cost • Privacy concerns • Needs to be pre-approved by MMAF • Hard to implement in small-scale vessels due to high cost and infrastructure limitations • In some cases, satellite tracking devices can be switched off by the captain or crew members
Time-lapse cameras	• Cameras capture and transmit still images over set intervals (Marine Change, 2020). • Example: Brinno Time Lapse Camera 2000 (Tested on handline vessels by MDPI and IPNLF) (Marine Change, 2020)	• Less data and power intensive compared to video-recording (Marine Change, 2020) • Some cameras have high autonomy and can be powered through solar power • Frames per minute can be adjusted to capture images only during fishing activity (can address fishers' privacy concerns)	• No real-time monitoring as images are downloaded and processed manually afterwards • High cost - US$ 450 (Marine Change, 2020) • Infrastructure limitations for small vessels as most cameras are powered through the engine

4.4 Evaluation of traceability systems

This section evaluates three traceability systems identified from a list of over 50 traceability systems compiled through a literature review and desktop research. The traceability systems are assessed through the evaluation framework developed in Chapter 3 to assess appropriate traceability tools for Indonesian small-scale fisheries. The systems are first described, followed by an evaluation of each.

i. Futuristic Aviation and Maritime Enterprise (FAME)

FAME is a vessel tracking system that uses maritime transponders to monitor fishing activity in real-time (FAME, 2020). In 2018, FAME and USAID Oceans and Fisheries Partnership (USAID Oceans) partnered to enhance catch documentation and traceability systems in the Philippines by installing marine transponders on 30 handline vessels (Marine Change, 2020; USAID, 2018). The technology developed by FAME targets traceability in the early stages of the seafood supply chain (i.e. from point of harvest). The transponders can be fitted on any vessel size and are equipped with a GPS that relays information via radio frequency (Marine Change, 2020). Additionally, the transponders are used for digital fish tagging using near-field communication (NFC) cards. When fish are harvested, fishers tap a NFC card on the marine transponder to log catch information (J. Jun, personal communications, August 27th 2020). The NFC card is tied to the tail of the fish, enabling each fish harvested to be traced back to the point of harvest. The transponder enables real-time monitoring of fishing activity (FAME, 2020). Data collected on the transponder is then transferred onto a cloud and later onto other platforms (J. Jun, personal communications, August 27th 2020). At landing, a mobile application can be used to enter additional information including the length and weight of individual fish. The NFC cards can later be tapped onto a mobile printer to print a QR code which includes all the data captured through the NFC card. This allows retailers and buyers to access information on the fish from the point of harvest to landing (J. Jun, personal communications, August 27th, 2020).

Evaluation results

As illustrated in Figure 5, both FAME technologies (marine transponder and mobile application) can entirely capture the KDEs on species harvested and landing. The KDEs on catch data can be relatively well captured (90%) by the technologies. Moreover, the FAME tools capture

50% of the KDEs on bycatch. However, the systems are not designed to collect KDEs on transshipment since transshipment is not authorized in the Philippines (J. Jun, personal communications, August 27th 2020).

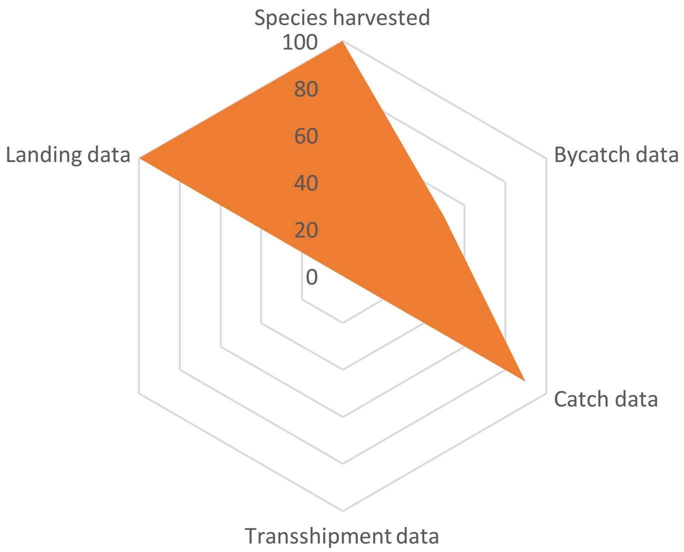

Figure 5. Percentage of KDEs satisfied by FAME technologies in each CTE sub-category.

The results from the KDE evaluation in Figure 6 demonstrate that the FAME technologies can do a thorough job at collecting the KDEs for point of harvest (77%) and landing (100%). However, the FAME systems do not have the potential to collect transshipment KDEs since the tools were not developed to capture data on transshipment. As mentioned previously, this is simply because transshipment is not permitted in the Philippines, where the tool was developed (J. Jun, personal communications, August 27th 2020). Overall, the traceability tool has the potential to capture 54% of the KDEs required for Indonesian small-scale tuna fisheries.

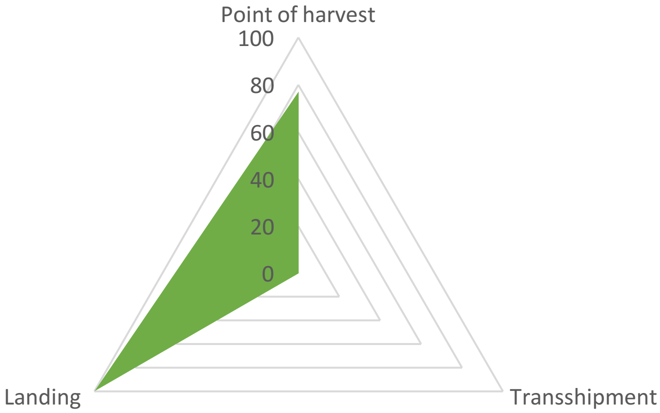

Figure 6. Results for the KDEs captured by FAME technologies at different critical tracking events.

The technologies developed by FAME were evaluated against several key attributes, and some of the challenges and opportunities were identified (Table 6). The information used for the evaluation of key attributes was obtained from company brochures, consultancy reports, and through discussions with a FAME representative.

Table 6. Evaluation of key attributes satisfied by the FAME tools.

Key attributes	**Description**
Scaling	• Easily scalable to Indonesian SSF as the technology was developed in a similar context in the Philippines • The data collected will need to be tailored suit Indonesian requirements (e.g. government reporting requirements)
Data validation	• Verifiable through real-time tracking • Coordinates and timestamp associated with fishing activity can be validated by analyzing vessel movements or patterns (J. Jun, personal communications, August 31th 2020)
Privacy	• Protects fishers' privacy as no data on fishers is collected through the transponder and NFC cards • Further evaluation is required to determine how data collected through the transponder and mobile application is protected
Accuracy	• Relatively high data accuracy since most of the system is automated • Human errors can occur if fishers tap the NFC card on the transponder at the wrong time (e.g. not at the time of catch) or while entering data on the mobile application at landing

Costs	• Transponder: US$ 72 (Marine Change, 2020) • NFC card reader: US$ 60 (Marine Change, 2020) • Reusable NFC cards: US$ 4 (Marine Change, 2020) • Single-use NFC bands: approximately US$ 0.25-0.5 each (Marine Change, 2020) • Airtime packages for vessel tracking: US$ 15/month (Marine Change, 2020)
Infrastructure	• Transponders are well-adapted to small vessels with limited infrastructure and can be mounted on any vessel size • Transponder is equipped with a waterproof housing and can be solar powered (J. Jun, personal communications, August 27th 2020) • Use of mobile application at landing means that fishers are not required to use smartphones at sea and reduces risk of damaging personal belongings
Data ownership	• Data collected are owned by the fishers, fishery or fishing company • For traceability, third parties (e.g. processors) can be given access to data collected (J. Jun, personal communications, August 31th 2020)
Interoperability	• An interoperable software is being developed for data to be transferred onto other platforms, including government databases (J. Jun, personal communications, August 27th 2020)

ii. Shellcatch

Shellcatch provides a monitoring platform for small-scale fisheries, governments and non-profit organizations in over 15 countries, including several developing countries (C. Valdivia, personal communications, 13th August 2020). In 2015, Shellcatch cameras were used in a study conducted by Bartholomew et al. (2018) to monitor a Peruvian elasmobranch small-scale fishery. The company has developed two technologies for data collection at sea: eReporting and eMonitoring. The eMonitoring system wirelessly collects information on fishing activity and GPS coordinates through a camera installed onboard. The camera is powered through solar panels or the vessels' energy source, and has over 24 hours of autonomy (C. Valdivia, personal communications, 13th August 2020). Data from the camera are transferred onto a database after landing, once fishers have access to a stable internet connection. After analyzing the images from the fishing trip, information can be extracted including data on bycatch, fishing effort, species harvested and more (A. Sfeir, personal communications, 24th August 2020). The eReporting system operates through a mobile and web platform to capture and export data on fishing effort, fishing license and landing. The mobile application is used by fishers to collect data at sea and functions both online and offline depending on cell phone coverage. The key data elements and information collected through the eReporting tool are tailored to fishery and government requirements (A. Sfeir, personal communications, 24th August 2020).

Evaluation results

As illustrated in Figure 7, the two systems developed by Shellcatch have the potential to capture all the KDEs for landing and bycatch. Both tools have the potential to capture 90% of catch data KDEs and 75% of KDEs for transshipment. Additionally, if the two traceability systems are used, 50% of KDEs for species harvested can be collected.

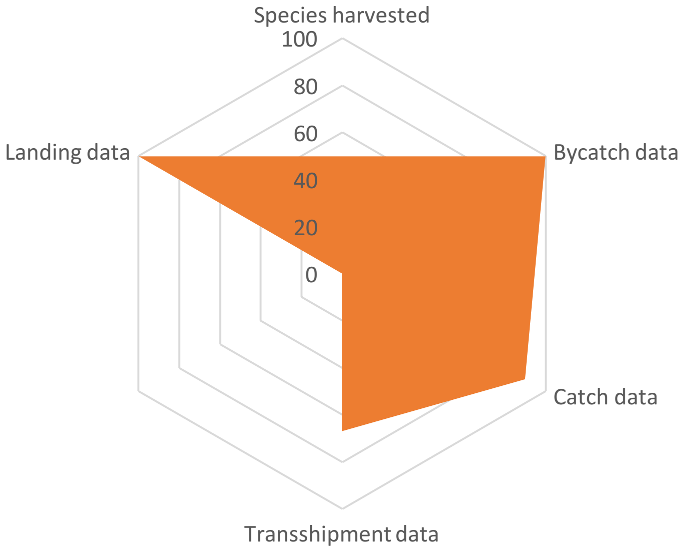

Figure 7. Results for the KDEs captured by Shellcatch technologies at different critical tracking events.

The eMonitoring and eReporting systems can capture well the KDEs for landing (100%) and point of harvest (86%) (Figure 8). However, both Shellcatch systems have a small potential to capture transshipment KDEs (25%). Overall, the Shellcatch tools have the potential to satisfy 67% of the KDEs required for Indonesian small-scale tuna fisheries.

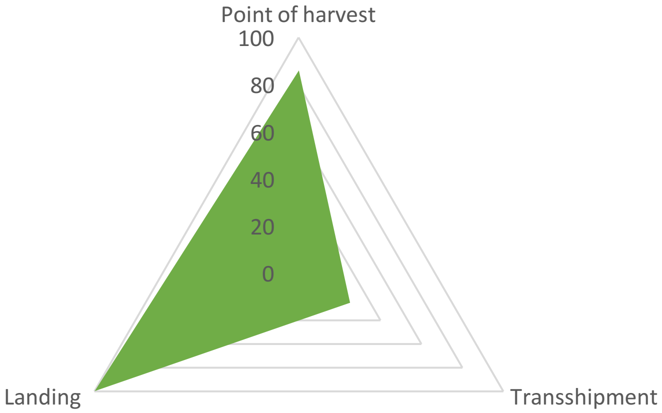

Figure 8. Results for the KDEs captured by Shellcatch systems at different critical tracking events.

The technologies developed by Shellcatch were evaluated against several key attributes, and some of the challenges and opportunities were identified (Table 7). The information used for the evaluation of key attributes was obtained from the company's website, brochures and through discussions with Shellcatch representatives.

Table 7. Evaluation of key attributes satisfied by the Shellcatch systems.

Key attributes	**Description**
Scaling	• Easily scalable to Indonesian SSF as both tools were developed for small-scale fisheries in several developing countries • Both traceability systems can be adapted and tailored to meet KDE requirements • Shellcatch provides support and assistance for the first month after installation
Data validation	• The web platform enables users to review information collected from video recordings • The system has a search mechanism to go directly to information collected from a vessel (Shellcatch, 2019)
Privacy	• Frames per minute can be adjusted to capture data during fishing activity so that fishers are not filmed constantly to address privacy concerns • Camera can be positioned and angled to respect fishers' privacy

	• Access to the web platform can be restricted and controlled by limiting the number of users (C. Valdivia, personal communications, 13th August 2020)
Accuracy	• Risk of errors while analyzing and transcribing data from the videos • Risk of errors while entering data on the mobile application
Costs	• eMonitoring: approximately US$ 7-10/ month (A. Sfeir, personal communications, 24th August 2020) • Information on the cost of other tools was not made available • There will be costs associated with hiring a photo analyst
Infrastructure	• The camera is well-adapted for small-scale vessels: waterproof housing, easily mountable and small size (Bartholomew et al., 2018) • Both camera and GPS logger can be charged by a battery, which can be recharged by a solar panel • Use of smartphones at sea may damage fishers' personal belongings. Some fishers' can be reluctant to use their mobile phones at sea • A photo analyst is required to analyze the images captured by the camera and transcribe data collected
Data ownership	• No information available
Interoperability	• All videos and coordinates can be downloaded from the web platform (Shellcatch, 2019) • Data can be transferred from the web platform onto government databases or other platforms

iii. Open Data Kit

Open Data Kit (ODK) is an online data collection tool that can be downloaded for free on Android phones or tablets (Jeffers & Nohasiarivelo, 2016). The data collection forms need to be designed ahead of time on Microsoft Excel and converted into a compatible format for the mobile application (ODK Collect), online storage website (ODK Aggregate) and software for transferring data from phone to computer (ODK Briefcase). The forms are composed of a pre-defined questionnaire that can consist of text, numbers, photos, list options, tables, predefined answers and more (Jeffers & Nohasiarivelo, 2016). The mobile application can document information in multiple languages and record GPS coordinates (provided there is mobile network). Once the data forms are completed, they are sent directly from the device to a computer with Wi-Fi or mobile internet. Data can also be transferred in bulk to a computer through the ODK Briefcase providing there is a stable internet connection. Once the data is transferred onto the online platform (ODK Aggregate), it can easily be transferred onto Microsoft Excel and other platforms (Jeffers & Nohasiarivelo, 2016). In 2013, the community-based mobile monitoring tool was trialed by Blue

Ventures in Madagascar's remote artisanal shark fishery to document shark landings (Blue Ventures, n.d.)

Evaluation results

An evaluation of ODK's traceability system to assess the potential to capture KDEs at point of harvest, transshipment and landing was not performed since the tool, by design, must be tailored to meet fishery, industry and government requirements. This means that once developed, the ODK tool has the potential to capture all the KDEs required. Table 8 analyzes the Open Data Kit tools against several key attributes, and identifies some of the challenges and opportunities. The information used for the evaluation of key attributes was obtained from Blue Ventures' ODK brochure.

Table 8. Evaluation of the key attributes satisfied by the Open Data Kit system.

Key attributes	Description
Scaling	• ODK Collect can easily be scaled to a specific fishery as the data collection sheets are pre-designed • Training fishers to use the application and other platforms is required • Mobile application can operate in multiple languages
Data validation	• Data validation can be challenging as the system is not automated and all data is entered by fishers
Privacy	• ODK Aggregate can be configured to restrict access to data on platform • A lock can be installed on the mobile application to protect data collected on ODK Collect
Accuracy	• Risk of human errors while entering data on the mobile application
Costs	• The mobile application (ODK Collect) is free • There is a cost associated with the download of Microsoft Excel through purchase of Microsoft Office
Infrastructure	• ODK Collect works offline and online (useful for SSF that operate in remote areas) • GPS coordinates can be hard to collect in remote areas with limited network • Although most fishers have smartphones, some may fishers may be unwilling to risk using their smartphones at sea • A trained and experienced team will be required to set-up the system and design the data sheets

	• A computer is required to transfer large amounts of data through the ODK Briefcase • Once the data is uploaded on ODK Aggregate, a trained individual with computer access will need to transfer the data on the desired platform
Data ownership	• No information available
Interoperability	• Easily interoperable as data can exported from the online database (i.e. ODK Aggregate) onto Microsoft Excel or other platforms

4.5 Discussion

The traceability systems developed by FAME, Shellcatch and Open Data Kit each have their strengths and weaknesses. Assigning a "one-size-fits-all" traceability solution for Indonesian small-scale tuna fisheries is challenging as the key attributes vary between fisheries and amongst contexts. Moreover, it is important to note that most traceability technologies can be tailored to meet specific requirements and capture data not previously collected through the technology. This is the case with ODK, which can be designed to capture data specific to a fishery. While comparing the KDEs that can be captured by FAME and Shellcatch, both systems have the potential to collect different KDEs. For instance, the FAME tools do not have the capacity to capture any data on transshipment, whereas the Shellcatch tools can capture a small proportion (25%) of data on transshipment. It is worth noting that transshipment is not an activity performed across all small-scale fisheries in Indonesia; very few pole-and-line fisheries perform transshipment at sea. Hence, fisheries that do not perform transshipment will not be required to collect transshipment KDEs or need a traceability system that can collect this data. Overall, the systems developed by Shellcatch have the potential to capture more KDEs (67%) than FAME (54%).

The three different traceability systems have several commonalities: (1) all tools are relatively simple to scale as they were developed in a similar context; (2) the three systems are interoperable across other platforms and databases; and (3) all technologies will require some amount of training to operate the tools and handle data. In comparison to FAME, Shellcatch will require more training once the data is collected since the images from the eMonitoring system need to be analyzed to extract and sort data. Additionally, fishers will need to be trained to enter data on the Shellcatch eReporting system. The same is true for FAME as fishers will need training to use the marine transponder and enter data on the mobile application. For ODK, a trained team of experts will be required to set-up and design the data sheets. Once the data sheets are completed, fishers will need to be trained to use the mobile application.

Another important attribute to consider while evaluating the three traceability systems is fisher privacy. The Shellcatch eMonitoring tool (i.e. camera) can cause privacy issues for fishers since they will be video recorded during fishing operations. Contrastingly, the ODK and FAME systems are less likely to have privacy issues associated with them as both tools do not collect data on fishers specifically.

While analyzing data accuracy, all three systems are prone to human errors. Through their mobile applications, ODK, Shellcatch and FAME are susceptible to human errors as data is entered on datasheets through the mobile phones. In this way, the automatized system developed by FAME (i.e. marine transponder and NFC cards) leaves less room for errors and can result in a higher data accuracy. In addition, the uptake of FAME transponders by fishers is likely to be higher compared to mobile applications since it is less time consuming and meticulous for fishers. In comparison to certain reef fisheries, one-by-one tuna fishing is very intensive as many fish are caught over a short period, and need to be sorted and stored immediately after harvest. Thus, systems such as the FAME transponder can work in favor of fishers since they can concentrate their efforts on fish harvest and storage, rather than data collection. The same is true for tools like the Shellcatch eMonitoring cameras which do not require fishers' engagement. However, processing the video footage from the eMonitoring tool can be time consuming and may result in poor data if the images are misinterpreted or poorly analyzed.

Chapter 5: Discussion and conclusions

This study aimed to obtain a thorough understanding of the legal and voluntary reporting requirements for SSF to demonstrate their traceability to global markets. It examined some of the challenges faced by SSF in adopting traceability systems and developed an evaluation framework to assess them. This chapter describes some of the limitations of the study, particularly with the evaluation framework developed in Chapter 3. Finally, it explores some of the questions that have emerged from this research. Based on the findings described in Chapter 3 the following questions appeared: *how can we balance transparency and privacy, and what are the benefits of adopting electronic traceability systems?* In addition, the insights gained from discussions with IPNLF team members while developing the case study (Chapter 4) lead to the following question: *what approaches can be used to adopt and implement traceability systems in small-scale fisheries?*

5.1 Limitations of the study

The evaluation framework was developed as a tool for small-scale fisheries, governments and NGOs to analyze different traceability systems with the goal of finding an appropriate tool for their fishery. The framework consists of a matrix used to analyze the potential of a traceability system to capture different KDEs. It also includes an assessment of the key attributes satisfied by the traceability system. The KDE evaluation matrix can be a useful tool to understand the KDEs that can be captured at different stages along the seafood supply chain. However, several limitations emerged while testing the framework through the Indonesia case study. First, it is important to recognize that most traceability technologies are designed to suit and meet customer needs. This means that many traceability systems can be tailored to capture the KDEs necessary before they are implemented. Since a small number of traceability systems (three systems) were assessed using the evaluation framework, it was challenging to draw conclusions on the efficacy of the framework itself. More technologies should be assessed with the framework to test it further and refine the matrix.

In the future, the small-scale fisheries' key features and details of the fishing operations should be identified early on. This can include but is not limited to: gear type, vessel size, number of fishers onboard, species harvested, type of processing onboard. This information can be useful for determining an appropriate traceability system as fishing operations can vary largely from one fishery to the next. For instance, though the ODK mobile application is well-suited for the artisanal shark fishery in Madagascar, it may not be appropriate for Indonesian tuna pole-and line fisheries. Though both fisheries are small in scale, they have different fishing operations as pole-and-line fishing is an intensive method where numerous fish are caught, handled and stored in a short time lapse. This can make data entry with the mobile application challenging for pole-and-line fishers as they are occupied during fish harvest.

In the KDE matrix, a limitation emerged concerning the weight assigned to KDEs and different events along the supply chain (point of harvest, transshipment and landing). Depending on the context and small-scale fishery, certain CTEs and KDEs may be more important than others. For instance, transshipment is not an activity performed across all small-scale fisheries since it is banned in some countries. Moving forward, the scoring system should be modified to account for the importance of certain CTEs and KDEs by adjusting the weight placed on each of these.

Given the context of COVID-19 during the study, it was beyond the scope of the research to interview small-scale fishers across different small-scale fisheries. In future research, it would be pertinent to interact with fishers to gain valuable insights on their experience using traceability systems to collect fishing data. This information can be useful to obtain a broader understanding on the barriers faced by SSF while implementing traceability systems and can help improve the design of pilot projects to trial different traceability technologies.

5.2 How can we balance transparency and privacy?

Privacy is an overarching concern for fishers and can consequently be a barrier to improving transparency and adopting traceability systems on fishing vessels. There is a fine line between achieving complete transparency or traceability in fishing operations and breaching fishers' privacy. As Popper (2007) suggests "traceability almost inevitably impinges on someone's or some organization's privacy" (p. 383). This section provides an approach towards balancing transparency and privacy.

As Janssen & van den Hoven (2015) explain “full transparency and privacy do not exist, and both concepts should be measured using continuous and not dichotomous values” (p. 366). In other words, evaluating and measuring these two competing properties is inherently complex. Weighing privacy against transparency requires a thorough understanding of the situation and context at hand. To illustrate this, Janssen & van den Hoven (2015) developed a conceptual model to demonstrate the interdependencies of the privacy and transparency landscape (Figure 9). Privacy and transparency are shaped by culture, information, policy, social preferences, organizations, circumstances and more. The authors affirm that social perceptions on privacy are influenced by the past and are constantly evolving. What can be considered as acceptable today, may be considered a privacy breach in the future as policies and social constructs evolve over time. This point is relevant to the rapid expansion of traceability in fisheries, particularly with the development of new data collection methods such as electronic traceability systems. In addition, Figure 9 can help us understand how privacy and transparency are influenced in different small-scale fisheries. For example, in South Asia SSF are likely to be heavily shaped by culture and traditional values; as Smith & Basurto (2019) found that a significant proportion of SSF in South Asia are defined by socio-cultural factors. In other cases, SSF may be largely influenced by policy and organizations. Understanding the complexities of transparency and privacy in different contexts can be useful in finding paths towards a healthy balance between the two competing properties.

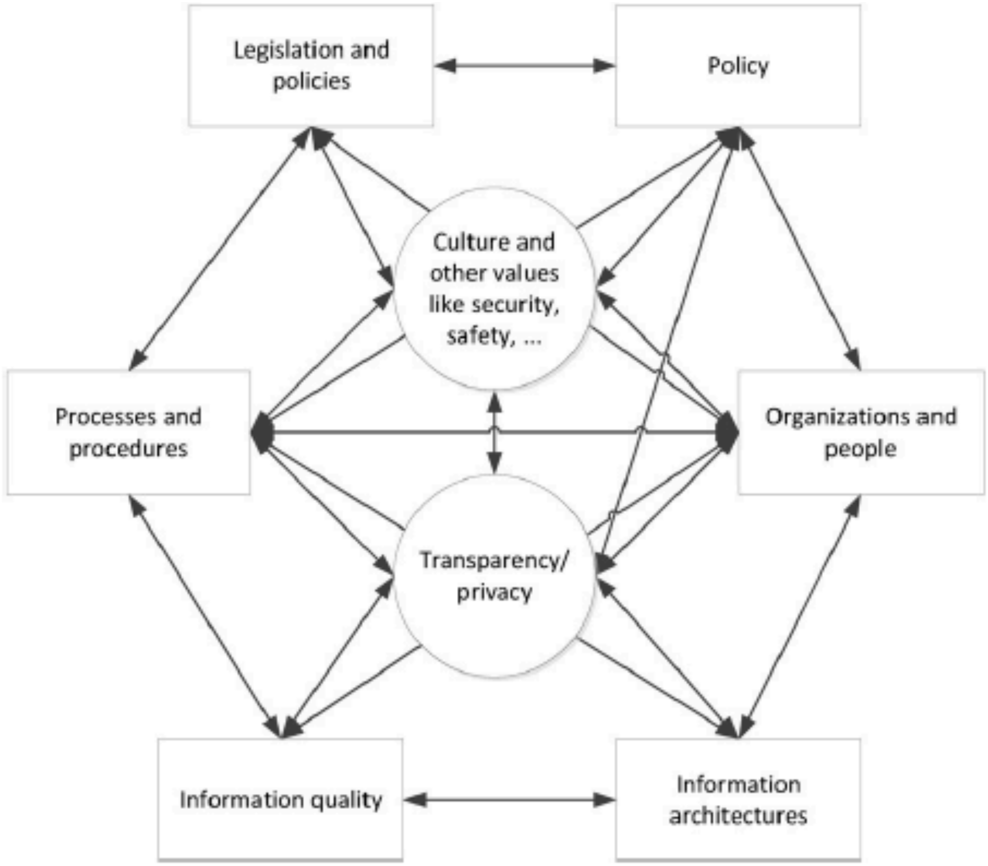

Figure 9. Elements and dependencies comprising transparency and privacy landscape (Janssen & van den Hoven, 2015).

One of the primary risks to privacy is not the information itself, but rather how the information is used once it is collected (Janssen & van den Hoven, 2015). This concern was raised in a report by the International Convention for the Exploration of the Sea (ICES) in 2006 "The problem is mainly with image data that could compromise the privacy expectations of vessel crew or reveal various techniques, work practices, safety procedures, etc., which were not part of the fishery monitoring objectives". This issue can be addressed by clearly defining of purpose of data collection and who may access the data before the program begins (Michelin et al., 2020).

Through electronic recording devices on fishing vessels have the capacity to threaten the crew's privacy, there are several ways this issue can be minimized and addressed. Recording devices can be positioned in a way to capture fish and fishing gear, instead of crew members

(Michelin et al., 2020). Moreover, electronic monitoring devices can be equipped with sensors or scheduled to record operations only while fishing activities are taking place on the vessel (Michelin et al., 2020). This can prevent the crew from being recorded continuously. Additionally, the resolution of the data recorded can be reduced to protect individual's anonymity (e.g. blurring faces). Another way to address the crew's concerns is to provide them with an opportunity to view what the cameras are recording before they are installed on the vessel (Michelin et al., 2020). This can improve trust and reduce barriers to collecting data at sea through electronic systems.

5.3 What are the benefits of adopting electronic traceability systems?

As the FAO (2020a) suggests, the benefits of adopting traceability systems within a seafood supply chain are not widely known. Thus, "communicating and understanding the benefits of a traceability system are important for successful implementation of traceability" (FAO, 2020a, p. 27). This section provides an overview of some of the advantages in adopting traceability systems.

Traceability systems have the capacity to improve time-management, logistics and overall efficiency within the supply chain. For instance, technologies that can communicate vessel position can facilitate logistics at landing, as buyers and processors know exactly when seafood will be offloaded from the vessel at port (Marine Change, 2020). Additionally, end-to-end traceability systems can help facilitate product recalls since seafood products can be easily traced back up the supply chain. This is particularly true for systems where seafood is accompanied by a label or tag (e.g. FAME traceability system). Moreover, traceability systems can also enable companies to track their progress and assess whether company objectives have been met (FishWise, 2018).

As FishWise (2018) suggests "The fishing industry is vulnerable to organized crime in part because of the logistical difficulties inherent in monitoring working conditions at sea and within an increasingly globalized seafood processing industry" (p. 9). By means of recorded information and automated systems, traceability systems can help determine the legality of seafood products and working conditions. Information on vessel position, harvest area, vessel data and more, can help local authorities and regulatory bodies verify the legality of seafood harvested.

With the increasing demand for social responsibility in the seafood industry, there is a push for fisheries to demonstrate their compliance to market requirements and commitments to social responsibility (Packer et al., 2019). In this way, traceability systems can enable fisheries to prove sustainability commitments and can encourage social and environmental responsibility. From a marketing standpoint, "boat-to-plate" traceability systems can help seafood producers promote their engagement to sustainability commitments by shedding light on sustainable practices used across the seafood supply chain. For instance, Storied Fish promotes seafood to consumers through storytelling that consists of information on the fishery, fishing methods or facts about fishers who harvested the fish (Future of Fish, 2016). Therefore, collecting key data on fishing operations through traceability systems can enable companies to story their fish with substantial claims. In turn, this can help small-scale fisheries obtain a higher market price for their sustainably-caught fish.

The use of traceability systems on small-scale vessels can bring several advantages to fishers. Technologies with communication platforms can enable fishers to send messages and information (e.g. GPS coordinates) to partners on land, their families or other vessels while fishing in groups. This can also improve trip efficiency and reduce fuel usage (Marine Change, 2020). Additionally, traceability technologies can enhance safety at sea by providing information on weather events (Marine Change, 2020). In the event of bad weather, some technologies can send distress signals to land, further increasing the crew's safety. Promoting these added features can also be a way to incentivize fishers to adopt traceability systems on vessels.

5.4 What approaches can be used to implement traceability systems in small-scale fisheries?

Chapter 3 developed a framework for SSF to assess different traceability systems, while Chapter 4 tested the framework through a case study on Indonesian SSF. Once an appropriate traceability system is identified, the next step is to implement the tool. While this study did not include implementation explicitly, it is an essential component to achieving transparency in the fishing industry. This section, therefore, provides different approaches to implementing traceability systems in SSF. Two main approaches can be used to implement traceability systems in SSF: top-down and bottom-up (Figure 10). Depending on the country, context and governance structure, one approach may work better than another. In some cases, a combination of both approaches can work best.

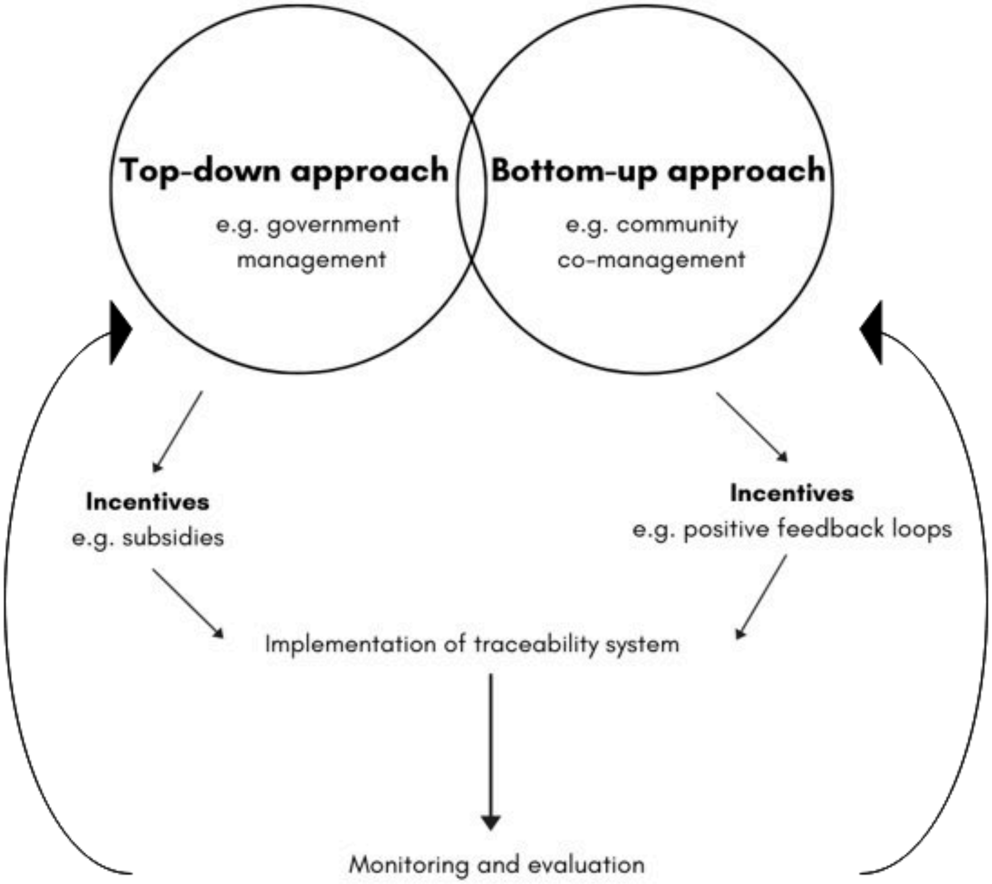

Figure 10. Approaches to implementing traceability systems in small-scale fisheries.

In a top-down approach, the implementation of traceability systems can be managed by a regulatory body such as the government. This type of implementation might make the most sense in support of programs like the EU IUU regulations, which are government to government. Once an appropriate traceability system is identified, incentives will need to be introduced to support the implementation of the system. The FAO (2020a) outlines three types of incentives used for the implementation of a traceability system: intrinsic incentives, extrinsic incentives and social incentives (Appendix III). Intrinsic incentives "originate within each entity or an actor of the supply chain depending on their own interest and specialization" (FAO, 2020a, p. 24). This can include awareness of crisis or strategy. Extrinsic incentives "originate external to each entity in the supply chain” (FAO, 2020a, p. 24). These can include legislation, government subsidies or financial rewards. Social incentives “originate from the supply chain entity’s perceived social relations” (FAO, 2020a, p. 24). These can include social pride, satisfaction with being transparent to society and more. Thus, the government can support the implementation of traceability systems in different ways. One way is through legislation, an extrinsic incentive. In Indonesia, the Ministry of Marine Affairs and Fisheries developed eLogbooks for fishing vessels to document and report catch. Through regulations, the government requires vessels over 30GT to use this traceability system (Marine Change, 2020).

Another extrinsic incentive is the use of subsidies. Through direct subsidies, governments can reward SSF for adopting traceability systems (e.g. subsidized market price for traceable seafood products). Given the economic contribution of certain SSF to national gross domestic product, it seems rational for governments to promote seafood traceability as it can provide access to more lucrative markets. Moreover, the information collected through traceability systems can help governments in management and decision-making. As Bush (2017) suggests, data can “contribute to the precision of relevant fishery indicators (e.g. standing biomass, fishing effort, reproductive capacity of stocks and ecosystem effects of bycatch), and comply to a large extent with RFMO data requirements” (p. 133). This information can then be used for ecological stock assessments and can infer conservation measures. From a social standpoint, traceability and transparency can also be considered a public good through food safety (Bantham & Oldham, 2003) and consumer awareness on seafood products. It is important to note that prioritizing subsidies directly linked with traceability is necessary to promote it and highlight the benefits brought to fisheries.

Rewarding comprehensive data collection and reporting can be used as an incentive to increase the adoption of traceability systems. As Bush et al. (2017) suggest, one way to reward fisheries for this is through lower tax rates on catch. In any case, incentives should be designed strategically to ensure that fishers are not mistakenly encouraged to misreport in the pursuit of benefits. If subsidies are used as incentives, they must be designed and allocated in a way that it does not drive unsustainable practices such as overfishing. Moreover, it is important to note that a top-down management approach may not always be successful as in some cases fishers mistrust the government and are apprehensive of management actions (Bradley et al., 2019).

A bottom-up approach is based on a collaborative process managed by several stakeholders, involving local communities. As Plummer (2009) explains, collaborative management or co-management is "highlighted in relation to knowledge generation, social learning and adaptation for transformative changes". Engaging several stakeholders in the management process, including fishers and local communities, can provide important insights on the implementation of traceability tools. Establishing shared goals and objectives that recognize the needs of all stakeholders early in the process can help build trust (Bradley et al., 2019), and will facilitate the adoption of traceability systems. Additionally, engaging communities in the management process can generate co-learning and capacity building amongst stakeholders (Burns et al., 2011). This can empower local communities (Wiber et al., 2009), and may generate a sense of ownership over the data collected using traceability systems. In this way, collaborating with local communities is likely to further increase incentives for adoption. Graaf et al. (2011) found that cost, fisher cooperation and time-consuming nature of the data collection systems, were significant incentives for implementation. Therefore, the complexity of the tool and fishers' perception on the traceability system are likely to influence adoption rates. Prioritizing tools that provide added benefits (safety at sea, communication features, weather forecasts) to fishers can further incentivize uptake of traceability systems.

Additionally, co-management can generate intrinsic incentives by creating positive feedback loops. Engaging local communities in the data collection process and management, will not only generate a sense of ownership; it can increase their contribution to the long-term data collection, particularly when fishers further realize the value of such information (Bush et al., 2017). This can be achieved by engaging fishery members through training and workshops to promote the importance and benefits brought by traceability. For example, the data collected can be used to provide a history of fishing or revenue to help inform future allocations of insurance or supporting finance. Though community co-management can be highly beneficial, it is important to recognize that it is a challenging process as there are no best practices that fit all contexts (Shalowitz et al., 2009). As Duggan & Kochen (2016) suggest co-management initiatives and training programs are not often prioritized by fishers. Thus, the success of co-management programs is dependent on many variables including community dynamics, cultural context, governance structures and more.

In some contexts, it may be appropriate to use a combination of bottom-up and top-down approaches to implement a traceability system within a SSF. In Indonesia, most traceability systems are currently implemented by the government (top-down approach). However, this has not encouraged the uptake of traceability systems in small-scale fisheries since the regulations and incentives laid out mainly target large-scale fisheries. In this case, adopting a bottom-up approach can be an efficient way to encourage the implementation of traceability systems within SSF. If both approaches are used, it is crucial for stakeholders to consider what tools are already in place to avoid duplication of efforts and ensure that data is easily interoperable across platforms to facilitate data transfer.

As illustrated in Figure 10, once the traceability system is implemented, it is critical to have a monitoring and evaluation process. This ongoing process is necessary to assess the traceability system's efficacy against the objectives and performance standards laid out at the start (FAO, 2020a), to enable the data collection process to be improved.

5.5 Conclusions

The increasing demand for traceable seafood globally provides an opportunity for small-scale fisheries to demonstrate their traceability and commitments to sustainable fishing practices. Increasingly, electronic traceability systems are replacing traditional data collection methods. Despite the push for traceability in the seafood industry and broad array of electronic systems available, small-scale fisheries face difficulties in realizing end-to-end traceability.

Critical tracking events and key data elements are two crucial components of traceability in the seafood supply chain. This study identified legal and voluntary requirements from point of harvest to landing, to enable SSF to trade their seafood to global markets. Different KDE requirements were examined under several CTE categories including species harvested, bycatch, vessel data, transshipment data and landing data. Overall, government import requirements varied at point of harvest, transshipment and landing, as some governments required more detailed information compared to others.

The study developed an evaluation framework for SSF to assess the capacity of an electronic traceability system to collect information on fishing operations at sea. Through this, traceability systems are evaluated using a KDE matrix and against key attributes including privacy, data ownership, accuracy, scaling, interoperability, infrastructure, costs and data validation. The framework was tested through a case study on Indonesian small-scale fisheries to evaluate three different traceability systems. The case study underlined that assigning a “one-size-fits-all” traceability solution for SSF may not be the best option. Instead, a case-by-case approach is recommended as each fishery has different fishing operations, infrastructure, crew numbers, data requirements etc.

As SSF work towards end-to-end traceability, it is crucial to understand the barriers they face in adopting traceability systems. Some of these challenges include privacy concerns, cost, lack of governance, infrastructure limitations and lack of incentives. Future research should incorporate fisher perspectives on traceability tools to overcome these barriers and improve traceability in SSF globally. Moreover, highlighting the benefits that can arise with the implementation of traceability systems is necessary. These include improved fisheries monitoring, supply chain efficiency, regulating IUU fishing, promoting sustainability commitments and other advantages to fishers including improved safety at sea. Finally, the study concludes that regardless of how traceability implementation proceeds, via top-down or bottom-up mechanisms, incentives are an integral part of the implementation process to support small-scale fishers and fisheries as they advance traceability in fishing operations at sea.

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Appendix I: Key data elements master list

The figures below illustrate the legal and voluntary KDE requirements at different critical tracking events: point of harvest, transshipment and landing. Additionally, the potential challenges faced by SSF in collecting this data are identified. The yellow fill indicates KDEs applicable to Indonesian SSF (used for the case study).

Critical Tracking Events (CTEs)	Category	Key Data Elements (KDEs)	Description	Legal & international market requirements	Voluntary guidelines	Potential challenges for SSF
Point of harvest	**Species harvested**	Species name	Latin (scientific) name of species. Format: "The ASFIS 3-alpha code would be added based on the scientific name supplied or the association with the local common name" (NOAA Fisheries, 2019)	US SIMP, EU catch certification scheme, EU simplified catch certificate, ACDS, CCAMLR	WWF, FAO	"The ASFIS 3 alpha coding system may not be familiar to local fishers, so it may be added by a port sampler or processing plant employee" (NOAA Fisheries, 2019) If multiple species are harvested, splitting the data for each species landed can be a challenging for SSF (Salas et al., 2007)
		Common market name		US SIMP		
		Estimated weight (kg)	"Numerically quantifiable amount of seafood with a standard Unit of Measure" (GDST, 2020a)	EU CCS, ACDS, CCAMLR, ICCAT, CCSBT		Lack of qualified enumerators or data entry operators, and limited training (Yuniarita et al., 2017)
		Estimated weight to be landed (kg)		EU CCS		Lack of qualified enumerators or data entry operators, and limited training (Yuniarita et al., 2017)
		Catch description		EU, ICCAT (including number of fish), CCSBT (including fork length & number of fish)		Lack of qualified enumerators or data entry operators, and limited training (Yuniarita et al., 2017)
	Bycatch data	Species name	Latin name of species. (Size and quantity are sometimes a requirement)		IPNLF	
		Location	Geographic location where bycatch was harvested		IPNLF	
		Date(s)	Calendar date (s) bycatch was harvested		IPNLF	
		Catch certificate/ license			IPNLF	

Catch data	Location of catch	Geographic location where seafood was captured. Format: GPS coordinates/ FAO fishing area code (IUU watch, 2020)/ RFMO list of fishing areas (NOAA Fisheries, 2019) / Sub national permit area (IUU watch, 2020) / Exclusive economic zone (IUU watch, 2020)	US SIMP, ACDS, RFMOs, CCAMLR, ICCAT * "SIMP exempts an importer from the requirement to individually identify small-scale vessels if the importer provides other required data elements based on an aggregated harvest report. Aggregated harvest report is defined as a record that covers: (1) harvests at a single collection point in a single calendar day from small-scale vessels (i.e., twelve meters in length or less or 20 gross tons or less); (2) landing by a vessel to which catches of small-scale vessels were made at sea."(NOAA Fisheries, 2019)	WWF, FAO	"If a catch report is not required in the local jurisdiction, or the catch area is not required to be specified, some locally meaningful description is needed or the US could specify use of FAO fishing area codes with an additional note regarding within or beyond the EEZ of a Coastal State (ISO 2 character country code)." (NOAA Fisheries, 2019)
	Type of processing authorized on board		EU CCS		Lack of qualified enumerators or data entry operators, and limited training (Yuniarita et al., 2017)
	Vessel trip date (s)	"Calendar start and end dates of a fishing vessel's voyage between the last point the fishing hold was empty and seafood discharged." (GDST, 2020b)	CCAMLR		Lack of qualified enumerators or data entry operators, and limited training (Yuniarita et al., 2017)
	Fishery improvement project	"Publicly listed name of the fishery improvement project that the harvest event is subject to" (GDST, 2020b)			Lack of qualified enumerators or data entry operators, and limited training (Yuniarita et al., 2017)
	Date(s) of capture	Calendar date(s) when seafood was extracted for capture, irrespective of the fishing vessel's voyage at sea.	US SIMP, ACDS, ICCAT, CCSBT	WWF, EU	Lack of qualified enumerators or data entry operators, and limited training (Yuniarita et al., 2017)
Vessel data	Type of gear or capture method	Name or code of equipment used to harvest seafood. Format: FAO gear code/ RFMO list of fishing gears (NOAA Fisheries, 2019)	US SIMP, EU catch certification scheme, ICCAT, CCSBT	WWF	
	Name of the captain or master		EU catch certification scheme, ACDS		
	Company name		US SIMP		
	Fishing vessel owner name		EU		
	Address & contacts		US SIMP, EU catch certification scheme		
	Vessel name	"Name used to identify the vessel visually or on vessel registries" (GDST, 2020b)	US SIMP, EU catch certification scheme, EU simplified catch certificate, ACDS, ICCAT, CCSBT , CCAMLR	WWF	
	Vessel registration #	"Standardized number (vessel ID) used to distinguish vessels registered under the same flag nation" (GDST, 2020b)	US SIMP, EU catch certification scheme, EU simplified catch certificate, ACDS, CCSBT	WWF	Some countries fishery regulations do not require small-scale fishing vessels to be registered (Graaf et al., 2011). Vessel registration number can change from year-to-year.
	Vessel type/tonnage		EU		
	Vessel length				

	Vessel data	Unique Vessel Identification (UVI) (if applicable)	“Identifier associated with a vessel for the duration of its existence that cannot be re-used by any other vessel with a permanent physical marking on the craft". Format: IMO number (GDST, 2020a)	US SIMP (optional)		UVI numbers may not be applicable to smaller fishing boats as they may not have a UVI. "If registration is not required in the local jurisdiction, some locally meaningful description or disclaimer (“identifier not applicable”) is needed"(NOAA Fisheries, 2019)
		VMS # (if applicable)		EU catch certification scheme, CCAMLR		Not applicable to all SSF as many small vessels do not have a satellite transponder (NOAA Fisheries, 2019)
		IMO/Lloyds # (if applicable)		EU catch certification scheme, ACDS		Not applicable to all SSF as many small vessels do not have an IMO or Lloyds number (NOAA Fisheries, 2019)
		Authorization to fish	“Unique number associated with a regulatory document, from the relevant authority, granting permission for wild-capture of seafood by a fisher or fishing vessel.” Format: Fishing licence/ permit or registration nymber (GDST, 2020a)	US SIMP (optional), EU catch certification scheme, ACDS, ICCAT	WWF	"If a permit or license is not required in the local jurisdiction, some locally meaningful description or disclaimer (“license not applicable”) is needed" (NOAA Fisheries, 2019)
		Vessel flag state	“Nation with supervision over safety, fishing operations and catch reporting”. Format: 6-1 alpha-2 code specifying the state under whose laws the vessel is registered or licensed. (GDST, 2020b)	US SIMP, EU catch certification scheme, EU simplified catch certificate, ACDS, CCAMLR, ICCAT, CCSBT	WWF	
		Existence of Human Welfare Policy	“Indicator of human welfare policies in place on a vessel/trip” (GDST, 2020b)			
		Human Welfare Policy Standards	“Name of the internationally recognized standards to which the policy on a vessel/trip claims conformity” (GDST, 2020b)			

Transshipment	Transshipment data	Vessel name	"Name used to identify the vessel visually or on vessel registries" (GDST, 2020b)	EU catch certification scheme, US SIMP, CCAMLR, ICCAT, CCSBT	FAO	
		Vessel flag state	"Nation with supervision over safety, fishing operations and catch reporting" (GDST, 2020b). Format: 2 alpha ISO country code (NOAA Fisheries, 2019)	EU catch certification scheme, ICCAT	FAO	
		Unique Vessel Identifier (UVI)	"Identifier associated with a vessel for the duration of its existence that cannot be re-used by any other vessel with a permanent physical marking on the craft". Format: IMO number (GDST, 2020a)	US SIMP, CCAMLR		"If registration is not required in the local jurisdiction, some locally meaningful description or disclaimer ("identifier not applicable") is needed. Free form text will be necessary because all potential formats cannot be determined in advance. In the event the vessel has an IMO Number, this should be used as the identifier. A prefix of "IMO" or "OTH" could precede the identifier" (NOAA Fisheries, 2019)
		Vessel registration	''Standardized number (vessel ID) used to distinguish vessels registered under the same flag nation" (GDST, 2020b)	US SIMP	FAO	

	Transshipment data	Carrier owner			IPNLF	
		Receiving master name		CCAMLR		
		Location	Geographic location where seafood is discharged from a fishing vessel to a transshipment vessel. Format: At-sea: geographic coordinates. In-port: unloading port name. (GDST, 2020b)	CCAMLR , ICCAT	FAO	
		Date(s) and time	Start and end dates of transshipment from a fishing vessel to a transshipment vessel (GDST, 2020b)	US SIMP (date), CCAMLR (date), ICCAT (date), CCSBT	FAO	
		Packing list			IPNLF	
		Estimated weight (kg)		ICCAT		
		Transshipment authorization	Unloading authorization or code (GDST, 2020a)	ICCAT, CCSBT		
		Observer ID (GDST, 2020a)				

Landing	**Landing data**	Species composition and volume	Latin (scientific) name of species and numerically quantifiable amount of seafood with a standard Unit of Measure (GDST, 2020a)	US SIMP	WWF, FAO	
		Product form	Form of the processed product (e.g. headed and gutted) (NOAA Fisheries, 2019)	US SIMP, CCAMLR, CCSBT		
		Date(s)	Start and end dates when seafood is discharged to land (GDST, 2020b)	US SIMP, CCAMLR, CCSBT		"In the absence of a local requirement for a numbered catch or harvest certificate, the harvest date together with the vessel/facility name and the location would establish a unique identifier
		Location	Name of unloading port where seafood was discharged to land	US SIMP, CCAMLR		
		Landing recipient	Name and contact information required. Format: Landing ticket or weigh-out slip (issued by the first receiver and submitted to competent management authorities via dealer reporting) (NOAA Fisheries Fisheries, 2019)	US SIMP	FAO	"Small scale buyers in remote coastal locations may not have formal or standardized contact information" (NOAA Fisheries, 2019)
		Landing authorization				
		Vessel ID and license				
		Verified weight landed (kg)	"Numerically quantifiable amount of seafood with a standard Unit of Measure" (GDST, 2020a)	US SIMP, EU catch certification scheme, EU simplified catch certificate, ACDS, CCAMLR	WWF	Lack of qualified enumerators or data entry operators, and limited training (Yuniarita et al., 2017)

Appendix II: Case study evaluation results

The three tables below outline the results from the evaluation of the Shellcatch and FAME traceability systems on the KDEs fulfilled for point of harvest.

Name of traceability system	Category: Species harvested		Score	Percentage (%) fulfilled
	Species name	Verified weight landed (kg)		
Shellcatch	Yes	Information not available	1	50
Fame technology	Yes	Yes	2	100

Name of traceability system	Category: Bycatch data				Score	Percentage (%) fulfilled
	Species name	Location	Date(s)	Catch certificate/license		
Shellcatch	Yes	Yes	Yes	Yes	4	100
Fame technology	Information not available	Information not available	Yes	Yes	2	50

Name of traceability system	Category: Catch data					Score	Percentage (%) fulfilled
	Location of catch	Time of catch	Vessel trip date(s)	Fishery improvement project	Date(s) of capture		
Shellcatch	Yes	Yes	Yes	Likely	Yes	4.5	90
Fame technology	Yes	Yes	Yes	Likely	Yes	4.5	90

The table below presents the results from the evaluation of Shellcatch and FAME traceability systems on the KDEs fulfilled for transshipment.

Name of traceability system	Category: Transshipment data								Score	Percentage (%) fulfilled
	Location	Date(s) and time	Packing list	Vessel name	Vessel flag state	UVI	Vessel registration	Vessel owner		
Shellcatch	Yes	Yes	Information	Informatic	Information not av	Information not avai		Information	2	25
Fame technology	Information	Information nc	Information	Informatic	Information not av	Inforn	Information n	Information	0	0

The table below outlines the results from the evaluation of Shellcatch and FAME traceability systems on the KDEs fulfilled for landing.

Name of traceability system	Category: Landing data				Score	Percentage (%) fulfilled
	Species composition and volume	Location	Date(s)	Vessel ID and license		
Shellcatch	Yes	Yes	Yes	Yes	4	100
Fame technology	Yes	Yes	Yes	Yes	4	100

Appendix III: Incentives for implementation of a traceability system

The table below compiled by the Food and Agriculture Organization, outlines the three main incentives necessary for the implementation of a traceability system. Source: FAO (2020a).

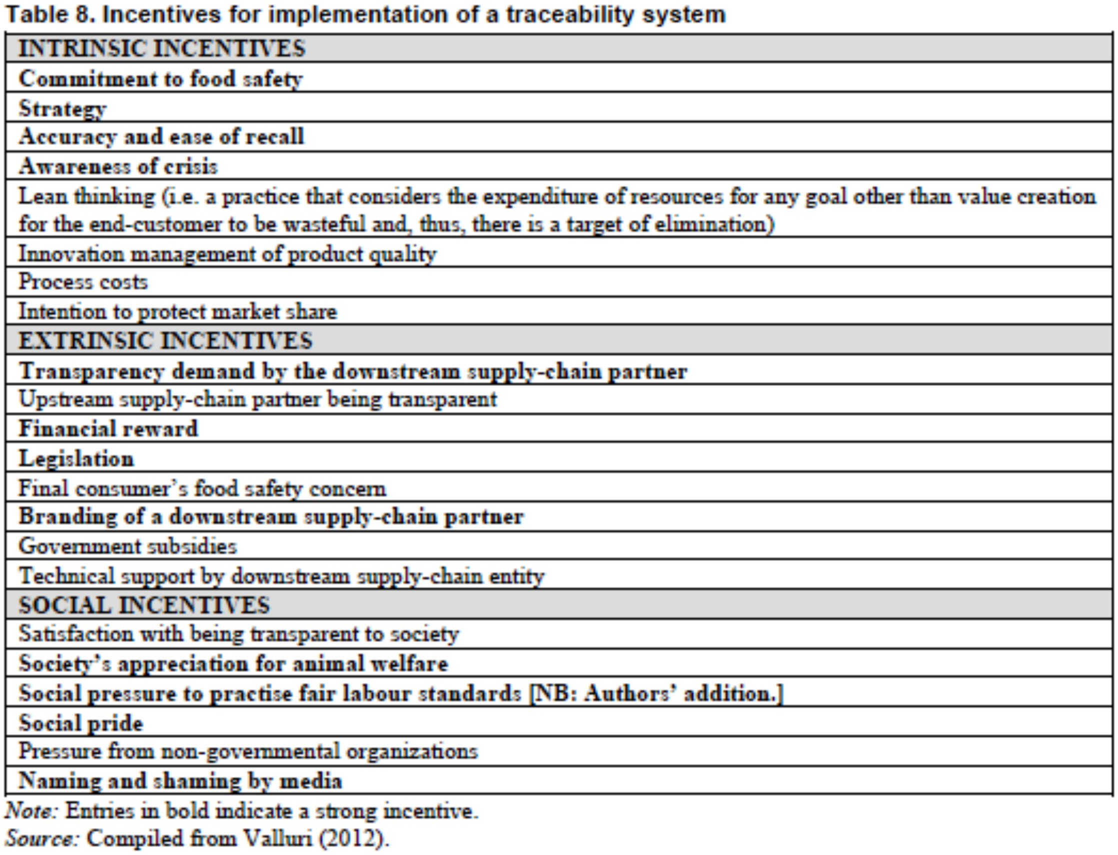

Table 8. Incentives for implementation of a traceability system

INTRINSIC INCENTIVES
Commitment to food safety
Strategy
Accuracy and ease of recall
Awareness of crisis
Lean thinking (i.e. a practice that considers the expenditure of resources for any goal other than value creation for the end-customer to be wasteful and, thus, there is a target of elimination)
Innovation management of product quality
Process costs
Intention to protect market share
EXTRINSIC INCENTIVES
Transparency demand by the downstream supply-chain partner
Upstream supply-chain partner being transparent
Financial reward
Legislation
Final consumer's food safety concern
Branding of a downstream supply-chain partner
Government subsidies
Technical support by downstream supply-chain entity
SOCIAL INCENTIVES
Satisfaction with being transparent to society
Society's appreciation for animal welfare
Social pressure to practise fair labour standards [NB: Authors' addition.]
Social pride
Pressure from non-governmental organizations
Naming and shaming by media

Note: Entries in bold indicate a strong incentive.
Source: Compiled from Valluri (2012).