University of Reading

Improving Traceability to Achieve Sustainable Development and Commercial Scaling-Up of Fisheries Resources in Tanzania

PhD in Agricultural, Environmental, and Food Economics

School of Agriculture, Policy, and Development
Department of Agri-Food Economics and Marketing

Charles Lufurano DOMICIAN

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DEDICATION

I dedicate this piece of work to the following family members who are precious to me: my parents Domician Nchinzo Tibhyampansa Lufurano and Helenestina Nyamichu Domician Gansonga both of whom have passed on (May their souls rest in everlasting peace, *Amina!*); lovely wife Chaurembo Jenifa Gasengaire Ruthabhara Mtajiri, and beloved kids Akodi-Nchinzo Domician Omubhezi Azega Mtajiri, Profo Gadi Owomugisa Aduorr Mtishibi Mtajiri, and Binti Mfalme Chausafi Clara Mungu-Atuheile Nyamichu Asta Mtajiri; and all other members and ancestors of the wider Lufurano Alyefao Mtajiri family.

DECLARATION OF ORIGINALITY

I confirm that this thesis, **'Improving Traceability to Achieve Sustainable Development and Commercial Scaling-Up of Fisheries Resources in Tanzania'**, is my own work, and the use of all material from other sources has been properly and fully acknowledged.

Charles Lufurano DOMICIAN.

ABSTRACT

This study identifies barriers to and drivers of sustainable development and commercial scaling-up of Tanzania's fisheries resources by exploring a market-based approach to improving traceability in fisheries to overcome these barriers. Data collection from Tanzanian and European stakeholders used Grounded Theory (GT) analytical framework. Lack of trust, credibility, and inadequacies in public governance were barriers that created opportunities for local and foreign rogue actors to unsustainably overexploit Tanzanian fisheries resources. A Basic Social Process (BSP) called Fishmining, which captured these barriers, was derived using the GT methodology. Literature on resolving these barriers suggested that market-based mechanisms would potentially increase transparency and traceability to improve accountability for sustainability in fisheries. A Blockchain technology-based traceability solution was thus devised, based on successful case studies in other developing countries, for testing in the Tanzanian context. A large-scale survey tested Tanzania's marine and freshwater fishers' willingness to accept/adopt this solution. An extension of the Unified Theory of Acceptance and Use of Technology (UTAUT2) conceptual framework explained the drivers of willingness to accept/adopt this solution, modelled using Partial Least Squares–Structural Equation Modelling (PLS-SEM). The solution's proposed monthly price of US$100.00 attracted fishers' potential uptake rates of over 80%. Overall, the PLS-SEM model explained 38.5% of variations in the fishers' Behavioural Intention to accept/adopt the solution, with more explanatory power in marine (43.6%) than freshwater (38.8%). Four drivers influenced positively and directly the fishers' intention: Complementary Technology, Effort Expectancy, Performance Expectancy, and Price Value. Also found were moderating and mediating effects that invariably revealed the drivers' influence on fishers' intention. Therefore, attaining sustainable development and commercial scaling-up of the fisheries resources requires increased uptake of this solution whose features of transparency and traceability enhance accountability through identification and mitigation of stakeholder trust issues and governance problems along the fisheries supply and value chains.

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LIST OF ACRONYMS

Acronym	Long form or meaning	Acronym	Long form or meaning
2D	Two Dimension	DFP	Digital Fishery Platform
3G	Three Generation	DIT	Diffusion of Innovation Theory
ACP	African Caribbean and Pacific	DL	Distributed Ledger
AEO	Agricultural Extension Officer	DNA	Deoxyribonucleic Acid
AI	Artificial Intelligence	DSFA	Deep Sea Fishing Authority
AIM	Asset Identification Method	EE	Effort Expectancy
API	Application Programme Interface	EEZ	Exclusive Economic Zone
BCOS	Be Credible, Open, and Secure	EFSA	European Food Security Agency
BI	Behavioural Intention	ERP	Enterprise Resource Planning
BMUs	Beach Management Units	EPAs	Economic Partnership Agreements
BSP	Basic Social Process	EU-CFP	European Union – Common Fisheries Policy
CB-SEM	Covariance Based-Structural Equation Modelling	FAO	Food and Agriculture Organisation
CIIs	Conceptual Incidental Indicators	FC	Facilitating Conditions
CPR	Common Pool Resources	FDSP	Fisheries Development Support Fund
CSC-UK	Commonwealth Scholarship Commission in the United Kingdom	FIDEA	Fishing Data East Africa
CSR	Corporate Social Responsibility	FIMIX-PLS	Finite Mixture-Partial Least Squares
CT	Complementary Technology	FSIS	Food Safety and Inspection Service
DDL	Digital Distributed Ledger	GDP	Gross Domestic Product

Acronym	Long form or meaning	Acronym	Long form or meaning
GFW	Global Fishing Watch	MGA	Multi-Group Analysis
GL	Governance Loss	MM	Motivational Model
GMP	Google Maps Platform	MPAs	Marine Protected Areas
GPS	Global Positioning System	MPCU	Model of Personal Computer Use
GT	Grounded Theory	NFC	Near Field Communication
HDI	Human Development Index	NGO	Non-Governmental Organisation
HM	Hedonic Motivation	P2P	Peer to Peer
HT	Habit	PE	Performance Expectancy
IBM	International Business Machines (Corporation)	PLS-SEM	Partial Least Squares-Structural Equation Modelling
ICT	Information and Communication Technology	PV	Price Value
ID	Identification	QLDB	Quantum Ledger Database
IIoT	Industrial Internet of Things	QR	Quick Response
INTERPOL	International Criminal Police Organisation	RFID	Radio Frequency Identification
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services	SACCOS	Savings and Credit Cooperative Society
IPOA-IUU	International Plan of Action to Prevent, Deter, and Eliminate Illegal, Unreported, and Unregulated Fishing	SC	Smart Contract
IRT	Innovation Resistance Theory	SCT	Social Cognitive Theory
LDCs	Least Developed Countries	SDGs	Sustainable Development Goals
MACEMP	Marine Conservation and Environmental Management Project	SI	Social Influence

Acronym	**Long form or meaning**	**Acronym**	**Long form or meaning**
SMS	Short Message Service	UNECE	United Nations Economic Commission for Europe
SOSSAT	SmartOne Solar Satellite Tracking	UNEP	United Nations Environmental Programme
SPS	Sanitary and Phyto-Sanitary	URT	United Republic of Tanzania
TAFICO	Tanzania Fisheries Corporation	US(A)	United States (of America)
TAFIRI	Tanzania Fisheries Research Institute	USDA	US(A) Department of Agriculture
TAM	Technology Acceptance Model	UTAUT	Unified Theory of Acceptance and Use of Technology
TBT	Technical Barriers to Trade	UTAUT2	Extension of Unified Theory of Acceptance and Use of Technology
TIFPA	Tanzania Industrial Fishers and Processors Association	VICOBA	Village Community Banks
TL	Trust Loss	VIF	Variance Inflation Factor
TPB	Theory of Planned Behaviour	VMS	Vessel Monitoring System
TRA	Theory of Reasoned Action	WFMTS	Wheat Flour Milling Traceability System
UAV	Unmanned Aerial Vehicle	WiFi	Wireless Fidelity
UK/EU	United Kingdom/European Union	WTO	World Trade Organisation
UN	United Nations	WYDDF	Women, Youth, and Disabled Development Fund
UNDP	United Nations Development Programme		

CHAPTER 1:

THE CONTEXT OF THE FISHERIES SECTOR

1.1 Introduction

Although fish is the world's leading commodity for food security, its sustainability and commercial development are threatened globally, leading to dwindling fish stocks, rising consumer prices, and lost revenues to fishing communities. The effects of these lost revenues are most acute in developing country communities, where economies are more dependent on farming and fishing. According to data from the Financial Transparency Coalition (2022) and Sumaila et al. (2020),[1] developing coastal countries, including Tanzania, lose an estimated US$50.0 Billion annually in revenues due to ongoing unsustainable fishing practices. This is happening at a time when the United Nations has admitted that a target to end overfishing of marine resources by 2020 was not achieved (FAO, 2020). This has resulted recently in an international agreement to expand, from 1.2% to 30% by 2030, the area of global oceans protected against unsustainability practices, including overfishing (Stallard, 2023). While fish/seafood is recorded as the most traded food commodity in the world (FAO, 2014), fisheries rank third among the three most badly governed natural resources globally after timber logging and mineral extraction (Financial Transparency Coalition, 2022). Also, according to the United Nations Food and Agriculture Organisation (FAO), about 90% of global fisheries are presently fully exploited, overexploited, or depleted, due to unsustainable and illegal, unreported, and unregulated (IUU) fishing practices (FAO, 2020). Motivated by these colossal losses from unsustainability in fisheries resources, this study sets out to identify barriers to and drivers of sustainable development and commercial scaling-up of Tanzania's fisheries sector to ensure the livelihoods and trade incomes of those dependent on fishing activities.

It is important at this juncture to draw a distinction between IUUs and unsustainable fishing. While all IUUs are unsustainable, some legally accepted fishing practices also lead to unsustainability (European Union, 2022; FAO, 2001; Petrossian & Pezzella, 2018). To illustrate, some countries (e.g., China, the EU, Japan, and South Korea) provide state subsidies to their national and private fleets to overfish globally, especially in oceans adjacent to African coastal states, to meet their respective countries' food security needs, jobs, and fishing industry profits (Sumaila et al., 2013; Caton, 2018; Wester, 2023). Although these state subsidies result

[1] https://www.globalissues.org/news/2022/11/02/32314

in overfishing which is unsustainable in nature (e.g., FAO, 2001), this funding and the fishing activities it supports remain legal under these respective countries' regulations. For the purposes of this study, however, unsustainable fishing includes both the IUUs and legal but unsustainable fishing practices like the offering of subsidies that enhance overfishing. These unsustainable fishing practices have affected 820 million people globally who depend on fishing for their livelihoods, namely food security, especially protein intakes, as well as fish sales income for meeting other socio-economic needs (FAO, 2020).

Unsustainable fishing activities are driven mainly by Europe, China, USA, Japan, and other major global fishing powers (Sumaila et al., 2020) by what appears to be a supply and demand mechanism. For instance, the overfishing practices occur when these countries offer huge state subsidies to their national and private fishing fleets, which go on to overfish on a global scale, including in African marine waters (Sumaila et al., 2013; Caton, 2018; Wester, 2023). While Asia, especially China, accounts for 55% of vessels involved in global unsustainable fishing practices (i.e., supply side), the trio of the EU, the US, and Japan make up 55% of the global seafood market (i.e., demand side) (Sumaila et al., 2020). These global powers undertake and protect these supply-demand mechanisms of global unsustainable fishing practices to safeguard their food security needs, job opportunities, and business profits for their industrial fishing fleets (Sumaila et al., 2013). However, these countries' safeguarding of their interests happens largely at the expense of poor developing coastal states in Africa including Tanzania. Based on the sheer scale of unsustainability, these unsustainable fishing activities by global industrial fleets have been categorised as international organised crime, because they fish illegally and unsustainably to deprive local communities' economies of vital food security, revenues, employment opportunities, and socioeconomic development (Sumaila et al., 2020). These activities occur when domestic and/or foreign vessels catch fish illegally in developing countries' Exclusive Economic Zones (EEZ), offload, and process the catches at sea on larger transshipment vessels, before they sell their output directly, usually in export markets (Sumaila et al., 2020).

To illustrate, of the US$50.0 billion annual losses sustained by the developing states from unsustainable fishing activities, Africa loses US$11.2 billion (i.e., 22%) with a concentration, especially in West Africa, of about half of all global unsustainable fishing vessels (Collyns, 2022; Sumaila et al., 2020). Sumaila et al. (2020) report further that about 84% of fish catches from West Africa enter the formal or legal global fisheries supply and value chains without undergoing any traceability checks for sustainability sourcing. Inadequacies in traceability systems along the fisheries supply and value chains potentially pose health risks for consumers, as they cannot figure out the origin and human health quality circumstances under which the fish and fishery products were sourced (FAO, 2001; Leal et al., 2015). This suggests a possible linkage between the inadequacies in the traceability systems and the ongoing unsustainable fishing activities (FAO, 2001; Leal et al., 2015). It appears that ineffective traceability systems in fisheries provide motives and opportunities for actors to commit and make business gains unnoticed and untraceable from these unsustainable fishing practices, thus avoiding chances of being held accountable or penalised (FAO, 2001; Leal et al., 2015). Traceability in fish and fisheries products means the ability of consumers or buyers to fully trace back the products' origins along the supply and value chains, thus ensuring their health safety, sustainability sourcing, and compliance with other relevant laws and regulations on seafood (Leal et al., 2015; Seafish, 2022). This entails the requirement that all suppliers of seafood must label their products clearly and accurately to make them fully and conveniently traceable by consumers and other actors on the fisheries supply and value chains (Seafish, 2022).

Aside from West Africa, externally driven unsustainable fishing practices have also been recorded in the Eastern Africa Indian Ocean waters. For example, in Somali waters, foreign fishing fleets engage in twice as much illegal fishing by volume as local fishermen (Agnew et al., 2009). Moreover, Caton (2018) reports that fish supplies have significantly diminished at Dar es Salaam, Tanzania's largest fish market; and this has been blamed on overfishing in the country's territorial waters by large foreign owned, largely Chinese, trawlers. These foreign actors have pushed the fishing limits beyond the sustainable levels, thus depriving local fishers of catch (Sumaila et al., 2020). As a result, the local fishers have compensated for these shortfalls through catching younger fish, often by illegitimate means,[2] thus worsening the unsustainable fishing problem (Caton, 2018; Petrossian & Pezzella, 2018). Therefore, because over 95% of fish catch in Tanzania is done by low-tech small-scale fishers, including through various forms of illegal and unsustainable means (Jiddawi & Öhman, 2002; URT, 2016), it is reasonable to assume that much of this output is consumed unnoticed and untraceable in the local and export markets. This is cemented by the fact that only Tanzanian fisheries exports into the developed world (e.g., the EU/UK) undergo safety checks at the processor/exporter level, thus leaving seafood consumed locally and exported regionally untraceable completely,

[2] These include using small size nets and dynamite fishing.

thereby offering no assurance of health safety and sustainability compliance (URT, 2016). This has lowered or erased the level of Tanzania's fisheries trust and credibility with key buyers, especially in the premium price markets in the UK/EU (URT, 2016).

As indicated above, these unsustainable fishing practices have been occurring in the Tanzanian fisheries sector (URT, 2016). This sector employs about 183,800 fishers directly and over 4.0 million indirectly – suppliers of fishing gear and other inputs, processors, and traders/distributors (URT, 2016). Over the period 2001–2017, Tanzania produced an average of 349,500 tonnes of fish annually, this being almost 48% of the total annual domestic fish demand of 730,000 tonnes (URT, 2018). When annual export demand is factored in, the country's level of fish production is seen to be even more inadequate. During this 16-year period, annual exports averaged 44,000 tonnes (i.e., 12.6% of production) while local annual supply estimates were 306,000 tonnes, that is, 42% of domestic demand. This supply shortfall resulted partially from the fact that 95% of active operators in Tanzania's freshwater and marine fishing sectors are low-tech artisanal fishers with limited fish catch capabilities, thus resorting most of the time to unsustainable fishing practices (Jiddawi & Öhman, 2002; Robertson, 2018). To illustrate, fleet motorisation rates are 1 outboard engine per 10 boats and 1 inboard engine per 73 boats (URT, 2016, 2018). The low-tech nature of these Tanzanian fishers also contributes to the ineffectiveness or the lack of traceability mechanisms for monitoring and communicating transparently their activities at sea to identify and limit unsustainable fishing practices (URT, 2016). Furthermore, over 85% of all fishing activity is undertaken on Tanzania's inland water bodies (mainly on Lake Victoria for Nile Perch and Tilapia), while marine fishing and aquaculture contribute just 14% and 1% of total fish production, respectively (URT, 2016). According to recent official data (URT, 2020), the GDP contribution of the Tanzanian fisheries sector has averaged 1.71% over the 2018 to 2020 period. The URT report (2020) highlights further that although the marine fisheries resources (territorial and exclusive economic zone) represent 83% of the country's total potential surface area for fishing, it only generates 14% in fish catch value. In contrast, based on Table 1, Lake Victoria with only 10% of the total fishing area potential generates about 58% of the total sales revenues from fisheries (URT, 2020). This huge disparity in fish catch between marine and freshwater fisheries is largely explained by the fact that the marine fishing environment is far more challenging with deeper depths where low-tech fishing equipment cannot operate effectively (URT, 2016). Indeed, no modern fishing investments have ever been undertaken in Tanzania's supposedly richer marine exclusive economic zone (EEZ) (URT, 2020) (see Table 1).

The preceding details show how failures in stakeholder trust and credibility, as well as inadequacies in public governance, have led to the flourishing of unsustainable fishing practices in both local and global fisheries supply and value chains (e.g., European Union, 2022; Petrossian & Pezzella, 2018; Sumaila et al., 2013, 2020; URT, 2016). However, given its socio-economic potential as a dependable source of food and support for employment, the fisheries sector needs more protection against unsustainable fishing practices to ensure compliance of seafood safety and sustainable fishing practices. One way to achieve this is to undertake investments into more credible seafood traceability systems that would guarantee compliance by fishers and other actors of minimum seafood safety standards, as well as sustainable sourcing or capture of the seafood. As the problem appears to have a global dimension, Tanzanian actors in fisheries may consider collaboration with its main fisheries trading partners (i.e., the UK/EU) who import about a third of the value of Tanzania's seafood exports (URT, 2020), at almost double the price received from the rest of the world (Table 4).

Table 1: Tanzania's Fisheries Resources in Size and Value (2020).

Fishery Resource	Fisheries area (sq.km.)	Proportion of total fisheries area	Value of fish catch (TZS billions)	Proportion of whole value
Lake Victoria	35,088	10%	1,374	58%
Marine (territorial waters)	64,000	19%	319	14%
Marine (EEZ)	223,000	64%	-	0%
Others	24,249	7%	675	28%
Total	346,337	100%	2,368	100%

Source: Adapted from Annual Statistics (2020), Ministry of Livestock and Fisheries.

Based on URT (2020, 2016) and Table 1, Tanzania's fisheries output and value are dominated by Lake Victoria freshwater fisheries, especially Nile Perch fillets, maws, and other products for local, regional, and export markets. Although the fisheries activities in Lake Victoria are undertaken in Kagera, Geita, Mwanza, Simiyu, and Mara regions, Mwanza leads the other regions by contributing close to half of the freshwater fisheries output (URT, 2020). Next in importance are marine fisheries activities that are carried out in the Tanga, Coast/Pwani, Dar es Salaam, Lindi, and Mtwara regions. These five marine regions demonstrate differences in some key variable attributes as presented in Table 2. It is shown in Table 2 that most marine fish catches, in terms of value, are recorded in Dar es Salaam, which suggests this city to be the largest fish market in the country (URT, 2020). On the other hand, Coast/Pwani and Lindi appear to have the highest numbers of fishing vessels and actors in fish supply and value chains. These actors include boat builders, boat engine and net repairers, fish traders and processors, and fish transporters. These attributes are indicative of these two regions being the most productive, as they include the famously rich fishing grounds of Mafia and Kilwa, respectively (URT, 2020). It is not surprising that most registered Beach Management Units (BMUs), being local community based participatory schemes to oversee sustainable fishing practices (URT, 2009), are recorded in Coast/Pwani region, with the highest fishing activity in terms of number of boats.

Table 2: Differences in Marine Regions' Characteristics

Variable attributes	Tanga	Coast/ Pwani	Lindi	Mtwara	Dar es Salaam	Total
Landed catch value TZS billions *(%)*	70.9 *(22.2%)*	69.5 *(21.8%)*	40.7 *(12.8%)*	31.9 *(10.0%)*	105.6 *(33.2%)*	318.6 *(100%)*
Number of boats *(%)*	1,769 *(18.3%)*	2,941 *(30.5%)*	2,452 *(25.4%)*	1,266 *(13.1%)*	1,220 *(12.7%)*	9,648 *(100%)*
Registered BMUs *(%)*	7 *(9.3%)*	33 *(44.0%)*	12 *(16.0%)*	13 *(17.3%)*	10 *(13.4%)*	75 *(100%)*
Actors in supply & value chains *(%)*	4,219 *(21.7%)*	4,378 *(22.5%)*	5,466 *(28.1%)*	2,718 *(13.9%)*	2,700 *(13.8%)*	19,481 *(100%)*

Source: Adapted from URT (2018, 2020).

1.2 The Socioeconomic Underperformance of Tanzania's Fisheries Resources

With a score of 0.549 in 2022, Tanzania falls in the lowest category[3] of Human Development Index (HDI) measures of life expectancy, education, and income levels (UNDP, 2022). Accordingly, among Tanzania's main contributors to national income in the form of Gross Domestic Product (GDP) are agriculture, forestry, and fishing (URT, 2017). These three sectors contribute about 65% of livelihood support for the Tanzanian population, mainly in terms of employment, food security, and a contribution to GDP of about 29% (Deloitte, 2017). However, most of the above-mentioned socio-economic development aspects (i.e., employment, food security, and GDP) have been coming from the other two sub-categories rather than fishing. Further analysis on the URT (2017) data shows that the contribution of the fishing sub-category to overall national GDP has on average stabilised at around 2.0% over the 2007 to 2016 period.

[3] See https://hdr.undp.org/system/files/documents/global-report-document/hdr2021-22pdf_1.pdf accessed Friday 11th November 2022.

Moreover, Tanzania's fish consumption per capita averaged just 7.9kg over the 2016 to 2020 period (URT, 2020) compared to the global annual protein intake per capita of 42kg (Desiere et al., 2018). When compared with similar developing countries, Tanzania trails Uganda and Nigeria whose annual seafood consumption rates per capita are respectively 13.7kg and 17.1kg (Desiere et al., 2018). This underperformance in protein food security has been blamed on overfishing and other unsustainable fishing practices (UNECE, 2016; URT, 2016). Table 3 below presents statistics for fisheries production, trade, and per capita fish protein consumption in Tanzania compared with a few developing countries over the 2016 – 2020 period.

Table 3: Fisheries Production, Trade, and Per Capita Fish Protein Consumption in Tanzania Relative to Comparable Developing Countries

	2016	2017	2018	2019	2020
Imports (Tonnes)	13,918	22,962	22,752	6	5
Total production (Tonnes)	362,595	362,645	387,543	470,309	473,592
Exports (Tonnes)	39,691	36,063	44,940	45,775	40,478
Local consumption (Tonnes)	336,822	349,544	365,355	424,540	433,119
Per capita intake (Tanzania)	6.84	7.10	6.76	8.15	7.99
Per capita intake (Egypt)	18.11	18.33	19.88	20.08	19.30
Per capita intake (Malawi)	9.27	11.93	12.68	8.74	9.43
Per capita intake (Uganda)	12.26	11.83	12.48	15.83	15.09

Source: Researcher's Table. Production, trade, and consumption quantities are adapted from URT (2020). Per capita fish consumption (kg/person/year) computed based on quantities from FAO's Fisheries & Aquaculture Statistics (https://www.fao.org/fishery/statistics-query/en/), https://www.statista.com/statistics/1121246/population-in-africa-by-country/ and https://www.worldometers.info/world-population/africa-population/

Table 3 suggests a general increase in both Tanzania's fisheries production and consumption volumes over the five-year period, while imports and exports are respectively declining or stagnating. Imports have mainly been marine fisheries products originating from Asian countries namely China/Taiwan, Korea Republic, Japan, and United Arab Emirates (UAE). As a result, Tanzania's overall per capita fish protein intakes have improved slightly over the same period from 6.84kg in 2016 to 7.99kg in 2020. However, these intake rates in Tanzania are by far below both the world average of 20.20kg in 2020 (The State of World Fisheries and Aquaculture 2022, 2022) and comparable developing countries namely Egypt, Malawi, and Uganda. It is to be noted here that Tanzania lags these African countries in fish protein per capita consumption despite their being either landlocked or a coastal state with fewer or limited access to fisheries resources in relative terms.

To improve the country's fisheries exports and protein intake per capita, there is need to scale up the production and supply of the fish and fisheries products above the levels presented in Table 3. However, this intensification of fisheries output needs to be attained sustainably by limiting the overfishing of the fisheries resources (Andriesse et al., 2022; Frost, 2020). One such way to achieve this is to enhance access of Tanzania's fisheries products to premium price markets in Europe and elsewhere where these higher prices are incentives for fishers to ensure the sustainable sourcing of the fisheries products (Leal et al., 2015). These premium price markets will enable fishers to make higher returns and profits which will in turn be reinvested into expanding their production and supply capacities. This is going to result in the desired expansion of the fisheries supplies for improving the country's fisheries export trade as well as food security through the enhancement of the presently low per capita fish protein consumption.

Tables 4 and 5 present three main markets for Tanzania's freshwater and marine fisheries products: Europe, Asia, and Africa. In terms of derivable sales revenues (Table 4), Europe offers the largest market for freshwater fisheries products, while Asia occupies the top spot for buying marine fisheries output. Despite the African market offering the least price/value per tonne for both freshwater and marine fisheries, the continent (i.e., Africa) generates more revenues for Tanzania from marine resources than Europe. Generally, the Asian markets offer higher prices per tonne for both freshwater and marine fisheries products than Europe and Africa. The key driver of the Asian high price per unit of fisheries products is the intensifying Chinese demand for fish maws (swim bladders) (Table 5), largely from Tanzania's marine fisheries, with an increasing industrial use utility, thus potentially triggering overfishing of fisheries resources (Ben-Hasan et al., 2021). To illustrate, prices for fish maws are as high as 72 times those of normal fish flesh which is largely for human consumption (Ben-Hasan et al., 2021). As shown in Table 4, fish maws have also been exported to African countries but have not been able to generate significant revenues to match those exported to Asia. A plausible and more general reason here is likely to be low quality and quantity of fish maws destined to African markets. Therefore, it is reasonable to assume here that if fish maws are not considered, Europe remains Tanzania's main premium price market for fish destined for human consumption. Nonetheless, it is noteworthy that the UK, being one of the major European consumer markets, does not appear in the list of key importers of Tanzania's fisheries products. Based on some statistics,[4] the UK imports much of fisheries' products from European suppliers,

[4] See https://thefishingdaily.com/latest-news/report-shows-seafood-imports-into-the-uk-from-eu-countries-increase-in-2019/

and it is quite possible that Tanzania's fisheries products could be getting onto the UK market through Germany and other European importers of Tanzanian fish as presented in Table 5. It would however be of great socioeconomic significance to Tanzania to explore and resolve the limiting factors that hinder direct exports of fisheries products from Tanzania into the UK.

Table 4: Tanzania Fisheries Exports (Quantities in Tonnes & Values in US$'000s)

	To Europe			To Asia			To Africa		
Year	Qty	Value	Value per tonne	Qty	Value	Value per tonne	Qty	Value	Value per tonne
				Freshwater Fisheries					
2019	13,934	49,755	3.57	4,386	19,187	4.37	2,984	2,518	0.84
2020	9,138	43,714	4.78	3,048	14,203	4.66	3,017	2,763	0.92
Average value per tonne (freshwater)			*4.18*			*4.52*			*0.88*
				Marine Fisheries					
2019	1,553	6,218	4.00	4,399	67,173	15.27	15,443	8,212	0.53
2020	1,261	5,513	4.37	721	51,927	72.06	13,737	7,824	0.57
Average value per tonne (marine)			*4.19*			*43.67*			*0.55*

Note: Qty = Quantity.
Source: Researcher's Table; Data extracted and adapted from FAO's Fisheries & Aquaculture Statistics (https://www.fao.org/fishery/statistics-query/en/).

As suggested earlier, the attainment of the desired levels of fish protein intakes needs to be achieved sustainably and responsibly through the expansion of fishing activities (URT, 2016). As Tanzania's fisheries products are consumed locally and in export markets (e.g., UK/EU), the sought solution for the unsustainability problem must meet the needs of both these markets. One such solution would be to invest in credible traceability systems that limit or eliminate the freedom of rogue actors to commit and gain from their unsustainable fishing practices (Leal et al., 2015). Therefore, resolving the unsustainability problem would commercially scale up the Tanzania's fisheries sector by opening marketing opportunities both locally and in premium export markets (e.g., UK/EU) (European Union, 2022; Prévost, 2010; URT, 2000). Based on available data (URT, 2016), 85% of Tanzania's fisheries production output comes from freshwater fisheries, 1% from aquaculture, while the remaining 14% is attributable to marine fisheries. On the other hand, fisheries annual exports quantities and values over the nine years period (2012 – 2020) averaged 41,259 tonnes and TZS395.00 billion (URT, 2020).

Table 5: Nature of Fisheries Products Exported and Imported by Tanzania (2019&2020)

	Europe		Asia		Africa	
Nature of trade	Main trading countries	Nature of fisheries products	Main trading countries	Nature of fisheries products	Main trading countries	Nature of fisheries products
• Freshwater fisheries exports	• Netherlands • Spain • Italy • Germany Greece	• Freshwater fish fillets – chilled or frozen	• Israel • UAE • Japan • Saudi Arabia • China	• Frozen freshwater fish fillets	• Kenya • Rwanda • Mauritius	• Fish fillets and others (Nile Perch & Tilapia)
• Marine fisheries exports	• Netherlands • Italy • Belgium	• Fish meat whether or not minced and/or frozen	• China (Hong Kong) • Myanmar • Viet Nam • Thailand • UAE	• Fish heads, tails, and maws (swim bladders) – smoked, dried, salted, in brine	• Uganda • DRC • Kenya • Rwanda	• Fish dried & salted • Fish heads, tails, and maws (swim bladders) – smoked, dried, salted, in brine • Sardines (*dagaa*)
• Freshwater fisheries imports	• Not applicable (N/A)	• Insignificant	• (N/A)	• Insignificant	• (N/A)	• Insignificant
• Marine fisheries imports	• (N/A)	• Insignificant	• China • Taiwan • Korea Republic • Japan • UAE	• Fish meat whether or not minced, fresh, or chilled	• (N/A)	• Insignificant

Source: Researcher's Table; Data extracted and adapted from FAO's Fisheries & Aquaculture Statistics (https://www.fao.org/fishery/statistics-query/en/).

Tables 6 and 7 below use 2020 figures from URT (2020) to show how Tanzania's annual fisheries output and values are distributed between local and foreign consumption. Overall, Table 6 shows that over 80% of the value of annual fisheries production is consumed locally. Therefore, as suggested elsewhere in this study, this huge proportion of locally consumed fisheries output goes without any form of traceability (URT, 2016) for sustainable sourcing as well as health safety quality checks to protect Tanzanian consumers. This happens because the country's public sector does not have effective or adequate mechanisms to carry out traceability checks in the fisheries supply and value chains (URT, 2016). Although the proportions of quantity and value of fisheries exports are small (Table 6), these exports earn the country almost double the price received in the local markets. This statistic justifies the motives to boost Tanzania's fisheries exports, particularly through measures like the establishment and enhancement of robust traceability systems to meet health quality safety and sustainability sourcing requirements in these lucrative export markets (European Union, 2022; Prévost, 2010). Table 7 indicates that the UK/EU imports about a third of Tanzanian fisheries exports in value terms; and this is about 5% of the value of all annual production (i.e., =125.5/2368=5.3%). Also, Table 7 shows that Tanzania receives higher prices from fisheries exports to the UK/EU market than from other export markets in the world. This justifies the strategic importance of the UK/EU market to Tanzania's fisheries products relative to the rest of the world. This forms another basis for Tanzanian actors/exporters in fisheries to invest in credible traceability systems as required by UK/EU markets to be able to expand and exploit this premium price market opportunity. The implementation of this credible traceability system in Tanzanian fisheries will help to achieve two main outcomes. These are the sustainable expansion (e.g., fishing intensification without overfishing) of fisheries production activities, hence addressing the fish protein food security; and meeting a key condition of accessing premium price markets in the UK/EU, hence being able to improve the incomes of fishers and other actors in fisheries supply and value chains.

Table 6: Tanzania's Fisheries Production and Consumption (Local & Export Markets).

Total Quantities (Tonnes)			Total Values (TZS Billions)		
Production	Local Consumption	Exports	Production	Local Consumption	Exports
473,592	433,114	40,478	2,368.00	1,982.00	386.00
100%	*91.5%*	*8.5%*	*100%*	*83.7%*	*16.3%*

Source: Researcher's own calculations, adapted from URT (2020).

Table 7: Tanzania's Fisheries Exports to UK/EU and Rest of the World.

Total Quantities (Tonnes)			Total Values (TZS Billions)		
All Exports	Exports to UK/EU	Exports to Rest of World	All Exports	Exports to UK/EU	Exports to Rest of World
40,478	11,539	28,939	386.00	125.50	260.50
100%	*28.5%*	*71.5%*	*100%*	*32.5%*	*67.5%*

Source: Researcher's own calculations, adapted from URT (2020).

The main operators on both freshwater and marine fisheries are small-scale artisanal fishermen with small boats, hence mostly low-tech with low fleet motorisation rates (URT, 2018). Moreover, freshwater fisheries are constituted by about 132,982 fishermen operating 42,288 small-scale fishing vessels, while their counterparts on the marine side have a mere 9,344 vessels (URT, 2016, 2018). Freshwater fisheries produced an average annual volume of 296,370 tonnes over the 16 years period from 2001 to 2016 (URT, 2018). Correspondingly, the number of fishing vessels rose in marine fisheries from 7,664 in 2009 to 9,344 in 2016; and operators (small-scale artisanal fishermen) increased from 36,000 to 47,000 during the same period. However, marine fisheries production levels remained low at an annual average range of 43,000 to 55,000 tonnes (that is one tonne per fisherman per year or 5.8 tonnes per vessel per year). A Food and Agriculture Organisation (FAO) 2006 study, as referred in URT (2016), shows that marine fisheries contributed 19% of fisheries production in 1996 while freshwater fisheries contributed 81%. By 2014, the contribution of marine fisheries had fallen to 14%, largely due to overexploitation coupled with illegal and environmentally threatening fishing practices (URT, 2016). These overfishing practices are largely caused by the concentration of fishing activities (90-95%) in shallower territorial waters because artisanal fishers' low-tech boats cannot operate effectively in supposedly richer yet deeper marine waters (URT, 2016). While quantifying Tanzania's freshwater fisheries resources' potential could be supported by an argument that greater access to export markets would lead to greater profits, thus allowing more technology investment, marine fisheries resources potential is a bit tricky to measure. The main challenge to estimate Tanzania's marine fisheries resources potential originates from the general lack of credible data on the volumes that foreign marine fishers catch in deeper waters. Despite these data shortcomings, it can still be argued that both freshwater and marine fisheries in Tanzania suffer from both limited production technology as well as unsustainable fishing practices (Kelly, 2018; Robertson, 2018; URT, 2016). It can therefore be assumed that some of fish catches made by foreign vessels in Tanzania's deep marine waters would be available for Tanzanian marine fishers if they had larger and more technologically advanced fishing boats. To address this problem, actors who commit these unsustainable fishing practices could be identified and held accountable through investments in credible traceability systems along the fisheries supply and value chains (Leal et al., 2015; Prévost, 2010; URT, 2016).

Based on the preceding, the Tanzanian fisheries sector is struggling to attain the desired levels of sustainable development and commercial scaling-up. The underperformance of the fisheries sector is mainly due to low-tech fishing equipment and failures in stakeholder trust and inadequacies in public governance of the fisheries sector which have paved way for rogue actors to commit and gain from unsustainable fishing practices (URT, 2016, 2018). These problems are worsened by the lack of reliable or credible traceability systems for enhancing surveillance, monitoring, and timely reporting of activities involving fisheries resources exploitation (European Union, 2022; URT, 2016). This is the backdrop for the country's ambitious development goal of raising the contribution of manufacturing[5] to 40% of GDP by 2025 (URT, 2000). Credible traceability systems in fisheries would transform the currently low-tech fisheries into a modern, environmentally friendly, socioeconomically sustainable, and commercially viable (profitable) sector (European Union, 2022; URT, 2016). This would be achievable if lucrative local and foreign fish markets placed requirements that to access these premium price buyers, Tanzanian fishers must prove that their catches were made sustainably. It is anticipated that fishers who met this sustainability requirement would receive higher/premium prices, thus being able to make profits that would in turn be reinvested to scale up their fishing businesses technologically and commercially.

1.3 Tanzania's Fisheries Supply and Value Chains

This section presents actors, activities, and inadequacies in Tanzania's fisheries supply and value chains. Although ideal fisheries supply and value chains should include financial flows data to demonstrate value exchange among the actors for the goods and services offered and received, this kind of data is not available in Tanzania at a segregated stakeholder level (see, e.g., FIDEA, 2019). In addition, the fisheries sector in Tanzania suffers from data quality loss due to relying heavily on expert opinion rather than using credible scientific methods (FIDEA, 2019). It is hoped that this study's proposed solution will overcome this data quality problem through the traceability features that ensure transparency and accurate data recording. Therefore, this study's presentation of stakeholders and their corresponding activities along the fisheries supply and value chains is based on accessible aggregate fisheries data (as presented in Tables 1, 3, 4, 6, 7). As such, these actors/stakeholders are input suppliers, fishers (fish producers), buyers/processors, and consumers.

[5] In the Tanzanian context, this is largely processing or value addition to agricultural and fisheries raw commodities.

1.3.1 Input Suppliers

1.3.1.1 Suppliers of Fishing Boats, Engines, and Nets

Fishing boats, nets, and engines are a key input in the fishing business in Tanzania (Falck, 2014; URT, 2016, 2018). Boat builders source almost all materials and labour from the local economy, but strict forest conservation and labour laws may limit this sourcing in future (Falck, 2014). Although Tanzania's fish export markets (e.g., the UK/EU) emphasise sustainable fishing, at least in policy or export procedures (European Union, 2022), there has been no reported case of hindering trade in fisheries because of anything to do with boat building. Therefore, fishing boat building in Tanzania has so far had no known issues in relation to traceability concerns in fisheries business. On the other hand, fishing nets are imported largely from China[6], although some local firms (e.g., Nyota Ventures)[7] have started local production. Fishing boat engines are obtained locally from large importers.[8] Although fishing nets with small mesh sizes have been a concern raised from time to time by Tanzanian regulators as tools for undertaking unsustainable fishing (McLean et al., 2014; Petit & Shipton, 2012), fishing boat engines have not been mentioned to cause unsustainability threats. Therefore, to resolve the issue of net mesh sizes, a traceability system would require fishers to report the specifications of allowable nets to comply with the sustainable fishing requirements. Generally, little has until this study been researched and reported about the fishing boats, engines, and nets as key inputs into the Tanzania's fisheries sector.

1.3.1.2 Suppliers of Financial (Banking & Insurance) Services

One of the most problematic challenges facing the fisheries sector in Tanzania is limited access to banking and insurance services (FAO, 2022). According to Tanzanian banks and insurance firms, the fisheries sector's limited access to these services is due to inconsistency in, or low fish catch volumes, and the general lack of basic financial and business management skills among fishers (FAO, 2022). The problem of low volume of fish catches can be addressed if fishers adopted collective production, or fish catch schemes in formal groups such as through cooperatives (Andriesse et al., 2022). Once formed, such formal groups' (i.e., cooperatives'), collective catch volumes would attract larger buyers in the seafood market, hence meeting a basic requirement to accessing formal banking and insurance services (FAO, 2022). Other researchers (e.g., Caton, 2018; Kelly, 2018) have associated the low fish catch volumes in

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[6] See https://www.exportgenius.in/import-data/tanzania/fishing-net.php
[7] See https://www.supplierss.com/nyota_venture_company_limited_e1553730.html
[8] See https://www.thesparepartshop.com/tanzania/motor-boats/yamaha/index.php

Tanzania to the ongoing unsustainable fishing practices. As such, there has been an initiative at the United Nations aimed at limiting access to finance (i.e., banking and insurance services) to businesses involved in unsustainable fishing practices, while channelling more funding to fishers who undertake sustainable fishing practices (UNEP, 2021). According to this initiative, one area of sustainable fishing that is eligible for this funding is the creation of robust traceability systems for ensuring the verification of sustainable production or sourcing of seafood in local, regional, or global supply and value chains (UNEP, 2021). Therefore, Tanzanian banks and insurance companies could learn from this UNEP (2021) mechanism of mitigating the risks posed by the fisheries sector (low or unpredictable catch volumes) by extending business loans to fisher cooperatives to set up credible traceability systems that enhance sustainable fishing practices. This traceability system would limit unsustainable fishing practices through the identification of rogue actors committing them, followed by punitive measures by relevant authorities, including denial of access to lucrative markets. By limiting the actions of these rogue actors, catch volumes would rise sustainably overtime, and fishers' cooperatives would make possible training for members in basic financial and business skills. Therefore, the two main barriers for Tanzanian fishers to access banking and insurance services (FAO, 2022) would be lifted, thus leading to both the sustainable development and business or commercial scaling-up of the fisheries sector.

1.3.2 Fishers (Fish Producers)

Tanzania produces fisheries products valued at US$1,018.00 million (TZS2,368.00 billion) annually (URT, 2020), and of this, only fisheries products worth US$161.0 million are exported (Kamer, 2022), while about a third of these exports go to the UK/EU market (URT, 2020). This suggests only about 5% of the value of Tanzanian annual fisheries production enters the UK/EU market (see Tables 5 and 6). Moreover, URT (2016) reports that fisheries products destined for the EU market undergo health quality safety checks in Tanzania (i.e., before being exported), suggesting the remainder of about 95% of fisheries output by value are consumed locally and regionally (mainly in Africa) without any quality checks for consumer health safety. According to FAO (2022), small-scale fishers contribute 97% of fisheries production in Tanzania, and they undertake their fishing activities with varying degrees of illegal and unsustainable fishing practices (Allegretti, 2019; Andriesse et al., 2022; Jiddawi & Öhman, 2002; McLean et al., 2014; Petit & Shipton, 2012). Therefore, based on the foregoing analysis, most (about 95%) of the fisheries output in Tanzania are consumed locally and regionally with potential health quality risks as well as without knowledge or provenance of their sustainable sourcing. Also, it has been reported that foreign actors (e.g., European, and Chinese vessels) have been fishing illegally and unsustainably in Tanzanian and neighbouring countries' marine waters and exporting without landing the catches (transshipment) (Caton, 2018; Sumaila et al., 2020). In Lake Victoria, there have been incidences of Ugandan and Kenyan operators crossing into Tanzanian waters to illegally and unsustainably fish and smuggle catches that are sold locally or even exported into markets like EU/UK especially through fish processing plants (Thibodeaux, 2003). To address this unsustainability problem in fisheries, researchers (e.g., Delpiani et al., 2020; European Union, 2022; Gallagher, 2022; Leal et al., 2015; Prévost, 2010; UNECE, 2016; UNEP, 2021) have suggested that robust traceability systems can be designed and implemented to limit or end these unsustainable fishing practices. These traceability systems can help this through the identification and onward prosecution of, including denial of market access to, those actors who commit and gain from these unsustainable fishing activities (Leal et al., 2015). Further to the above researchers' observations, both Tanzania and the EU admit (e.g., European Union, 2022; URT, 2016) the existence of inadequacies in the traceability systems for Tanzania's fisheries activities. Therefore, this study attempts to fill this gap by identifying the sustainability development challenges facing the Tanzanian fisheries sector as a key step to suggesting a robust traceability system to commercially scale up the sector.

1.3.3 Fish Buyers/Traders and Processors

Almost all the fish catches in Tanzania are sold by small-scale artisanal fishers right at the landing sites to local women and youth vendors, merchants/traders, and processing factory agents/buyers (FAO, 2022; URT, 2016). Most fish with limited quality (usually in size and freshness) are processed largely in low hygienic environments (URT, 2016). This is undertaken mainly by women (called *bucket women*, as they characteristically use buckets to carry fish) using traditional technologies namely cleaning/washing, scaling, gutting, frying, salting, drying, and smoking (URT, 2016). This mode of processing is associated with high post-harvest losses as well as poor quality of fisheries products that are marketed and consumed locally and in the neighbouring country export markets (URT, 2016). The quality of processing improves to include cold storage, packaging, and even canning for merchants, factory processors and those foreign rogue actors who undertake transshipment in deep sea marine fishing (Caton, 2018; URT, 2016). Other local market chains for fish include local wholesale traders, retail shops, and supermarkets. Nonetheless, Tanzanian fisheries exports, especially those destined for the UK/EU market, undergo consumer health safety checks before exporting them (European Union, 2022; Prévost, 2010; URT, 2016). Tanzanian exporters into this lucrative premium price UK/EU market are members to Tanzania Industrial Fishing & Processors Association (TIFPA). According to the TIFPA website,[9] there are thirteen industrial processors of fisheries products in the country (10 on freshwater/Lake Victoria, and 3 on the Indian Ocean marine coast). These are certified by Tanzania's Ministry of Livestock and Fisheries[10] through compliance to hygienic requirements to export fresh Nile Perch fillets and high value marine fisheries products into the EU market (URT, 2016). TIFPA is a self-regulating, member-based trade association that binds its members to comply to sustainability measures including ensuring a minimum length of 40-50cm for Nile Perch processed for export into the EU markets. Some of these high-quality fisheries' products are also supplied to local restaurants and hotels with high income customers like tourists and local political and business elites (URT, 2016).

Although the preceding details indicate buyers/processors of EU-bound fisheries products undergo better formal health quality checks than locally and regionally consumed fish, both small-scale and industrial fish buyers/processors require varying degrees of traceability system enhancements (European Union, 2022; Prévost, 2010; URT, 2016). This traceability system is needed to improve data availability and accessibility on sustainability sourcing of Tanzanian fisheries products that are exported into the EU (European Union, 2022; Prévost, 2010). While a traceability system is also needed to enable Tanzanian and regional consumers to trace and track health quality safety *and* sustainability sourcing data along the fisheries supply and value chains (URT, 2016). Furthermore, 50% of fish landing sites in Tanzania are not accessible by road throughout the year (URT, 2018). As a result, 50% of fish catches are moved from landing sites and distributed to markets by people on foot, 30% using motorcycles, and 14% by using bicycles (URT, 2018). There could be two obvious implications of this: (i) access by monitors from regulators would be difficult; (ii) it would be difficult to quickly transport catches off the beaches to urban fish market centres inland. This leads to higher rates of postharvest losses as well as higher prices due to reduced supplies (URT, 2016). The other category of fish buyers and processors are those involved in unsustainable fishing through trans-shipment in Tanzanian EEZ or deep-sea waters who undertake onboard vessel processing and onward export of fish and fishery products (Caton, 2018). Therefore, this study investigates the scale of limitations on the data for health quality safety and sustainability sourcing of Tanzania's fisheries products

[9] https://tifpa.org/members.html & https://tifpa.org/sustainability.html accessed 26th December 2022.
[10] According to URT (2016), the European Union nominated the Ministry of Livestock & Fisheries as the Competent Authority in Tanzania for the official control of fishery products exported to the EU market.

to suggest a robust traceability system to address these problems on both local, regional, and UK/EU export markets.

1.3.4 Consumers

Researchers (e.g., Maestas et al., 2020) have found that whenever faced with data limitations about the sourcing of food, consumers manage this risk through preference of government regulated over unregulated food. However, government regulation on food items for health quality safety varies across countries, with the developed world (e.g., the EU/UK). In general, government regulation in the developed world is well developed (e.g., European Union, 2022; Prévost, 2010; URT, 2016) while Tanzania and most other African countries are lagging (URT, 2016, 2018). This means consumers in Tanzania are more likely than those in the EU/UK to eat contaminated or unhygienic fish and fisheries products due to limits to, or non-existence of, effective regulations and fish quality preservation infrastructure. This problem is worsened by the fact that most (about 95%) of Tanzanian fish catches in value terms are consumed locally and in neighbouring country markets where food regulation and fish quality preservation are no better than Tanzania (Kamer, 2022; Prévost, 2010; URT, 2016, 2020).

Figure 1 below summarises the preceding sustainability and quality traceability challenges involving the actors in Tanzania's fisheries supply and value chains (input suppliers, producers/ fishers, processors/buyers, marketers/distributors, and consumers). Figure 1 captures the sustainability problems in both marine and freshwater fisheries in Tanzania as well as covering actors in Tanzania (i.e., upstream, where production and processing are done) and in Tanzania and UK/EU (downstream, where marketing and consumption of fish products occur). To solve the emerging problem of public governance failure to protect consumers in the fisheries sector, researchers (e.g., European Union, 2022; Leal et al., 2015; Prévost, 2010; UNECE, 2016; UNEP, 2021; URT, 2016) have advocated for the design and implementation of credible traceability systems to help with the tracing and tracking of data for health quality safety and sustainability sourcing of fisheries products.

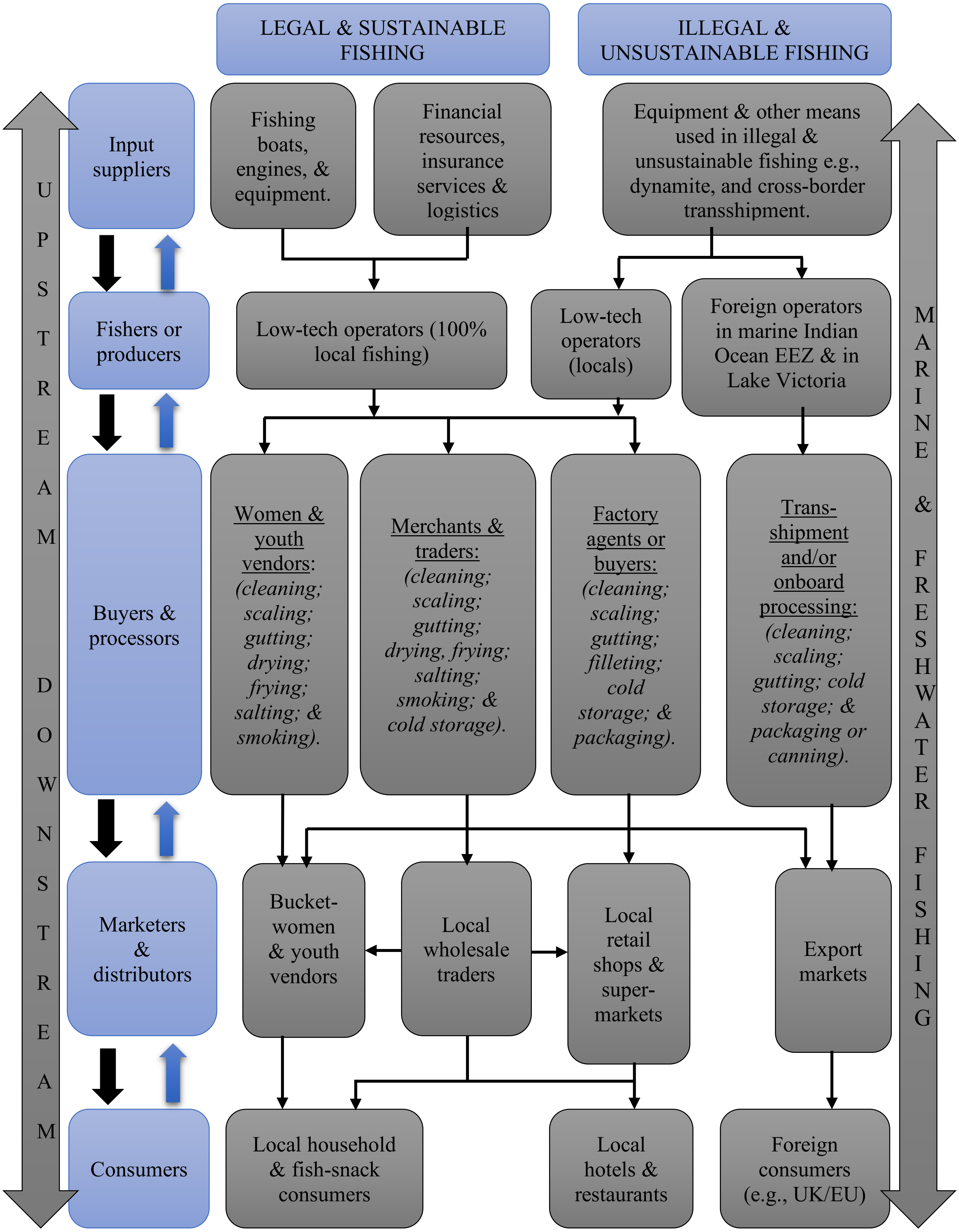


Figure 1: Interactions of Actors and Activities in Tanzania's Fisheries Supply and Value Chains.

Key: Movements of physical goods & fisheries products with value added. Movements of corresponding financial transactions/flows.

Source: Researcher's Figure.

The proposed credible traceability system would help with compliance with hygienic production environment requirements, as well as ensuring sustainable sourcing of fisheries products through its ability to identify who did what and when along the supply and value chains (Leal et al., 2015). This identification would help relevant authorities to undertake countermeasures against responsible actors, including imposition of penalties/prosecution and denial of market access, thus limiting the scale of these unsustainable fishing practices while enhancing the seafood quality for consumers and the sustainability of fisheries resources (Leal et al., 2015; Prévost, 2010; URT, 2016). However, some researchers (e.g., European Union, 2022; URT, 2016) think that the continuation of illegal and unsustainable fishing practices is partly caused by the lack of digitisation in the EU member-wide paper-based fisheries certification procedures and inadequacies in sustainable sourcing of fisheries imports from developing countries like Tanzania. These limitations result in inefficient data sharing, and they make these EU certification procedures prone to seafood fraud which poses potential threats to consumer health and fisheries resources sustainability (Delpiani et al., 2020; European Union, 2022).

1.4 EU/UK Policies and their Influence on Tanzania's Fisheries Sector

As highlighted earlier, it is notable that the sustainability challenges in the Tanzanian fisheries sector are not completely localised, but a global phenomenon. Notably, the EU/UK influences the dynamics in Tanzania's fisheries sector largely through their huge demand or market for Tanzanian fish products (Kelly, 2018). This is because about 33% of Tanzania's fisheries exports in value terms go to the European market (i.e., the UK/EU) (Table 7). Therefore, external demand for Tanzanian fish products has also been driving the way the country's fisheries resources are managed or exploited, including the unsustainable fishing practices (Kelly, 2018; URT, 2016). The external influences on the Tanzanian fisheries can be categorised as direct or indirect. A good illustration of direct European influences on Tanzanian fisheries relate to exports of Nile Perch fillets from fish processors around Lake Victoria. This commercialisation of the Nile Perch industrial processing since the 1990s led to installation of more fish processing plants around Lake Victoria to exploit the then emerging huge demand in Europe (Kelly, 2018). This policy led to more Nile Perch products being exported, thus diverting most fish consumption of locals from Nile Perch to other species namely Tilapia and others. As such, more Nile Perch supplies were made available to installed processing factories which drove the overfishing of the Nile Perch species such that when supplies declined, factories started operating at almost 50% of their initially installed capacities (URT, 2016) (see

Table 8 below). Therefore, this overexploitation resulted in fish stocks falling dramatically in Lake Victoria compared to the pre-commercialisation period of the lake (Kelly, 2018). This led to the indirect form of overfishing. Faced with diminishing fish supplies for their subsistence (food security) and trading, local fishers adopted unsustainable fishing practices (catching juveniles and/or applying illegal methods such as poison fishing) to sustain their living (Caton, 2018). Being a predatory carnivorous species, the introduction of the Nile Perch in Lake Victoria had reduced previously dominant species from 80% to 1% (Kelly, 2018). As most fishers and other community members depended largely on these other species, the diversion to Europe of much of the Nile Perch products helped only to worsen these people's livelihood problem. These unsustainable fishing practices have largely resulted from the UK/EU's continued use of paper-based certification of seafood safety requirements from exporting countries like Tanzania rather than enforcing digitised traceability for sustainability sourcing (European Union, 2022; URT, 2016). As a result, the current UK/EU's focus on legal fish catches that involves health safety certification of fisheries exports by competent authorities misses the fact that legal catches could be obtained unsustainably, hence the need for digitised traceability mechanisms that cover both issues (European Union, 2022). Digitised traceability systems would relay fisheries data quicker, thus enhancing sustainable fishing and transparency through efficient identification and limitation of the fraudulent activities in the seafood supply and value chains (European Union, 2022; URT, 2016).

Table 8: Tanzania's Underutilised Fishery Processing Capacity.

Type of fisheries	Installed capacity (tonnes/day)	Actual production (tonnes/day)	Capacity utilisation (%)
Freshwater	790.0	395.0	50%
Marine	54.1	20.9	39%
Overall total	844.1	415.9	49%

Source: Adapted from Tanzania Fisheries Annual Statistics Report (2017), Ministry of Livestock & Fisheries.

1.5 Traceability Systems in the Fisheries Sector

The foregoing sections present failures in Tanzania's local and global public governance and regulatory mechanisms meant to protect and preserve the sustainable development of fisheries resources (Agnew et al., 2009; Andriesse et al., 2022). As a result, unsustainable fishing practices have ensued (Petrossian & Pezzella, 2018). Some of these unsustainable fishing practices are sponsored by capable state actors (e.g., subsidies regime under the EU's Common Fisheries Policy (CFP) (Sumaila et al., 2020) and others are spearheaded by private rogue actors (e.g., overfishing, and dynamite fishing) (URT, 2016). This revelation points to the inadequacies in the existing local and global traceability systems (European Union, 2022; URT, 2016). For instance, Delpiani et al. (2020) find that mislabelled seafood causes negative consequences on consumers and the environment namely economic losses resulting from commercial fraud, consumer or public health problems, and potential depletion of specific fish species due to overfishing. The authors focused on the largest Argentinian fish market of Buenos Aires and used a modern DNA barcoding traceability system to assess and detect the extent of mislabelling (mixing-up or substitution) of fillets of various fish species sold to seafood consumers. They found over 20% of mislabelling incidents whereby sharks' species were sold as some other types of fish (Delpiani et al., 2020). Regarding the Tanzanian fisheries, only exports destined to the developed world markets (e.g., UK/EU) undergo health safety checks at export points rather than tracing their sustainable nature of sourcing (European Union, 2022; URT, 2016). There are no official health safety checks and traceability compliance procedures undertaken by relevant authorities on the rest of the catches (mainly for local and regional markets) (URT, 2016). Worried about their health safety risk following the preceding sustainable seafood sourcing failures, seafood consumers in high income countries (like Europe) have increasingly demanded and expressed potential willingness to pay premium prices on seafood with sustainability provenance (Hajipieris, 2007; Santos et al., 2023).

On a similar mission to enhance traceability mechanisms, Gallagher (2022) reports on private actor initiatives meant to tackle unsustainable fishing practices through the setting up of certification standards of sources of canned tuna supplies. The American leaders of this initiative, Whole Foods Market, believe that catching tuna one by one using pole-and-line and handline catch methods, prevents the presently ongoing unsustainable overfishing through the limiting of by catch losses. In addition, this fishing approach widens job opportunities for fishers and other coastal community members. To address the existing traceability inadequacies such as tuna mislabelling and the associated problems of overfishing and other illegal and unsustainable fishing practices, a traceability software package called Trace Register was employed. This traceability tool tracked each lot of tuna along the supply and value chain from vessel to can. Moreover, Trace Register is among the certification requirements on all participating suppliers and importers of tuna in this initiative. The implementers of these sustainability standards in this fisheries sustainability policy are the Marine Stewardship

Council, Monterey Bay Aquarium, and The Safina Centre. These revelations of ongoing seafood mislabelling and other unsustainable fishing practices, and private actors' initiatives to address them in the seafood market, emphasise the need for robust traceability systems for fish species identification in fisheries. The functioning traceability system would provide undisputable scientific evidence to support actions against potential and reported fraudulent activities in seafood business by law enforcement authorities (Delpiani et al., 2020; European Union, 2022; URT, 2016).

1.6 Statement of Problem and Research Questions

Tanzania is largely endowed with significant freshwater and marine fisheries resources. The fisheries sector poorly performs socio-economically because the public sector and other stakeholders fail to limit the impact of unsustainable fishing practices committed by local and foreign rogue actors. Investments into the sector, both local and foreign, have also not been sufficient and effective to sustainably develop and scale up the fisheries sector through credible traceability systems. However, despite the preceding public and stakeholder failures in the governance of the sector, there has not been an inclusive mechanism for all value chain actors in the fisheries sector, to identify the barriers to sustainable development and opportunities to scale up the fisheries resources commercially. This identification of barriers and opportunities would help to unlock the fisheries sector's vast food security and commercial potential. As such, this study's main goal was to identify the barriers to, and opportunities for, the sustainable development and commercial scaling-up of Tanzania's fisheries resources. This was a necessary first step to identifying possible solutions. These solutions were to address two issues:

(i) improving sustainability of the relevant fishing resources, i.e., preventing over-exploitation; and,

(ii) enhancing redistribution of value or opportunity for those involved in the supply and value chains to meet their food and income needs.

Of relevance in this case was the potential for in the introduction of credible traceability systems to meet both these requirements. This study, therefore, addressed the following research questions:

(i) What are the drivers of, and barriers/opportunities to, the sustainable development of Tanzanian fisheries supply and value chains?

(ii) To what extent are limitations in stakeholders' trust/credibility and institutional public governance failures a barrier to the sustainable development and commercial scaling-up of these fisheries?

The answers to these questions given by industry stakeholders would be used to inform a quantitative survey of fishers for possible solutions to these sustainability challenges, with the proposed solution(s) being subsequently tested for economic and technical viability and level of potential stakeholders' acceptance. The potential solution(s) would be expected to improve the governance of the fisheries sector through a credible traceability system that lowers or eliminates the unsustainable fishing practices along the fisheries supply and value chains. As a result, fish supplies and markets would stabilise in the long-term, thus addressing legally and sustainably the food security needs, jobs, and scaling-up of the fisheries operations and profits.

Regarding the redistribution of value or opportunity, it is anticipated that the traceability solution to be proposed by this study will enhance transparency and accountability among all actors along the fisheries supply and value chains. These actors include fishers, regulators/government agents, traders/processors/distributors, and consumers. The features of transparency and accountability will help to enhance sustainable fishing practices (i.e., limiting illegal and unsustainable fishing practices). Therefore, this study's proposed solution will help the sustainable scaling-up of fishing activities, thus helping the redistribution of value and opportunity to more actors, or a wider public, which would have been impossible or limited if illegal and unsustainable fishing practices were not curtailed. Also, the study's proposed solution would, through the transparency and accountability features, enhance taxes and levies payable by relevant actors in the fisheries supply and value chains. These revenues in the public coffers would constitute another form of redistribution of value and opportunity to actors in fisheries and a wider public, especially if the revenues so collected were to be reinvested into the scaling-up and sustainable development of the fisheries sector. These initiatives would potentially enhance the security of fish protein dietary supply and intakes, while also improving catch volumes and access to premium price markets in the UK/EU where prices are about double those received locally (URT, 2020).

1.7 Significance of the Study

The study is set to contribute towards the sustainable development and commercial scaling-up of Tanzania's fisheries sector. By identifying the barriers to sustainable development of the fisheries sector and opportunities to improve these, the study is poised to contribute to the socio-economic development of the sector. The study's findings are going to guide fishers, the government (i.e., regulators or policy makers), and other key public and private stakeholders in terms of necessary reforms for transforming the currently untapped marine and freshwater fishery resource potentials into real socio-economic benefits. In addition to addressing livelihoods and food security concerns especially dietary protein intakes, output of this research is also poised to boost the country's manufacturing sector which largely depends on agricultural, forestry and fisheries sub-sectors as major sources of raw materials for processing (value addition). Although the manufacturing sector has on average contributed 6.5% of overall annual national GDP over the 2007 to 2016 period (URT, 2016), this study is conducted at a time when the country's Development Vision 2025 (URT, 2000) envisions ambitiously to raise the contribution of manufacturing from the current bottom (i.e., 6.5%) to 40% of GDP by 2025. Therefore, this study is geared towards identifying ways to improve the fisheries sector's socio-economic contribution to the country's development, including fisheries GDP growth, productivity, and exports through the benefits of traceability systems. Moreover, the United Nations (2015) text on sustainable development goals (SDGs) states that despite its socio-economic importance, especially in terms of driving innovation and job creation opportunities, manufacturing value added per capita is as low as US$100 in Least Developed Countries (LDCs), including Tanzania, compared to over US$4,500 in the developed world – mainly USA, Canada, Japan, South Korea, and Europe. This study identifies problems along the fisheries supply and value chains and devises a potential traceability solution to addressing them. Therefore, this study potentially offers a chance of improving on the above manufacturing value-added statistic. Finally, the study is geared towards opening the Tanzanian Blue Economy (i.e., marine, and freshwater fisheries potentials). This will enable Tanzania to take advantage of untapped trade opportunities for fisheries products in the yet unsaturated and highly demanding local and lucrative foreign markets (especially the UK and EU).

1.8 Structure of the Thesis

The rest of the thesis is structured as follows. Chapter 2 undertakes an extensive literature review on how the unsustainability problems identified in Tanzania's fisheries resources exploitation are linked to, or influenced by, global phenomena as highlighted in Chapter 1. Following this identification of unsustainability problems, further literature review is undertaken to identify potential solutions used for similar unsustainability challenges in the food and seafood sectors. Chapter 2 concludes by identifying a specific package of options including a tentative adaptable cross-border traceability solution model based on the reviewed relevant literature. In chapter 3, results from the consultations (using Grounded Theory (GT) approaches) with Tanzanian fishers and other stakeholders in fisheries are presented. This GT analysis identifies unsustainability problems experienced by fishers and other stakeholders in Tanzanian fisheries, as well as other actors in potential export markets (e.g., UK/EU). To conclude, chapter 3 undertakes an assessment of how the traceability solution proposed in chapter 2 can be used to address the unsustainability challenges identified in the Tanzania's fisheries sector. Chapter 4 presents a survey methodology and the results of this quantitative survey that tested fishers' willingness or behavioural intention to accept/adopt the proposed traceability solution, as well as identifying the drivers and barriers to this acceptance/adoption. Chapter 5 discusses these results and concludes with policy implications, recommendations, and future research directions.

CHAPTER 2:
LITERATURE REVIEW ON FISHERIES UNSUSTAINABILITY PROBLEMS AND POTENTIAL SOLUTIONS IN TANZANIA

2.1 Introduction

This chapter undertakes a deeper review of the problematic themes identified in Chapter 1 relating to the ongoing local unsustainability challenges, and their global linkages, which impair development of Tanzania's fisheries sector. The identified thematic challenges, as previously noted, were generally rooted in the failure of public institutional governance to ensure the sustainable management and exploitation of fisheries resources. In this chapter, these failures are explicitly identified as: overfishing driven by market demand and state subsidy support; deceptive/fraudulent marketing of fisheries products; ineffective regulatory regimes; the lack of, or ineffective, systems to address Technical Barriers to Trade (TBTs) in terms of fisheries and Sanitary and Phyto-Sanitary (SPS) measures; and general institutional weaknesses or failures. It will be shown that the last of these problems, i.e., institutional failure, is so encompassing as a core challenge that the resolution of this problem would most likely ease problems experienced via the other four. This review of these problematic themes attempts to identify both gaps in evidence and evidence of opportunities for remediation. The exploration of the opportunities for remediation is done with a focus on opportunities to create new or strengthen and expand the effectiveness of existing traceability systems in Tanzania's fisheries. Where there is insufficient relevant literature based on Tanzania's fisheries, topical literature sources from the rest of the world are used to draw implications and lessons for the Tanzanian fisheries context.

2.2 Defining Unsustainable Fishing Practices

This study defines[11] unsustainable fishing practices as: the overexploitation and depletion of fisheries resources to the extent of, depriving future generations an opportunity to derive similar benefits, and beyond the recovery potential of the fisheries resources' ecosystems. The main forms of unsustainable fishing practices include Illegal, Unreported, and Unregulated (IUU) fishing (FAO, 2001). However, while IUUs are generally considered as unsustainable, there exist forms of unsustainable fishing practices, such as enhanced overfishing through state subsidies, which are regarded as legal, especially in rich countries (European Union, 2022; FAO, 2001; Petrossian & Pezzella, 2018; Wester, 2023). The legal status of state subsidised

[11] https://en.wikipedia.org/wiki/Unsustainable_fishing_methods

global overfishing is maintained despite its negative consequences for food security and socioeconomic development of fishing communities in Tanzania and other African countries (Caton, 2018; Wester, 2023). The term IUU fishing was originally coined by the United Nations Food and Agriculture Organisation (FAO) in 2001 during its International Plan of Action to Prevent, Deter, and Eliminate Illegal, Unreported, and Unregulated Fishing (IPOA-IUU fishing) (FAO, 2001). According to the FAO (2001), the term 'illegal' in IUU means a situation where a fishing vessel is operated in violation of laws of a country e.g., without a licence, in contravention of terms of licence, using illegal fishing gear, fishing in marine protected areas, or fishing during closed seasons. On the other hand, 'unreported' in IUU represents misreporting fish catches to relevant national, regional, or global authorities – in defiance of existing regulations. Finally, 'unregulated' fishing means catching fish in international waters without a flag of a party recognised by a local or any other relevant Regional Fisheries Management Organisation (RFMO). Each of these three components of IUUs is explained further below to contextualise them in the setting of this study.

2.2.1 Illegal Fishing

Tanzania's fishing regulations (The Fisheries Act (CAP. 279) Regulations, 2009) encourage a controlled fishing environment that promotes sustainable fishing practices, such as the preservation of marine protected areas and scaling down fishing activities during closed seasons. Despite this regulation, Tanzania's fisheries resources have constantly suffered incidences of unsustainable fishing practices in the category of illegal fishing to meet livelihood needs (e.g., Andriesse et al., 2022). While the use of poison fishing and illegal fishing gear like trawl nets are common illegal fishing methods on Lake Victoria (Daghar, 2019), dynamite fishing using blast charges is the main illegal fishing method in Tanzania's marine waters (Wells, 2009). However, illegal fishing practices appear to be driven in both freshwater and marine fisheries contexts by corruption practices and misunderstandings resulting from diverging governance perspectives between fishers and regulators/scientists (Andriesse et al., 2022; Daghar, 2019; Luomba et al., 2016; Wells, 2009). Another driver of illegal fishing is overfishing activities in Tanzania's waters by Chinese and European fishing fleets (Caton, 2018; Wester, 2023). These illegal fishing activities by foreign actors result in food security challenges among Tanzania's local fishing communities who, in turn, react by committing illegal and unsustainable fishing practices to make up for the resulting seafood supply shortfalls.

2.2.2 Unreported Fishing

Tanzania's laws and regulations on fishing require operators in the fisheries sectors to provide various forms of data and information on their fishing activities (The Fisheries Act (CAP. 279) Regulations, 2009; URT, 2020). The data so provided is used by relevant authorities for the planning and implementation of various programmes including policies supporting the sustainable development of fisheries resources. However, evidence has surfaced to show that Tanzania does not have credible systems in place for the capture and processing of fisheries data and statistics (FIDEA, 2019). This shortcoming limits the quality and quantity of fisheries data collected by relevant authorities in Tanzania. To illustrate, Daghar (2019) reveals that undeclared/unreported fish catches in Lake Victoria that reach the market are twice as much as those reported. This level of IUU is driven by corruption practices whereby customs officers in Tanzania and East Africa could be bribed by rogue actors as much as US$3,000.00 per shipment in 'protection fees' to grant legal permits/certifications to illegally sourced and unreported fish consignments (Daghar, 2019). Moreover, Tanzania's fisheries regulations (The Fisheries Act (CAP. 279) Regulations, 2009) provide that Beach Management Units (BMUs) are by law tasked, among other things, with collection and reporting of fisheries data on catches landed on local beaches. However, Kanyange et al. (2014) found in their study on the performance of BMUs in Tanzania's marine fisheries that 85% of these BMUs are not formally registered, 88% lack formal offices, and over 90% lack sustainable funding sources. This leads to underperformance by BMUs and suggests that most catches in Tanzania's marine fisheries are likely to go unreported.

2.2.3 Unregulated Fishing

Being largely low-tech and predominantly operating in shallower waters, Tanzania's marine fishers have not been able to operate in potentially richer and much deeper international waters (URT, 2016). Therefore, unregulated fishing has so far not been part of the reported challenges facing stakeholders in Tanzania's fisheries. However, fish are migratory resources that are constantly on a move in global oceans, including those waters adjacent to Tanzania. As such, the ongoing unregulated catching of fish in international waters by Chinese and/or European fleets (Agnew et al., 2009; Sumaila et al., 2013, 2020) significantly reduces the quantity of fish that would have migrated to national (generally shallower) waters of coastal states like Tanzania, hence affecting fish supplies there. It would appear, therefore, that unregulated fishing by these global powers results in illegal fishing practices in Tanzanian waters as explained earlier. Nonetheless, a recent agreement by member countries at the United Nations (i.e., the International Ocean Treaty) to expand the monitoring of fishing and other activities on the high seas (i.e., international waters) from the current 1.2% to 30% (Stallard, 2023) may scale down these international overfishing activities. If implemented, the agreement would lower the food security problems and improve livelihoods in Tanzania's local marine fishing communities as explained earlier.

2.3 Drivers of Unsustainable Fishing Practices (IUUs)

This section presents and discusses the main factors that drive unsustainability problems in fisheries resources, notably the IUUs. These problems are high demand for seafood (Petrossian & Pezzella, 2018), provision of state subsidies (Sumaila et al., 2010, 2013), deceptive/fraudulent marketing (Buck, 2010), and ineffective regulatory regimes (The Fisheries Act (CAP. 279) Regulation, 2009; URT, 2020b). Other drivers are non-conformity with Technical Barriers to Trade (TBTs) and Sanitary and Phyto-Sanitary (SPS) measures (FAO, 2022; URT, 2016), and weaknesses or failures in institutional governance (Acheson, 2006; Ostrom E., 1990; Ostrom E et al., 1994).

2.3.1 Demand for Seafood as a Driver of Unsustainable Fishing in Tanzania

Several researchers (e.g., Petrossian & Pezzella, 2018; Palma et al., 2010) found that the primary factor driving unsustainable fishing is market opportunity arising from high global demand for seafood, as well as ever-rising prices for fish and fish products. This problem is aggravated by state subsidies (see below) that governments in China, Europe, USA, Japan, South Korea, Canada, and Russia give to national and private fishing fleets to overfish globally (Rininsland, 2023) to meet pre-existing local and export demand (food security needs), jobs, and industry profits (Sumaila et al., 2010, 2013). To illustrate the enormity of overexploitation pressure on fisheries resources due to rising demand, fish consumption per capita has doubled globally since the 1950s, because of a tripling of the world population (Rininsland, 2023). This overexploitation pressure has resulted in over 80% of global fisheries resources being overfished and/or fully depleted (Agnew et al., 2009; FAO, 2020).

As a Tanzanian illustration, during the 1990s Tanzania oversaw huge investments in processing factories to produce Nile Perch fish fillets around Lake Victoria that targeted the premium price EU export markets (URT, 2016). As these factories competed to meet the huge demand in the EU to maximise profits, the Lake Victoria common fisheries resource was at the same time undergoing overexploitation (Kelly, 2018). As a result of a lack of sustainable conservation of the fisheries resources, all parties to this common resource lost out. As fish stocks fell, fish processing factories experienced up to 50% production capacity underutilisation due to a fall in raw material (fish) supplies (URT, 2016). Because of low production volumes, hence the declines in exports, factory revenues fell and so did tax revenues and levies payable to government and other local authorities. With low quality catches (e.g., juveniles), fishers could no longer realise premium prices (i.e., income) in the market (URT, 2016). Also, this fish stock shortfall led to food security problems as Tanzanian fishers opted to overfish to compensate for dwindling fish supplies (Andriesse et al., 2022).

2.3.2 State Subsidies as Drivers of Unsustainable Fishing

Governments in rich and resourceful countries namely China, Europe, USA, South Korea, Japan, and Russia have been identified as key subsidisers of global overfishing operations (Rininsland, 2023). As a global leader, China offered state subsidies amounting to US$7.3 billion in 2018, more than the total of the next two leading providers, namely Europe (US$3.8 billion) and USA (US$3.4 billion) (Rininsland, 2023). Although these subsidies might have been put to beneficial use, such as supporting the sustainable fishing practices among fishers, most of the subsidies have been used to fund activities or items that enhance global overfishing (Sumaila et al., 2010). These activities/items include artificial enhancers of profitability namely subsidies for fuel costs, repairs and maintenance, high- and deep-sea fishing support, and price support and market access facilitation measures (Sumaila et al., 2010). It is important also to note here that these global overfishing activities have led to supply shortfalls and food security challenges among local fishing communities (Sumaila et al., 2020). To illustrate, fishers in Tanzania and West Africa have started experiencing dwindling fish stocks resulting from overfishing activities in Tanzanian and West African waters, largely by foreign state-subsidised vessels including those of Chinese origin (Caton, 2018; Wester, 2023).

The two problems above (i.e., excessive demand for seafood and rising state subsidies) appear to be interlinked in a demand and supply mechanism. To illustrate this, about 55% of vessels involved in global overfishing practices originate from Asia, mainly China, a leading provider of state subsidies (i.e., supply side) (Sumaila et al., 2020; Rininsland, 2023; Wester, 2023). On the other hand, Europe, USA, and Japan consume up to 55% of the global seafood output, effectively providing a possible market (i.e., demand side) for unsustainably sourced seafood by China (Sumaila et al., 2020; Wester, 2023). This supply-demand mechanism occurs mainly to safeguard these countries' food security needs, job opportunities, and business profits for their industrial fishing fleets (Sumaila et al., 2013). However, as stated earlier, the mentioned global powers derive the above benefits at the expense of African fishing communities (Wester, 2023). Furthermore, shortages of fish supplies in Tanzania's marine waters have been closely associated with overfishing by Chinese vessels (Caton, 2018). This has forced local fishers to adopt illegal and unsustainable fishing methods like dynamite fishing to be able to blast, kill and catch more fish, largely including juveniles, to compensate for supply shortfalls caused by foreign trawlers (Actman, 2015; Andriesse et al., 2022; Caton, 2018; Wester, 2023).

2.3.3 Deceptive/Fraudulent Marketing in Fisheries

Based on a description by an online source[12] and Buck (2010), deceptive or fraudulent marketing of seafood occurs when one species of seafood is sold, usually intentionally, as another species, mainly with a motive to commit economic fraud, where low value fish species are sold as high value. This practice also has a potential to cause health safety risks to seafood consumers who would use the mislabelled seafood. Ineffectiveness of existing traceability systems has led to limited detection and prosecution of the seafood fraudsters, thus allowing them to commit and profit continuously from this form of unsustainability (European Union, 2022; FAO, 2001; Leal et al., 2015; Petrossian & Pezzella, 2018). Deceptive marketing of seafood can drive overfishing through mislabelling and substitution of overfished or endangered marine species to appear as if they were being exploited sustainably. For instance, if the mislabelled species is itself over-exploited, then it will impact sustainability because it makes the over-exploitation invisible, thereby making monitoring difficult and circumventing quotas on catches. According to Buck (2010), deceptive or fraudulent marketing practices of fisheries products can take various forms namely mislabelling or substituting fish species, low weights or undercounting, over-treating or added water weight, altered colour, and transshipment to avoid paying legitimate duties in export markets. Mislabelling/substitution of fish species is difficult to identify especially for ready to consume seafood products, hence an incentive by rogue actors to substitute expensive species of fisheries products with low value alternatives. To illustrate, an inspection by the US Seafood Laboratory Service found that over a 9-year period (1988-1997), 37% of fish and 13% of other seafood were mislabelled (Buck, 2010). Liou et al. (2020) tested 120 fish fillets from grocery stores in California for mislabelling and found that 13% had species substitution, 9% had unacceptable/unstandardised names not generally recognisable by the market, 23% did not comply with rules/regulations of country of origin, and that about 39% of the fillets had at least one mislabelling error. It has been argued

[12] https://en.wikipedia.org/wiki/Seafood_mislabelling

(e.g., Buck, 2010) that failures to limit the seafood mislabelling practices have mainly been due to shortcomings in existing traceability systems. An example of this has been the ineffectiveness/inaccuracy of public DNA testing equipment, hence the increasing tendency of seafood importers to hire more accurate/effective private DNA testing services. Mislabelling of the country of origin of seafood constitutes another problem that facilitates seafood deceptive marketing fraud (Buck, 2010; Liou et al., 2020). To illustrate, rogue actors along the fisheries supply and value chains may claim falsely by labelling their fisheries products as originating from a country regarded widely by the market or consumers as higher quality producer, hence a potential higher priced seafood supplier.

Another aspect in the deceptive seafood marketing fraud is transshipment. Despite its legality in a broad sense, transshipment which means shipping goods (e.g., seafood) to a country through another country (i.e., third party), can be abused or used illegally to avoid or circumvent legitimate tax or levy payments or even smuggling unsustainably sourced seafood. To illustrate, shrimps shipped directly from China to the US would attract antidumping duties of 112%, while shrimps originating from Indonesia would enter the US market without such charges. Therefore, Chinese exporters would initially disguise shrimp exports for the US market as exports to Indonesia. Once in Indonesia, Chinese rogue actors would collaborate with local Indonesian counterparts to relabel the imported seafood products as originating from within Indonesia for reexporting to the US market, hence circumventing US antidumping charges and accomplishing their deceptive/fraudulent marketing of the seafood. This transshipment method can be used by rogue actors to trade in unsustainably produced/sourced seafood products. Therefore, transshipments can reduce the sustainability of the source fishery if over-exploitation of this source fishery is disguised by hiding the actual source of the fish.

The preceding deceptive/fraudulent marketing practices of seafood products are worsened by shortcomings in existing traceability systems whose ineffectiveness is caused mainly by the complexity of the fisheries supply and value chains that consist multiple actors from fishing vessels to processors, to traders, and down to consumers (Leal et al., 2015). As presented earlier, the rogue actors exploit these weaknesses by committing fraud involving mislabelling or deceptive marketing strategies with regards to quality, origin, quantity, or even substitution (mix-up) of fish species (Petrossian & Pezzella, 2018). It is further reported (Warner et al., 2013) that about 33% of all seafood consumed in the US is mislabelled or substituted and sold as other seafood. This degree of mislabelling/substitution of fish species is as high as 70% of the seafood marketed in the US (Warner et al., 2013). These unsustainable fishing problems are also driven by inadequacies in traceability systems in Tanzania whereby local and regional fisheries trade is completely untraceable while exports into the EU focus more on quality rather than full traceability (European Union, 2022; URT, 2016).

2.3.4 Ineffective Regulatory Regimes

To enhance the sustainability of fisheries resources in Tanzania, there have been enacted two regulatory regimes, namely the Fisheries Act (Cap 279) Regulations (2009) and Deep-Sea Fisheries Management and Development Act of 2020. In the following sections, the provisions of these Acts will be explained, together with what they are designed to do, followed by a review of studies that have shown their weaknesses/limitations.

2.3.4.1 Fisheries Act (Cap 279) Regulations of 2009

These regulations contain key provisions on the registration and licencing of operators in the fishing business; development, management, and control of the fishing industry; ensuring quality and production standards in fisheries; and fines and penalties to be levied on those who contravene these provisions (The Fisheries Act (CAP. 279) Regulations, 2009). It is stated that Beach Management Units (BMUs) must be established in all fishing communities in both marine and freshwater fisheries to promote sustainability practices through monitoring and surveillance activities as well as fish quality controls at landing sites. Based on these regulations, BMUs are constituted by fishers, local village government members, and other fisheries stakeholders in local fishing communities. These BMUs are tasked with ensuring collaborative management, protection, and conservation of fisheries resources, biodiversity, and the environment in their local marine jurisdictions. As such, this legislation prohibits illegal, unreported, and unregulated (IUU) fishing through engaging BMUs in monitoring activities as well as collection of relevant data to guide appropriate decisions on the fisheries resource's conservation and management. However, this legislation does not empower the BMUs to access necessary resources to be able to enforce these roles. To illustrate, it has been reported that BMUs in Tanzania have limited budgets (inadequate funding) for their activities, including those for ensuring the sustainability of fisheries resources (Kanyange et al., 2014). The regulation also requires that all fishing vessels have a trackable Vessel Monitoring System (VMS) that is linked to a satellite signal. This satellite-enabled VMS must be installed on the fishing vessels to facilitate real time transmission of data on fisheries activities at sea to relevant authorities in Tanzania. According to URT (2009), the VMS transmittable data include vessel identification mark, latitude, longitude, date, time, course, and speed of the vessel. Whenever the VMS system malfunctions, the regulations (URT, 2009) waive the requirement for instant transmission of the data by allowing vessel owners to transmit data at intervals of 24 hours. However, this 24-hour window is wide enough to grant an opportunity for rogue actors to deliberately switch off or cause any technical fault on the VMS devices to hide unsustainable fishing activities. Moreover, the data collected through the VMS cannot help authorities ascertain, for instance, the size and weight of the fish catch, fish species caught, and the fishing method (URT, 2009). Another shortcoming of the VMS (URT, 2009) regulations is its mandatory use on industrial fishing vessels, but not on small scale fishers while most fishing activities in Tanzania including the committing of unsustainable fishing practices are undertaken by small-scale fishing operations (Andriesse et al., 2022; Robertson, 2018). One way to address these VMS shortcomings is to invest in electronic regulatory systems that would enhance transparency, inclusiveness, and efficient monitoring of activities along the fisheries supply and value chains (European Union, 2022). This would extend into designing new or transforming available mechanisms into electronic traceability systems that facilitate the sharing of data among all actors along the fisheries supply and value chains, thus enhancing compliance with regulation to combat unsustainable fishing practices (UNECE, 2016).

As for quality requirements, the regulations state that no fish and fisheries products shall be marketed or exported by established businesses unless they possess a health or sanitary certificate. It can be noted throughout the regulations that these requirements focus mainly on formal businesses that supply the export markets, while no such requirements are emphasised or placed on small scale fishers who produce and supply over 90% of fish and fisheries products in Tanzania (URT, 2016, 2020b). This can be illustrated by a provision on page 56 that states clearly that quality inspections should be undertaken on fish and fisheries products destined for the export market – without any provision or mention about those fish products for local consumption. These shortcomings in the regulations regarding the fish quality requirements suggest the need for an effective traceability system that would help to address the identified gaps in a comprehensive way, covering the health safety of consumers in both local and export markets.

Marine Protected Areas (MPAs) have been mentioned in Tanzania's fisheries laws and regulations as a safeguard to sustainable fisheries resources management. However, Katikiro et al. (2021) find the MPA scheme to be too dysfunctional and problematic for stakeholders to collaborate to enforce existing regulations. As a result, this lack of coordination between relevant authorities and other stakeholders, especially those at a local level, has offered another loophole for rogue actors to continue their unsustainable fishing activities in and around the MPAs against the existing regulations (Katikiro et al., 2021). Nonetheless, because unsustainability in fishing flourishes due to the complexity of the fisheries supply and value chain (Leal et al., 2015), there is need for a regulatory transformation to enhance efficiency and effectiveness in compliance measures. Because the Tanzanian fisheries sector is integrated in the global value chain (e.g., Kelly, 2018), the country can benefit from collaborating with their major importers of fish products (e.g., the EU) to build an inclusive global electronic traceability system based on 2030 United Nations Sustainable Development Goals (European Union, 2022; UNECE, 2016). This way, the Tanzanian regulatory system for monitoring and compliance against unsustainable fishing practices would be improved and strengthened.

Controlling and limiting overexploitation of fisheries resources is another aspect addressed in Tanzania's fisheries regulations (The Fisheries Act (CAP. 279) Regulations, 2009). The regulations do not appear to have performed adequately in this regard. While much of unsustainable fishing practices by local fishers in Tanzania are caused by pressure to support local livelihoods (Andriesse et al., 2022), unsustainable exploitation of fisheries resources on a global level, including in Tanzanian waters, is largely influenced by commercialisation trends (e.g., Agnew et al., 2009; Caton, 2018; Sumaila et al., 2010, 2020). This local and global commercialisation of fisheries resources has exerted a huge exploitation pressure on fisheries resources beyond sustainable levels (Agnew et al., 2009; Caton, 2018; Kelly, 2018; Pauly & Zeller, 2016; Villasante et al., 2012). This commercialisation of fisheries has transformed Tanzanian fishers to perceive fisheries resources as objects of economic overexploitation rather than natural resources for sustainable exploitation and management (Allegretti, 2019). This thinking is not only established in Tanzania, but it is also a global phenomenon due to growing food security needs, jobs, and need to maintain industry profits (Sumaila et al., 2010, 2013, 2020; Teh & Sumaila, 2013).

2.3.4.2 Deep-Sea Development and Management Act of 2020

This Act gives a mandate to the Tanzanian Deep Sea Fishing Authority (DSFA) to develop, implement, monitor, and enforce conservation and management measures necessary for the sustainable use of Tanzania's deep-sea fisheries resources (URT, 2020). Articles within the act, see pages 40 – 41, focus on ensuring the quality of fish and fisheries products before they are cleared for export markets. However, no similar provisions in the Act focus on fisheries products consumed locally. This suggests that in terms of ensuring fish quality for the health safety of consumers, the Act focuses more on the export-oriented markets and misses the local market that consumes over 90% of the country's fisheries production (URT, 2020b). Another aspect of concern appears to be the implementation of this Act's mandate. Although the mandate is on the fishing activities in the deep sea, DSFA's recent performance report (DSFA, 2020) does not mention significant accomplishments in the deep-sea fishing operations (i.e., no increase in deep-water fishing activity by Tanzanian and foreign fishers has been recorded). Instead, the report lists support measures[13] made, based on its corporate social responsibility (CSR) policy to small-scale fishers who operate in shallower waters. This suggests that DSFA faces challenges to attract local and foreign investments in deep sea fishing which is a capital and technology intensive area. In the past, Tanzania tried to address this problem within the negotiated framework of Economic Partnership Agreements (EPAs)[14] between African, Caribbean, and Pacific (ACP) countries and the European Union (EU). However, it turned out that the EU failed to give ACP countries including Tanzania, acceptable offers (Domician, 2008; LSE Consulting, 2021). During these negotiations, the EU was unable to provide a contractually binding commitment that EU businesses or actors in the fisheries sector would form joint ventures with Tanzania's fishers and other relevant stakeholders to ensure sustainable exploitation, trade, and development of the fisheries resources sector (Domician, 2008; LSE Consulting, 2021). In the absence of such a negotiated strategic partnership to invest in joint counter measures, fisheries trade between Tanzania and the EU has been plagued with increased unsustainable fishing practices (European Union, 2022; Caton, 2018; Sumaila et al., 2020; URT, 2016). Tanzania needs the support of EU and other maritime powers like China to counter illegal and unsustainable fishing practices in its (i.e., Tanzania's) deep-sea and adjacent waters because much of the overfishing practices in these waters is committed by rogue actors from these rich countries (European Union, 2022; Caton, 2018).

In addition, the Act requires that DSFA monitor and ensure that fisheries products from the deep sea that enter the local market meet minimum set sustainability requirements in terms of their sourcing. However, Tanzania does not have effective monitoring mechanisms for ensuring the sustainable sourcing of fisheries products in the local market (European Union, 2022; URT,

[13] These include training or capacity building on the identification of potential fishing zones (PFZs), and the provision and installation of fish aggregate devises (FADs).
[14] See https://trade.ec.europa.eu/access-to-markets/en/content/economic-partnership-agreements-epas

2016). This monitoring would be achievable if the proposed credible traceability mechanism was instituted to comprehensively cater for the sustainable sourcing of seafood products for both local and export markets to ensure the health safety of consumers (Leal et al., 2015; Prévost, 2010). Another key aspect of the Act relates to strategic collaboration with local and foreign investors to scale up sustainable fishing in the deep-sea fisheries sector. This would require setting up policies that are attractive to deep-sea fishing investors, such as tax breaks/concessions subject to sustainable fishing practices, technology transfer (joint ventures of foreign and Tanzanian local operators), and creation of employment opportunities for locals. However, available information suggests little progress has been registered in this regard, because fishing activities in Tanzania remain by and large low-tech (URT, 2016, 2020b). This means prospects of exploiting the richer deep-sea fisheries resources will depend on future scaling-up in terms of access to adequate capital and necessary technology. On the other hand, a report by DSFA, (2020) suggests that monitoring and surveillance efforts by DSFA helped to arrest about 10 foreign vessels which committed illegal and unsustainable fishing prior to 2019, and that no such incidences of illegal fishing were registered in 2019. However, this conclusion has been challenged by other researchers (e.g., Agnew et al., 2009; Caton, 2018; Sumaila et al., 2020) who report that foreign vessels have regularly been undertaking unsustainable fishing practices in Tanzania's deep-sea fisheries resources. DSFA admits, however, that a satellite linked surveillance video camera system has not been installed on licenced vessels that operate in Tanzania's Exclusive Economic Zone (EEZ) waters (DSFA, 2020). This failure to enforce one of the best practices implied in the Act poses a possibility for rogue fishing vessels continuing to undertake illegal and unsustainable fishing practices unnoticed.

2.3.5 Non-Conformity with Technical Barriers to Trade (TBTs) and Sanitary and Phyto-Sanitary (SPS) Measures

According to the World Trade Organisation (WTO),[15] TBTs and SPS measures relate to each other in that TBTs are generally instituted to ensure the quality and safety of products while SPS measures are usually intended to protect the health safety of consumers (e.g., people or animals) (Kang & Ramizo, 2017; WTO, 1995b, 1995a). These TBTs and SPSs relate to minimum technical specifications, rules of origin, and quality standards that must be met by producers/suppliers for their goods to enter other markets (WTO, 2022) like the UK/EU. These requirements have held back trade flows between low-income fish exporting countries (including Tanzania) and the developed world – most notably the European Union (EU)

[15] See https://www.wto.org/english/thewto_e/whatis_e/tif_e/agrm4_e.htm#TRS

(Prévost, 2010). This is because meeting these TBTs and SPS requirements needs investments in relevant infrastructure. Despite their negative effects on the fisheries exports, TBTs and SPSs are legitimately imposed in line with WTO rules (WTO, 2022). These rules include the right of WTO members to institute trade regulatory regimes for the purpose of protecting human health, safety, as well as upholding environmental conservation standards (in the supplier countries) when conducting international trade in food products (WTO, 2022). Nonetheless, Gnassounou (2017) supports the developing world outcries for lifting or loosening the TBTs and SPS barriers without carefully considering the potential environmental consequences of this action. This is because researchers (e.g., Fontagné et al., 2005) have scientifically established that failures to meet these TBTs/SPS requirements create encouraging circumstances for unsustainable fishing activities to continue.

As TBTs/SPSs are instituted to ensure the quality standards of products for health safety of consumers (Kang & Ramizo, 2017; WTO, 1995b, 1995a), the absence of necessary infrastructure for testing seafood products' compliance with TBTs/SPSs could risk consumption of the unhealthy/unsafe and unsustainably sourced seafood. These risks to human health safety could be addressed through the institution of border restrictions such as quarantines, inspections, and bans to limit such imports in ways that would not be interpreted as imposition of non-tariff barriers (NTBs) or unjustified restrictions to trade (Fontagné et al., 2005; WTO, 1995a, 1995b). To limit such potential misinterpretations, the enforcement of these trade restrictions to safeguard or protect consumers' health safety needs to meet the following criteria: be undertaken transparently, pass scientific assessments and evaluations, and be compatible with internationally accepted similar trade practices (OECD, 2000). As such, conditions to implement TBTs/SPSs requirements may include the need to apply and report fish catch and processing methods that ensure consumers' health safety and sustainable conservation of the fisheries resources (Fontagné et al., 2005). To illustrate, the EU banned imports of Nile Perch products from Tanzania, Kenya, and Uganda in the 2000s following the excessive contamination of the fish fillets with pesticides which were unsafe for both human consumption and the fishing environment (Fontagné et al., 2005). Also, during the same period, the EU banned East Africa's seafood imports due to proven disease outbreaks that potentially contaminated the fisheries products (Mutegi et al., 2001). These measures to ban the seafood imports were undertaken to protect the health safety of EU consumers after fish producers and exporters in East Africa failed to employ scientifically proven, safe and sustainable methods, as well as maintaining hygienic environment of seafood production and processing (Fontagné et al., 2005). Relatedly, URT (2018) reports that only 8% of marine landing sites had functioning toilets, while only 2% of these sites had cold rooms for preserving fish quality. These inadequacies in quality and hygiene conditions point to the need to enhance compliance with TBTs/SPS measures to address the potential human/consumer health dangers associated with contaminants in fish and fisheries products consumed locally and in export markets. Therefore, compliance with TBTs and SPSs mitigates against illegal and unsustainable fishing practices such that failure to exploit market opportunities which have these requirements (e.g., UK/EU) encourages continuing unsustainable fishing activities. As both Tanzania and the EU admit to inadequacies in the existing fisheries traceability system to efficiently monitor the implementation of the TBTs/SPS regimes (Prévost, 2010; URT, 2016, 2018), this offers an opportunity for both parties to work together to resolve the matter.

Despite their original purpose, countries may intentionally raise the consumer health and safety requirements of TBTs and SPS measures as disguised trade protectionist tools, thus shielding domestic producers against external competitors (Kang & Ramizo, 2017). Kang & Ramizo (2017) found that the implementation of TBTs and SPS measures have largely benefited exporters in developed countries at the expense of less developed exporting economies). This imbalance occurs because developed world countries (e.g., UK/EU) have far more resources than their developing counterparts like Tanzania to invest in necessary infrastructural and institutional systems for implementing the TBTs and SPS measures (URT, 2016). Therefore, the unsustainability in Tanzania's fisheries resources resulting from failures to meet the quality and consumer health safety of seafood products (i.e., the TBTs and SPS measures) can be linked to the country's inability to invest in necessary technology and infrastructure (URT, 2016). This inability has caused a potential limitation for Tanzania's producers of fisheries products to access lucrative premium price markets in the UK/EU (Kang & Ramizo, 2017; URT, 2016). To illustrate Tanzania's capacity limitations to fulfil the TBTs and SPS measures requirements, only about 5% of the country's annual fisheries production by value enters the UK/EU markets, which are considered among the most stringent in the world in terms of TBTs and SPS requirements (URT, 2016, 2020b). This small proportion is mainly confined to Lake Victoria freshwater fish processors (e.g., exporters of chilled and frozen Nile Perch fillets) and marine fish processors (exporters of minced and frozen fish meat). These fish processors and exporters are by and large members of Tanzania Industrial Fishing & Processors Association (TIFPA) who meet the TBTs and SPS measures requirements as stipulated by European importers (European Union, 2022; Prévost, 2010; URT, 2016). The vast majority (up to 95%) of

Tanzania's annual fisheries output is usually bought at local landing sites and this can also include rejected fish that do not meet export quality requirements (URT, 2016). These are processed by local women and youth vendors, merchants, and traders in quality-constrained environments and less hygienic conditions (FAO, 2022; URT, 2016). The primary value-adding methods include sun-drying (especially *dagaa* – i.e., sardines), frying, salting, and smoking (URT, 2016). These low quality and sometimes unhygienic processing methods result in low value/price products while risking the health safety of consumers in local and neighbouring country markets (URT, 2016).

However, provisions in the TBTs and SPS agreements emphasise the need for developed countries to consider, and where possible support, the efforts of developing countries to meet the TBTs and SPS measures requirements that promote sustainable cross-border trade in fisheries based on meeting product quality and consumer health safety (WTO, 1995b, 1995a). According to the TBTs and SPS measures agreements, the envisaged support requirements of the developing countries include relevant infrastructural and institutional development needs and assistance related to technology, finance, and trade. Limited volumes and values in fisheries supply and value chains have been a key feature in fisheries trade between the developing world including Tanzania (the suppliers) and the rich nations (the buyers) (URT, 2016). Among the key challenges faced by the supplying countries are inadequacies in production and supportive infrastructure to meet TBTs and SPS measures (European Union, 2022; Prévost, 2010; WTO, 2022).

2.3.6 Institutional Governance Failures

2.3.6.1 Introduction

The economics literature shows that unsustainable use of jointly owned assets, or common pool resources (CPR), such as fisheries, can be linked to institutional governance failures (Acheson, 2006; Ostrom, 2012; Derwort, 2016; IPBES, 2023). These CPR (i.e., public or jointly owned assets like fisheries, forests, air, and water) have two distinct properties, the combination of which causes resource management problems: (i) resource subtractability (i.e., resource consumed by one actor cannot be used by another); and (ii) resource non-excludability (i.e., it is difficult to exclude people from use/exploitation of the resource) (Ostrom et al., 1994). Therefore, the ongoing unsustainability of these CPR in the world (including fisheries resources in Tanzania) is a result of failure of responsible people or authorities to develop the right rules and governance structures (Acheson (2006). As such, an effective solution to this unsustainable exploitation of global natural resources such as fisheries, would require matching the fisheries resources problems with specific governance institutions and relevant management approaches (i.e., governance structures), namely private property, government control, and/or local-level management (Acheson, 2006). Furthermore, the problem of natural resource unsustainability, as in fisheries, is worsened by some communal beliefs (e.g., African/Aboriginal societies believing game provision comes from supernatural powers, hence not being able to link the current shortages of fish to overfishing practices) (Anderson, 1996; Brightman, 1993) and failures to develop effective management institutions or rules (Acheson, 2006).

According to Derwort (2016), institutional governance failure can be defined in terms of neo-classical economics (market governance failure by private actors and government), in terms of sustainability (resource unsustainability/overexploitation or inability to conserve resources), and in terms of innovation approach (failure of legal/regulatory regimes, and failure of political and social values). It is important to explain and distinguish how the government and private actors interact to cause institutional governance failure in fisheries resources. Based on an online economics resource,[16] market governance failure occurs when there is an excessive demand (or under-supply) of goods and/or services in an economy beyond the resource sustainability levels. This is illustrated by the ongoing overfishing practices in Tanzania and globally as explained elsewhere in the current study. To correct this problem, world governments including that of Tanzania have intervened with such measures as setting fishing quotas per specific period(s) and fishers' registration and licencing requirements. When these policy measures to correct the market governance failure backfire/worsen the problem or are ineffective, we say 'government governance failure' has occurred. This is also the case as illustrated by a recent United Nations report that about 90% of global fisheries resources are presently fully exploited, overexploited, or depleted (FAO, 2020). These unsustainable fishing activities continue unabated due to the ineffectiveness of government policy measures to address illegal, unreported, and unregulated (IUU) fishing practices (FAO, 2020).

Based on the preceding definition and succeeding explanations, institutional governance failure can be presented in four distinct forms or categories (IPBES, 2023) namely: (i) failures in laws/regulations and policies (e.g., offering subsidies that enhance overfishing), (ii) market failures (e.g., negative externalities like over-/misuse of public or common resources, including

[16] https://www.studysmarter.co.uk/explanations/microeconomics/market-efficiency/government-failure/

overexploitation of fisheries resources), (iii) organisational failures (e.g., lack of transparency, accountability, and political legitimacy in decision-making over fisheries resources exploitation), and (iv) informal institutional failures (e.g., lack of co-management success in collective or joint use of fisheries resources resulting from agency problems like erosion of trust among multiple parties to co-share or co-manage the resources). Literature on these four categories of institutional governance failure is going to be adapted in the sections following below to highlight how the central government and local communities influence unsustainability practices in the exploitation of CPR including fisheries. Finally, these four categories will be adapted, at least partially, to explaining institutional governance failures following next in the Tanzanian fisheries context.

As highlighted earlier in this section, prevention of people from overexploiting or depleting these CPR-like fisheries needs rules or institutions to enhance the resources' long-term sustainability (Acheson, 2006). However, because each user of the resource has free access to it (i.e., free rider problem), there is a disincentive for individuals to voluntarily cooperate collectively as a community or group to ensure the sustainable exploitation of the resource (Taylor, 1990; Acheson, 2006). It would therefore appear that institutional governance failures form a core of problems from which the already mentioned and explained sustainability challenges emanate (i.e., excessive demand, state subsidies, deceptive/fraudulent marketing, ineffective regulations, and non-conformity with TBTs/SPSs). This suggests that resolving institutional governance failures would automatically address many other unsustainability or conservation management challenges. To illustrate, demand-driven overfishing results from an ever-rising consumer demand for seafood globally, while on the supply side are state/institutional subsidies encouraging rich countries' technologically advanced fleets to overexploit in local and global waters to feed local and export markets (Sumaila et al., 2013, 2020). This interplay of excessive demand for seafood and unsustainable state-sponsored subsidy supply mechanisms constitutes institutional governance failure of fisheries resources (Sumaila et al., 2013, 2020). In the developing world, including Tanzania, relevant institutions have failed to end unsustainable fishing among fishers who overfish to meet their subsistence as well as short term income needs (Andriesse et al., 2022; Allegretti, 2019).

Accordingly, it can be suggested, based on Boschetti (2016), that market failures in common resources like fisheries decrease overall productivity, and limit long-term sustainability, thus resulting in inefficient allocation of such investments (i.e., negative externalities). These negative externalities may include the ongoing illegal fishing practices by rogue actors who circumvent underfunded and thus ineffective Beach Management Units (BMUs) tasked with the implementation of fisheries conservation programmes in Tanzania (Kanyange et al., 2014). However, markets do not operate independently of institutional factors, such as policies which predictably reflect the behavioural perceptions or thinking of people behind these organisations (Boschetti, 2016). This suggests that efforts to address market failures, as a manifestation of any form of institutional failures, as defined above, must focus on the behaviours and actions of people charged with the ultimate policy decision-making in these institutions.

To solve these common-pool resources problems, two sets of rules are needed (Acheson, 2006): first, devising and enforcing property rights for the users (e.g., fishing permits/licences), and second, formation of an agreement by permitted users to establish rules or management mechanisms on resource/fisheries exploitation rates (e.g., fish quotas per month/year per fishing vessel or fishing method). Based on Acheson (2006), institutional governance failure occurs when the community or group fails to undertake one or both these tasks. This has happened in the Tanzanian context as it will be presented in sections following below. Furthermore, it has been shown in the literature on natural resources management (e.g., Berkes, 1989; Acheson, 2006) that property (i.e., the natural resources) can be owned and/or controlled by private people, central government, and/or local communities. However, in the case of Tanzania, freshwater and marine fisheries resources are commonly owned, managed/controlled, and exploited as public property under government regulation (The Fisheries Act (CAP. 279) Regulations, 2009; URT, 2020c). Nonetheless, the occurrence of illegal and unsustainable fishing practices in both freshwater and marine fisheries in Tanzania (Allegretti, 2019; Andriesse et al., 2022; Daghar, 2019; Kanyange et al., 2014; Luomba et al., 2016; Wells, 2009) is proof of mounting institutional governance failures of government and local fishing communities to manage and sustainably exploit fisheries resources (Acheson (2006). Therefore, the following sections review literature on how the unsustainability of natural resources like fisheries is influenced, first by the overall control of government, and secondly, by users of the fisheries resources (i.e., local communities).

2.3.6.2 Unsustainability in Government-Controlled Fisheries Resources

Generally, governments preserve and sustain natural resources either by owning, or exercising control of, lands and natural resources (e.g., forests, national parks, marine protected areas, territorial waters, and exclusive economic zones) through enacting laws and regulations to protect these resources (Acheson, 2006). However, despite these efforts, much has been recorded to show that governments have failed to preserve fisheries resources, whereby global fisheries, for instance, have been overfished and depleted by over 70% (Acheson, 2006; Agnew et al., 2009; Sumaila et al., 2013, 2020). This has been framed as the failure of centralised, hierarchical, and bureaucratic natural resource governance, and this has occurred in both the developed and developing world (Baland & Platteau, 1996; Durrenberger & King, 2000; Wunsch, 1999).

These government failures to preserve natural resources have been explained variously. The main reason for government failure to preserve/sustain natural resources it controls has been documented as the Agency Problem/Theory, whereby managers or agents (i.e., politicians and regulators/government officials) of these natural resources have generally not been able to meet sustainability/conservation goals expectations of principals (i.e., the public/resource owners) (Cook & Levi, 1990; Moberg, 1994; Shleifer & Vishny, 1998). According to Chen et al. (2022), an agency problem arises from a conflict of interest that is generally inherent in any relationship whereby one party called an agent or manager (e.g., government institutions regulating fisheries resources) is expected to act in the best interest of another party, called the principal or owner of property (e.g., the general public) that expects the government to institute laws and regulations that ensure the sustainable conservation and exploitation of fisheries resources. Chen et al. (2022) say that these agency problems occur because there emerge opportunities that incentivise and motivate an agent to not act in the full best interest of a principal. One such opportunity is the absence of effective laws and regulations in fisheries, hence allowing rogue actors to overfish with impunity and access markets to make huge, short term financial profits/gains. Governments around the world including Tanzania are constantly under public pressure to meet current needs such as seafood security, jobs, and fishing industry profits, and this pressure weakens their ability to create and strictly implement effective regulations to limit unsustainability practices such as overfishing. To solve this agency problem, an optimal package of regulations and incentives can be devised to motivate and empower agents (i.e., government actors) to act in ways that maximise the principals' (i.e., the public/resource owners') best interests and expectations (Chen et al., 2022). This can be achieved through investments in transparent mechanisms to enable government actors (i.e., agents) to monitor fishing activities effectively to identify and prosecute rogue actors involved in unsustainable fishing practices.

Elsewhere, this agency problem has manifested itself in incidences of bribery/corruption and rent-seeking behaviours (where public resources are used to fulfil the interests of a small group at the expense of the public at large), thus resulting in voting or decision-making that never prioritises the wider public interests with regards to resources conservation (Becker, 1983; Bickers & Williams, 2001; Wade, 1985; Yandle & Dewees, 2003). Furthermore, Miller (1992) and Sproule-Jones (2002) report that government bureaucracies can make it harder for agencies (e.g., regulators of the natural resources) to cooperate and communicate effectively and efficiently to deliver the sustainability goals expected by the public. Other researchers (e.g., Moe, 1990; North, 1990) argue that some institutional failures by government to safeguard resources occur by design, to protect their illegally and unsustainably sourced gains/profits. For instance, politicians and government officials see an incentive to design and implement government institutions poorly (e.g., loopholes for deriving corruption gains from granting overfishing permits to rogue actors) to limit these tools' ability to uncover for possible prosecution the politicians'/officials' involvement in such corruption practices when they leave office (Moe, 1990; North, 1990). There is sufficient evidence to show that the problems theoretically described above, including the agency problems, have been occurring in practice in Tanzania due to the absence of effective law enforcement mechanisms to ensure compliance with laws and regulations on fisheries resources sustainability, leading to continued illegal and unsustainable fishing practices (Andriesse et al., 2022; Allegretti, 2019). One such enforcement mechanism would be a system that identifies actors' fishing activities with clear transparency to ensure accountability for those committing illegal and unsustainable fishing practices (Leal et al., 2015).

Another reason for institutional failure to conserve/sustain natural resources stems from mistakes made by government officials, namely scientists and engineers, in their provision of expert advice to politicians, policy makers, or other decision makers in government (Acheson, 2006). For instance, scientists in fisheries have failed to accurately measure fish stock sizes where they make errors ranging between 30% and 50%, thus skewing associated policies and decisions made thereto away from the truth, resulting in overfishing practices when stocks are overestimated (Acheson, 2003; Wilson, 2002; Acheson, 2006). Aware of the possibility of these expert shortcomings, fishers in Tanzania and elsewhere have tended to ignore expert advice included in fisheries management/development plans, laws, and regulations, thus worsening the already challenging fisheries resources governance or enforcement problems (Acheson, 2006; Andriesse et al., 2022; Katikiro et al., 2021). Finally, there have been arguments (e.g., Acheson, 2006) that government institutional failures to safeguard natural resources including fisheries have mainly been due to its centralised nature (i.e., hierarchical government or top-down management/decision-making). Decentralised government management systems appear to perform much better in managing fisheries resources (Acheson, 2006; Aligica & Sterpan, 2017; Ostrom, 2012). Failures of centralised government systems result from their strong penchant for uniform rules and governance structures without regard to variations across people, ecology, and places (Acheson, 2006). In many other cases, government officials in natural resources management agencies tend to be too immersed in their scientific and technical areas of specialism to be able to connect and communicate well with local populations of farmers and fishers who have experience and indigenous knowledge about the natural resources (Anderson, 1996; Freeman & Lowdermilk, 1985; Weeks, Durrenberger & King, 2000). As a result, these small-scale producers, like fishers, decide to limit or avoid engaging with these government experts, as evidenced in the fisheries sector in Tanzania (Andriesse et al., 2022; Katikiro et al., 2021). There are other examples where government officials or experts induced producers/users of natural resources into decisions that turned out to be catastrophic. For instance, Kenyan government experts encouraged their small-scale livestock keepers to invest more in cattle production for supplying major cities like Nairobi, Mombasa, Nakuru, Kisumu, and even across the southern border into Tanzania's Dar es Salaam, Mwanza, and Dodoma, with beef and keeping less goats which are drought resistant and relatively low cost in production (Dyson-Hudson, 1985). However, when these producers were hit with a drought which was not predicted initially by the experts, many head of cattle were lost, and the livestock keepers were impoverished beyond recovery (Dyson-Hudson, 1985). In addition, fishers have been misled in Tanzania and elsewhere in the world by politicians and government scientists/experts who influenced policies, laws, and regulations that benefited them personally, including through corrupt gains derived from overfishing practices by rogue actors (Allegretti, 2019; Andriesse et al., 2022; Lematre, 2021; McEvoy, 1986; Scott, 1998; Townsend & Pooley, 1995).

2.3.6.3 Unsustainability in Local Community-Managed Fisheries Resources

Although local communities including fishers in Tanzania (Mulyila et al., 2012) and elsewhere (Berkes & Folke, 1998; Ostrom, 1990) have demonstrated some degree of successful conservation of their natural resources, there are also numerous cases of failures in Tanzanian contexts (Lematre, 2021; Wells, 2009) as well as in the developing and developed world contexts (Jackson et al., 2001; Acheson, 2006; Lematre, 2021; Wells, 2009). Failures to end the ongoing unsustainable exploitation of natural resources like fisheries in these communities have largely been due to members', such as fishers, inability to devise rules to manage the resources and/or the ineffectiveness of the rules after they have been put in place (Acheson, 2006). Researchers (e.g., North, 1990; Ostrom, 2000a, 2000b) have identified factors that determine successful establishment and enforcement of conservation laws on local community-managed natural resources as: a sense of community, social capital or networking, social homogeneity, dependence on the resource, leadership, and secure resources' boundaries. As such, these are community-level policies or attributes that are seen to be successful in protecting common natural resources (i.e., community-based agreements), and there are socio-demographic factors that determine whether these policies/attributes will work. Failure to fulfil one or more of these attributes results in the inability to devise and successfully implement conservation laws on local community-managed natural resources, including fisheries (Acheson, 2006).

Researchers (e.g., North, 1990; Ostrom, 2000a, 2000b) suggest that it is the strength of community factors or characteristics such as togetherness/cooperative attitude and socio-cultural commonality of users of a natural resource like fisheries that drives trust among members for a common conservation cause. Therefore, failures to conserve natural resources at a communal level have been driven by a sense of distrust among community members as well as a 'free riding' spirit arising from the free access nature of common (public) resources, hence the disincentive among individual community members (i.e., lack of demand) to cooperate to build institutions to conserve the resources (Acheson, 2006). Moreover, as explained earlier, the poverty demographic (i.e., limited food supplies and income inadequacies) among many fisher communities in Tanzania has driven unsustainable fishing practices (Andriesse et al., 2022; Caton, 2018; Allegretti, 2019), this being an indicator of community members' failures to devise and implement effective fisheries resources conservation institutions (Katikiro et al., 2021).

Another driver of communal failure to conserve or sustain common natural resources has been several factors acting in combination. It has been found that diversity in terms of community member size, cultural differences, the level of dependence to the resource for livelihood, and the extent of control over access to the resource determine, in combination, a collective communal response towards the conservation of the resource (Acheson, 2006). In Tanzania's Mafia Island, where natural resource conservation including fisheries is among the best in the country, the community social capital/networking and cultural-social homogeneity among fishers have been demonstrated through shared ownership of fishing gear/vessels and the extent of fishers' affiliation and willingness to engage in sustainability enhancement initiatives (Mulyila et al., 2012). In addition, less diverse fisher communities in the Mafia Island have performed well to conserve its fisheries resources (Mulyila et al., 2012), thanks to factors like natural marine borders and high community dependence on the marine resources. Pailler et al. (2015) find that Community-Based Natural Resources Management improves food security among Tanzania's rural communities while increasing other socioeconomic benefits in the long run rather than in short periods of time, hence suggesting that resource sustainability goals are achievable over longer rather than shorter implementation periods. Furthermore, external interference by third parties, including central government, has contributed to the failures by fisher communities to meet conservation goals for their common fisheries resources (Acheson, 2006; Aligica & Sterpan, 2017; Ostrom, 2012). To illustrate, government's influence on, and interference in, local fisheries resources management and conservation systems resulted in worsening unsustainability problems in Tanzania and Sierra Leone (Kanyange et al., 2014; Okeke-Ogbuafor & Gray, 2021). In Tanzania, the government has denied fishers' communities powers to collect and invest revenues from landed catches through BMUs to improve the sustainable development of local fisheries (Kanyange et al., 2014). Similarly, the government in Sierra Leone appeared to protect rogue actors using illegal fishing gear to overfish in Sierra Leonian waters, thus undermining the marine conservation efforts of local fisher communities (Okeke-Ogbuafor & Gray, 2021).

2.4 Institutional Governance Failures in Fisheries Activities in Tanzania

This section lists different types of fisheries resources governance activities, followed by explanations on how failures in these activities have impacted on the sustainability of fisheries resources in Tanzania. These activities are creation of regulations, setting best practice guidelines, monitoring and enforcement, and incentivising and co-ordination. Most failings described here are drawn/adapted from the sections above titled 'Unsustainable Fishing Practices Caused by Ineffective Regulatory Regimes' and 'Institutional Governance Failures'.

2.4.1 Creation of Regulations

According to some researchers (e.g., Andriesse et al., 2022; Verheij et al., 2004; Katikiro et al., 2021), failures in creating and enforcing regulation which result in unsustainable fishing practices derive mainly from the lack of collaboration between relevant authorities, such as regulators, and other actors along the fisheries supply and value chain. It has been found that imposition of laws, regulations, and other scientifically proven procedures on fisheries actors including fisher communities without their active participation generates limited positive outcomes (Andriesse et al., 2022). Generally, users of natural resources like fisheries fail to conserve them, mainly because they lack the willingness to collaborate on devising, creating, and implementing effective laws and regulations (Acheson, 2006; Andriesse et al., 2022; Ostrom E., 1990; Ostrom, 2012). Resolving these limitations and other natural resources conservation problems in fisheries management requires a careful contextual analysis and evaluation of existing rules and regulations (Ostrom, 2012; Aligica & Sterpan, 2017; Acheson, 2006). To illustrate, Sala & Giakoumi (2018) find that the introduction of legislation for Marine Protected Areas (MPAs) through stakeholder collaborative approaches is 3.5 to seven times more effective in conserving marine resources than other measures without stakeholders' collective marine resources conservation mechanisms. These successes in sustainable conservation of fisheries resources through MPAs are attributable to inclusive or collaborative regulatory and enforcement mechanisms that integrate common interests while addressing diverging aspects of multiple stakeholders including regulators and fishers (Andriesse et al., 2022). However, other researchers (e.g., Bruno et al., 2018) observe that while there is some contribution of MPAs in helping recovery in depleted marine life, they find no evidence of socioeconomic gains associated with MPAs. Whereas MPAs protect against the deleterious effects of legal fishing, they cannot control such threats as marine acidification, global warming, plastic waste pollution, oil spills, illegal fishing, and agricultural wastes (Bruno et al., 2018). Despite these shortcomings, a new agreement has recently been reached through a collaborative effort of several countries at the United Nations in New York (i.e., the International Oceans Treaty) to expand the designated protection areas of global oceans including those under deep-sea fishing from 1.2% presently to 30% by 2030 to limit unsustainable practices including overfishing (Stallard, 2023).

Lack of participation or inadequate involvement of key stakeholders, such as fishers, contributes to the failure to create and implement effective laws and regulations to safeguard the fisheries resources in Tanzania (Andriesse et al., 2022; Katikiro et al., 2021). It has been observed that fisheries regulations in Tanzania have not been able to effectively address the ongoing overfishing activities because they were created without a comprehensive consultation with key participants, namely fishers and other players at a community level (Andriesse et al., 2022). By not involving the participation of these players in their creation, these fisheries regulations were doomed to fail at the implementation level, as they missed fishers' and other actors' inputs to understand the nature of, and ways to address effectively, overfishing and other forms of unsustainable fishing problems. For instance, fishers' continuation of unsustainable fishing in MPAs in Tanzania was motivated by their feeling that they were not adequately consulted in the creation of the rules and regulations that safeguard these MPAs, hence making the legislation inappropriate for local circumstances (Katikiro et al., 2021).

2.4.2 Setting of Best Practice Guidelines

Tanzania established Beach Management Units (BMUs) as a fisheries resources co-management initiative at a local community level (Luomba, 2014; URT, 2009). These BMUs were meant to help with, among other things, the prevention of unsustainable and illegal fishing practices through monitoring and surveillance routines.[17] These BMUs were also expected to promote fish quality controls at landing sites and to collect and compile data to support appropriate decisions to achieve effective fisheries resources management. Although there are some success stories of BMUs in Kilwa and Mafia, thanks largely to external financing support from the EU,[18] the BMUs project has generally failed to deliver this co-management initiative in the rest of Tanzania due to the lack of local ownership such as supportive policies and appropriate implementation mechanisms (Luomba, 2014; URT, 2018; Kanyange et al., 2014). This failure has been worsened by the refusal by authorities in higher government hierarchies to grant BMUs control over collection and usage of locally sourced revenues like fees and levies at fish landing sites and markets (Luomba, 2014). This underfunding has resulted in, among other things, inadequate financial compensation (i.e., salaries or wages) to BMU members in Tanzania who have reacted by collaborating with rogue actors to overexploit fisheries resources unsustainably to meet their basic food and income needs (De la Torre-Castro, 2006).

2.4.3 Monitoring and Enforcement

Fisheries resources governance/conservation rules and their enforcement are responsibilities falling under Tanzanian government provision (Acheson, 2006) and government-sponsored Beach Management Units (BMUs) (The Fisheries Act (CAP. 279) Regulations, 2009). This suggests a potentially important role that government must play to ensure the effective monitoring and enforcement of sustainable fisheries conservation measures. However, the government in Tanzania has been failing in its role to fund BMUs' monitoring and enforcement

[17] In Tanzania BMU programmes cover both freshwater and marine fisheries resources, see https://www.au-ibar.org/sites/default/files/2020-11/pb_20180926_bmus_east_africa_en.pdf.
[18] See https://wwf.panda.org/wwf_news/?309550/Pombwe-BMU---Best-Performing-Award-winners-2017 accessed Tuesday, 24th April 2023.

activities as explained elsewhere in this study. Moreover, according to Mkuna & Baiyegunhi (2019), overfishing activities of Nile Perch fish in Tanzania's Lake Victoria were largely driven by fishers' membership of formal groups like BMUs. It was found that failures to monitor the fisheries resources and enforce sustainable fishing practices were due to fishers in BMUs sharing information about when patrols were due, thus undertaking overfishing activities outside these government-sponsored surveillance routines (Mkuna & Baiyegunhi, 2019). On the other hand, BMUs in Tanzania also fail to undertake monitoring, surveillance, and enforcement of fisheries resources conservation laws (De la Torre-Castro, 2006). Because the BMUs are underfunded and thus unable to adequately pay their members to do their jobs, these members opt to divide their time between their fisheries conservation role and seeking bridging income for their basic livelihoods (De la Torre-Castro, 2006; Kanyange et al., 2014). By not being available on a full-time basis to monitor and oversee the conservation of fisheries resources, BMU members offer opportunities for rogue actors to undertake and gain from unsustainable and illegal fishing practices. This failure to fund and successfully operationalise the BMU scheme in Tanzania has rendered as ineffective the monitoring and enforcement of fisheries regulations (Kanyange et al., 2014).

Another failure of fisheries resources governance laws and regulations in Tanzania is the lack of credibility among the people entrusted with monitoring and enforcement roles. For instance, it was reported during the current study's field interviews in Tanzania that some marine police officers collaborated with rogue actors to ensure illegal/unsustainable fishing practices went on undetected by relevant authorities. This happened when these police officers leaked the authorities' activity plans of surveillance and monitoring of fisheries resources to these rogue actors such that illegal/unsustainable fishing activities happened outside the planned routine compliance missions at sea. It was found that the motive of these marine police officers to support these rogue actors was driven by their potential sharing in the gains/profits derivable from these illegal/unsustainable fishing practices.

2.4.4 Incentivising and Coordination

Apart from the requirements to meet minimum quality standards and traceability conditions to access export markets, Tanzania's fisheries policies, laws, and regulations do not offer direct and effective incentives and coordination to achieve sustainable conservation, harvesting, and management of fisheries resources (The Fisheries Act (CAP. 279) Regulations, 2009; URT, 2016). This happens despite the existing evidence that Tanzania's fisheries products fetch about twice as much the price in UK/EU export markets that promote sustainable fishing practices relative to prices received locally (URT, 2020a). This lack of policy and institutional incentives and coordination to promote sustainable fishing practices affects the whole Tanzania's annual fisheries output consumed locally and that exported regionally and in lucrative markets like in the UK/EU (URT, 2020a). The fisheries legislation could incentivise more stakeholders in fisheries to meet sustainability requirements if its provisions stated that permits to access lucrative markets both locally (e.g., hotels and recreation centres used by tourists and other elites) and abroad (e.g., UK/EU) were subject to proof by these actors to have adhered to sustainable fishing practices. These data for proof of sustainable fishing could be accessible centrally by relevant authorities, thus being able to identify those fishers and other actors involved in sustainable fishing practices and rewarding them accordingly. If access to these data were to be paid for and became too costly for average fishers, these fishers would need to organise in groups, to be coordinated to afford access to the data through such mechanisms as member contributions and/or government sponsored bank or other commercial loans.

While the preceding paragraph has focused on market-based incentives, other researchers (e.g., Grafton et al., 2006) emphasise the importance of governance-based incentives to promote the sustainability of fisheries resources. To successfully achieve governance-based incentives, fishers need to be provided with economic rights alongside the accompanying obligations or responsibilities that incentivise individual fishers and/or fisher groups to adhere to sustainable fishing practices (Grafton et al., 2006). Specifying fishing and territorial access rights to fishers (i.e., those with the biggest impact on the fisheries resources) is likely to create a long-term interest among these users to conserve these fisheries resources and bear the cost of overfishing (Grafton et al., 2006). However, Tanzania's legislation on fisheries resources provides that fisheries resources are public or commonly owned resources (i.e., cannot be privatised) (URT, 2003, 2009, 2020c), thus making it unfeasible to implement the fisheries resources governance-based incentive scheme as proposed by Grafton et al. (2006). This unfeasibility to incentivise and implement sustainable fishing practices on a long-term basis may explain the ongoing overexploitation of fisheries resources in Tanzania (Andriesse et al., 2022; Kelly, 2018).

2.5 Possible Solutions to the Identified Unsustainability Problems in Fisheries

This section attempts to answer the question: does there exist a common solution that could deal with all, or most, of the diverse problems identified above. To do this, the section recaps on the identified problems above and reviews possible different solutions for each, with a view to identifying one single solution that might solve most of the identified problems. Relevant literature is cited to support arguments, but whenever such literature is unavailable, logical arguments are presented.

2.5.1 Meeting Excessive Seafood Demand Through Supply of State Subsidies

Presented earlier was the interlinkage of these two problems and the resulting unsustainable overexploitation of fisheries resources in developing countries like Tanzania. To address these problems, Rininsland (2023) suggests the need to secure the commitment of the largest subsidisers of global overfishing operations, namely China, Europe, USA, South Korea, Japan, and Russia to reduce or eliminate these subsidies. This would be difficult to achieve because of the already existing business relationships in seafood trade (i.e., demand-supply mechanism) especially between these same global fishing powers (Petrossian & Pezzella, 2018; Palma et al., 2010; Rininsland, 2023; Wester, 2023). To illustrate this difficulty, Rininsland (2023) notes that only Canada and USA out of the ten-leading global drivers of overfishing have formally acceded to the World Trade Organisation (WTO)-sponsored Agreement on Fisheries Subsidies which was negotiated internationally and agreed on the 17th June 2022. This agreement is meant to prohibit state subsidies that cause unsustainable fishing practices, resulting in the extensive global depletion of fisheries resources. While two thirds of the world countries are needed to sign-off and accede to this agreement to make it enforceable to limit the funding of overfishing, only seven governments had done so by May 2023 (Rininsland, 2023). Given these circumstances, there remains a question of how to resolve the rising seafood demand in a sustainable manner that engages both the leading global subsidisers of overfishing and developing countries whose fisheries resources are negatively impacted by these subsidies such as Tanzania. A possible solution in this regard is the creation of a credible electronic traceability system that captures the cross-border trade in fisheries products between Tanzania and these global fishing powers, like the EU (UNECE, 2016). This solution is meant to exploit the emerging market niche of seafood consumers, especially in Europe, who are demanding and potentially willing to pay premium prices on traceability-enhanced seafood provenance of sustainable sourcing (Hajipieris, 2007; Santos et al., 2023). This electronic nature of the traceability system is key to addressing the risk of fisheries data tampering fraud which is prevalent in paper-based traceability systems (UNECE, 2016; URT, 2016). The electronic traceability solution appears to be both plausible and potentially feasible because there already exists some level of Tanzanian fisheries exports into Europe at a price premium to those received locally (URT, 2020). To limit the effect of potential bureaucratic inefficiencies of governments, as observed earlier, this electronic traceability solution should be spearheaded by the private sector (Hajipieris, 2007; Santos et al., 2023). It is anticipated that access to premium price markets in Europe, as well as among Tanzanian local consumers, will incentivise fishers and other actors to adopt/comply with the requirements of sustainable fishing practices (URT, 2016). Therefore, to be successful, the proposed traceability system needs to be able to identify, for possible penalisation, those involved in unsustainable fishing practices, by limiting their market access, gains, and other derivable socioeconomic benefits (Leal et al., 2015).

2.5.2 Deceptive/Fraudulent Marketing

Some methods have been employed to identify and limit the occurrences of seafood marketing fraud (i.e., deceptive/fraudulent marketing). One of these methods is laboratory verification to analyse the proteins patterns of various fish species and compare the results with scientifically known patterns (analogous to comparing fingerprints in humans) (Foulke, 1993). However, this method would appear cost-effective when used on relatively few batches of fish and other fisheries products, but it could potentially prove expensive or ineffective when considered in the context of large volumes of seafood bought and consumed daily from multiple outlets. Education and training programmes for regulators/enforcement agents, distributors, and consumers of fish and fisheries products constitute another method to counter seafood deceptive/fraudulent marketing (Foulke, 1993). To implement this method, relevant authorities, like the Food and Drugs Administration (FDA) in the USA, undertake such programmes to impart knowledge and skills about the identification and reporting of incidences of deceptive/fraudulent marketing of seafood. Following this identification, responsible rogue actors would be pursued and held accountable or penalised, thus discouraging similar future behaviours. However, many seafood quality agencies, including those in Tanzania, have not been able to implement effective training to enable consumers to acquire and appropriately use basic skills and knowledge about identifying the deceptive/fraudulent marketing of seafood. This is because, for instance, some forms of seafood substitution involve fish colour deception/fraud and excessive weight/content of water in seafood – both of which most consumers may easily fail to notice (Foulke, 1993).

Other researchers (e.g., Petrossian & Pezzella, 2018; Leal et al., 2015; Warner et al., 2013) have blamed the ongoing deceptive/fraudulent marketing of seafood on the absence of traceability systems. Similarly, due to the absence of credible traceability systems in Tanzania (URT, 2016), the country is likely facing significant deceptive/fraudulent marketing in its seafood industry.

According to Leal et al. (2015), this lack of effective traceability systems is a result of the complexity of the fisheries supply and value chains comprising multiple types of stakeholders – fishers, fish traders, processors, and distributors. It has been argued (e.g., Buck, 2010; Leal et al., 2015; UNECE, 2016) that robust traceability systems can resolve the problem of deceptive/fraudulent marketing of fisheries products. This would happen, in part, through the ascertainment of the precise geographical origins of seafood involved in these incidences, thus being able to ensure transparency and accountability on seafood quality from fish producers all the way down to consumers (Buck, 2010; Leal et al., 2015; UNECE, 2016). To illustrate, private businesses at a Seafood Expo in Boston (USA) namely Marine Stewardship Council, Monterey Bay Aquarium, and The Safina Centre have initiated traceable seafood certification standards on sustainable sources of canned tuna to limit incidences of tuna mislabelling (Gallagher, 2017). These businesses, who are official implementors of this traceability project, devised and deployed traceability software called Trace Register which successfully tracked each lot of tuna along the supply and value chain from vessel (i.e., fishing grounds) to final consumers (Gallagher, 2017).

2.5.3 Ineffective Regulatory Regimes

To improve the effectiveness of Tanzania's fisheries regulations and their corresponding enforcement, there is a need to engage and train stakeholders on sustainable exploitation and management of fisheries resources. While Tanzania's fisheries regulations provide for active involvement of all stakeholders (e.g., regulators, fishers, etc.) to ensure the preservation of fisheries resources (The Fisheries Act (CAP. 279) Regulations, 2009), available evidence suggest this has not been happening in Tanzania (Katikiro et al., 2021). Correspondingly, McIntyre et al. (2016) propose a system of training fishers, conservationists, and all other relevant stakeholders in fisheries on sustainable fishing management practices to ensure fishing communities harvest fisheries resources in a balanced sustainable manner. Raising the opportunity cost of unsustainable fishing practices through existing policies, laws, and regulations would also help to resolve the current conservation problems in fishery resources management. To test this, Ben-Hasan & Christensen (2019) used a bioeconomic model to measure the profitability levels under open access and limited entry scenarios and found that sustainable profitability was attained while overfishing was minimised when fishers had seasonal access to alternative socioeconomic activities that earned them compensating incomes. This is indicative of the fact that sustainability in fishing requires purposeful endeavours in other complementary socioeconomic sectors, especially crop and fish farming, livestock keeping, and forestry (Ben-Hasan & Christensen, 2019). This is ideal for the developing world where countries like Tanzania employ large sections of their populations in agriculture. Favourable agricultural policies and supportive laws and regulations would shift pressure from the illegally and unsustainably overexploited fisheries resources to alternative sources of income. Such favourable policies and laws would include those on quality and timely inputs, rural-urban/market transportation and communication links, fish farming support, as well as reasonable price guarantees. However, caution is needed while implementing fish farming as a solution to unsustainable capture fishing (freshwater and marine). This is because Longo et al. (2019) found that out of their study's nine fish farming models, only one had a significant solution to resolving the ongoing unsustainable fishing problems in marine and freshwater fisheries. The main reason here was that relative to capture fisheries, fish farming projects require higher initial investments, and input costs (e.g., protein feeds) tend to be high, hence the low prospects of profitability.

For the foregoing legal and regulatory initiatives to be effective in transforming fishers and other actors into agents of sustainable fishing practices, they would require a robust system to monitor their compliance (UNECE, 2016; Leal et al., 2015). One way to achieve this is increasing the use of traditional methods for ensuring compliance with regulation, i.e., inspections by trained agents. However, the lack of transparency and other unfavourable working conditions would limit the effectiveness of this approach. To illustrate, it has been presented elsewhere in this study that corruption practices and inadequate budgets have hindered the effective implementation of fisheries laws and regulations in Tanzania. To illustrate, Daghar (2019) reports that rogue actors have been able to trade in seafood and other fisheries products from Lake Victoria by not declaring or reporting significant amounts of these fish catches, as required by existing laws and regulations (The Fisheries Act (CAP. 279) Regulations, 2009; URT, 2020). This was possible because the rogue actors were able to bribe customs compliance officers in Tanzania and East Africa, paying as much as US$3,000.00 per shipment for protection and acquisition of legal permits/certifications on these fish consignments (Daghar, 2019). Additionally, Beach Management Units (BMUs) are by law tasked with carrying out monitoring activities to limit unsustainable fishing practices in their localities as well as collect, compile, and report fisheries data and statistics (The Fisheries Act (CAP. 279) Regulations, 2009). However, it has been found that the government has not been supporting these BMUs with necessary and sufficient financial and other resources to effectively enable them to discharge these tasks (Kanyange et al., 2014).

A plausible alternative to relying on trained human inspectors of compliance with regulation is to institute electronic mechanisms of sharing data more efficiently and transparently, thus being able to hold all stakeholders accountable for their actions along the fisheries supply and value chains (European Union, 2022; Leal et al., 2015). In this regard, the globally integrated Tanzanian fisheries sector would benefit more from participating in building an electronic cross-border traceability system for sustainable trade in fisheries with major partners, e.g., the UK/EU (Prévost, 2010; UNECE, 2016). Such a cross-border traceability system would help to ensure sustainable fishing practices along local (Tanzanian) and global (export markets like UK/EU) fisheries supply and value chains (UNECE, 2016). This traceability system would help to monitor compliance with sustainable fishing practices by fisheries stakeholders, through transparency and accountability features, while enhancing the sector's trade development (UNECE, 2016).

2.5.4 Non-Conformity with TBTs & SPSs

It was presented earlier that failure to meet TBT/SPS requirements risks the health safety of seafood consumers and potentially worsens the unsustainability of fisheries resources (Fontagné et al., 2005) as well as loss of premium markets for Tanzanian suppliers. The main conditions limiting the access of high volumes of Tanzania's fisheries products into the UK/EU markets include inadequacies in production methods and supportive infrastructure to meet TBTs and SPS requirements (European Union, 2022; Prévost, 2010; WTO, 2022; URT, 2016). One way of resolving these inadequacies is provided in these TBT and SPS agreements themselves (WTO, 1995b, 1995a). Provisions in the TBTs and SPS agreements emphasise the need for developed countries to consider, and where possible, support the efforts of developing countries to meet the TBTs and SPS measures requirements (WTO, 1995b, 1995a). According to these TBTs and SPS measures agreements, the envisaged support needs of developing countries include relevant infrastructural and institutional development and assistance related to technology, finance, and trade.

As previously noted, Tanzania lacks a credible traceability system for monitoring the compliance with sustainable fishing practices that would hold fisheries stakeholders accountable in a transparent manner (Leal et al., 2015; UNECE, 2016; URT, 2016). Therefore, to be effective, even the implementation of TBTs/SPS infrastructural and institutional mechanisms, through potential UK/EU and Tanzania collaboration, would require the existence of the credible traceability system to monitor compliance (Prévost, 2010; UNECE, 2016; URT, 2016; Leal et al., 2015). One of the mechanisms in which Tanzania and the EU could cooperate, to develop and strengthen such a traceability system, is the Special and Differential Treatment Provisions in the WTO sponsored TBT Agreement (Prévost, 2010; WTO, 1995a, 2022) As stated earlier, this TBT Agreement is about special needs and conditions of developing countries that should be taken advantage of by Africa (and Tanzania) to collaboratively work out long term solutions with the developed economies to combat unsustainable fishing practices. Collaboration between Tanzania and the UK/EU, to secure investments in robust fisheries traceability infrastructure, would fit well into this category. To increase efficiency, Tanzanian private actors (e.g., fishers/processors/exporters) and key European importers and distributors of fishery products could jointly build a cross-border electronic traceability system that would enhance transparency in fishing activities and facilitate timely sharing of relevant data on sustainable trade in fisheries (Leal et al., 2015; UNECE, 2016). As a result, Tanzania would be able to improve on its technological and infrastructural bottlenecks to meet most TBTs/SPS requirements on fisheries products. This development would address the sustainable sourcing of seafood, resolve the related health quality concerns for consumers in both local and export markets, and boost the fisheries trade volumes into these lucrative markets.

2.5.5 Institutional Governance Failures

As previously noted, Tanzania's marine and freshwater fisheries resources are commonly owned and exploited under government regulation (The Fisheries Act (CAP. 279) Regulations, 2009; URT, 2016, 2020c). According to economists (e.g., Acheson, 1989, 2006; Hardin, 1968), the sustainability of common-pool (public/jointly owned) resources can be improved by adapting them so that they share some of the characteristics of private (sole ownership) natural resources. These researchers find that owners of private natural resources have an incentive to protect/conserve and invest in them because the owners are assured of ultimate benefits accruing to them and not to anybody else. Common-pool natural resources properties like capture fisheries, on the other hand, are generally overexploited and depleted because users over-compete each other to exploit them due to their free accessibility nature, hence the disincentive by the individual users to preserve or sustain them in the long-run (Acheson, 2006) as they cannot capture the benefits of doing so. These economists also mention other advantages of private natural resources over common-pool resources, namely usage efficiency due to ease and freedom of owners to invest in more productive and profitable options, while users of common-pool natural resources have the right to exploit it, not to own it. Furthermore, private natural resources are said to be more efficient in the allocation of capital while common-pool natural resources tend to be overcapitalised where more users/firms over-compete to harvest resources leading to, for instance, the ongoing overfishing practices. Finally, these economists suggest that transaction costs are lower with private natural resources because an individual owner can easily claim and get compensation (e.g., in court) if third parties damage or destroy their property, but this is not easily achievable with common-pool natural resources due to free accessibility without automatic ownership and control. These advantages of private fisheries resources property over common pool fisheries have prompted economists to advocate resolving common-pool natural resources problems by applying private property rights and/or simulating these rights, such as through offering fishing permits/licences and quotas (Acheson, 2006).

However, the preceding advantages of sustainable management of private resources over public/common pool resources are not without limitations. For instance, some common-pool natural resources, such as migratory marine fish species cannot be privatised, leading to market failure (i.e., incomplete property rights) (Acheson, 2006). It has also been found (e.g., McCay & Acheson, 1987) that complete property rights among such producers as pastoralists, farmers/fishers, and loggers are no guarantee of sustainable resource exploitation. Some economists (e.g., Acheson, 2006) have suggested reasons why private owners of natural resources like fisheries would fail to sustain or conserve their own properties. Profit maximisation motives, or short-run gains, may incentivise private owners to overexploit their natural resources and forgo long-run benefits associated with the resource conservation or sustainability (Clark, 1973). A classic scenario for this to happen is where the growth rate in the value of the natural resource (i.e., the potential rate of return on investment) is lower than the discount rate (i.e., the cost of invested capital or interest rate on bank borrowings). Given these circumstances, it would be rational to overexploit or deplete the natural resources and invest the derived money or capital into other projects generating better returns. Uncertainty about the availability of a resource forms another reason for potential natural resource overexploitation or depletion. According to Wilson (2002), such natural resources as forests, wildlife, and fisheries tend to be overharvested and depleted because their supply environment is unpredictable and chaotic because of disease, predation, and weather. This unpredictability disincentivises individuals to invest in the conservation and sustainability initiatives of these resources (Acheson, 2006). Finally, poverty or socioeconomic underdevelopment have been found to influence overexploitation or depletion of natural resources by their private owners. To illustrate, extreme poverty has forced people in developing countries including Tanzania to overharvest their common-pool fisheries and other natural resources to meet current consumption and income needs at the expense of long-run benefits derivable from the resource conservation/sustainability (Baland & Platteau, 1996; Andriesse et al., 2022; Allegretti, 2019; Wester, 2023). Similar pressures like overfishing to meet current food security needs, industrial profits, and jobs are common in the developed world (Sumaila et al., 2013, 2020; Wester, 2023). Therefore, improving the sustainable management of public/common pool resources like fisheries through privatisation (e.g., issuance of permits/quotas) to promote conservation behaviours would first require resolving the above problems. Among the above-listed problems, poverty and socioeconomic underdevelopment appear to be the most relevant among Tanzania's fishers and other stakeholders (Allegretti, 2019; Andriesse et al., 2022; URT, 2016). As such, a potential solution to these problems in fisheries must address poverty and socioeconomic underdevelopment challenges while at the same time meeting sustainable conservation criteria.

Given the preceding fact that privatising common fisheries resources in some way, e.g., through permits, does not solve all unsustainability problems in fisheries, it is suggested here that a robust traceability system be used as an addition to privatisation, to make it more effective. To this end, the traceability system must address the income poverty problem that compels private common fisheries resources owners/users (i.e., Tanzanian fishers) to overexploit the resources. As evidenced earlier, premium price seafood markets like the UK/EU offer two main opportunities to address the above problems of poverty, socioeconomic underdevelopment, and unsustainability. These are (i) potential lucrative prices (as much as double the local prices) for resolving income poverty (URT, 2020b); and (ii) growing niche markets of consumers in high income countries (e.g., UK/EU) requiring provenance of quality and sustainable sourcing of the seafood to ensure their health safety (Fernández Sánchez et al., 2020; Fontagné et al., 2005; Leal et al., 2015; URT, 2016). Also noted previously is the fact that Tanzania's fisheries output predominantly supplies the local market, with exports accounting for less than 10% (URT, 2020b). It is therefore expected that more fishers would be incentivised to adopt sustainable fishing practices to be able to access lucrative premium price seafood markets in UK/EU.

The preceding recap on possible solutions to the identified unsustainability problems in fisheries suggests that a traceability-based solution stands the best chance, among the alternatives, of addressing most of these problems, either singly or in combination with other methods such as trained human compliance experts or privatisation approaches. This suggested solution entails the establishment of a credible traceability system for sustainable exploitation of local supply, and cross-border trade, in fish and fisheries products (UNECE, 2016). Below, a literature review is undertaken with a focus on traceability-based solutions to similar unsustainability problems in the food and fisheries sectors, as a step towards proposing a credible solution to unsustainability challenges facing the fisheries sector in Tanzania based on (UNECE, 2016).

2.6 Enhanced Traceability as a Solution to Unsustainability Problems in Fisheries

The preceding literature has highlighted unsustainability problems in Tanzania's fisheries sector that have a linkage to ongoing unsustainable fishing practices in the rest of the world. It has been noted, however, that much of the unsustainability in fishing operations in Tanzania and elsewhere in the world is caused by the absence, or ineffectiveness, of existing traceability systems (FAO, 2001; Leal et al., 2015). In terms of potential solutions for the identified unsustainability problems, there seemed to be a possibility for developed countries (e.g., UK/EU) to collaborate with Tanzania to invest in relevant infrastructural traceability systems for ensuring the quality and sustainable sourcing of seafood for the health safety of consumers (URT, 2016; UNECE, 2016; WTO, 1995a, 1995b). This was the case even though the EU's certification procedures for seafood imports from Tanzania and elsewhere are currently paper based (not digitalised), hence becoming prone to fraud (e.g., deceptive marketing) which is a key feature of unsustainability in fishing (European Union, 2022; Prévost, 2010). Moreover, both the EU and Tanzania were still limited in terms of identifying and efficiently sharing data on sustainable sourcing of seafood products (European Union, 2022; Prévost, 2010; URT, 2016). This deficiency offered another opportunity for rogue actors to undertake unsustainable fishing by continuing to fish illegally and unsustainably and profiting through existing legal fisheries supply and value chains.

Nonetheless, an ideal solution was proposed in UNECE (2016), i.e., credible traceability systems for sustainable cross border trade. While it is generally understood that traceability systems are usually initiated and operated by private actors to fill the public/institutional governance vacuum, government involvement remains vital (UNECE, 2016; Acheson, 2006). Because this proposed solution aims to protect consumers' health and ensure the sustainability of fisheries resources, the government would require these private actors to share details to prove the claimed robustness or veracity of the traceability system to protect consumers and resource sustainability (UNECE, 2016). Therefore, this study sets out to propose a solution to the unsustainability of fisheries in Tanzania, namely the establishment of a credible traceability system that will involve all relevant actors along the fisheries supply and value chains in Tanzania and in its main export markets (e.g., UK/EU). According to UNECE (2016), the architecture of any credible traceability system must have the following four components: policy claim or statement, entry/exit points and conditions, traceability conditions, and an audit agency.

2.6.1 Proposed Architecture of Credible Traceability System

This section articulates the architecture of a credible traceability system based on UNECE (2016), guidelines for potential adaptation to this study. The four components of the system listed in the previous section are explained in detail below.

2.6.1.1 Policy Claim or Statement

The policy or claim statement defines the purpose of the traceability system. In the case of the system proposed in this study, the envisaged policy claim would be to ensure Tanzania's local and export (traceable assets) supply chains comply fully and electronically with Tanzania/export market consumer health quality safety and sustainability requirements.

2.6.1.2 Entry/Exit Points and Conditions

Entry and exit points relate to where the fish and fisheries products would enter and leave both the supply chain and traceability system. To be able to capture sourcing sustainability conditions, this study's traceability entry point would be when fish catches enter the fishers' boats, whether at sea or on freshwater bodies, such that data on catches are captured automatically and shared to all participants electronically using some form of Asset Identification Method (AIM).[19] This would be an improvement on the current EU procedures which start collecting data from the point of arrival at fish processors or exporters, hence missing much sustainability information on sourcing (European Union, 2022; Prévost, 2010). The exit point would be when final local consumers and those in the UK/EU buy the fish and fishery products for household consumption. Regarding entry and exit conditions, these relate to the collected fisheries data type requirements to be met by fish and fishery products when they enter and leave the traceability system. In the case of this study, the entry conditions would include fishing vessel registration and ownership, surrounding water temperature, weight of fish catch, and other environmental conditions around the area of catch including chemical or

[19] AIMs include devices like Bar Code, Quick Response (QR) codes, Radio Frequency Identification (RFID), etc.

any other traces as proof that fish were caught sustainably at source while meeting the stipulated minimum health quality safety conditions. Exit conditions would be to ensure all the details relating to the history of the fish are accessible. These include data from catch at sea/source, plus intermediate value-adding activities, on down to the final supply-chain actor. These must be displayed on labels or retrievable when the fish and fishery products' bar codes or any other digital or electronic asset identifiers are scanned, usually using devices like smart mobile phones, iPads, or anything similar.

2.6.1.3 Traceability Conditions

These are rules that must be followed by handlers/owners of fish and fishery products as product moves along the supply and value chain, consistent with the policy claim or statement. First, the fish and fishery products would be registered on the system and a unit reference number issued. These would include transformation rules, for instance, that fish weight at entry point should not vary by more than 5% when the item gets to the exit point. Also, to maintain/preserve their quality, temperature for fish and fishery products would not be allowed to go above the set maximum from entry to exit points. Traceability conditions would also apply to the maximum allowable level of chemical and other contaminants of the product between entry and exit points. This kind of monitoring and compliance would involve government oversight because the procedures relate to health safety of consumers, hence the need for sharing of these data electronically to enhance efficiency while limiting the chances of seafood fraud to which paper-based procedures are prone.

2.6.1.4 Audit Agency

This would be an independent and professional institution staffed with competent people who monitor and ensure all rules and conditions relating to the traceability system are being fulfilled. This audit agency would monitor the traceability system's activities, including events at entry and exit points, as well as over the intermediate transformation processes for fish and fishery products. Audit would usually be constituted and operated on public-private partnership basis to enhance a vital collaborative effort between the government and the private sector. In this study, however, the audit agency would be private sector-led but enforcing compliance with existing sustainability rules/laws and other relevant consumer health safety requirements. This leadership role of the private sector is meant to limit the negative effects of ongoing public institutional failures in the governance of fisheries resources. The audit agency would primarily work to verify that the policy claim has been fulfilled or not. Specifically, the tasks performed by the audit agency would include:

(i) to collect, record, and share fish and fisheries data electronically at fish catch points on boats at sea in Tanzania and all the way to the point when the final consumer buys the fish products at the end of the supply and value chain. The captured data to include the boat/vessel registration and ownership, location of catch, date/time, and fish product health quality conditions.
(ii) to collect weight, temperature, and other quality data electronically on intermediate fish and fisheries products at various points along the supply chain.
(iii) to ensure that electronically recorded data for traceability of fish and fisheries products reflect the real fisheries trade activities along the supply and value chains.
(iv) to monitor and safeguard the traceability system to ensure the fish and fisheries products meet all requirements or rules at source/catch points at sea, during the intermediate transformation phase along the supply and value chains (fish buyers, processors, exporters, importers in EU/UK, distributors, and retailers), and that these are retrievable electronically by final consumers when they buy the fish products and scan them using their mobile devices. Data capture at sea to use any Asset Identifier Method (AIM) such as Quick Response (QR) coding, Bar Coding, Radio Frequency Identification (RFID), etc.
(v) To report to relevant authorities in Tanzania and/or the UK/EU periodically, or on demand, data confirming the efficient and effective functioning of this traceability system to prove its credibility. The authorities would be interested in the traceability system's ability to identify or flag those who do not comply, so law enforcement mechanisms could be applied against them to keep the system safe.

Below, Table 9 summarises the architecture of this study's envisaged traceability system. Based on Table 9, traceable assets in the current study are fish and fishery products (i.e., seafood). Also, Table 9 shows that for the envisaged traceability solution to govern both local consumption and cross-border or international export of fisheries products from Tanzania to the UK/EU, there is a need to achieve efficiency through electronic data sharing (UNECE, 2016). Furthermore, because producers are Tanzanian small-scale fishers, the traceability system must be inclusive of these actors with low skills, especially in the technology area (UNECE, 2016). Moreover, to ensure inclusive community-based sustainable fishing practices (Andriesse et al., 2022), Tanzania has enacted laws (URT, 2009) requiring both freshwater and marine fishers to be members of beach management units (BMUs). This requirement of BMU membership has therefore been made part of this proposed traceability system. This proposed credible traceability system is electronic to address the weaknesses of inefficient paper-based seafood certification procedures in the seafood trade between Tanzania and the European Union (European Union, 2022; Prévost, 2010; URT, 2016). Also, the proposed traceability solution would address the current data capture shortcomings at entry and exit points of the Tanzania-UK/EU fisheries supply and value chains as illustrated next. By having its entry point at landing sites and at customs, where seafood imports enter the EU, the current EU's traceability system misses very important information about sustainable sourcing of the seafood, whereby data on fishing conditions at sea cannot be collected, potentially failing to identify and report on seafood fraud activities. Moreover, having exit points at import customs, the current EU traceability system misses key provenance details on the supply and value chains, especially in relation to value-added activities by distributors (wholesalers and retailers). Having reviewed the architecture of the ideal traceability system, the following sections present literature on the effectiveness of various adaptable traceability mechanisms in the general food sector, with a specific focus on seafood/fisheries.

2.6.2 Existing Food Traceability Solutions

There have been food safety concerns as well as practices of unsustainability in various food sectors all over the world. According to Qian et al. (2022), these concerns have been fuelled by such events as the bovine spongiform (mad cow disease) outbreak that killed 178 consumers in the United Kingdom in the 1980s/1990s through infected beef. Similar health safety problems occurred through contamination of chicken feeds with harmful dioxin chemicals that were detected in chicken meat and eggs in Belgium in 1999 (Qian et al., 2022). Another safety failure was the 2008 Chinese milk scandal whereby infant milk and other food materials were adulterated on purpose with melamine, a harmful chemical used to raise the milk's nitrogen content to falsify protein ratio to be able to pass quality control checks (Qian et al., 2022). To satisfy consumer/regulator requirements to overcome these food safety concerns and unsustainability issues, the following solutions have emerged, including traceability mechanisms.

Table 9: Architecture of Credible Traceability System for Tanzanian Local Consumption and Export of Fishery Products to UK/EU

No.	Architecture component	This study's example
1	Policy claim	Tanzania's local and export (traceable assets) supply chains comply fully and electronically with Tanzania/export market consumer health quality safety and sustainability requirements.
2	Entry/exit point and conditions (with electronic verification capabilities)	
2.1	Entry point	• When fish caught at sea and placed on boat.
2.2	Entry conditions	• If boat/vessel legally registered, owned, and with compliant fishing gear. • If catch source area and fish species have no legal restrictions (e.g., marine protected area?). • Synchronising with credible databases to verify authenticity of boat/vessel registration, licencing, ownership, owner's membership of BMUs, and other legitimate legal entities.
2.3	Exit point	• When fishery product is bought by local/foreign (UK/EU) consumer.
2.4	Exit conditions	• Electronically retrievable data on fish history, weight, temperature, source catch area, chemical/trace contamination levels, etc • Electronically accessible quality certification, e.g., via mobile phone.
3	Traceability transformation rules	• Ability to trace electronically the history and track other activities in relation to the fishery products along the system to ensure consumers' health quality safety and sustainable sourcing of the fishery products.
4	Audit agency	• To set up an audit agency to monitor fisheries data and activities through a robust traceability system. This traceability system to have electronic capabilities to monitor and capture data on fisheries activities on boat at sea (entry point), along the intermediary transformation phases on the supply chain (fish buyers, processors, local distributers/sellers, exporters, importers, foreign distributors, and foreign retailers), and at exit point when final consumers in Tanzania and the UK/EU buy the products and scan them electronically on their smart mobile phones and/or other devices to retrieve all historical provenance data.

Source: Researcher's Table, adapted from UNECE (2016).

Based on Qian et al. (2022), traceability mechanisms can be categorised as traditional methods which are predominantly in use today and novel technologies which are by and large still at testing stages.

2.6.2.1 Traditional Traceability Methods

These include physical separation of different food lots, defining and associating food batches, isotope analysis and DNA testing, and internal traceability system development.

Physical Separation of Different Lots

This involves putting food materials from different suppliers into separate batches to minimise recall costs. Cleaning and processing of batches (e.g., milk) is done separately to avoid contamination. Also, for religious purposes, some meat products are separated for processing using different methods (e.g., Halal meat and bacon/pork products). These separations elevate operational costs, thus limiting the economies of scale in the production process. Therefore, this traceability method is considered costly due to its being labour intensive with high energy consumption.

Defining and Associating Batches

This traceability method involves using production time and date to refer to batch products instead of mentioning their nature or ingredients. However, this lack of data on ingredients or composition of batch products has been a cause of costly recalls of products especially for large lots of food products with a high possibility of containing some defects. Furthermore, it is challenging to attach labels, markers, and identifiers to many different lots in a particular batch. To solve this problem, markers based on Radio Frequency Identification (RFID) technology are used in tracking, logistics, and anti-counterfeit missions in the food sector. For instance, an RFID traceability system for high value cheese products was implemented in a diary factory in Valle Josina (Italy) by attaching RFID tracers/labels to the cheese products to automatically track their movements or identify their various processing stages. These stages which were automatically captured or recorded were handling in maturing room or store, delivery, packing, and selling. It is important to note, however, that these RFID markers must not compromise the quality or use convenience of products to the consumer. These RFID tracking devises should therefore be easily and safely identifiable, removable, and disposable by the final product consumer, such as from a bag of maize before consumers process or grind them into edible flour.

Isotope Analysis and DNA Tracking

According to Qian et al. (2022), raw material characteristics or features constitute a key factor for food quality and safety. As such, stable isotope analysis helps to track the geographical origins of food material features to ensure its quality for human health safety use (Qian et al., 2022). This traceability method has been able to successfully identify and differentiate food sources for products as meat, milk, cereal crops, wine, and oil. For instance, stable isotope ratio tests using Carbon, Nitrogen, and Hydrogen were performed and used to successfully identify and differentiate the origins of defatted dry beef samples from Mexico, New Zealand, Australia, Korea, and the United States. This method was also used to identify the origins of Italian lambs with about 98% accuracy, and European production areas of 8 olive oil samples with 95% accuracy. Testing of sample DNA, which is a material that remains stable under some types of processing has also been used in traceability systems. For instance, DNA-based batch identifiers have been used to identify the origins of beef in manufactured batches of ground beef packages.

Internal Traceability System Development

This is generally a food processing traceability system that uses a data management procedure to combine data on internal operational activities and quality control measures. This database can process information on incoming, internal, and outgoing lots/batches including relating a particular incoming lot of food materials to outgoing processed product sales. To illustrate, a Wheat Flour Milling Traceability System (WFMTS) was implemented over three transformation batch stages namely raw materials, processing, and final product. To facilitate traceability, Quick Response (QR) codes (i.e., 2-dimensional barcodes) were attached to wheat flour packages and RFID sensory tags were put on wheat flour bins to automatically record logistical path details. By implementing this traceability system, operational costs rose by about 17% while sales income increased by 33%, thus confirming the value added to the business.

Despite these capabilities, the preceding traditional traceability approaches have not been able to entirely eliminate the food safety problems and unsustainability practices in the food supply and value chains as noted by Qian et al. (2022). To improve on these shortcomings, there are ongoing developments in the novel traceability technologies as presented in the next section.

2.6.2.2 Novel Traceability Technologies

According to Qian et al. (2022), novel traceability technologies are being developed around use of big data, artificial intelligence (AI), and Blockchain. These are largely still in piloting stages, but preliminary indications suggest they could potentially lead to huge improvements in the performance of current food traceability practices.

Food Traceability with Big Data

This traceability mechanism involves the use of huge and complex datasets on various food quality factors such as human health safety, nutritional content, and sustainable sourcing to computationally predict or reveal potential food quality patterns. These datasets could be compiled over time from consumer databases, social media networks, public surveys, and other relevant internet sources involving public domains. This traceability method could use the revealed food quality patterns to forecast and evaluate potential risks associated with the human consumption of the processed food items. For instance, Fernández-Caramés et al. (2019) designed and used an Unmanned Aerial Vehicles (UAVs)-based big data automated system to perform inventory management tasks that used RFID sensory tags to ensure the traceability of industrial goods such as processed food items. This UAV-based big data system used a Blockchain technology distributed ledger (DL) database to store the collected data, validate them to ensure their trustworthiness, and disseminate them to various stakeholders via the traceability mechanism. This UAV-based traceability system was able to analyse and share the inventory data much quicker than the traditional methods, such as inventory tasks performed manually.

Food Traceability with Artificial Intelligence (AI)

This involves the use of machine technologies to undertake automated business decisions in relation to food traceability activities (Ling et al., 2021). According to Qian et al. (2022), artificial intelligence (AI) can undertake complex analysis of food related data such as genetic origins and historical quality details to automate decisions on the minimisation of food batch recall costs while optimising their traceability mechanisms. One way to optimise this food traceability system is to integrate the capabilities of AI with those of Blockchain, namely real-time secure storage and sharing/transparency of food related data, prevention of food counterfeiting, and enhanced consumer trust (Ling et al., 2021). To illustrate, a Blockchain-Artificial Intelligence (AI)-enhanced food traceability system has been validated and verified through the FISCO-BCOS Blockchain platform[20] for food traceability businesses and regulatory agencies in China in 2020 (Ling et al., 2021).

[20] This is a Chinese based Blockchain platform established by FISCO company. BCOS stands for “Be Credible, Open, and Secure”, see http://www.fisco-bcos.org/

Blockchain Technology-based Food Traceability Mechanisms

According to Qian et al. (2022), Blockchain technology has been associated by various researchers with credible food traceability systems. Blockchain's credibility is based on its ability to ensure transparency and accountability, traceability and food fraud prevention, food-related data security and authentication, and protection against cybersecurity threats (Qian et al., 2022). To illustrate, Walmart and Kroger used a Blockchain-based food traceability system to track the supplies of Chinese pork and Mexican mangoes (Qian et al., 2022). It was found that this Blockchain-based traceability system used a few seconds to determine the source and transport path of the mangoes from farm to supermarket compared to more than a 6-day turnaround without the Blockchain-based traceability system.

The preceding sections have described different traceability mechanisms in the general food sector. The next section focuses on current and novel traceability methods in the seafood/fisheries sector, as this is the focus of the current study.

2.6.3 The Current State of Traceability Methods Used in the Seafood/Fisheries Sector

Ibáñez (2015) devised an approach to traceability based on analysis of the geometry of fish scale shape (i.e., geometric morphometric methods) to predict the origins of fish species using collected fish specimens from different markets in Mexico City. This author used discriminant analysis to correctly classify the origins of over 80% of the collected fish species (Ibáñez, 2015). It was thus concluded that fish scale shape geometry was a quick and an inexpensive traceability mechanism that could help in the sustainable management of fisheries resources along the supply and value chains. However, one of the limitations of this approach is that not all fish species are scaled, therefore this solution cannot be applied across all fish species. Another traceability solution was based on chemical profiling of octopus samples from Southeast Asia and Southern Australia (Martino et al., 2022). This method was able to establish chemical signatures of about 95% of the octopus samples back to their respective origins, thus potentially resolving the traceability, transparency, and accountability issues along the seafood supply chains. Nonetheless, this method appears to be capital or resource-intensive in terms of chemical testing skills and the requirement to transport samples across long distances for testing (Martino et al., 2022). These requirements make chemical profiling potentially expensive and thus unsuitable for adoption and usage by Tanzanian small-scale fishers with low- or moderate-income levels. Moreover, this method was applied on boneless fish species (i.e., octopus), so it is not clear whether this chemical marker approach can be transferred to bony fish species which are prevalent in Tanzania's fisheries.

Islam et al. (2022) found that inadequacies in the governance of seafood supply and value chains resulted in the loss of quality or incompleteness of fisheries data such as provenance on sustainable sourcing. These shortcomings jeopardised the sustainability of fisheries resources and safety of the seafood in Bangladesh. To improve on these seafood data quality limitations, Islam et al. (2022) proposed the exploitation of Blockchain and Internet of Things (IoT) capabilities to enhance the quality, integrity (including resistance to tampering), completeness, and traceability of fisheries data. These capabilities would improve the transparency of fishing and trading activities along the supply chains which could make it easier to identify and prosecute those rogue actors carrying out unsustainable fishing practices. Other researchers (e.g., Paolacci et al., 2021) have investigated and tested the level of compliance to existing EU regulations on the labelling of seafood products to help consumers to access the sustainability and health safety history of their seafood. It was found that there were variations in compliance levels with the EU labelling regulations across six countries[21] whereby Portugal achieved the most compliance rate of 87.2% while the United Kingdom (UK) was the least compliant at 63.7% (Paolacci et al., 2021).

The preceding results (Paolacci et al., 2021) indicated further that supermarkets were more compliant than fish mongers' shops; and that the most often missing data on the seafood labels included fishing gear, scientific names, fishing or production method, and date of freezing. It is possible the supermarkets' higher compliance rate than fish mongers' shops could be explained by the former's potential higher resource/capital base relative to fish mongers. Therefore, it can be assumed here that compliance with sustainability and health safety requirements in fisheries or seafood is strongly linked to the actors' abilities to invest capital in necessary infrastructure. These results are consistent with other studies whereby failures to invest in credible traceability systems have led to the growth in unsustainable fishing practices, hence risking consumer health safety (URT, 2016, 2018). Moreover, other studies (e.g., European Union, 2022; Lewis & Boyle, 2017; Prévost, 2010) have argued that limitations in the EU traceability systems were due to their being largely paper based (not digitalised) and that they prioritised seafood quality for consumer health safety without regard to enforcing sustainable sourcing requirements. The

[21] These were France, Germany, Ireland, Portugal, Spain, and the UK.

EU's paper-based traceability systems posed dangers of seafood fraud risks as data on the seafood or fisheries products could easily be tampered with; and the potential solution for this could be the adoption of a digitalised traceability system (Leal et al., 2015; Lewis & Boyle, 2017). A digitalised traceability system of some form, such as Blockchain and IoT capabilities, would improve sustainability by ensuring the integrity of the fisheries (seafood) data while fostering transparency and accountability of those involved in the fisheries supply and value chains (Islam et al., 2022; Leal et al., 2015; Lewis & Boyle, 2017).

The preceding inadequacies of existing seafood traceability solutions point to the need to improve on these paper-based systems through use of digital or electronic capturing and sharing of data on the sustainable sourcing and quality of the seafood for consumer health safety (European Union, 2022; Lewis & Boyle, 2017; Prévost, 2010). In the next section, Blockchain technology is defined, and its characteristics/features are explained in the context of the potential Blockchain-based traceability solution to the identified unsustainability problems in the fisheries/seafood sector.

2.6.4 Defining Blockchain Technology

A review of recent literature has shown that Blockchain technology is one of the most promising tools to address erosion of compliance with sector regulation and trust in governance-related regulatory actors (De Filippi et al., 2020). An interesting development in this direction occurred in June 2021 when Tanzania[22] joined other countries[23] by expressing openly its readiness to embrace cryptocurrencies and Blockchain technology to enhance local innovations. This is a significant departure for the Tanzanian government, which issued negative statements in 2018 and 2019, about cryptocurrencies and, at least indirectly, the Blockchain technology behind these virtual currencies.[24]

Blockchain has been defined variously by different authors. Butijn et al. (2020) define Blockchain technology as a distributed ledger (DL) spread over a network of users/actors. This

[22] *https://www.thecitizen.co.tz/tanzania/news/experts-why-tanzania-is-not-ready-for-cryptocurrencies-3437842*
[23] In Africa, these include Nigeria, South Africa, Ghana, and Kenya, see *https://weetracker.com/2020/03/25/leader-in-african-blockchain-adoption/* and https://internationalfinance.com/the-rise-of-crypto-adoption-in-africa/. Globally, they include China, the USA, Japan, UAE, Australia, Switzerland, the UK and Singapore, see *https://www.blockchain-council.org/blockchain/top-10-countries-leading-blockchain-technology-in-the-world/* and *https://www.pwc.com/gx/en/industries/technology/blockchain/blockchain-in-business/make-the-business-case.html*.
[24] *https://www.mondaq.com/finance-and-banking/896866/the-ban-on-cryptocurrency-in-tanzania* and *https://www.theeastafrican.co.ke/tea/business/tanzania-issues-warning-against-cryptocurrencies-1385026*

DL is a shared record of activities or transactions which enables participating actors to enter and verify transactions. This ensures data integrity through transparency and traceability. In turn, these features of transparency and traceability enhance trust and activity compliance between and among the actors without the involvement of any trusted intermediary, authority or third party. Unlike centralised information systems, this is a common database shared among all members/participants (Casino et al., 2019). This means, a data entry by one participant on the Blockchain network replicates and updates instantly all the records into identical copies on all DLs maintained by all other actors. This way, therefore, Blockchain acts as a trusted and dependable third party itself (Ismail & Materwala, 2019). The exclusion of non-participant intermediaries by Blockchain technology boosts data security while cutting down on transaction costs (Firdaus et al., 2019). Dennis & Disso (2019) and IEEE Staff (2018) find transparency, decentralisation, cost savings and time efficiencies in business processes to be the defining features of Blockchain technology. The overriding feature of the Blockchain technology that makes it suitable for use in situations of trust loss and governance-related regulatory compliance issues is its ability to ensure the integrity, immutability, transparency and traceability of data and activities (Blaha & Katafono, 2020). As such, Blockchain technology has the potential to restore loss of trust and confidence in supply and value chains, through enhancing data integrity and transparency, traceability, and security in multi-actor food governance systems (Saberi et al., 2019).

According to de Filippi et al. (2020), Blockchains can either be public and permissionless (i.e., no access limitation) or private and permissioned (i.e., accessible only by organisational members). Examples of public Blockchains are Bitcoin and Ethereum, while private Blockchains include Linux Foundation's Hyperledger[25] and Amazon's Quantum Ledger Database (QLDB).[26] While members on public Blockchains have full accessibility, security, and immutability of data relative to private Blockchains, the former suffer from slower speed and more costly transactional inefficiencies (Blaha & Katafono, 2020). This suggests that the Tanzanian fisheries, with socio-economically underdeveloped actors (e.g., fishers/boat owners), would be best served by private or permissioned Blockchains. Also, the fisheries sector is not of interest to all public stakeholders, but rather a section of them, namely fishers, regulators, processors, traders, and customers in the fisheries supply and value chains. Despite much acclaim, it has been argued that the widely promoted capabilities of Blockchain

[25] https://linuxfoundation.org/projects/case-studies/hyperledger/
[26] https://docs.aws.amazon.com/qldb/latest/developerguide/what-is.html

technology have not been fully tested, proven, and adopted in the real-world environment (Blaha & Katafono, 2020). It has thus been reported that most Blockchain technology projects are still at testing stages, i.e., prototypes or case studies, meaning that there haven't been serious investments in the Blockchain technology space yet (Blaha & Katafono, 2020).

Key barriers to large-scale commercial adoption of Blockchain technology are said to be regulatory uncertainty, potential interoperability challenges with existing systems, potential high cost of adoption, as well as failure to integrate different Blockchain projects (Blaha & Katafono, 2020; Patelli & Mandrioli, 2020). However, despite these uncertainties, increases in Blockchain use cases have been evidenced in both the agrifood (Patelli & Mandrioli, 2020) and the seafood (Blaha & Katafono, 2020) sectors. These trends have largely been motivated by food consumers' ever rising awareness of the importance of food safety for their healthy eating and living (Losasso et al., 2012). Because they have concerns about the origins and quality of the food they eat, these consumers have increasingly demanded reliable food certification regimes and traceability systems for safeguarding their healthy eating and wellbeing (Zhang et al., 2020). This food traceability and certification governance system would help to track the origins and ensure health or quality conditions of the food items from 'farm to fork' (Patelli & Mandrioli, 2020). The concept of 'farm to fork' means that the proposed food traceability system would work to ensure compliance of food quality and safety along the whole length of supply and value chains, from local producers to local and global consumers (Patelli & Mandrioli, 2020). Blockchain technology is thus a timely arrival; and it presents suitable features for addressing the above consumers' and/or stakeholders' trust issues, as well as the regulatory compliance issues in relation to the governance of the food supply chain. This is achievable because Blockchain technology enables a cryptographic and immutable record of activity transactions as well as transparency and traceability of the associated metadata along the whole length of supply and value chains (Patelli & Mandrioli, 2020; Pearson et al., 2019). The said metadata can include details on food origins, seller/buyer contractual terms or smart contracts, a record of food process steps, weight/volume, and environmental variables – temperature, humidity, microbial or contamination levels, etc. at various stages in the handling and processing of the product.

2.6.5 Blockchain's Seafood Traceability Capabilities

Traceability occurs when actors along the whole length of fisheries supply and value chain can access any or all information about specific units of a fisheries product from the time of first capture to when specific units are consumed; with this facilitated through the product units' recorded identifications (Olsen & Borit, 2013). To illustrate, fishers and other actors in fisheries (e.g., regulators, processors, traders and buyers or consumers) can pool resources and establish a Blockchain DL network linking them all. On this network, they could add data about names of fishing boat owners, boat or vessel registration and specification, as well as fish catches. These fish catch details may include fish species, weight, volume, catch location, catch method or type, storage, and environmental conditions (temperature, humidity, contamination levels, etc). These textual or numerical data could also be complemented with images and real time video footage as facilitated by vessel-mounted and internet-linked gadgets like digital cameras. Other data to be entered would be those relating to exchange of ownership of fish catches by various parties along the fish supply and value chain.

Contractual arrangements between fishers and buyers (processors, traders, or importers) would be best served with Blockchain technology's in-built smart contracts (SCs) (Blaha & Katafono, 2020; Nugent et al., 2016). SCs are forms of automated self-executing contracts which are made as part of the Blockchain DL network to ensure credible/trusted execution of transactions while limiting intentional and unintentional manipulation of data (Nugent et al., 2016). In simple terms, a smart contract (SC) would assume a form of: *"If fisher A delivers amount/weight/volume X of fish to buyer B, buyer B would then present evidence of (e.g., bank deposit or mobile money) funds transfer to A on the Blockchain, which fisher A would accept by unlocking or entering a special code on the Blockchain, thus triggering an instant change of the fish catch ownership title from A to B."* To lower transaction costs and enhance processing and verification speed of business transactions between buyers and sellers/suppliers, these Blockchain-based SCs are powered by Artificial Intelligence (AI) (Anglen, 2023). These AI-powered SCs are more intelligent and efficient due to their automated ability to analyse, predict potential outcomes, and execute transactions instantly when all contractual terms and conditions are met (Anglen, 2023). Execution of these AI-powered SCs transactions in typical fisheries supply and value chain would require a trusted intermediary where fish stocks could be kept, like a secure cold room at a typical landing site or any other appropriate fish stock exchange facility. This way, smart contracts could help the management and exchange, or transfer of fish catch ownership data on the Blockchain from fishers or producers to initial buyers (e.g., processors or traders/exporters) all the way to final consumers (Blaha & Katafono, 2020). Other data included here would be that on fish processing and distribution or shipping/transportation methods. Therefore, by enabling this data capture at various value chain stages, the Blockchain DL network ensures standard or minimum safety or hygiene conditions of fish supplies (Blaha & Katafono, 2020; Nugent et al., 2016). These features of Blockchain-enabled traceability systems would simplify the identification of contaminated fishery products, frauds, risks as well as limiting entry of illegal and unsustainably caught fish catches into legitimate value chains (Caro et al., 2018; Pearson et al., 2019). This way, Blockchain technology could help actors to enhance the assessment of food safety and integrity. This could be realised through the enhanced ability to mitigate food safety failures in terms of quick identification and linkage of these incidences back to their origin (Caro et al., 2018; Pearson et al., 2019). These steps would improve the taking of appropriate accountability measures against parties responsible for the identified food safety failures.

To illustrate the above Blockchain traceability capabilities, ZetoChain[27], a Blockchain site for compliance with food safety standards, monitors temperature at every stage in the cold food chain, thus identifying and relaying temperature problems in real time for quick responses that continuously ensure food safety. Similarly, Blockchain traceability capabilities are being considered for adoption by world leading food safety agencies, such as the United States Department of Agriculture (USDA) and European Food Safety Agency (EFSA) (Patelli & Mandrioli, 2020). According to these authors (Patelli & Mandrioli, 2020), USDA's Food Safety and Inspection Service (FSIS) is presently working with the US-based International Business Machines Corporation (IBM) on the development of a Blockchain proof-of-concept initiative meant to optimise traceability systems in food export certification regimes. If successful, Blockchain adoption by the USDA's FSIS could simplify and increase efficiency of the tracking of the cases of food adulteration or contamination as reported in some countries (Meagher, 2019; Morales-de la Peña et al., 2019). To hasten this process, the Blockchain technology would allow food safety agencies to eliminate or reduce time inefficient paper-based systems of tracking food items for ensuring health safety of consumers from production sources, to processing and warehousing, all the way to delivery. Food items tracked and identified during this process as unfit for human consumption could be eliminated quickly from the supply and value chains before reaching consumers.

[27] See *https://www.zeto.ie/*

2.6.6 Blockchain and Other Complementary Technology Use-Case Studies in Fisheries

The major fisheries supply chains in which Blockchain case studies have operated include Pacific tuna, Patagonian toothfish and farmed shrimps (Blaha & Katafono, 2020; and Provenance, 2016).[28] In this section, these use cases are presented to show that Blockchain and other complementary technologies are ideal use in fishing and fisheries supply and value chains. To realise this performance, Blockchain is used in conjunction with other technologies, namely mobile phone apps and satellite GPS devices. These and other communication-enhancing equipment use inbuilt and downloadable utilities such as Apps, QR/RFID technologies, and digital cameras to safely create, store and transmit data in real-, or near real-time on Blockchain platforms (Blaha & Katafono, 2020).

2.6.6.1 The Indonesian Provenance Case Study

This was an early attempt to use Blockchain technology in marine seafood value chains. It was spearheaded by Indonesia-based Project Prevenance Limited in 2016, with a focus on two fisheries supply chains, namely yellowfin tuna and skipjack tuna for canning. In 2016, this Provenance project team interviewed and collected various data on tuna fisheries supply and value chains from multiple actors namely: fishermen, boat captains, engineers, quality assurance experts, suppliers, supply chain auditors of international retailers, fish processing factory workers, managers, and company owners. The main aim of this use case was to demonstrate how Blockchain technology could be used to make data interoperable or transmittable along the whole supply chain, and between various stakeholders and systems. The second aim was to link that data to retailer and consumer experiences for registering a change in buyer or consumer behaviour while reinforcing regulatory and voluntary quality and environmental standards. To achieve this, Provenance developed an App running on Blockchain technology, designed to work through a simple mobile smartphone interface. The App was to do this either independently, or by linking up with existing data capture systems along the supply and value chains. This Provenance Blockchain App linked material attributes, audit details, location, identity and certifications with a specific item or batch ID. The data was stored in a globally auditable, decentralised, and immutable form, thus ensuring its secure protection, identification, and verification.

[28] *https://www.provenance.org/tracking-tuna-on-the-blockchain#overview*

Case Study Goals

This fisheries case study's goals were to establish:

(i) Whether Blockchain technology could be used to demonstrate proof of compliance with environmental and seafood health quality standards.

(ii) Whether Blockchain technology could prevent the double-spend of certificates (helping proof of ownership transfer, so that a seafood item on the Blockchain belonged to one individual or actor at one time).

(iii) The efficacy of Blockchain technology as an open system for traceability.

Results

The case study was able to:

(i) Collect and share data by tracking fish from catch to landing, on to the factory and into retail outlets using the Ethereum Blockchain operating on mobile smart phones, and smart tags.

(ii) Integrate the Blockchain Technology system with existing factory enterprise resource planning (ERP) systems (i.e., interoperability with Tally-O system) – e.g., financial, stock, and procurement management functions.

How the Case Study Worked Out

(i) Firstly, fishers, buyers/suppliers, retailers, and other relevant actors were registered with the Provenance App.

(ii) Then, fishers sent SMS messages while at sea from their mobile phones to the Provenance App to register their entire catch. This initiated the recorded catch as being a new asset on the Blockchain. The identification of specific tuna fish within the catch was helped with physical tagging.

(iii) On arrival at landing sites, the fishers transferred the catch to suppliers both physically and digitally using the Provenance Blockchain App. Trusted local NGOs verified that the fishers complied with relevant social and environmental conditions.

(iv) Then, suppliers (i.e., buyers of fish from fishers or factory agents) transferred the catch to the factory and used the Blockchain App to transfer its digital data. Provenance integrated with at least one enterprise resource planning (ERP) system called *Tally-O System* to further track the tuna through the processing stages and out to shipment.

(v) Finally, a retailer was engaged using near-field communication (NFC)-enabled smart labels on tuna products to communicate the provenance history. NFC is a wireless or contactless data transfer technology where two devices each loaded with a turned-on NFC chip can share or transfer data to each other in proximity e.g., smart phones, laptops, tablets, QR and RFID scanners.

Case Study Barriers and Lessons (Potential Areas of Improvement)

(i) There was a challenge associated with connecting the physical asset (i.e., the tuna fish) to the digital asset (i.e., a record or token on the Blockchain indicating who owns the fish at various times and value chain stages) using tags and labels with various Asset Identification Methods (AIMs). These AIMs are two-dimensional (2D) Quick Response (QR) codes, radio frequency identification (RFID) and near-field communication (NFC) devices. Detached and lost QR/RFID tags worsened this problem further.

(ii) A lot of time was spent on digitising each stage – hence a recommendation to make use of public Blockchains to ensure interoperability, equality, and consensus.

(iii) Lack of clarity in process steps including whether the tuna was individually tagged and recorded on the blockchain, or whether the entire catch was tagged and recorded as a single unit. The process of tracking the fish from suppliers to the factory and within the factory was also unclear.

(iv) All eight companies surveyed during the research phase used pen and paper to account for material flowing in and out of factories, with some Excel reporting for government purposes, sent via email once completed. Only one company (PT Harta Samudra) had digital accounting method for fish products using *Tally-O system* by Ecotrust Canada. They were also the only company able to handle Fair Trade fish. To comply with Fair Trade requirements, their supplier used plastic tags on tuna loins to identify the fisherman that caught the fish, before shipping to the factory.

(v) Quite a few actors had devices and systems in place for truly enabling data interoperability, access, and exchange across the whole length of supply and value chains. However, every fisherman, supplier and factory worker met or surveyed had a mobile phone. Also, 3G and WiFi internet services were patchy but accessible from most of the visited towns and villages. Blockchain technology can build on these initial conditions to enhance interoperable traceability across multiple actors along the tuna fisheries supply and value chains.

(vi) Most data are collected privately by actor groups and not shared publicly in Indonesia. This includes vessel registration and tracking, self-reporting of catch and effort, independent port sampling programs, Fair Trade data capture, fish tagging, internal traceability systems and Apps for fishermen and suppliers. This contributed to difficulties in securing the sharing of data among all the actors (including fishers) to build a trusted Blockchain based traceability system.

2.6.6.2 WWF-New Zealand/WWF-Australia & WWF-Fiji, ConsenSys, Sea Quest (Fiji) Ltd and TraSeable Solutions

This project[29] involved a collaboration of several organisations in 2017 to use Blockchain Technology in a tuna longline fishery. These entities were the global nature conservation organisation World Wide Fund for Nature (i.e., WWF offices in New Zealand, Australia & Fiji), Blockchain company ConsenSys, and Fijian fisheries processing factory Sea Quest (Fiji) Ltd and Fiji ICT company TraSeable Solutions partnered to implement the project in Fiji.

Case Study Goal

(i) To create a completely transparent and traceable supply chain, utilising innovative Blockchain Technology, for the fresh and frozen tuna supply chain.

How the Case Study Worked Out

(i) The supply chain was mapped into the Treum (previously Viant) Blockchain App, and the needed activity roles and permissions for all supply chain actors were set. These actors were tuna fish producers (fishers), technology suppliers (ConsenSys & TraSeable), tuna fish buyers/processors (Sea Quest), and fisheries sustainable conservationists (WWF). This Blockchain App created the data entry interfaces and rules to capture and share fisheries data among all these actors.

(ii) Upon being captured aboard a long-liner fishing vessel, each tuna was tagged with unique identifiers initially using RFID tags, and later with QR code tags. Key data about the tuna catch were captured automatically and recorded into the App, thanks to these RFID and QR devices.

(iii) Given an Internet connection, data were transmitted through the App in real time to the Blockchain database; otherwise, in the absence of the network, this was done on return to port (leading to delays in data transmission or sharing).

(iv) At landing sites, each unloaded tuna was likewise tracked by scanning its RFID or QR tag.

(v) In the tuna processing facility, at key stages along the processing line, the tuna was tracked, and key data collected. If a whole tuna was transformed into other products such as loins,

[29] https://www.wwf.org.nz/what_we_do/marine/blockchain_tuna_project/

then each new product unit was given a new identity on the Blockchain platform and tracked separately.

(vi) On distribution, actors along their supply chains could participate and continue to track the tuna products through the value chains all the way to the consumer.

Case Study Barriers and Lessons (Potential Areas of Improvement)

(i) As in the Provenance project, each stage of the supply chain had to be digitised, as the fishing company, Sea Quest, was previously reliant on manual data collection.

(ii) RFID tags and equipment were not available locally in Fiji, and so had to be sourced abroad and imported (usually at a much higher cost).

(iii) Due to the costs and difficulty in sourcing the equipment locally, the project team opted for a cheaper alternative: QR code tags.

(iv) Mapping Sea Quest's supply chain was a challenge due to difficulties in persuading other actors (namely fishers, fish retailers and buyers) to participate. This was largely due to these actors' limited familiarity with Blockchain technology, hence their hesitancy to participate.

(v) Some RFID and QR code tags were detached when moving the fish catches from sea to landing sites and along the value chain. This affected the precise matching of digital data on the Blockchain to the physical assets (i.e., the tuna fish).

2.6.6.3 OpenSC, WWF-Australia, and BCG Digital Ventures (Patagonian Toothfish)

OpenSC (Open Supply Chain) in partnership with WWF-Australia and BCG Digital Ventures announced their Blockchain project for traceability of Patagonian toothfish in early 2019.[30] One of the beneficiaries of OpenSC technology is Australian based Austral Fisheries (AF) which is a member of Maruha Nichiro Seafood Group. AF were supported to implement this Blockchain technology in its catches of Patagonian Toothfish Sea Bass in Chile. This was also to be implemented in AF's existing global supply chain across Africa, Asia, Europe, and the Americas. OpenSC's Blockchain Technology helped AF to digitally identify and verify the registration of its fishing vessels as well as determining whether these fishing vessels operated in waters away from marine protected areas. Therefore, the OpenSC's Blockchain technology improved AF's efficiency and traceability in managing the sustainable fishing activities involving its vessels.

[30] https://opensc.org/case-studies.html

Case Study Goals

(i) To use OpenSC's Blockchain Technology to implement a traceability system for Patagonian toothfish through capture and transmission of its fisheries data using devices like RFID.

(ii) Integration or interoperability of Blockchain platform with other data sources like machine learning and satellite-guided GPS devices to help guide vessels at sea to avoid fishing in marine protected areas.

How the Project Worked Out (Case Study Results)

(i) Much like the Provenance and WWF-New Zealand/Australia/Fiji projects, this project required the tagging of individual fish with RFID tags on their capture and then recording data about the movement of the fish through the cold supply chain.

(ii) The project was able to integrate into OpenSC's Blockchain Technology platform other technologies, thus enabling interoperability. These technologies are machine learning (i.e., artificial intelligence), internet of things (IoT) and GPS.

(iii) Traceability of Patagonian toothfish fillets was done from catch at sea to customers/consumers in Asia, Europe and the Americas using internet of things (IoT) and Blockchain Technology. When the Patagonian toothfish were filleted, the fish RFIDs were converted into unique QR codes for each fillet on packaging.

(iv) The exact Patagonian toothfish origin was established through an RFID tag put on each fish on board immediately after capture at sea. This was followed by taking the exact satellite-enabled GPS location of the vessel and feeding this data into the fish RFID tag.

(v) Temperature for individual fish was monitored and tracked throughout the cold supply and value chain using devices attached to the fish. This ensured fish quality was communicated constantly along the supply chain.

Case Study Barriers

(i) There was no clarity about the technology or devices used to record and transmit the temperature of the fish along the supply chain.

(ii) There was no clarity on the method used to avoid the problem of RFID/QR code tags detaching from the fish or fish fillets as observed in other use cases above.

2.6.6.4 Fishcoin

Fishcoin[31] describes itself as a Blockchain-based data ecosystem that is backed by a stablecoin[32] token that incentivises the collection of data about seafood products through the supply and value chain. Fishcoin is not an application per se, but a series of open-source tools and software development kits that can be used by supply chain actors and developers to integrate their decentralised applications to the ecosystem.

Project Goal

(i) Using a stablecoin token on a Blockchain-based data ecosystem to incentivise the collection of data about seafood products along the fisheries supply and value chains.

How the Case Study Worked Out

(i) Fishers collected data about their catches. They exchanged their Fishcoin's stablecoin tokens for airtime from a local mobile network operator that participated in the ecosystem.

(ii) Fishers sold their catch to the first receiver and, in return for the catch data, they received Fishcoin's stablecoin tokens.

(iii) At each stage in the supply chain, every actor in custody of the fish added more data to the ecosystem and got Fishcoin's stablecoin tokens in return or exchange.

(iv) Actors that bought the seafood product/products exchanged the Fishcoin's stablecoin tokens with the previous actor on the fisheries supply and value chain for the catch data until the seafood reached the retailer that sold it (the seafood) to the final consumers. To illustrate, fisher A offers his fish catch for sale by registering it on Fishcoin's Blockchain platform. Based on this digital registration, fisher A gets an allocation of Fishcoin's stablecoins on his digital account as a reward for contributing fisheries data on the platform. If fisher A sells the fish catch to buyer B, this buyer B will transfer, through bank or mobile money, the purchase price to fisher A and place the payment evidence in accessible form to fisher/seller A on the Fishcoin platform. By agreeing to register the change or update of the data on ownership title of the fish catch from fisher A to buyer B on the Fishcoin platform, fisher A transfers all or part of the Fishcoin's stablecoins in his custody to buyer B's digital account. This process goes on such that whoever is in custody

[31] https://fishcoin.co/fishcoin-protocol/

[32] A stablecoin is any cryptocurrency whose price is stabilised through regulation of its supply by a cryptographic algorithm or by pegging its value on a valuable commodity or other currency. Examples of stablecoins with highest market capitalisation include Tether (USDT) and USD Coin (USDC) (https://coinmarketcap.com/view/stablecoin/ accessed on Thursday 21st April 2022).

of the fish catch (i.e., the buyer) pays the seller the purchase price, gets the fish catch ownership title, and receives Fishcoin's stablecoins tokens as a reward for accepting to update the platform with his new fisheries (seafood) ownership data. This means, eventually, fish consumers who are ultimate buyers or owners of fish catch will become final recipients of Fishcoin's stablecoins. This will happen following their purchase of and payment for the fish catch, and updating the data on the Fishcoin platform on their new fish catch entitlement. As explained earlier in (i) above, these stablecoins can be exchanged for goods and/or services with participating actors such as network providers of airtime for mobile communications or internet services.

Case Study Barriers

(i) Many value chain actors in the fisheries supply chain were hesitant to adopt the Fishcoin tokens system due to its newness (actors' limited familiarity with this new technology).

(ii) Because the Fishcoin tokens system is highly digitised, efficiency problems occurred in data capture where fisheries were used to operating on manual data handling systems.

2.6.6.5 Sustainable Shrimp Partnership Case Study

Sustainable Shrimp Partnership (SSP)[33] is a group of major shrimp producers in Ecuador. SSP joined the IBM Food Trust Blockchain platform[34] in 2019 to provide transparency and traceability for its Ecuadorian farmed shrimp. SSP did this following the rise of food fraud and poor-quality products entering the market.

Project Goal

(i) To farm shrimps to the highest standards, with full traceability, with zero antibiotics and in a sustainable manner.

How the Case Study Worked Out

(i) SSP developed strict protocols for shrimp production, guided by its credible advisory board members (WWF, Sustainable Trade Initiative, Aquaculture Stewardship Council, and the Colombian Institute of Technical Standards & Certification).

[33] https://www.sustainableshrimppartnership.org/3-years-in-3-words-challenge-innovation-trust/
[34] https://www.ibm.com/blockchain/resources/food-trust/seafood/

(ii) SSP producers were subjected to constant verification at each stage of shrimp production to ensure compliance with best quality production practices (zero use of antibiotics, full traceability, and no negative impact on the local environment).

(iii) SSP shrimp producers in Ecuador recorded data on the IBM-sponsored Blockchain App on how the shrimps were produced, and how the data were accessible to retailers and consumers through scanning of QR codes. This scanning enabled them to view the provenance data as shrimp supplies moved along the value chains around the world.

Case Study Barriers and Lessons (Potential Areas of Improvement)

(i) No clarity on how consumers or retailers scanned QR codes on shrimp packs (whether they used mobile phones or other devices).

(ii) SSP encountered barriers related to members adopting a completely new technology for transparency and traceability (Blockchain) and the adoption of strict consumer health quality standards for shrimps.

2.6.6.6 Other Technology Cases (Complementary to Blockchain)–Global Fishing Watch

According to de Schepper et al. (2015), there are instances where higher benefits can be derived from employing combinations of complementary technologies than the sum of the benefits of individual technological solutions. This is because combinations of complementary technologies yield economic synergies called benefits of combined technologies (BoCT) (De Schepper et al., 2015). As noted in the reviewed Blockchain use cases above, weak internet signals and unreliable conventional telecommunications were a major hindrance to instant or real time transmission of data and transactions by actors along fisheries supply and value chains. This low performance resulted mainly from the fact that the Blockchain system devices were powered by poor terrestrial telecoms-based internet connections. As expected, the further out to sea the fishers went fishing, the weaker these land-based telecoms internet signals became. Therefore, a stronger and more effective alternative data transmission mechanism must be sought to ensure the real time transmission of fisheries data. One such option is the satellite-based global positioning system (GPS) data transmission system (Zong et al., 2022). Devices running on satellite-based GPS systems can relay fisheries data seamlessly and in real time for sharing on Blockchain Technology platforms without any dependence on unreliable terrestrial internet links. This would ensure timely data transmission (Blaha & Katafono, 2020). This integration of Blockchain and satellite GPS systems as complementary technologies would enhance coordination between trading partners in fisheries, hence addressing the trust issues identified in collective fisheries multi-stakeholder initiatives. Also, this merging of technological capabilities has potential to enhance compliance with the government regulation of fisheries resources. This would happen through the deterrent effect of enhanced identification, monitoring and controlling the activities of fishing vessels, as well as holding accountable all actors carrying out illegal and unsustainable fishing practices. Global Fishing Watch (GFW)[35] offers a widely successful and proven satellite-based GPS communications system that presents a potential complementary technology to the proposed Blockchain-based traceability system. GFW collects fisheries data globally using modern satellite-based technologies including GPS devices and uses the data to support partner countries to devise appropriate measures against illegal and unsustainable fishing practices in their waters. Therefore, GFW presents a potential opportunity for Tanzania to engage with. This would enable Tanzania to access data on fishing activities far out into the ocean/sea, including illegal and unsustainable fishing practices, where terrestrial telecoms networks cannot be used to transmit these data. Below is an elaboration, through case studies, about how GFW has benefited the fisheries sector both globally and in specific member countries.

Global Fishing Watch (GFW) Initiative

Global Fishing Watch is an international non-profit organisation registered in the US. It is funded by charitable donations from both the private sector and governments in ways that guarantee its independence. GFW's main purpose is to use modern satellite-based technology (e.g., GPS devices) to collect data and analyse it to report transparently about fishing activities in the oceans around the world. This is done to safeguard the sustainable exploitation of fisheries resources including fish. As such, GFW works to ensure convenient public access to knowledge about sea fishing activity in a manner that informs and supports responsible governments to act on illegal and unsustainable fishing practices. These practices include illegal, unregulated, and unreported (IUUs) fishing activities. Africa has been mentioned by GFW as among the areas of focus[36] where IUUs are commonly depriving coastal African states (e.g., Tanzania) of much needed resources for scaling-up their underdeveloped fisheries sectors. GFW helps governments that participate in its global fishing transparency initiatives to make their fisheries data publicly available with sufficient integrity to better support fisheries management decisions. The GFW's satellite-based GPS systems are so important to fisheries activities because they facilitate the reliable transmission of data at sea where network signals

[35] See Global Fishing Watch (GFW) - *www.globalfishingwatch.org*
[36] *https://globalfishingwatch.org/transparency-program-africa/*

for conventional mobile telecoms and internet signals are weak or non-existent. It is to be noted, however, that GFW has not integrated its data storage and communication systems with Blockchain Technology. This remains a value adding possibility given the experience gained in the reviewed Blockchain-based use cases above.

GFW Goals

(i) To use modern satellite-based technology (e.g., GPS devices) to collect data and analyse it to report transparently about fishing activities in the oceans around the world.

(ii) To safeguard the sustainable exploitation of fisheries resources including fish.

(iii) Ensuring convenient public access to knowledge about sea fishing activity in a manner that informs and supports responsible governments to act on illegal and unsustainable fishing practices.

How GFW Operates

As elaborated in specific case studies below, developers of satellites and marine tracking devices approach GFW to obtain vital technical guidance for building IUUs problem-solving technologies. These technologies, which are tailored to addressing specific problems, help these developers to provide GFW's partner countries' maritime authorities with tools for generating evidence-based maritime policies that guide fisheries management decisions. These decisions include the identification and control of illegal and unsustainable fishing activities, including by fishers who operate illegally in protected areas. GFW's primary data sources are publicly available global satellites[37] including the GPS devices. GFW occasionally provides technical input to launchers of satellites on what should go on maritime tracking technology sensors to make them most valuable and suited to ocean surveillance and monitoring. GFW works to help partner countries by providing maritime data maps on fishing activity for free and by trying to engage with government officials and/or local scientists/experts. This engagement helps to explain how GFW's platform works and how it can be used to monitor these countries' waters. In some cases, GFW and these governments develop memoranda of understanding (MOUs) and working arrangements to provide targeted training to enhance local analysis/research capacity. For countries with their own vessel monitoring systems (VMS),

[37] These help the tracking of night fishing vessels that commit IUUs unidentified. These satellites include Automatic Identification System (AIS) and Visible Infrared Imaging Radiometric Suite (VIIRS), see *https://globalfishingwatch.org/research/viirs/*

GFW may apply its analytical models to their data to provide advanced analysis and, in some cases, display these data publicly on GFW global map.

GFW Case Studies

Indonesia

GFW bought small-scale tracking devices from various developers including Globalstar's SPOT X, SPOT Gen4 and SPOT Trace[38] and evaluated them in the real fishing environment in Indonesia. For illustration purposes, these devices are presented in Figures 2, 3, and 4 below. These devices were mounted on fishing vessels and configured to use satellite-based GPS locator technology to track, monitor movements, and transmit locations of these assets (i.e., the fishing vessels) at sea. These data were transmitted via instant SMS text message notifications or email alerts sent from the devices on the vessels at sea to the vessel owners' mobile phones, computers, or any other internet-linked devices. These boat/vessel owners would usually be waiting on land while employed skippers and other fishers undertook fishing activities at sea. In some cases, these data would be transmitted or shared instantly with other actors on the fisheries supply and value chain including regulators, traders/processors, and buyers. These SMS text messages and email alerts contained coordinates of vessel locations (i.e., latitudes and longitudes) including links leading to visual maps of these places, thus enabling owners of these fishing vessels/boats, regulators, and other actors to monitor or ascertain movements and potential nature of fishing activities at sea. In some cases, boat/vessel owners would communicate with skippers to change navigational course if the data in the notifications showed them heading towards prohibited locations like marine protected areas (MPAs). Therefore, these SPOT X/SPOT Gen4/Trace devices helped boat skippers to navigate their fishing vessels safely in legal locations thus avoiding MPAs to ensure sustainable fishing. Also important, SMS text messages and email notifications transmitted by these devices helped fishers to send fisheries data in real time along fisheries supply and value chains even when internet network signals were weak or non-existent at sea.

[38] *https://www.globalstar.com/en-gb/products/spot-for-business/*

Figure 2: Globalstar's SPOT Trace™

FEATURES: TURNKEY ASSET TRACKING & MONITORING

SPOT Trace simplifies managing mobile inventory from a distance and helps to prevent potential loss/theft of assets (e.g., fishing boats/vessels, vehicles, & other mobile assets).

Figure 3: Globalstar's SPOT Gen4™

FEATURES: GLOBAL SATELLITE GPS MESSENGER

This rugged, pocket-sized safety device helps you as personal protective equipment (PPE) to stay connected to your remote or lone workers, no matter how far off the grid they go.

Figure 4: Globalstar's SPOT X™

FEATURES: 2-WAY SATELLITE MESSENGER WITH BLUETOOTH® WIRELESS TECHNOLOGY

SPOT X provides reliable, 2-way satellite communications so you can stay connected to remote and lone workers outside of terrestrial coverage.

Peru

Peru, the second largest fishing nation in the world,[39] was the first country in Latin America to share its vessel monitoring system (VMS) data on the GFW map. This proved Peru's leadership and commitment to fisheries transparency, which has led to improved policies and effective actions in fisheries management. Since the signing in 2017 of an MoU between Peruvian

[39] https://globalfishingwatch.org/transparency-program-peru/

authorities and GFW, more than 1,400 industrial and artisanal vessels have been publicly monitored on GFW's map. These vessels are used to fish high value species of anchovy, hake, cod, eel, tuna, squid, and mahi-mahi. Peru's partnership with GFW has improved the country's vessel monitoring to help address illegal, unreported, and unregulated (IUU) fishing in Peruvian waters. This also supported the implementation in 2018 of the mandatory use of satellite technology-enabled vessel monitoring system (VMS) devices on all domestic and foreign fishing vessels that dock in Peruvian ports. In addition to using collated VMS data, Peru also uses GFW technology to track vessels using night-time imagery, especially useful for monitoring squid fisheries, for which vessels use bright lights at night.

GFW has, since 2017, been supporting Peru's authorities with information to support their well-informed decision-making on fisheries and ocean management. This support has included capacity building training on how to use GFW's technological platform. In 2019, Peruvian officials were trained to search for individual vessels, interpret routes, and identify fishing grounds through the GFW public map. These training sessions served as fora to share information and analyse the technological solutions to help address problems that affect the country's fisheries sector. Included here was the monitoring of local, national, and foreign vessels to specific cases of illegal and unsustainable fishing activities. In addition, GFW helped Peruvian authorities with technical expertise for marine protection, which supported the creation of the first Protected Marine Area in Peru.

Chile

Chile began collaborating with GFW in 2019. This started when the country's National Fisheries and Aquaculture Service (SERNAPESCA) agreed, through a joint memorandum of understanding (MoU), to publish its fishing vessel data on GFW map. As a result, since 2020, the maritime activities of over 2,200 vessels from the Chilean industrial and artisanal fleets, including transport and aquaculture vessels, are visible on the GFW map. This has helped Chile to control, monitor and protect its enormous marine wealth and high-value fisheries such as anchovy, sardines, and hake. Other benefits to Chile include the publication of satellite technology-enabled vessel monitoring system (VMS) data on GFW global map, which is used to track Chilean domestic fishing activity.

Chile has also been able to create and safeguard marine protected areas thanks to the collaboration with GFW. These collaborative steps have helped Chile to discourage most IUU fishing activities in its waters. GFW has been supporting Chile with actionable information to enable the country's fisheries authorities to optimise their ocean policy and management decisions. This has included the training of Chilean officials on the use of GFW technological platform, the provision of analysis reports to quantify the amount of fishing that is occurring in the artisanal fishing reserve area and their artisanal fishing effort for anchovy. GFW has also provided SERNAPESCA with expert analyses to help them better understand the behavioural patterns of the foreign squid fleet that crosses Chile's waters annually.

Panama

Collaboration between GFW and Panama's Aquatic Resources Authorities (ARAP) began in 2019 after the signing of an MoU on collaboration. They agreed to jointly harness the power of satellites and cutting-edge technology including GPS devices to strengthen the monitoring of the Panamanian international fishing fleet. Following this, about 350 fishing vessels became visible on the GFW map in 2019, thus reaching a key milestone on fisheries transparency. It is this acquired transparency in fisheries that enabled Panama to monitor and control efficiently and effectively fishing transshipment procedures (i.e., loading and offloading of fish catches at sea followed by landing them at port). The joint work between Panama and GFW aims to show how transparency can help combat IUU fishing practices and improve the monitoring and sustainability of fisheries. A joint work plan between GFW and ARAP empowers both entities to carry out monitoring activities on the Panamanian international fleet, thereby helping the assessment of compliance with applicable laws.

GFW provides technical support to Panama through analysis of satellite GPS device imaging that identifies vessels of interest and verifies, in detail, the types of activities that the vessels engage in at sea. This helps the identification of vessels committing illegal and unsustainable fishing practices. Also included in the joint work plan is GFW's provision of advanced training on its technology portals to ARAP experts. To illustrate the benefits of joint effort against IUUs, Indonesia apprehended in 2019 the Panamanian-flagged vessel MV NIKA, which was wanted in several jurisdictions for committing IUUs. This rogue vessel's capture was achieved thanks to international cooperation between INTERPOL, Indonesia, the authorities of South Georgia and the South Sandwich Islands, the United Kingdom, Korea, and Panama. All these countries have had experience in satellite-based vessel monitoring technology from GFW.

As observed earlier in the reviewed literature, the fisheries sector in Tanzania lacks technology to monitor and instantly communicate the fish quality metrics or factors including preservation of the seafood at low temperature and its freshness. One of the technology devices that can capture and transmit these seafood quality data seamlessly along fisheries supply and value chains is Globalstar's SmartOne Solar Satellite Asset Tracking (SOSSAT) device[40] (Figure 5) whose detailed features are presented below. To illustrate, if attached to a fish container loaded on a ship or any other transport vehicle (e.g., fresh catches from Mafia, Kilwa, Mwanza, and Karagwe/Bukoba fishing grounds being transported to Dar es Salaam main market at Magogoni), the SOSSAT device has inbuilt sensor capabilities to capture and continuously relay in real time fish quality data to all actors on the supply and value chain. These data include fish weight, temperature, humidity as well as present and historical satellite-GPS location tracking. Another key strength is the device's power supply that would last over 10 years if it is initially fully charged.

2.6.7.1 Features of Globalstar's SmartOne Solar Satellite Asset Tracking (SOSSAT) Device

Installation of SOSSAT

- Easy to install this simple physical unit. It requires no harnesses, external power, or external antennas.

Maintenance

- The SmartOne Solar's NiMH rechargeable batteries deliver up to 10 years of usable service, drastically reducing maintenance time and cost for labour and parts.

Tampering and System Control

- It is impossible for the crew, and or captain, to change settings on the Smart One Solar (SOSSAT) device.
- There are no cables that can be cut to prevent the unit from working.
- To program the unit, one needs a special programming cable as well as access to the main user profile, which is protected with a unique username and password.
- The system is almost 100% tamper proof.

[40] See https://www.globalstar.com/en-gb/products/iot/smartonesolar

Transmission of Live and Historical Locations

- SOSSAT is 100% satellite communication technology, so it does not suffer from the unreliability of land-based telecoms networks which are ineffective in maritime or fishing environments.
- The SOSSAT device has external sensors with the capability of capturing external data inputs including temperature, weight, pressure, and humidity.
- The SOSSAT delivers reliable GPS location reporting for assets deployed worldwide – providing security and improved efficiency in the transmission of data.
- Records a vessel's historical location, with the ability to view exact route travelled.
- Live view shows the map in the main viewport, with only the most recently reported SPOT location(s). The live view updates and refreshes in near real time, so there is no need to constantly refresh the browser to display the most recent GPS locations.
- From the live view, users will see the asset groups in the first panel and will have the ability to interact with those on that list, or directly on the map itself. Asset groups/categories may include fishing vessels at sea and seafood distribution vehicles.
- Historical view is the interface that gives users the ability to trace the path(s) of assets in SPOT Maps over a defined period. It shows the map in the main viewport, with SPOT track points as reported during the date range defined by the user (default range is most recent 48 hours). Like Live View, the historical view also updates and refreshes in near real time, so there is no need to constantly refresh the browser to display the most recent data.
- From the historical view, users will see the asset groups in the second panel and will have the ability to interact with them from that list, or directly on the map itself. The users will also see path lines on the map, connecting the dots of location reports to allow for a more accurate understanding of the movement of SPOT devices on the map.

Figure 5: Globalstar's SmartOne Solar Satellite Tracking (SOSSAT) device (USA).
Source: Globalstar's website (www.globalstar.com).

2.7 Conclusion

We have seen in the preceding literature review that unsustainability practices in fisheries are driven by failures in the public governance of the fisheries resources, which are in turn a result of institutional underperformance. These institutional failures are manifested in various forms, namely state subsidy support-driven overexploitation, deceptive/fraudulent marketing of seafood, ineffective regulatory regimes, and non-conformity with TBTs/SPS measures. While literature on the causes of, and resolutions to, these institutional failures appear to favour enhanced property rights on fisheries resources, each of the three forms of suggested ownership (i.e., privatisation, government regulation, and community management) have downsides that can be/are exploited by rogue actors, hence the continued practices of unsustainable fishing. It appears that common pool (i.e., public, or jointly owned) fisheries resources cannot not be easily 'privatised' due to the open access nature of the fisheries resources and free riding problems among users. Also, fisheries resources owned or controlled by the state/government suffered from the agency problem, where public institutions run/managed by government officials were not able to enact and implement effective laws and regulations that would achieve goals of fisheries resources sustainability as anticipated by the public. Finally, fisheries resources managed by local communities faced internal and external challenges. While users of the fisheries resources in the communities failed to set up and implement collectively effective conservation rules, some conservation initiatives of these communities were interfered with and weakened by the actions of their respective central governments, or even global actors. It emerged from the literature that effective ways to resolve the unsustainability problems in fisheries resources exploitation must meet two conditions. These are (i) the consideration of the local context of fisheries resources and the users, and (ii) matching the resources'/users' context with an appropriate governance system (i.e., the appropriate mix/package of ownership and management, namely privatisation, government controlled, or community managed). This appropriate way to own and manage the fisheries resources is called co-management and it entails the distribution of rights and obligations of conserving and exploiting fisheries resources among stakeholders or actors. These stakeholders/actors include the central government (e.g., setting up policies and regulations at state level), local government (e.g., ensuring compliance of laws/regulations at local level), and local communities/users who are obliged to manage and exploit the fisheries resources sustainably and responsibly.

However, the literature on institutional failures to conserve natural fisheries resources highlighted reasons why owners or managers of the resources would choose to deplete or overexploit the resources now rather than conserve them to achieve long-term benefits of sustainability. If private owners perceived the cost of fisheries resource conservation to be higher than the long-term return on this investment, then they would opt to overfish and deplete the resources now. Corruption practices and rent-seeking have been identified as among the key drivers of ongoing overfishing in public/government-controlled resources. While the developed world justifies their unsustainable fishing support measures (e.g., subsidies) to meet food security, local job needs, and profits for their fishing industry (Agnew et al., 2009; Sumaila et al., 2013, 2020), fisher communities in Tanzania undertake unsustainable fishing largely to meet their food security and livelihood needs, like household income (Andriesse et al., 2022; Allegretti, 2019). These unsustainable fishing practices threaten the health safety of consumers of fish products, as well as the sustainability of fisheries resources. There appears to be an interlinkage between unsustainable fishing in Tanzania and the actions of global actors in unsustainable fishing. The linkage is that whenever these powerful global actors overfished on a large scale near territorial waters of countries like Tanzania, supplies of fish available for local fishers diminished, hence forced local fishers/actors to adopt unsustainable fishing practices to meet their food security and other livelihood needs. This happened because it became difficult to get adequate supplies of fish legally or sustainably following the actions of these rogue actors.

Given these unsustainability problems in fisheries, the literature provided a solution, this being the creation and implementation of a credible traceability system for monitoring compliance with sustainable fishing practices and desired seafood trading activities (UNECE, 2016). This proposed solution originated from literature on traceability solutions in the food sector with a specific attention to the application of Blockchain technology. The suggested Blockchain-based traceability system proposed for the current study would be private-sector led, but involving all actors along the fisheries supply and value chains. This multi-actor involvement would, it is hoped, achieve the same co-management benefits identified in the literature, and the private-sector leadership of the new traceability system would hopefully address the current public institutional failures underlying ongoing unsustainable fisheries problems. To achieve this, the traceability system will help with the identification of rogue actors committing these activities of unsustainability along the fisheries supply and value chains in a timely way, thus limiting their access to lucrative local and foreign (e.g., UK/EU) premium price markets. This access to premium-price markets would act as an incentive to lure rogue actors away from the agency problem (negative externality of overexploitation), thus encouraging them to adopt sustainable ways of fishing. In addition, this identification of unsustainable fishing practices could also enable relevant authorities in local and central governments to take counter measures like administering financial penalties, or prosecutions of the identified rogue actors.

The next chapter (Chapter 3) undertakes a stakeholder consultation exercise to first, further explore and identify the unsustainability challenges faced by various actors in Tanzania's fisheries supply and value chains. Then, the proposed Blockchain technology-based traceability system will be evaluated in terms of its potential effectiveness to resolve the identified fisheries unsustainability problems in the Tanzanian context through its capacity to enhance transparency and accountability.

CHAPTER 3:
STAKEHOLDER CONSULTATIONS TO IDENTIFY AND RESOLVE PROBLEMS IN TANZANIAN FISHERIES

3.1 Introduction

The stakeholder consultations, data collection, and analysis were undertaken using Grounded Theory (GT) approaches (Belgrave & Seide, 2020; Glaser, 1978, 1992; Glaser & Strauss, 1967). Problems in the action scene emerged thematically from the data in the form of codes and categories using this approach (Chapman et al., 2015; Floersch et al., 2010). The GT methodology was developed by Glaser and Strauss and first reported in their 1965 publication *"Awareness of Dying"* and a 1967 follow-up publication, *"The Discovery of Grounded Theory – Strategies for Qualitative Research"* (Glaser & Strauss, 1965; 1967). The authors argued that the key purpose of conducting studies using the GT approach is to generate a new theory by discovery (i.e., inductive theory building analysis), rather than the conventional research approach of verification of a pre-existing theory (i.e., deductive analysis) (Glaser & Strauss, 1965; 1967; Corley, 2015). Although not all GT studies end up generating a theory (Chamaz & Belgrave, 2012), GT seeks generally to explore, identify, and explain behavioural patterns observed in 'action scenes' which are relevant and/or problematic to those participants involved (Corley, 2015; Glaser, 1992), where these conceptions do not have to be verified[41] or even closely described (Glaser, 1978, p.93). Simmons (2011, p.27) defines an 'action scene' or 'substantive area' as synonymous with the research subject (i.e., fisheries in this study) and its participants (i.e., in this case fisheries stakeholders such as fishers or boat owners).

There has been a debate about the research settings that are suitable for application of the GT methodology. Some researchers (e.g., Glaser, 1992; Holton, 2008) argue that GT is a fully fledged general methodology suitable for both inductive and deductive research settings using all types of data – qualitative, quantitative, or a combination thereof. However, other researchers (e.g., Corley, 2015) disagree, arguing that, because GT is appropriate for exploring and explaining problems from the perspective of those living or experiencing them (Corley, 2015; Glaser, 1992; Glaser & Strauss, 1967), it is most suited for inductive (theory building/development) rather than deductive (theory testing/verification/validation) studies. However, Lasner & Hamm (2014) employed both inductive and deductive approaches in their

[41] Glaser (1978 and 1992) argues that while GT generates theory through analysis of data from an action scene, testing and verification of this theory is left to other enterprises with relevant research mandates. Accordingly, the testing and verification of an emergent GT is out of scope of the current study.

study, resulting in the grounded theory (GT) of ecopreneurship'. This theory explained, in a balanced way, the factors that influence the adoption of ecologically innovative fish farming methods consistent with Roger's Diffusion of Innovations Theory (Rogers, 2003). Lasner & Hamm's (2014) GT of ecopreneurship explains the reasons for and against the adoption of ecological/sustainable fish farming (aquaculture) practices. This GT suggests that fish farmers' decisions on adopting ecological/sustainable innovations follow a balanced risk and return management approach involving economic cost-benefit (profitability) analysis, ecological/sustainability motives, and relevant social aspects (Lasner & Hamm, 2014). On the other hand, Georgakopoulos et al. (2008) generated a GT of Organic Fish Farming through an assessment of the degree of stewardship required to conserve fisheries resources and associated marine ecological damage risk levels among fish farmers in Scotland. Georgakopoulos et al. (2008) had assumed that granting fish farmers exclusive property ownership rights of fisheries resources would incentivise them to sustainably conserve resources (i.e., stewardship), thus lowering the risk of marine environmental mismanagement and overexploitation. This assumption was due to the fact property rights provide guaranteed/predictable long-term returns (i.e., intergenerational sustainability) (Perman et al., 1999). However, the GT of Organic Fish Farming explains that the fish farmers' risk and return strategies do not necessarily support the view that property rights incentivise the stewardship of the marine environment (Georgakopoulos et al., 2008; Hotelling, 1931). Finally, Patten (2006) produced a GT of Law Enforcement Officers' Receptivity Towards Collaborative Problem Solving in fisheries and wildlife resources in the US. This GT explained and predicted that unsustainable overexploitation and mismanagement of fisheries and other wildlife resources were largely a result of regulators' limited willingness to accept and adopt collaborative sustainability measures involving fishers and other resource users (Patten, 2006).

In summary, what distinguishes GT from conventional qualitative and quantitative analytical techniques (hereafter called 'non-GTs') is its use of a "ground–up" (i.e., inductive), rather than a 'top-down' (i.e., deductive) approach ((Belgrave & Seide, 2020; Glaser, 1992, 1998). Non-GT qualitative and quantitative studies begin with rigorous literature reviews to identify research gaps and concepts/theories that need to be verified. In contrast, GT studies build new concepts/theories based on primary data, avoiding or minimising–at least in theory–preconceptions that may contaminate researchers' impartiality in data interpretation (Glaser, 1978, 1992). It is these new qualities and approaches presented by GT that the current study intends to exploit. GT approaches have been used by researchers to explore and explain, or resolve, ongoing problems in the fisheries sector.

Despite its immense marine and freshwater fisheries resources, Tanzania reaps insignificant benefits from them, i.e., fisheries contribution to GDP is below 2% (URT, 2020a). This underperformance in fisheries is worsened by unsustainable fishing practices by local and foreign agents, thus limiting the sector's commercial scaling-up potential (Caton, 2018; URT, 2016). This study is motivated by the need to mitigate these problems. As such, the study sets out to apply GT analysis techniques to identify barriers and drivers of sustainable development and commercial scaling-up of Tanzania's immense fisheries resources. This is a necessary first step towards proposing a credible solution. The next section elaborates the GT methodological steps used in this study. As such, the study follows in the footsteps of Lasner & Hamm (2014) by using the GT inductive approach to explain the main concern (problems) facing fishers and actors in Tanzania's fisheries supply and value chains and applying deductive procedures to explore and propose potential solutions to the identified problems.

3.2 Methodology

3.2.1 The Choice of Grounded Theory as a Methodological/Analytical Framework

The choice of GT for this study is based on the fact that, according to Glaser (1992), GT research approaches are most appropriate for studies undertaken in one of the two settings: (i) where the research subject is a new area of exploration, where the study is being done to open initial inroads into the wealth of knowledge there; and (ii) where the research is done in an already well studied domain, but where the area remains 'problematic', i.e., where more research effort is required to address the unresolved concerns. The fisheries sector, both locally (in Tanzania) and globally, as explored in this study, remains problematic despite the large amount of research work put into it to-date (e.g., Agnew et al., 2009; Allegretti, 2019; Caton, 2018; Lasner & Hamm, 2014; Sumaila et al., 2020; Georgakopoulos et al., 2008; Patten, 2006). As indicated in the introduction section, the GT analysis appears suitable to address the ongoing research gaps in the fisheries sector, namely the unresolved challenges pertaining to the sustainable development and commercial scaling-up of Tanzania's fisheries resources. To do this, field data were collected and analysed initially using GT approaches, followed by a thematic analysis to capture emerging problematic patterns, topics, or issues about what was going on in the fisheries sector that were common, or different, across both freshwater and marine fisheries (Caulfield, 2022; Chapman et al., 2015; Floersch et al., 2010).

3.2.2 Background to Grounded Theory (GT)

3.2.2.1 How GT Compares with Non-GT Techniques

GT exhibits similarities and differences with non-GT methods (i.e., traditional qualitative research methods) and quantitative research approaches). For purposes of clarity, GT is understood here to represent all forms of GT – Glaserian/Classic and otherwise.

Similarities

In terms of similarities, both GT and non-GT approaches employ data collection from action scenes, followed by some form of analysis before arriving at final research outputs. Indeed, GT studies are capable of not only processing any qualitative or quantitative data but also any combination of the two (Glaser, 1978, 1992; Holton, 2008).

Differences

Based on the literature (e.g., Glaser, 1978, 1992; Glaser & Strauss, 1967; Belgrave & Seide, 2020), GT changes the way in which data are collected and analysed from stakeholder interviews and other sources. Under traditional research approaches, the issues, and questions to be explored with stakeholders are at least partially developed in advance of the interviews, usually based on a review of existing literature. Then, a set of interview questions, or topic guides for questions, are prepared before interviews are undertaken. The data from the interviews are then 'content' or 'thematically' analysed, using existing concepts and understandings as an interpretive framework. In the case of GT, however, such rigid and detailed assumptions about the issues and questions to be explored are not made in advance of the data collection phase. Instead, more general questions are generated as conversation starters. A smaller group are first interviewed using the more general questions and the data collected is analysed to extract key messages about what is going on in the action scene (i.e., the substantive research area, like fisheries in the current study). These extracted messages are called Conceptual Incidental Indicators (CIIs) (Glaser, 1978, 1992). A detailed definition of CIIs is provided below, under 'Unit of Analysis' sub-section. The issues emerging from this analysis of CIIs (substantive or theoretical codes/concepts) are then used to frame the issues to be addressed and suggest questions to be examined in the next round of consultation. This next round of data collection is called 'theoretical sampling' in GT terms (Glaser, 1992; Walsh et al., 2020). According to Glaser & Strauss (1967), theoretical sampling is named as such to reflect the fact that the nature, or characteristics, of the next participants or data being sought are theoretically determined or informed by the gaps emerging from the previous round of data collection and analysis. The data so collected is used to build themes, i.e., thematic analysis of the emerging CIIs/concepts (Chapman et al., 2015; Floersch et al., 2010). By means of this iterative approach, the questions, and issues which stakeholders themselves deem to be critical are identified. This set of issues may be very different from those first envisioned by the researcher prior to fieldwork, but they are by far the most relevant, as they naturally emerge from the data.

Practical Problem Solving

Research experts in non-GT domains require a reasonable mix of theoretical and practical exposure to deliver policy advisory and consultancy work (Glaser & Strauss, 1967). For these non-GT researchers, competence develops through more time spent in applying their knowledge base to solve practical problems (e.g., business consultancy or training) and less of it in studying or researching underlying causes of the challenges faced. However, GT emphasises the primacy of first developing a strong theoretical grounding as a framework to understanding the nature of problems in specific substantive areas (Glaser, 1978; Glaser & Strauss, 1967; Belgrave & Seide, 2020). A typical grounded theorist begins by accumulating knowledge through critical understanding of participants' problems in terms of 'what is actually going on' in their lives and activities, followed by the discovery of the most fitting pattern (i.e., the GT) revealed in the data. This prior grounded understanding of problems in substantive areas, therefore, makes the GT expert best suited to addressing relevant practical issues (policy change and business consultancy).[42]

Types of Data Used

Non-GT quantitative and other traditional qualitative research analysis studies depend on a relatively limited range of data source types, i.e., usually interviews, observations, and focus group discussions (FGDs) (Glaser, 1992). In contrast, GT studies are open to applying all forms of data e.g., interviews, FGDs, conversations, observations, photographs/pictures, web-based internet sources, secondary data, including statistical reports, newspaper articles, professional publications, lectures, seminars, expert group meetings, and TV shows and can draw from these multiple types simultaneously (Glaser, 1992; Glaser & Strauss, 1967; Ralph et al., 2014).

[42] Practicality of GT in resolving real world problems is detailed in Glaser and Strauss (1967, pp.237-250).

Unit of Analysis

Non-GT approaches use persons, households, firms, and even specific quantities of items as units of assessment in the collection, analysis, and reporting of data (Glaser, 1992). In contrast, the units of assessment for GT studies are 'conceptual incidents', which in the current study are called 'Conceptual Incidental Indicators (CIIs)', which may or may not contain indicators of 'what is going on' in a substantive research area (Glaser, 1992, p.40). According to Glaser, 1978, 1992), CIIs are messages that emerge from collected and analysed data hinting at underlying patterns that explain how participants address, process, or resolve their main social problem(s) – (called the main concern in GT). These CIIs give an early information signal about what is going on in the action scene. While hundreds, or thousands, of respondents may be required to form an adequate sample for non-GT studies, a few tens of persons/participants, or any other sources of data, may offer sufficient CIIs to draw stable conclusions in a typical GT analysis (Glaser, 1992). The number of CIIs identified in a GT study might, in some cases, be in the hundreds; but in practice, far fewer (say, tens) are usually sufficient to saturate an emergent GT core category (Glaser, 1996).

Role of Statistical Analysis

Quantitative non-GT studies rely heavily on statistical analyses as they navigate their way to research conclusions (Glaser, 1992). These studies are therefore deductive in nature, seeking to verify and test predetermined theoretical frameworks using field data(Glaser, 1992; Corley, 2015; Holton, 2008). GTs, on the other hand, are inductive, i.e., GTs process collected empirical field data towards the emergence of conceptual/theoretical patterns (i.e., hypotheses or probabilities) that solve/resolve a concern in the action scene (Glaser, 1992; Corley, 2015). This process results in the emergence of hypotheses that 'may or may not have equivalence' with hypotheses found in the existing literature. If the CIIs or concepts that emerge from GT are at odds with those from past studies (i.e., the extant theories in the literature), this does not invalidate the current results, but merely calls for further testing (usually by means of deductive studies) in order to explain why these differences exist (Glaser, 1992).

Validity Testing

Testing of the validity of results is another area where GT and non-GT studies diverge (Glaser, 1992). Non-GT studies validate data through statistical estimation of probabilities of error and tend to have a strict and rigorous scientific orientation (Glaser & Strauss, 1967, p.235). GTs, on the other hand, produce non-statistical patterns of aggregated conceptual incidental indicators (CIIs) that constitute messages that explain what is going on in the action scene (i.e., the problem or main concern) as derived from empirical data (Glaser, 1998). Furthermore, GT is not a statistical method because its sampling process of participants or contexts (i.e., ‘theoretical sampling’) does not involve ‘statistical randomness’ to ensure a certain degree of representativeness in selection (Thomas, 2011, p.135). Studies invoking GT approaches are invariably exploratory in nature and thus do not have to be subject to the same conceptions of scientific rigour in terms of testing and verification. This is because GT studies focus on phenomena that are quickly changing/emerging in society across time, people, and place (Glaser, 1992). Phenomena researched in GT studies tend to be less permanent than are found in enquiries undertaken in hard or physical sciences; and this implies new trends in social phenomena may occur much more quickly than the necessary period for their extensive scientific testing and verification (Glaser, 1992). Therefore, validity in GTs is measured by their fit, workability, relevance, and modifiability in addressing phenomena in an action scene (Glaser, 1978, 1992, 1998; Glaser & Strauss, 1967). In this regard, the conclusions of GT studies are therefore never absolutely right or wrong but have a constantly changing (i.e., variable) degree of fit, workability, relevance and modifiability depending on time, people and place (Glaser, 1992).

3.2.2.2 What Form of GT Was Used in This Study?

There are currently three main forms of GT: Glaserian/Classic GT, Straussian/Corbin GT, and Charmazian GT (Chun Tie et al., 2019). This study has adopted the Glaserian or ‘Classic’[43] GT approach (Glaser, 1978, 1992). The Glaserian/Classic GT approach ensures that only participants’ or interviewees’ opinions influence the final theoretical outcome, thereby leading to an appropriate solution roadmap (Glaser, 1992; Holton, 2008; Walsh et al., 2020). Other forms of GT (Chamaz, 2006; Strauss & Corbin, 1990) have a tendency of allowing some degree of researcher’s tampering or modification of collected data to suit their (i.e., researchers’) *a priori* expectations, hence called ‘data contamination’ (Glaser, 1992). The Classic Grounded Theory Methodology (CGTM) process (Glaser 1978, 1992; Holton, 2008; Walsh et al., 2020) involves the identification of conceptual incidental indicators (CIIs) in the data, then through constant comparison, collating these CIIs into more abstract codes and categories, with a view to identifying one main category as the core, by virtue of it explaining the most variation in the substantive area. After this point, constant comparison is used with new data to generate and

[43] Other names for Glaserian Classic GT method are “Orthodox”, “Traditional”, “Objectivist” and “Positivist”.

refine codes and categories that are aligned with the core category (i.e., the emerging main problem/concern). This is called 'attainment of saturation point' in GT; where the core category becomes fully saturated, based on an emergent 'theme' with the highest analytical occurrences, frequencies, or behavioural pattern variations. In this regard, full saturation means that adding new data could not increase the number of CIIs aligned with the core category.

3.2.2.3 Limitations of GT Methodological Approaches

Despite the above-listed advantages and features, GT approaches have got their drawbacks. According to Backman & Kyngäs (2018), one of the main drawbacks of GT is the lack of general clarity on the required depth and breadth of familiarisation by a novice GT researcher about the subject matter before undertaking an empirical GT study. Classic/Glaserian GT argues that, to avoid preconceptions (i.e., conceptual contamination) before the emergence of the main concern (i.e., the problem being investigated), novices should completely avoid a review of extant literature on the subject (Glaser, 1978, 1992; Holton, 2008; Walsh et al., 2020). There is an exception to this rule whereby those who are already experienced in GT approaches and have preconceptions about the substantive area should maintain a 'mental wall' between the extant knowledge and the emerging GT findings to avoid a potential distortion of the emerging GT patterns. However, some GT researchers (e.g., Chamaz, 2008; Layder, 2018) disagree with Glaser by stressing the importance of preliminary literature review to help researchers with the familiarisation and focusing on the problem to be investigated using GT approaches. Another limitation of GT is that its multi-stages of data collection and analysis tend to generate multiple themes (conceptual codes and categories) that require extra resources (e.g., specialised skills and time) to analyse, manage, and saturate (Backman & Kyngäs, 2018).

Layder (2018) presents the shortcomings of GT by comparing it with Investigative Research (IR) methodologies that he considers to be more comprehensive, inclusive, and empirically realistic in relative terms. According to Layder (2018), IR emphasises the notion of 'inclusive social reality', meaning research phenomena being investigated are best explained by an interaction of several social domains (including situated activities, settings, resources) the combined effects of which are ignored by GT approaches that dwell exclusively on a single situated activity (i.e., an action scene or substantive area) to derive generalisable conclusions in the form of GTs (Glaser, 1992; Walsh et al., 2020). Therefore, GT limitations are driven in this regard by its one-dimensional (i.e., singular, and exclusive) approaches to research phenomena that ignore cross-cutting yet interconnected social aspects. This makes GT outputs, including theories and concepts, to be considered inferior to those of IR's richer multidimensional and diversified research views and applications that largely mirror the social empirical reality. To avert this GT limitation, the current study adopted an 'inclusive' approach within the fisheries substantive area where multiple stakeholder groups of participants were consulted to provide empirical data for GT conceptual analysis and theory emergence. These were freshwater fishers, marine fishers, regulators, traders, processors/exporters, and researchers/industry experts. The involvement of these multiple actors helped to address the one-dimensional limitation in GTs, thus transforming the current study's GT into an inclusive social domain of various fisheries stakeholders and settings, much like in IR.

Power relationships form another area where the performance of GT falls short of IR. While Glaser's (1992), Holton's (2008), & Walsh's (2020) 'pure' or 'original' GT version considers *a priori* knowledge and analysis of power relations in an action scene as preconceived, received, imposed, and thus ungrounded, hence not emergent from the data, Chamaz (2006) presents a softer GT view that recognises the role of power interactions at individual and/or collective levels. However, Layder (2018) challenges Glaser and Chamaz that both versions of GT do not capture and present a comprehensive picture of complex forms of power relations in wider and inclusive empirical social settings. Layder (2018) argues that structural or systemic power interactions depend more on prior conditions related to, for instance, access to various forms of authority and control in existing social contexts/settings, as well as asymmetric access to various forms of resources based on singular or combinations of different demographics – gender, age, education, ethnicity, social class/status, etc. In a situation where several participants share, and simultaneously compete for, a common resource like fisheries, an individual participant's power (e.g., their individual abilities to overexploit the fisheries resources for personal gain) differs from, but is interconnected in some social realities to, other participants (e.g., individual, or collective reactions by other participants following the consequences of unsustainable fishing practices) (Layder, 2018). Correspondingly, commercial and public entities' collective or agency powers (e.g., major seafood processors and distributors; or public regulatory bodies of fisheries resources) differ but are empirically influenced by the 'formal' powers entrusted to those individuals running and making critical decisions in these organisations (Layder, 2018; Ritzer, 2011). Therefore, Glaser's view of power relations as extant or ungrounded and Chamaz's exclusive focus of power interactions on a single substantive area both fail to appreciate the interconnectedness of different forms of power relations in complex social phenomena (Layder, 2018).

To improve its ability to capture power relationships in action scenes, GT research needs to adopt some of IR's empirical approaches like *a priori* recognition of reality that power exists in all facets of life (Layder, 2018). This means GT research needs to have an *a priori* understanding that power relationships come in different forms and influences that vary across multistakeholder groups in political, social, and economic domains. These include authority/control power relationships in social settings as well as material goods/resources power relationships due to access asymmetries based on society demographics (class, gender, age, and ethnicity) (Layder, 2004). Therefore, the current GT study needs to analyse and derive conceptual meanings from CIIs and other relevant GT theories to capture power relationships, based on data collected from multiple stakeholders with interrelated yet varying degrees of authority/control powers over the fisheries resources.

3.2.3 Sampling, Data Collection Instrument (Questionnaire), and Data Analysis

Figure 6 presents a methodological framework that shows the 4 GT analytical steps followed in this study. These steps, in the order of execution, are data collection (theoretical sampling), identification and derivation of key messages (Conceptual Incidental Indicators (CIIs)) from the collected data and formulation of codes/categories (concepts) therefrom (i.e., open coding), aggregation of similar or related concepts around the main problematic pattern (i.e., selective coding around one code - the core category - with the most CIIs), and finally, derivation of a theoretical code/concept to represent the GT that explained the main concern. CIIs are messages that flag out or indicate problems (i.e., what is going on) in the substantive action scene (say in fisheries) based on the data being analysed. During each of these 4 steps/stages, the researcher operationalised simultaneously the 4 Glaserian/Classic GT principles namely theoretical sampling, constant comparative analysis, memoing, and emergence (Glaser, 1992; Walsh et al., 2020, pp.23-32). To meet the GT methodological requirements, the sample size for the current study was not determined beforehand. Instead, the target stakeholders were identified first, namely fishers, regulators, processors/exporters, and industry experts/researchers in Tanzania; and a few traders/importers, distributors, and industry experts in the UK/EU. The study interviewed 195 Tanzanian stakeholders and 5 stakeholders in the UK/EU. Although the researcher had prepared a list of questions/issues to explore based on the literature (see Appendix C3), this list was not put forward in advance, but was used as a guide to seek more clarifications or as follow up questions. This is a key requirement in GT to allow an undistorted flow of stakeholder views with minimal or no interference from the researcher or extant literature (Glaser, 1992, 1998). This approach resulted in the identification of questions and issues which stakeholders themselves deemed to be critical and relevant to the topic of investigation. During the interviews, the identified stakeholders could voice issues that were potentially very different from those first envisioned by the researcher prior to fieldwork, but the stakeholders' views were by far the most relevant, as they naturally emerged from the data (Glaser, 1992).

The researcher chose to begin interviews with fishers, although it was irrelevant which group were consulted first, because starting with any particular group would not have affected the eventual outcome of the GT analysis (Walsh et al., 2020). The fishers were asked to discuss generally, in an interview format, the developments, challenges, and any improvement potentials in their ongoing fishing activities. The researcher was keen during the process to capture and take note of issues/responses or messages (hereinafter called CIIs) that related to the main research question: 'development barriers and drivers that limit the sustainability and potential commercial scaling-up of the Tanzanian fishing industry.' As suggested earlier, these CIIs are non-statistical but probability hypothetical statements about what is going on in the action scene (i.e., the stakeholders' main concern) (Glaser, 1998). The issues (i.e., CIIs) that emerged from this analysis were thematically grouped according to their similarities or relationships (i.e., to obtain substantive or theoretical codes/concepts) (Chapman et al., 2015; Floersch et al., 2010) and these were used to frame the next set of stakeholder interviews, including the suggestion of questions to be examined in the next round of consultation. This next round of data collection is called theoretical sampling in GT. This sampling process stopped when saturation was reached.

During the whole data collection phase, memoing was undertaken continuously, as a mental and physical memo/note-taking activity, during each of the four GT stages (Glaser, 1978, 1992). While memoing, the researcher derived theoretical meanings and patterns of CIIs emerging from the collected data. At the same time, the emerging patterns guided the researcher on use of possible codes – open codes, selective codes, and theoretical codes (for definitions of these, see Figure 6 below). It is through this coding process that the researcher eventually arrived at the final output: the emergent GT, hence the emergence principle. As suggested above, the category with the highest number of associated CIIs became the core category, suggesting it represented the main concern or problem facing the stakeholders in fisheries. This core category constituted the basis for the emergent GT (Glaser, 1978, 1992). The study also undertook steps to establish the nature of the core category, to see if it constituted a Basic Social Process (BSP), which is defined by Glaser (1978) as a special type of core category that occurs in at least two processes, or stages, over time. A detailed description of the GT methodological framework adopted in this study is presented below (Figure 6). This framework is structured according to the four GT stages namely: data collection (theoretical sampling), open coding, selective coding, and theoretical coding that derives a substantive GT.

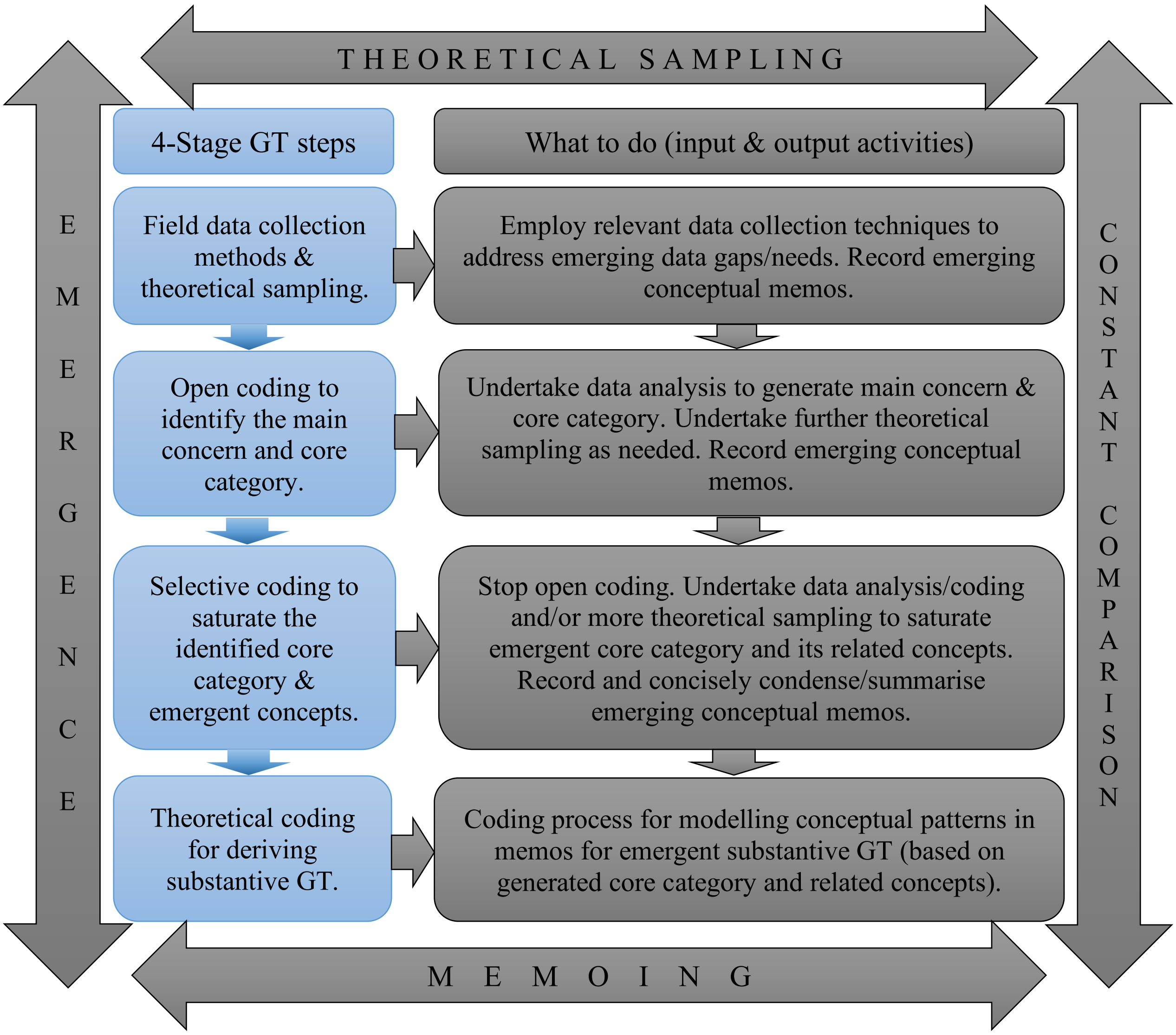


Figure 6: The Four-Stages and Four-Principles of GT Methodological Framework

Source: Researcher's Figure, based on Glaser (1978) and Walsh et al. (2020).

Also, Figure 6 presents the four key principles adhered to in this GT study. These are theoretical sampling (i.e., data collection), constant comparative analysis (i.e., identifying similar and varying data patterns), memoing (i.e., conceptual meanings of derived data patterns), and emergence (i.e., emerging concepts and main problem/concern in the action scene, hence the emergent GT).

3.2.3.1 Data Collection Method (Theoretical Sampling Process)

According to Glaser (1992), the GT methodology has its own unique sample selection approach called theoretical sampling, i.e., sample size is not predetermined based on precedent or power calculations. Theoretical sampling in GT is a continuous addition of observation data to a GT dataset until saturation is reached, whereby no new patterns emerge from additional data (Glaser, 1978, 1992). For this reason, there is no clear distinction between the data collection and analysis phases of research, as is the case with non-GT methods. In this study, the sampling process (i.e., theoretical sampling in GT) was undertaken in Tanzania and the UK/EU during the period June 2019 to September 2020. The participants were fishers in Tanzania; regulators in Tanzania and the UK/EU; experts, suppliers of goods and services, processors, and traders/distributors – including exporters and importers in both the UK/EU and Tanzania. These were surveyed by means of 195 physical interviews in Tanzania, five phone interviews in the UK/EU, 12 observations in Tanzania, and a review of 18 content material items on fisheries actors in the UK/EU (see Tables 10 and 11 below). By the time the data from the last of these stakeholders had been analysed, no new concepts were emerging, i.e., saturation point had been reached (analogous to adequate sample size being achieved in non-GT studies). This sample size of 200 (195 in Tanzania and 5 in UK/EU) was considerably larger than the range observed by Glaser (1996, pp.xvi-xvii) in the review of past PhD GT studies, i.e., 60 to 100 interviews. This seemingly larger than average sample for the current study was caused by the wide range of data and concepts derived from multiple theoretically sampled stakeholder groups. These were marine fishers (31 from Dar es Salaam – the largest seafood market; 25 from most sustainable fisheries in Lindi and Coast/Pwani based on active BMUs, 35 from other regions – Tanga and Mtwara), freshwater fishers (26 from Mwanza), regulators (47 from Tanzania, 7 from UK/EU), processors/exporters/traders (13 from Tanzania, 12 from UK/EU), and industry experts/researchers (30 from Tanzania, 4 from UK/EU). This current study's theoretical sampling of 200 interviews as broken down into the above six varied groups of respondents is not comparatively different from Patten (2006). Patten (2006) generated a GT in his PhD study by conducting 43 interviews with only one category of interviewees namely fisheries resources law enforcers. Also, Lasner & Hamm (2014) generated a GT by conducting 60 interviews with two categories of respondents, namely organic and conventional fish farmers. If the current study interviewed fewer respondents than 200, it is possible the analysis for the emergent GT would not have reached the required saturation level. This means, by interviewing fewer than 200 stakeholders, the current study would have rendered the analysis insufficiently rich in conceptual GT terms, thus becoming a loosely descriptive and unsaturated piece of qualitative work (Glaser, 1992).

Respondents (stakeholders in fisheries) were invited to discuss the 'development barriers and drivers that limit the Tanzanian fishing industry's sustainability and potential for scaling-up'. Selection of initial GT exploratory interview questions was informed by a review of relevant literature on fisheries resources sustainability in developing countries (Simmons, 2010; Walsh et al., 2020). Unstructured interview techniques and informal conversations were employed to both put participants at their ease (Goulding, 2002), and to elicit their in-depth stories about what was going on in the fisheries sector (Glaser, 1992; Goulding, 2002; Walsh et al., 2020). Thereafter, semi-structured interview techniques were used to narrow down the focus of discussion once a coalescing pattern started to emerge from interview responses; and this was followed by the search for corroborative or refuting evidence (i.e., GT's constant comparative analysis), including observational data (Goulding, 2002). This approach helped increase the participants' engagement with enhanced confidence and trust, thus lowering their fear and motivation to hide the truth through 'properlining'[44] and 'vaguing out'[45] (Glaser, 1998, pp.110&112; Walsh et al., 2020, p.34). According to Glaser (Glaser, 1998, p.9), properlining is a source of bias that affects the quality of data used to derive GT relative to the best that participants can offer (called bias-free baseline data).[46] This is usually driven by participants' sense of insecurity about telling the truth, hence their motive to only portray the positive side of events. 'Vaguing out' results in the loss of quality in baseline data through participants' intentional provision of distorted data due to its sensitivity/restriction. 'Properlining' and 'vaguing out' were avoided or minimised in the current GT study through the researcher's use of unstructured interview approaches followed up next with semi-structured interviews (Goulding, 2002). For instance, by asking fishers unstructured questions, such as 'describe your

[44] According to Glazer, 'properlining' occurs when respondents know they are being recorded using audio or video devices. In this situation respondents/participants feel insecure and so decide to hide the truth being sought by the researcher but instead talk only about 'what they believe to be proper and correct'. They therefore hide negative scenarios in their respective substantive areas (i.e., what is actually going on) and speak instead about normative contexts (i.e., what ought to be happening).

[45] Interpreted data is about the way a trained expert presents data in his own professional way, although this view may alter the natural or original meaning by participants (e.g., overfishing, and dynamite fishing are categorised as illegal and unsustainable practices by experts and regulators while some fishers see and practice it as a normal fishing method). Vaguing-out data, on the other hand, means participants giving uncertain or unclear responses to researcher. This is motivated by the fact that data is sensitive or restricted in some way (based on the data owner's intentions), hence its concealment or confidentiality or a certain degree of distortion when it is given out to the researcher.

[46] Baseline data reveal the real situation by providing the full truth about what is going on in the substantive area (i.e., the participants' main concern).

daily experience as a fisher', the researcher lowered the chances of leading the interviewees to form opinions about the object of the research interest. 'Vaguing out' was lowered through theoretical sampling and comparative analysis (interviews with multiple participants followed by systematic comparison of responses). These steps helped to maintain and/or improve the quality of data as provided by participants in the fisheries action scene.

Table 10: Data Collection Sources for the Sample (Theoretical Sampling) in Tanzania and UK/EU

Area/location	Interviews	Observation and other sources*	Total
Tanzania	195	12	207
UK/EU	5	18	23
Total	**200**	**30**	**230**

Source: Author's fieldwork. * Official emails & website/internet data.

Table 11: Number of Sampled Participants in Tanzania and UK/EU

No.	Region	Regulators	Industry experts (researchers & suppliers)	Processors, traders (importers/exporters), distributors	Small scale fishers/ traders
			Tanzania Marine Fisheries		
1	Dar es Salaam	10	11	5	31
2	Zanzibar	5	3	-	7
3	Tanga	7	2	1	18
4	Kilwa	4	2	2	11
5	Mafia	3	2	1	5
6	Bagamoyo	1	6	-	4
7	Lindi	4	-	-	5
8	Mtwara	4	-	1	10
9	Dodoma	4	-	-	-
			Tanzania Freshwater Fisheries		
10	Mwanza	5	4	3	26
			UK/EU Marine Fisheries		
11	UK	5	2	7	-
12	EU	2	2	5	-
Sub-totals		**54**	**34**	**25**	**117**
Total				**230**	

Source: Researcher's own data.

To illustrate, one interviewee at the Dar es Salaam main fish market told the researcher that there was a relatively robust system for traceability of revenue collection and control activities at the market (i.e., the 3% levy charged on sales of fishers' landed fish catches). When the interviewee was asked for a review of some revenue reports, the interviewee said these could not be shared by themself, but possibly by their boss who worked at a location very far from the market. A few days later, the researcher undertook observations at the market floor where fish were sold entirely on a cash basis. It was observed that there was, in fact, no consistent revenue recording, as market agents collected fish sales levies and pocketed the money in their coats while only intermittently issuing receipts. This largely manual revenue collection system led to traceability problems, as it was clearly possible that some agents could hand in or deposit less cash than the actual amount collected. Therefore, the interviewee had engaged in 'properlining' by talking about what ought to be done rather than what was actually done, and tried to conceal information (i.e., 'vaguing-out') so that they did not have to provide revenue reports. This subsequent observation explained the motivation behind the interviewee's hiding of the truth. In addition to interviews, data was also derived from observations and analytics on web-based electronic materials (see Tables 10 and 11). Soon after the preceding data collection, there followed the 'open coding' process as explained in the next section.

3.2.3.2 Open Coding

The first step in extracting data from transcripts is called 'Open Coding.' Open coding is an unguided GT analysis process whereby the data from the transcripts was first broken down into multiple pieces with derivable meanings which reflect what is going on in the fisheries action scene (i.e., the generation of conceptual incidental indicators, CIIs). These CIIs were next transformed into multiple memos, these memos being aggregations of CIIs (i.e., a body of data with similar or mixed conceptual meanings). Then, these aggregated CIIs (i.e., memos) with similar meanings were grouped into codes and these codes aggregated further into higher order themes/categories (Belgrave & Seide, 2020; Glaser, 1978, 1992). Therefore, while a memo might contain CIIs with mixed or different meanings from one or more data transcripts, codes and themes/categories were constructed from aggregated CIIs (i.e., memos) with similar meanings. As such, CIIs with different meanings in a memo were distributed across multiple concepts (i.e., codes and themes/categories) to which they derived similarity. The 'words' that form 'codes' or 'themes/categories' are constituted by verbs and/or gerunds. A gerund is a verb that ends in *-ing* to signify an action noun in GT for which describes what is going on in action scenes (Glaser, 1996) (Glaser, 1978, pp.93-113). Examples of gerunds include 'positioning', ‘strategising’, ‘manipulating’, ‘dominating’, and ‘fishing’ being respective gerunds for position, strategise, manipulate, and fish, verbs. To stay focused and derive verifiable codes that capture what is going on in the action scene, the following questions were asked of the collected data (Glaser, 1978, 1992): *(i) What is this fisheries data a study of? (ii) What category or property/dimension of a category, of what part of the emerging theory, does this incidental indicator relate to in fisheries? (iii) What is actually happening in the fisheries data – in terms of ongoing social processes or actions that resolve the main concern of participants in fisheries?* Therefore, ‘open coding’ is an ‘incident by incident’ coding of the transcripts and memos to come up with theoretical concepts (codes) that characterised meaningful elements of the problem being investigated (Glaser, 1992). This stage of ‘open coding’ was the first of two successive steps in the GT substantive coding process, the second being ‘selective coding’ (see next sub-section). Emergent substantive core categories can take one of two forms: (i) a basic core category, and (ii) a Basic Social Process (BSP) (Glaser, 1978, pp.96-100). According to (Glaser, 1978), a basic core category is that category that relates most to other categories and their properties, and as such, it accounts for most variation in what is going on in the action scene (i.e., the main problem or concern in the substantive area). A BSP is a special type of core category, which differs from other core categories, in possessing two properties of (a) being processual (having two or more emergent stages); as well as (b) being subject to change over time. A BSP is usually formed or represented by a gerund. (Glaser, 1978, pp.93-113). As explained before, these BSPs are special representations of phased or staged processes which embody constant change over time in action scenes. As presented in the results section, this current GT study generated a core category in the form of a gerund BSP called Fishmining.

3.2.3.3 Selective Coding

During the preceding ‘open coding’ process, a point was reached where repetitive CIIs would emerge signalling that no new conceptual meanings are being added, and that the coding process would slow down. These signs suggested the attainment of saturation point (Glaser, 1978, 1992). At this point the open coding process stops, and selective coding begins. According to Glaser (1992), selective coding is a process which only occurs after the emergence of a core category (in the case of this study, the Fishmining BSP) and concentrates on the saturation of this emergent core category and related concepts including its dimensions/properties. Concepts or codes not closely related to this emergent core category are dropped or set aside for the moment.[47] This is achieved by carrying out a critical review through more theoretical sampling and constant comparing of the core category, its constituting or related concepts, as well as its CIIs.

3.2.3.4 Theoretical Coding

A theoretical code is a hypothetical conceptualisation of how empirical or substantive codes (i.e., open and selective codes, categories, and their related properties) relate to each other (i.e., a relational hypothesis). The theoretical code therefore begins the process of integrating the substantive codes into a theoretical GT framework (Glaser, 1978, pp.55&72). There are numerous theoretical codes which Glaser (1978) has grouped together into several families. Of these, the following eleven coding families (Table 12) appeared to have relevance to the current study.

To illustrate the application of these theoretical codes, Glaser (1978, p.55) provides two substantive or empirical codes which emerged from a hospital intensive care unit as ‘social loss’ and ‘attention.’ Glaser (1978) suggests that the above two substantive/empirical codes can be theoretically coded into a relational hypothesis using the theoretical codes ‘cause’ and ‘degree’, where ‘cause’ is based on ‘degree’, thus: *the higher the social loss, the more the attention received by nurses.* Theoretical coding is otherwise termed ‘axial coding’ in non-classic GTs (Glaser, 1992, p.61; Julmi, 2020; Strauss, 1987). Therefore, the established connections between substantive concepts result in the formation of new and original ideas, hence the grounded integration of GT (Glaser, 1978). As presented in the results section, these theoretical code families were adapted to generate a theoretically predictive statement for the current study’s emergent Fishmining BSP GT, which connected the identified problems. These problems are the lack of trust and credibility among fisheries stakeholders and the inadequacies in public institutional governance of the fisheries resources.

[47] Incidental indicators and concepts unrelated to the core category can be referred to later by the researcher (if so desired) for analysis and development of another separate GT from the main one presently carried by the core category.

Table 12: Selected Coding Families of Theoretical Codes

Coding Family	General Usage and Relevance to the Current Study
6 C's	These are causes, contexts, contingencies, consequences, covariances and conditions. These appeared relevant to provide explanations for answering the GT question about "what is going on" in the fisheries sector.
Process	Stages, staging, phases, phasings, progressions, passages, gradations, transitions, steps, ranks, careers, orderings, trajectories, chains, sequencing, temporaling, shaping and cycling. For instance, current study's emergent Fishmining BSP GT has 3 processes: *hidden planning, unclear/uncertainty*, and *clear/visible.*
Degree	Limit, range, intensity, extent, amount, polarity, extreme, boundary, rank, grades, continuum, probability, possibility, level, cutting point, critical juncture, statistical average (mean, medium, mode). These were used to capture the degree to which the fisheries sector achieved sustainability, regulatory compliance, etc.
Dimension	Dimensions, elements, division, piece of, properties of, facet, slice, section, portion. These capture notions of the whole being broken into parts, e.g., categories making up codes and incidental indicators (slices of data). Also, relevant to 3 processes of Fishmining BSP GT as presented above.
Strategy	Strategies, tactics, mechanisms, managed way, manipulation, manoeuvrings, dealing with, handling, techniques, ploys, arrangements, dominating, positioning. These appeared relevant to the fisheries sector, e.g., how the rogue actors manage or coordinate unsustainable fishing operations in a hidden planning manner.
Interactive	Mutual effects, reciprocity, interdependence. These terms captured level of interdependence and responsiveness between actors in the fisheries sector. For example, opportunistic rogue actors undertook unsustainable fishing practices in response to existing poor institutional governance of fisheries resources.
Culture	Social norms, social values, social beliefs, social sentiments. These cultural aspects or dimensions would in some way affect the main concern in the fisheries sector as data were sourced from places with different cultures: Tanzania and UK/EU. Also, some Tanzanian fishers believed illegal/unsustainable overfishing (e.g., by dynamite) was legitimate based on their socio-cultural backgrounds.
Consensus	Clusters, agreements, contracts, conflict, differential perceptions, cooperation, non-conformity. For instance, rogue actors cooperated or agreed in secrecy to undertake unsustainable fishing practices that conflicted with public interests.
Mainline	Social control (keeping people in line), socialisation (training people for participation), social organisation (organising people in groups), social order (keeping the organisation of life working normatively). For instance, fishers complained that they were excessively controlled as they were denied freedom to effectively participate in setting relevant policies and laws/regulations in fisheries.
Theoretical	Parsimony, scope, conceptual level, fit, relevance, modifiability. For instance, the study's emergent Fishmining BSP GT attained parsimony with 3 processes namely *hidden planning, uncertainty*, and *clear/visible.*
Models	This is about presenting diagrams or pictures of a conceptual flow or connectedness of substantive codes, thus a theoretical coding. For instance, diagrammatic models were used to present the emergent Fishmining BSP GT.

Source: Adapted from Glaser (1978).

3.3 GT Results of Stakeholders' Consultations

3.3.1 Background

To present the results, this GT analysis adopts a bottom-up approach by initially explaining and illustrating the conceptual incidental indicators (CIIs) that emerge first from the transcripts. However, the reader is hereby advised to expect some form of overlap of interpretation between these CIIs and their respective groupings (i.e., the emerging different conceptual themes or codes). Along with the identification of each of these concepts, a theoretical description will be provided. This will be followed by contextualised illustrations from the fisheries substantive area (i.e., action scene). These CIIs will be subsequently conceptualised and grouped into representative thematic concepts (codes and categories) according to their similarity. Following this will be the identification of the core category, that is, a category with most CIIs representing the main concern/problem facing stakeholders in the fisheries sector. The next stage will be to determine whether the emerging core category constitutes a Basic Social Process (BSP) as defined elsewhere in the current study. As the reader will notice, identifying the BSP is a critical step towards the generation of an emerging Substantive Grounded Theory (SGT). In each of these cases (i.e., the presentation of CIIs and the formulation of the BSP), illustrative Figures and Tables will be presented to help clarity and understanding.

3.3.2 Emerging Conceptual Incidental Indicators

Table 13 below presents a frequency distribution table for this study's derived 634 conceptual incidental indicators (CIIs). At this point, no new CIIs emerged from addition and further analysis of the data through the GT processes of theoretical sampling and constant comparative analysis – a state known as full analytical saturation or 'full interchangeability' (Glaser, 1978, 1992). The CIIs frequency of occurrence table is presented in two parts: the first represents those CIIs that are favourable to the sustainable development of the fisheries sector in terms of plans and actions. The second part is about unfavourable CIIs that are indicative of unsustainability practices that worsen or hinder the sustainable development and commercial scaling-up of the fisheries sector. The overall finding (Table 13) is that favourable CIIs accounted for 24% only of all indicators; and these were thematically grouped into and represented by the categories of Democratising Governance, Sustainable Fishing, and Socioeconomic Contribution. On the other hand, 76% of CIIs were unfavourable and were thematically grouped under the categories of Trust Loss and Governance Loss. This suggests that three quarters of what is going on in the action scene mitigates against sustainable practices.

Table 13: Conceptual Incidental Indicators (CIIs) Collected into Higher Order Categories - Frequency Distribution Table

Category	Code	CIIs frequency of occurrence	Percentage (%)
Positive/Favourable Conceptual Incidental Indicators (CIIs):			
Democratising Governance (DG)	Regulatory Enforcement	26	4.1%
	Human Capital	20	3.2%
	Participatory Representation	17	2.7%
Sub-Total: Democratising Governance (DG)		*63*	*10.0%*
Sustainable Fishing (SF)	Fishing Operations	13	2.0%
	Surveillance Routines	9	1.5%
	Fish Quality	9	1.5%
Sub-Total: Sustainable Fishing (SF)		*31*	*5.0%*
Socioeconomic Contribution (SC)	Levies Payment	25	3.9%
	Foreign Aid	13	2.0%
	Fish Sales	20	3.1%
Sub-Total: Socioeconomic Contribution (SC)		*58*	*9.0%*
Sub-Total: Favourable CIIs		*152*	*24.0%*
Negative/Unfavourable Conceptual Incidental Indicators (CIIs):			
Trust Loss (TL)	Human Undercapitalisation	40	6.3%
	Technology Gap	44	7.0%
	Traceability Inadequacy	42	6.6%
	Non-Cooperatised Fishing	52	8.2%
	Unbanked/Underbanked Fishing	36	5.7%
Sub-Total: Trust Loss (TL)		*214*	*33.8%*
Governance Loss (GL)	Data Corruption	31	4.9%
	Political Manipulation	34	5.4%
	Policy Confusion	45	7.1%
	Prohibitive Regulation	33	5.2%
	Corrupt Survival	20	3.2%
	Resources Unaccountability	25	3.9%
	Resources Profiteering	35	5.5%
	Globoverfishing	29	4.5%
	Petty Disguise	16	2.5%
Sub-Total: Governance Loss (GL)		*268*	*42.2%*
Sub-total: Unfavourable CIIs		*482*	*76.0%*
Overall Total		634	100.0%

Source: Researcher’s own Table.

Thematic analysis of the data (CIIs) emerging from the GT process (Caulfield, 2022; Chapman et al., 2015; Floersch et al., 2010) revealed variations between freshwater and marine fisheries sub-populations at the (conceptual) level of emerged themes (codes and categories) (Table 14, Appendix A3). In overall terms, marine fisheries appear to be more unsustainable (CIIs=68%) than freshwater fisheries (CIIs=32%). This huge variance in the levels of unsustainability suggests the existence of significant quantitative differences in the type of unsustainability going on between the two sub-populations of marine and freshwater fisheries. This suggests the existence of near universal resource profiteering happening in the marine context, but little of this in the freshwater context.

Table 14: Frequency Distribution of Unfavourable Conceptual Incidental Indicators (CIIs) Variations Between Freshwater & Marine Fisheries

		Freshwater & Marine	Freshwater fisheries		Marine fisheries	
Categories	Codes	Total CIIs	No. of CIIs	% of CIIs	No. of CIIs	% of CIIs
Trust Loss (TL)	Human Undercapitalisation	40	4	10%	36	90%
	Technology Gap	44	12	27%	32	73%
	Traceability Inadequacy	42	22	52%	20	48%
	Non-Cooperatised Fishing	52	20	38%	32	62%
	Unbanked/Underbanked Fishing	36	16	44%	20	56%
Sub-Total: Trust Loss (TL)		*214*	*74*	*35%*	*140*	*65%*
Governance Loss (GL)	Data Corruption	31	7	23%	24	77%
	Political Manipulation	34	11	32%	23	68%
	Policy Confusion	45	19	42%	26	58%
	Prohibitive Regulation	33	9	27%	24	73%
	Corrupt Survival	20	8	40%	12	60%
	Resources Unaccountability	25	8	32%	17	68%
	Resources Profiteering	35	4	11%	31	89%
	Globoverfishing	29	7	24%	22	76%
	Petty Disguise	16	6	38%	10	62%
Sub-Total: Governance Loss (GL)		*268*	*79*	*29%*	*189*	*71%*
Overall Total-Unfavourable CIIs		**482**	**153**	**32%**	**329**	**68%**

Source: Researcher's own Table.

These differences could possibly be a result of Tanzania's freshwater fisheries, especially Nile Perch production and exports into the EU markets, being subjected to more strict quality and sustainability requirements than marine fisheries (URT, 2016, 2020b). Also, marine resources are relatively larger in size with huge sea expanses, hence more challenging and costly to protect against unsustainable fishing practices than is the case for freshwater fisheries (URT, 2020b).

Therefore, it is reasonable to assume that these differences in sub-populations of freshwater and marine fisheries are quantitative rather than qualitative, that is, the same concepts arose in each sub-population but with different frequency. As such, if GT analyses were undertaken separately on each of the sub-populations of marine and freshwater fisheries, they would possibly have resulted in similar core categories and GTs.

In the next sections, in-depth contextual explanations are provided on the emergent two problematic themes (categories) of Trust Loss (TL) and Governance Loss (GL). The detailed aggregation of CIIs into these two themes/categories will be provided and explained in the sections following. These will include details of their respective constituent codes, as well as their associated conceptual meanings (CIIs), considering the identified variations between freshwater and marine fisheries.

3.3.2.1 Trust Loss (TL) Category

TL is constituted by codes built from CIIs that represented the lack of and/or inadequacies of trust- and credibility-enhancing mechanisms. The codes forming TL are Human Undercapitalisation, Technology Gap, Traceability Inadequacy, Non-Cooperatised Fishing, and Unbanked/Underbanked Fishing. Human Undercapitalisation represents conceptual incidental indicators (CIIs) that portray the lack of credibility, trust, skills, productivity, and creativity qualities in human capital resources, hence failing to transform unsustainability problems in fisheries resources into sustainable and commercially scalable opportunities. As such, Human Undercapitalisation involves failures of people or actors, individually and/or collectively, to exercise creativity and innovation to sustain, scale up and develop the fisheries sector. This implies the inadequacy of innovative thinking (i.e., mindset) by actors to transform existing potentials or problematic circumstances in the fisheries sector into exploitable or realisable and scalable opportunities. As such, these human capital resources cannot be reliably trusted as capable to improve the unsustainability of fisheries resources. Technology Gap is about the abuse or misuse of advanced fishing technologies to overfish or use other forms of illegal and unsustainable fishing, hence failing a trust and credibility test in lucrative markets like the UK/EU that emphasise sustainable fishing methods. Technology Gap also means limitations in fishing technology, especially by small-scale Tanzanian fishers, thus limiting their ability to access richer deep-sea fisheries resources. Traceability Inadequacy means the inability of customers at various points in the supply chain, to access the seafood provenance – the information on the sustainable sourcing and quality aspect of the fisheries products, thus potentially risking the health safety of consumers. This limitation in seafood provenance lowers the potential trust and credibility that these customers would place on the suppliers of the fisheries products. Non-Cooperatised Fishing is defined as the lack of collective coordination, trust, and credibility among actors in fisheries, including the weak or non-existent fishers' cooperative entities, for enhancing quality production and marketing of fisheries products. Unbanked/Underbanked Fishing represents a situation where actors in fisheries such as fishers are considered by suppliers of investable resources like commercial banks and insurance companies as too risky and untrustworthy to do business with, hence resulting in limited access to financial products like loans for their commercial scaling-up of fishing activities. Under the TL category, incidences (i.e., CIIs) of unsustainability were higher in marine fisheries (65%) than in freshwater fisheries (35%) (Table 14 & Appendix A3), but the same CIIs were present in each subgroup. The concepts under TL are thematically derived, defined, elaborated, and illustrated below as they emerged from conceptual memos based on stakeholder interview responses.

Human Undercapitalisation

Human Undercapitalisation was found to be problematic in Tanzania but not in the UK/EU (Figure 11). Incidences (i.e., CIIs) of unsustainability from this problem appeared to be extremely challenging in marine fisheries (90%) relative to freshwater fisheries (10%) (Table 14 & Appendix A3). One stakeholder from government at the Tanzania Fisheries Corporation (TAFICO) had this to say:

"…during the late 1980s up until the 1990s, TAFICO was operational with a couple of seagoing fishing vessels and ready local and foreign fish markets, especially in Japan. Around the 1990s, the government ordered the cessation of TAFICO fishing operations following pressure from the IMF and the World Bank for it to be privatised. This happened even though TAFICO was making profits and so it was not being a burden to the public resources. Eventually, TAFICO did not get a buyer, and so the government has decided lately to take it back and recapitalise it for commercial deep-sea fishing. This happens after a loss of over 20 years based on badly thought decision to privatise it." (Interviewee TZ101, Tanzania, 2019).

It was also noted that further sizeable investments were made largely by Norway followed by Japan at Mbegani Fisheries training facility near Bagamoyo (to the north of Dar es Salaam). But the conspicuous problem relates to mismanagement and failure to maintain and grow these investments sustainably. An interview with one stakeholder who in 2019 worked at the Mbegani institute revealed the following:

"This [Mbegani] facility was a national centre of excellence in marine fishing knowledge and practice. It was able to deliver consistently and effectively a weekly minimum of ten tons of fish using its marine vessel [MV Mafunzo] over 20 years of its operations. These were subsequently kept in cold storage facilities, processed right there, and sold to the public. Our engineering section built quality boats which were also sold locally and across the border into east Africa. The fall began when internal power struggles to control the money from these investments started and intensified. Following the lack of trust among internal members, the [MV Mafunzo] ship was later commissioned to third parties [investors] through bidding procedures. As we speak now, the ship is docked out there for three years to-date in need of very expensive overhauls. The engineering section is now also like a museum of what happened then. Nothing is left of anything after 20 years of glory, just buildings, scrap metal and wood leftovers." (Interviewee TZ126, Tanzania, 2019).

Another classic illustration of the Human Undercapitalisation concept is that of fishers having a lot of cashflows between them and yet failing to collectively use this capital base for scaling-up their fishing activities. This has always been due to rampant mistrust that reigns among them, leading to their failure to undertake collective development initiatives. They instead keep blaming third parties, especially the government, for their underdevelopment. For instance, one stakeholder from one of the most active groups of fishers called *Chama cha Wavuvi Minazi Mikinda* (*CHAWAWAMI*) stated:

"We have a collective total of 72 boats and 3,222 fishers, say 45 fishers per boat. In 2019, we made monthly fish gross sales of about TZS250.0 million among us [UK£83,000 or US$107,500]. Despite these huge sums, members are unwilling to contribute more than TZS5,000.00 [UK£1.66 or US$2.15] per daily catch landings. These contributions are too small for achieving the modernisation of our fishing activities. We always keep our daily records intact, especially the sales levy that we pay to government agents at every morning fish landings. However, the government keeps harassing us, they do not take us seriously in terms of modernising our fishing activities." Interviewee TZ02, Tanzania, 2019.

If trust reigned between these fishers such that they pooled their revenues together, the money would have amounted annually to TZS3.0 billion (UK£1.0 million; or US$1.29 million). If well-coordinated and managed collectively, these funds are sufficient to achieve sustainable development and commercial scaling-up of fishing operations of these fishers with a fleet of under 100 fishing vessels. However, the lack of trust among members and limited entrepreneurial attitude/mindset appear to rank high as key derailing factors based on field interviews. Because they cannot organise and coordinate themselves, they have low credibility with potential resource providers namely the government and commercial banks.

Technology Gap

There have been regular reports of technology inadequacies, or misuse and abuse of technology, in fisheries supply and value chains. The Technology Gap was found to be problematic in both Tanzania and the UK/EU (Figure 11). While Tanzanian actors exhibited inadequacies through largely low-tech fishing equipment and means, actors in the UK/EU were mostly overfishing, thus misusing, or abusing their modern fishing technologies by fishing unsustainably. Historically, Tanzanian waters have always been rich in fish stocks, readily accessible by small-scale fishers using their traditionally low-tech boats and canoes. This primitive and inefficient fishing technology has been a factor for the ongoing under-exploitation of the fisheries resources as well leading to the inaccessibility of richer, deeper waters by Tanzanian fishers. These low-tech equipment operators were observed in action by the researcher during his fieldwork in Tanzania. Incidences of unsustainability (CIIs) from the Technology Gap problem were found to be higher in marine fisheries (73%) than freshwater fisheries (27%) (Table 14 & Appendix A3). One stakeholder in the fisheries research sector stated:

"The ongoing underdevelopment of the fisheries sector in Tanzania is a result of several complex challenges. In the past, our fishers used to get adequate catch volumes without much effort, just in adjacent shallower waters. This was possible even with the poor fishing gear, including wooden boats and even traditional canoes. But when the leading nations of the world came to our oceans to fish with advanced ships or through exports, our local fishers no longer catch enough fish. The problem is worsened by the fact that these small boats cannot make a catch in deeper waters." Interviewee TZ43, Tanzania, 2019.

The Technology Gap concept can also be demonstrated through illegal fishing practices by foreign fishing fleets in Tanzanian coastal waters. Interviews with staff at Tanzania's Zanzibar-based Deep Sea Fishing Authority (DSFA) revealed that the country does not have the modern technology and other accompanying resources needed for undertaking routine surveillance activities in the country's vast Indian Ocean marine resources. One of the interviewees said:

"We have a vast ocean rich in marine resources but as a country we have not been able to exploit even a tiny bit of it. DSFA has a limited routine of surveillance operations due to lack of adequate budgetary resources. But even these few budgetary resources have yielded good results as many foreign vessels have been caught in our waters and fined. One of [the] shortcomings in our work is the use of an outdated surveillance system called Vessel Monitoring System (VMS). This VMS helps with ascertainment of marine vessel's sailing speed, direction, and position of vessels. The system does not help with instant discovery of ongoing illegal, unregulated, and unreported (IUUs) practices being committed by the vessels at sea. This offers loopholes to foreign vessels to continue to commit IUUs unnoticed. Modern surveillance technology would help us very much to secure and sustainably exploit the country's deep-sea resources." (Interviewee TZ67, Tanzania, 2019).

Traceability Inadequacy

Traceability Inadequacy was found in both Tanzania and UK (Figure 11). In this study, traceability is the ability to access information about the activities involving sourcing and quality status of food items (like seafood/fishery products) along the food supply and value chains. Traceability is usually performed to ascertain a source of any possible health safety concern or credit. As explained further below under the Governance Loss (GL) category, results revealed that once fishers are let off the hook for illegal catches by authority agents or regulators – thanks to financial and/or material or in-kind bribes, the corresponding fish catches get incorporated, without trace, into the black market of fisheries supply and value chains. Under this problem of Traceability Inadequacy, the unsustainability indicators (i.e., CIIs) were found to be slightly higher in marine fisheries (52%) than freshwater fisheries (48%) (Table 14 & Appendix A3). A fish quality expert employed by government said:

"Ensuring fish and other perishable food quality for consumer safety is really a challenge in Tanzania. We conduct frequent surveys on this aspect and come up with many instances of chemical contamination during preservation to such a high degree that if we acted stringently, many fish and food businesses would be forced to close. This is where the traceability mechanism is needed, but the difficulty to act boldly would still render it ineffective. So, lenience

in food safety measures puts local and foreign consumers' health at risk, except for fish destined to Europe who require certified food safety tests before granting fish cargo entry permits." (Interviewee TZ05, Tanzania, 2019).

Challenges to implementing a robust traceability system for ensuring sustainable fisheries are not only confined to Tanzania or the developing world, but rather the whole globe. However, some fishing supply and value chain actors seem to prioritise quality of seafood for consumer health purposes over where it was sourced from (i.e., provenance), thus encouraging demand for fisheries products that are potentially sourced unsustainably or illegitimately. A UK expert with over 15 years in UK and European seafood supply cold chains stated:

"Today, traceability is still a buzzword in academic circles that has not gotten enough traction in the real business world. What the seafood industry emphasises is quality that meets all the necessary health safety standards for the consumer. While the illegally sourced catches may struggle to clear border checks into the EU as they lack credible papers on sourcing legitimacy, the same consignment could still get a good price in the black market if it met all quality tests, thus getting to EU consumers through other means." (Interviewee EU02, UK/EU, 2020).

Non-Cooperatised Fishing

It was found during stakeholder interviews that the government gave more support to agricultural cooperative systems than it did to the fisheries sector. For instance, each of the coffee, cotton, and cashew-nut sectors has a state funded board that oversees producer cooperatives to promote quality production and marketing, especially in export markets. Despite the economic significance of the fisheries sector, there has not been established a public/government agency in Tanzania for promoting quality production and marketing of fisheries/seafood products. This skewed sectoral development support happens without regard to the fact that the fisheries sector contributes far more export revenues than any single agricultural sector.[48] Although it is the fishers' legal right and responsibility to establish and nurture robust cooperatives to exploit local and foreign commercial opportunities, some stakeholders in fisheries thought the government has been less favourable to the sector relative to agriculture. As a result, the fisheries sector cooperatives remain weak or non-existent, leading to the sector's continued socioeconomic underperformance. These concerns were more

[48] For example, in 2019, the fishery sector alone earned the Tanzanian economy US$154.5 million in export revenues while the combination of coffee, tea and spices fetched US$181.6 million, see http://www.worldstopexports.com/tanzanias-top-10-exports/ accessed on Monday 5 October 2020.

prevalent among interviewees from Southern Tanzania marine regions (Coast/Pwani, Lindi and Mtwara). These occurrences were identified in the Tanzanian fishing environment only; and not in the UK/EU (Figure 11). The Non-Cooperatised Fishing had more indicators (CIIs) of unsustainability in marine (62%) than freshwater fisheries (38%) (Table 14 & Appendix A3). One of the interviewed leaders of fishers' group said:

"Since this country's independence and the time prior to that, many schools and learning centres were built in the north, north-west (lake zone) and the south-west (the southern highlands). This followed the colonial inherited cooperative systems in those areas where economically important agricultural commodities and livestock with high export potential were grown and farmed. These cooperatives enabled farmers and livestock keepers in those areas to build schools and educate their children. Later, these children occupied most decision-making positions in government, thus maintaining the skewed allocation of national developmental resources towards their home regions. The fisheries resources which are our main socioeconomic sector did not get this privilege during the colonial era and the government did not correct this imbalance after independence. Until today, the fisheries sector lacks a robust government supported cooperative system for promoting guaranteed product quality levels and marketing systems. We have been left out on our own. This will continue as we have fewer political and technical representatives in key areas of allocating national development resources because these are historically dominated by children of farmers and livestock keepers." (Interviewee TZ11, Tanzania, 2019).

The preceding interview memo details were constantly compared with other field data. It was found that fisheries cooperatives constituted only 1% of active cooperatives in Tanzania, while agricultural and financial cooperatives accounted respectively for 34% and 52% of active cooperatives in the country (Table 15). Fish processors and exporters constitute another group of interviewees who are not happy with the current situation in the fisheries sector. The lack of formal coordination among small-scale fishers constitutes a challenge in fisheries supply and value chains. Had fishers been in robust formal groups or cooperatives, processors would have hired them as credible and reliable fish collectors rather than hire costly agents who buy fresh fish from these uncoordinated fishers and resell expensively to the processors.

Table 15: Status of Registered and Active Cooperatives by Sector in Tanzania – February 2018

Type of cooperative	Total registered	Of which are active	% of active coops	% of overall coops activity
Agricultural crops & marketing (AMCOS)	3,338	1,806	54%	34%
Banks (Coop banks)	13	1	8%	0%
Mineral/mining	204	148	73%	3%
Livestock	207	100	48%	2%
Savings & Credit Societies (SACCOS)	5,737	2,782	48%	52%
Fisheries/fishing	85	38	45%	1%
Others	1,038	399	38%	8%
Total (or overall average)	10,622	5,274	49%	100%

Source: Adapted from field interviews and various sources of statistics.

One middle level manager in one of the major fish processors and exporters gave the following statement:

"As processors and exporters of fish products, we face numerous problems which appear to worsen by the day. Among these, is the unreliability of fishers who cannot formulate themselves as credible formal groups. Therefore, we pay more to buy most of our raw materials from specialised agents near the EU approved centres in Mafia, Kilwa and Rufiji. Small-scale fishers work mostly individually rather than in coordinated teams or groups. Some fisher groups would rather divide fish among themselves, and each go out to find buyers than market and sell their catches collectively. AlphaKrust tried in vain to advise the formation of formal fisher groups whereby the former was ready to supply the latter with fishing equipment and gear so that their catches could be sold automatically to AlphaKrust." (Interviewee TZ52, Tanzania, 2019).

Unbanked/Underbanked Fishing

The Unbanked/Underbanked Fishing problems were only exhibited by actors in the Tanzanian fisheries and not by those in the UK/EU (Figure 11). It was found that the problem of marine Unbanked/Underbanked Fishing exhibited higher levels of unsustainability (56%) than freshwater fisheries (44%) (Table 14 & Appendix A3). One stakeholder who was a leader of a vibrant marine fishers' group complained:

"Banks have always been there to support other sectors especially agriculture but not fishing. Even the government prioritises loan guarantees for agricultural and livestock-based activities – not fishing. I recently approached a bank for a loan to acquire one more fishing boat. When

they visited to verify and assess my business potential, they said they wouldn't accept my two boats which were currently operational as collateral, but they wanted an immovable and marketable house. I eventually failed to secure the loan. I gave up." (Interviewee TZ02, Tanzania, 2019).

Seeking corroboration of these assertions, views of practitioners in bank lending were sought. These interviews revealed the lenders' perception of actors in fisheries as being untrustworthy, thus classified as potentially high-risk customers. As a result, these fishers and operators in fisheries are often excluded financially because they fail to meet minimum collateral security requirements of the financial industry, such as re-saleable modern boats, credible business history (e.g., bank accounts and business records) and demonstrable basic business skills. The banking sector also appeared to admit their role in the current financial exclusion of the fisheries sector, especially small-scale operators. One operations manager at Tanzania's biggest bank by assets said:

"Bank lending to the fishing sector, particularly small-scale fishers, is quite low at present. The main reasons for this poor bank-borrower relationship are (i) credit mismanagement, (ii) lack of business knowledge and embedded risks, (iii) lack of bank's proper consultancy to borrowers, (iv) lack of financial discipline - diversion of funds to unplanned causes; (v) lack of proper market research by both bank and borrower. Eventually, any lending to most fisheries activities is regarded as extremely risky, which could potentially threaten banking operations and sustainability. So far, there has been no assuring mechanism that would enable the banking industry to limit the risks posed by the fisheries sector." (Interviewee TZ13, Tanzania, 2019).

Another stakeholder confirmed the unpredictability of the fishing operations due to dependence on natural factors, as well as the bad public image of fishers, in part resulting from government crackdowns on illegal fishing. This exercise entails taking custody of fishing equipment and gear, the assets base on which revenues should be generated to repay the loans. To illustrate, an assistant branch manager of a leading bank said:

"Lending to fishing and agriculture generally poses significant risks mainly due to the unpredictable nature of the activities – i.e., high dependence of natural conditions rather than predictable human performance. Therefore, most loans extended to this industry end up becoming unrecoverable debts, thus causing heavy losses to banks. The bank has been

incurring costly expenditure trying to engage third parties, usually auctioneers / debt collectors to help, although they are expensive. If there arose a solution to address this problem in a simple and cheaper mechanism, it would be advisable for the banks to adopt it. The bank has not had a good business footing with the fisheries sector, especially small-scale fishers. The sector is generally considered risky because it is always on the news especially in terms of government bans and destruction of fishing gear and equipment due to frequent illegal fishing activity. What if a fisher or a group of fishers take up the loan and end up in jail due to illegal fishing practices, or their fishing boat gets seized in the crackdown?" (Interviewee TZ18, Tanzania, 2019).

Another credit manager at a fast-growing commercial bank in Dar es Salaam confirmed the above issues, but also noted that fishers and other small-scale business operators are shunning bank accounts for depositing cash and managing their sales transactions. She said these small-scale operators do this, among other reasons, to hide their money from Tanzania Revenue Authority (TRA) who have legal powers to seize any bank accounts for tax purposes. This may be justified, especially where fishers have a lot of money in a bank without clear records on tax payments and clearance. She said:

"[There is] a culture of not depositing sales proceeds with banks for fear of them being seized and estimated for higher tax payments by Tanzania Revenue Authority (TRA). Fishers and other small-scale operators should organise themselves and establish a culture of building trust with third parties, especially banks. It should begin with doing away with informal and outdated practices of operating without business bank accounts. This is an area a bank would evaluate a client in terms of trust in their financial discipline. Fishers and small-scale operators should be able to tell how they spend their own money from daily cash flows before seeking extra funds in bank loans for furthering their fishing operations." (Interviewee TZ25, Tanzania, 2019).

Another challenge faced by fishers in Tanzania is limited access to insurance services to cover business risks associated with fishing operations One insurance expert gave the following quote:

"The fishing business in Tanzania is largely uninsured; and this is obvious with regards to small scale fishers. The insurance industry sees a problem in the nature, quality and standard of fishing vessels used by these fishers. They are all low-tech and wooden. We are giving cover

to vessels with obvious risk of going under; and this certainty of risk disqualifies any offering of insurance policy. Uncertainty of risk, which could open fishers' access to insurance products and services would require the fishers to operate modern or hi-tech fishing boats or vessels. The working model would be for them to get reliable fishing vessels through bank guarantees or facilities, and then, as insurers we would cover these assets in the names of the lending banks. Cover policies in fisher group names would follow ownership transfer after the loans are fully repaid." (Interviewee TZ29, Tanzania, 2019).

3.3.2.2 Governance Loss Category

Governance Loss (GL) is characterised by CIIs with such properties as taking advantage or exploiting institutional governance loopholes in the fisheries sector to drive and make gains from unsustainable fishing practices. GL is constituted by the following basic concepts: Data Corruption, Political Manipulation, Policy Confusion, Prohibitive Regulation, and Corrupt Survival. Other basic concepts under GL are Resources Unaccountability, Globoverfishing, Petty Disguise, and Resource Profiteering. GL begins with Data Corruption, which means the purposeful data misrepresentation to hide rogue actors' bad intentions that drive unsustainability in fisheries. This data misrepresentation leads to sub-optimal political decisions (Political Manipulation) and misguided policy formulations (Policy Confusion). These poor policies generate bad regulations that inhibit, rather than facilitate, sustainable fisheries operations (Prohibitive Regulation). Put together, this long chain of governance loopholes provides a window of opportunity that is exploited by rogue actors to the maximum. Included here are behaviours of unaccountability by some corrupt and irresponsible custodians and managers of fisheries resources (Corrupt Survival and Resources Unaccountability). Ultimately, this opens a way for syndicated rogue actors to prioritise their private short-term gains at the expense of long-term public benefits through overexploitation of fisheries resources. These actions include Globoverfishing (i.e., unsustainable fishing practices undertaken everywhere, especially in Tanzanian waters, by both local and foreign actors), Petty Disguise (i.e., disguising profitable fisheries business as small or unprofitable to pay lower taxes/levies) and fisheries resource profiteering (driving excessive illegal gains from fisheries overexploitation). These basic concepts do have overlaps. Indeed, there are instances when some of these concepts are combined to present illustrations more clearly about what is going on in the fisheries sector. Overall, the GL category exhibited more incidences (CIIs) of unsustainability in marine fisheries (71%) than freshwater fisheries (29%) (Table 14, Appendix

A3). The constituent basic concepts of GL are explained in depth below, in illustrative text, Figures or both.

Data Corruption

These problems of manipulating or misrepresenting official fisheries data to suit the intentions of networks of rogue actors rather than depict the real picture of what is going on in the sector were identified with actors in Tanzania alone, not in the UK/EU (Figure 11). The Data Corruption problem had more incidences (CIIs) of unsustainability in marine fisheries (77%) than freshwater fisheries (23%) (Table 14 & Appendix A3). It was observed by the researcher that when fishers landed their catches, others would unload the fish and move them to the waiting crowds of buyers awaiting auction procedures.[49] Nowhere during the observations could the catches be weighed, and measurements taken for official records. Regarding this, one of the interviewed staff at the Dar es Salaam-Magogoni Main Fish Market observed:

"…when the Government of Japan handed this main fish market over to the Government of Tanzania in 2000s, it was a fully-fledged facility, with functioning weighing scales for incoming/inbound and outgoing/outbound fish cargoes. However, it was not long before these scales were dismounted and kept in store. As we speak, nothing is measured and recorded here, whether the landed catches or fish coming in from Mwanza or Kilwa by road…" (Interviewee TZ33, Tanzania, 2019).

Another interviewee at Msasani landing site in Dar es Salaam had similar views, thus:

"…that room over there had a weighing scale installed for measuring weights for fish catches here before they could go out to the market. However, the equipment became unusable later and needed repairs that were offered intermittently. Eventually, officers from the district council came over and dismounted it and carried it away. It had never been returned to-date and no weighing of fish catches is done currently." (Interviewee TZ37, Tanzania, 2019).

[49] It is debatable as to whether this is the most appropriate way to set stable prices for fishers. While some fishers favoured it during interviews, huge price fluctuations have been observed, mostly unfavourable to the fishers. For instance, price for a bucket of *dagaa* (small-sized Sardine species) would fall from a height of TZS80,000/- (say US$35/-) to under TZS15,000/- (say US$6/-). This happens when fish supplies surge while fishers have nowhere to keep them (i.e., lack of cold storage facilities), thus fire-selling at low prices to avoid imminent post-harvest losses.

Asked about the low contribution of fisheries to national GDP (1.7% in 2019), one stakeholder quipped:

"…Charles, where did you get that figure? We have never seen any government official come to us the way you have done and introduce themselves as collectors of fish catch statistics or volumes; and we are the most active and productive fishers here in Dar es Salaam. Can you tell me any agricultural commodity that generates more money for the government daily than levies on our landed fish catches at every site? Maybe you need to visit the Dar es Salaam [Magogoni] fish market one early morning so you can see for yourself. Our fishing activities contribute far more to the economy than what you are telling us." (Interviewee TZ01, in Tanzania, 2019).

One middle management officer in the statistics department of the government institution dealing in marine fisheries also expressed doubts on the accuracy of the officially reported GDP contribution of the fisheries sector. He said:

"...when you go to any typical fishing site across the country you will find it full of people...possibly more people than you would find at other agricultural market gatherings. What are they doing there every day? They are buying and selling fish...and cash is changing hands constantly. If they made losses, they wouldn't be there every morning...and they are paying government revenues every day as well. I have not seen a sector as vibrant as the fishing sector, yet TBS [Tanzania Bureau of Statistics] would keep reporting the fisheries as insignificant contributors to national economy." (Interviewee TZ78, Zanzibar, Tanzania, 2019).

The preceding memos on data misrepresentation were constantly compared with existing 2019 official statistics and reconstructed interview data and estimates for the marine fisheries in 2019. There were indications of data corruption/misrepresentation when 2019 official total annual marine fisheries output was recorded at 60,997 metric tonnes (valued at TZS 287 billion) (URT, 2019), while reconstructed figures for 2019 based on interviews with marine fishers amounted to 615,000 metric tonnes (valued at TZS 2,375 billion) (see Figure 7 below). These indications of fisheries data misrepresentation are consistent with the government's admission that most of landing sites on both marine and freshwater fisheries, especially those in remote rural areas, are not frequently visited by fisheries officers to collect fisheries data and revenues like levy on fish sales (URT, 2018, 2021). As presented in Figure 7, the preceding calculations suggest that Tanzania's official marine fisheries statistics are extremely underreported and misrepresented by accounting for about 10% only of actual output and about 12% only of the actual value.

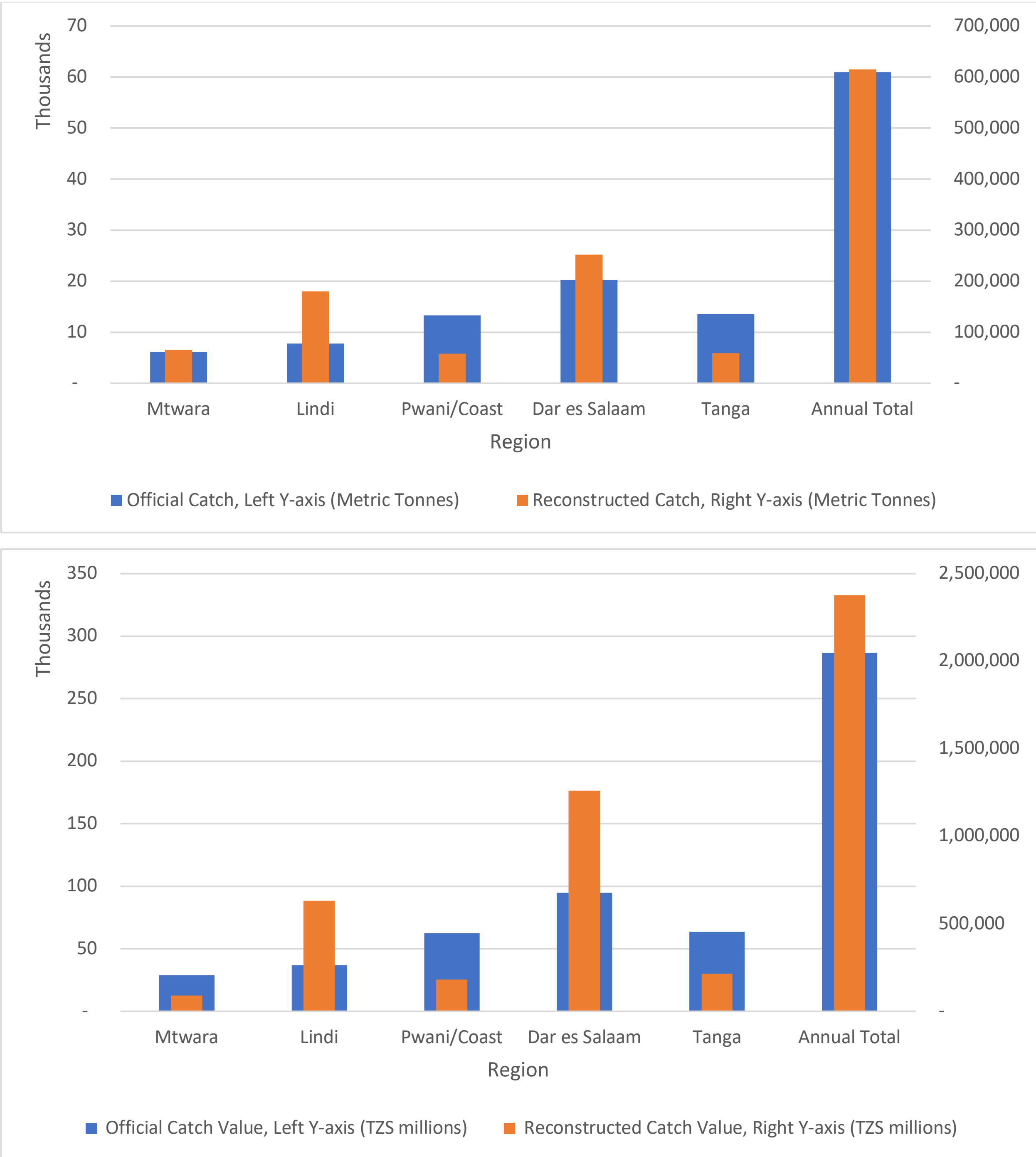


Figure 7: Comparing Tanzania's Official Fisheries Statistics & Reconstructed Marine Fisheries Data for 2019

Source: Researcher's own Calculations and Figure.

Local government staff at fish landing site auctions were usually seen taking note of final prices to establish levies[50] payable by fishers. The environment at the auctions was so chaotic that some fishers could possibly have slipped away without paying the levies, or these payments could have been made with some form or irregularities including without records. One leader of a prominent fishers' group in Tanga had this to say:

"…we had a couple of disagreements with one of the levy collectors who had a habit of harassing us to pay more than necessary. One day we decided to go to his boss so we could report him at the local authority. We were armed with records from our daily register. On arrival, we requested the boss to cross-check our levy payment records against the local government's database. To our surprise, we found that for one day when we recorded in our register to have paid TZS345,000/- in levy payments, the records at the local government showed it to have received TZS26,000/- only. The boss' reaction in the days that followed was to switch the responsible levy collection officer to other duties and replace him with another staff. He was not suspended at all." (Interviewee TZ81, Tanzania, 2019).

When asked why they were not keeping records of daily catch volumes and the corresponding government levy collections, one of the statistics supervisors at one of the main fish markets in Tanzania responded:

"…I don't do what my boss doesn't ask me to do; he only wants me to send him daily figures of levy collections. I understand that some things here are not proper regarding data, but I cannot go beyond what my bosses require me to do. Periodic fisheries data are compiled and reported based on estimates rather than real daily catches. Maybe I will be able to undertake this task when I write my master's dissertation…" (Interviewee TZ102, Tanzania, 2019).

Political Manipulation, Policy Confusion, Prohibitive Regulation & Corrupt Survival

These four basic concepts (i.e., codes) represent processes that encouraged or facilitated unsustainable fishing practices, whether at local, regional and or global level. The Political Manipulation concept is closely related to the concepts of 'Policy Confusion', 'Prohibitive

[50] Local government authorities charge fishers instant levies ranging from 3-10% on fish sales. This has been a matter of contention, as fishers seek a harmonisation of the rate nationally to create uniformity and limit congestion of fish catch landing vessels at stations charging lower levies. While the government policy caps the rate at 5%, some councils appear to have been able to charge varying rates over or under this provisional rate.

Regulations', and 'Corrupt Survival' because in practice, political manipulation often uses these other processes to achieve its ends. Policy Confusion and Prohibitive Regulations represent CIIs that capture policies and regulations that contain loopholes that allow regulators and other actors to make illegal personal gains in fisheries despite constraints embodied in the broader policy. Policy Confusion also captures CIIs about ill-informed policy due to use of unrealistic data (hence the term policy confusion). Prohibitive regulations capture CIIs that depict restrictive rather than facilitative regulations. These shortcomings may happen accidentally; but there is also a chance of them occurring by design. This happens when rogue actors do so with some potential opportunistic gains in mind, especially after their spotting of clear opportunities like loopholes in existing fisheries policies, laws, and regulations. Sometimes, these fishers and other actors in fisheries face constraints that force them to bargain for their freedoms, hence the instances of bribery or corruption. Such CIIs have been grouped and conceptualised as 'Corrupt Survival.' CIIs for Political Manipulation, Policy Confusion and Prohibitive Regulations were identified in fisheries actors and systems in both Tanzania and the UK/EU; while Corrupt Survival problems were identified in Tanzania only, not in the UK/EU (Figure 11). Those disadvantaged by these unfavourable occurrences (i.e., CIIs) are most fishers or small-scale operators, fish traders and processors who end up as victims at the hands of the few highly capable rogue actors or opportunists. Incidences of unsustainability (CIIs) were found to be higher for marine fisheries than freshwater fisheries as follows: in Political Manipulation (marine fisheries 68%, freshwater fisheries 32%), in Policy Confusion (marine 58%, freshwater 42%), in Prohibitive Regulation (marine 73%, freshwater 27%), and in Corrupt Survival (marine 60%, freshwater 40%) (Table 14 & Appendix A3).

During the January-March 2019 crackdown in Tanzania on IUUs, a lot of illegal fishing gear was destroyed including 8mm nets that were specifically used for *dagaa* fishing (small size Sardine species). This exercise was largely preceded by preparatory visits to fishers at landing sites by local political leaders who had promised fishers and other operators in fisheries of peaceful participatory engagements with enforcers. This occurred later to be a political trap or manipulation as it turned out that the fishers suffered property losses and physical injury resulting from punishments sustained during the crackdown operations. It is notable that *dagaa* are the cheapest type of fish and are almost 100% consumed by the low-income groups in society, who make up the majority. During the 3-month operation, this largest section of the society could not access these fish (i.e., *dagaa*) due to the banning of the 8mm fishing nets, and this triggered discontent that threatened the government. The government immediately initiated a process that involved Tanzania Fisheries Research Institute (TAFIRI) to quickly undertake marine experiments using three nets: 6mm, 8mm and 10mm. They ended up suggesting that it was okay to use 8mm nets for *dagaa*, revoking the previous ban. TAFIRI had in the first instance proposed the ban on 8mm nets on the scientific basis of the harm caused by the nets, only bowing to political pressure this time around from the elites in power. Despite the apparent disagreement between fishers and fishery experts on appropriate sizes of nets and other fishing gear, both sides agree that there has been no concerted effort to jointly work together towards resolving the conflicts. One fisher who was a victim of the crackdown complained as follows:

"These people [the government] are unpredictable. Their decisions are always impractical. You can't catch dagaa [sardines] with a 10mm net as its holes are too wide, so the small fish could escape easily. We had always been ready to go fishing with these officials so they show us how their prescribed fishing methods can be done practically but they don't invite us, they do it themselves and dictate to us what we cannot realistically implement. Whenever they need our votes, our political representatives always come to us with politically reassuring gestures or promises saying that bans on prohibited fishing gear including small-hole nets have been lifted. Once in power, they change their previous positions and start punitive crackdowns on us, thus inflicting heavy losses on our fishing businesses." (Interviewee TZ94, Tanzania, 2019).

In each of Tanzania's local government district, town, municipal and city councils, there has been established, by law, a Women, Youth, and Disabled Development Fund (WYDDF). This fund caters for low interest credit needs of small-scale operators such as fishers, livestock keepers, crop farmers and other entrepreneurs and producers identifiable as women and/or youth. However, almost all fishers interviewed appeared to not have any knowledge of the facility, let alone benefitted from it. One of the knowledgeable staff at the Ilala Municipal Council in Dar es Salaam (the largest debtor of the WYDDF fund in 2019) confirmed that political manipulation was largely to blame when he said:

"A lot of the money from this fund is lent out and not repaid, thus turning bad and/or irrecoverable. Political figures at these councils have been blamed on the dysfunctional nature of the scheme, as most loans are issued on political lines rather than on commercial terms, thus resulting by design into mass defaults and non-recoverability." (Interviewee TZ59, Tanzania, 2019).

One scientist who had participated in marine research leading to advising the government on the formation of regulation with respect to the use of the 6mm, 8mm and 10mm nets appeared to somehow agree with fishers' complaints regarding their exclusion in key processes leading to important regulatory and policy decisions. She observed:

"It is true that we had advised the government to ban 8mm nets and those below for catching sardine species (dagaa) as they lead to overfishing, particularly the catching of juveniles. However, as a public institution, we must follow the government directives as issued to us from time to time. These do sometimes result into reviewing and changing previous positions…. We also do not invite fishers as we undertake marine research because our scientific approach does not require them to be there to render more credibility to its results. My experience engaging with these small-scale fishers has not been good…they usually behave and present themselves as being so knowledgeable about fishing, even more so than us marine scientists. This behaviour puts me off when it comes to working together with them." (Interviewee TZ127, Tanzania, 2019).

Another illustration of the nature of political manipulation in respect of fisheries policy involves the targeting of fishers in areas dominated by opposition politicians. Some interviewed fishers gave impressions that they suffered more consequences from the government illegal fishing crackdown than peers in other regions where the ruling regime exercised more political control. They believed their economic and moral support to opposition politics is largely to blame. One interviewee from these victims was quoted saying:

"You know, we're the bravest and most successful fishers because we learned the skill from our ancestors. We come from Pemba and some of us are in Unguja [Zanzibar] and we have no other major socioeconomic activity than fishing. The government has never been serious to develop or support our fishing activities…so we chose to support opposition politics with every little resource we have. I think this punitive crackdown and targeted destruction of our fishing gear is a hidden government reprisal against our political orientation. If not the case, why fishers in Dar es Salaam and other ruling party strongholds did not suffer a similar fate while their fishing activities are larger in scale than us?" (Interviewee TZ132, Tanzania, 2019).

Other illustrations of unsustainable practices occur when fisheries policies and regulations are formulated in a manner that they are either impractical or difficult to follow. These tend also to confer discretional interpretation that is prone to potential abuse or exploitation by those undertaking enforcement or monitoring of compliance activities. Due to the low-tech nature of their fishing equipment, fishers find themselves operating without reliable and objective guidance such as that provided by the Vessel Monitoring System (VMS). The VMS helps with the monitoring of fishing activities at sea to ensure sustainable fisheries management. To make this happen, fishers need to have VMS compatible devices mounted on their boats so they can be monitored and be able to transmit data on their fishing activities. As almost all small-scale fishers do not have such devices, their fishing activities go unmonitored, hence creating loopholes or opportunities for them to undertake unsustainable fishing practices. Now, faced with such operational limitations, most fishers have resorted to committing illegal fishing acts, sometimes getting caught up in punitive situations. These are the circumstances that lead fishers to make quick choices between paying legal penalties which tend to be exorbitantly high or opt for paying bribes to these legal enforcers to buy their precious freedom. They would usually go for the latter option as it tends to be more affordable. To illustrate, the Tanzania Shipping Agencies Corporation (TASAC) penalty for overloading fishing boats with fishing hands (there is a maximum of 30 allowed) is TZS2.0 million for each fisher. Boats carrying 80 fishing hands are common. If caught, the owner of such a boat could be fined TZS100.0 million (say UK£33,000) which would likely be far more than the total investment made by an average boat owner. One owner with two operational fishing boats indicated his total investment in the range of TZS70.0 million (say £23,000.0). One regulator in the compliance monitoring role had the following to say:

"On the lack of clarity about allowable fishing depths, we usually advise fishers verbally that they must carry out fishing operations at sea locations with such depths one cannot see the sea floor. This is usually 50 metres and above, as interpreted from the laws and regulations – but also with some flexibility from bylaws set by implementing local governments. This is meant to ensure fishing nets are hung in the water without touching the seabed, which could endanger coral reefs and other marine natural habitats. But they must do this without the use of diving gear [oxygen cylinders, eye protector-masks, swimming flaps/shoes] as they may use it to commit illegal fishing activities. To limit this possibility, we only allow them 2 to 3 cylinders of oxygen for emergencies only on a boat of 30 fishers maximum; but we understand they are practically in a range of 50 to 80 fishers per boat when fishing out there. The law allows us to penalise them TZS2.0 million [UK£650] for any extra gas cylinder found with them and TZS2.0 [UK£650] for any extra fisher found on the fishing boat. However, although it is generally

public knowledge that many fishing boats carry between 70 and 80 fishers, there hasn't been much received by TASAC in penalty fines revenue." (Interviewee TZ135, Tanzania, 2019).

Another stakeholder interview settled on a potential occurrence of prohibitive regulation and corrupt survival concepts. There have been instances where clashes between law enforcers and fishers have resulted in deaths of fishers. Whenever apprehended and fined, or made aware of impending court cases against them, these fishers might then offer bribes to enforcement officials; literally being a more convenient and affordable way to buy back their freedom. Although these laws and regulations contain some provisions to protect consumers' health as well as preserve the sustainability of the fisheries resources, there remain loopholes in the governance of these resources that rogue actors capitalise upon. To illustrate, one of the interviewed fishers' group leaders gave the following quote:

"One morning we were returning to land our catch. As we passed that mini-island with a navy base, we were quickly surrounded with their armed boats and ordered to change course and move towards their camp. Our catches were abandoned rotting in the sun as we were interrogated as if we were illegal fishers. It later became unbearable, and we decided to forcefully break loose and leave with our boats. Gunshots ensued, one of us died and a couple more fishers sustained injuries from these gunshots. As we speak now, there is an ongoing court case relating to this incident which we consider as unsubstantiated fabrication case of illegal fishing. Other similar incidents in the past that involved surveillance officials would usually be settled unnoticed by people as we offered them baskets of fish and some cash." (Interviewee TZ22, Tanzania, 2019).

Political actors that take advantage of, and proceed to exploiting, the fisheries sector are not confined to Tanzania alone. This happens also in the developed world, including Europe where the UK provides a classic example. For instance, while the UK waters are generally considered among the richest in fishery resources within the EU, the former's fishers could be the unhappiest in the bloc. This is because UK politicians have, since the 1970s until the recently signed Brexit deal, been using its rich fishery resources as an expendable bargaining chip during its trade and economic negotiations with the EU.[51]According to Stewart & Carpenter (2021), one such political voice is the Scottish Seafood Association (SSA), whose representative

[51] See https://www.bbc.co.uk/news/46401558 on the Brexit deal with EU entered on 24th December 2020.

leaders complained recently in the media following the consequences of the signed Brexit deal on their members:

"The UK government has once again betrayed us…the new export custom procedures take longer [since the Brexit Deal] as checks cover the whole consignments and not samples as done previously… Documentation, especially export health certificates, constitute other time consuming and costly financial challenges, especially when multiple fish species and several [EU] destination ports are involved. We are now required to complete up to 71 pages of paperwork for every truck of fish entering the EU." (Analysed media interviews 01, UK/EU, 2021).

Globoverfishing as a Driver of Illegal/Unsustainable Fishing

Globoverfishing represents the practices of overfishing everywhere globally, but especially in Tanzanian waters, as undertaken by local and global rogue actors. In this study, Globoverfishing has been identified as problematic in both Tanzania and the UK/EU (Figure 11). This Globoverfishing problem exhibited higher incidences (CIIs) of unsustainability in marine fisheries (76%) than freshwater fisheries (24%) (Table 14 & Appendix A3). Globoverfishing drives illegal and unsustainable fishing practices in Tanzania in two major ways: directly and indirectly. Globoverfishing direct consequences occur when, for instance, foreign fishing trawlers overfish in or adjacent to Tanzanian marine waters. This drives down fish supply in local shallower waters, meaning that local artisanal fishers cannot obtain catches of sufficient value by legal means to meet their minimum requirements and are under pressure to fish illegally, such as catching juveniles or even dynamite fishing. The indirect consequences of Globoverfishing happen when, for instance, high international demand for fish drives overfishing in local fisheries. One stakeholder at Zanzibar-based Tanzania's Deep Sea Fishing Authority (DSFA) observed:

"Despite the resource challenges faced by DSFA, we have been able to identify and sometimes catch foreign fishing vessels especially from European countries and China that overfished illegally in Tanzanian marine waters. These activities have been driven by the rising demand for seafood in these countries, hence going out to overfish in global oceans. When these large global fishing vessels operate in Tanzanian waters, they reduce fish supplies for local fishers who operate in shallower waters, thus encouraging them to commit unsustainable fishing

practices like dynamite fishing to fulfil their normal catch requirements." (Interviewee TZ76, Tanzania, 2019).

According to one interviewee, who operated a seafood chain in England, Globoverfishing (local and global illegal and unsustainable overfishing) is likely to be on the rise. He one day witnessed these unsustainable fishing practices while out at sea with colleagues. On return from this adventurous fishing trip, he sat down with the colleagues and decided to close the seafood business, opting instead for vegan foods. This decision came after his team witnessed for themselves horrible scenes of unsustainable fishing practices at sea. He said:

"Our [UK] fish suppliers have been telling us that fishing is getting more costly, fish have been declining in the sea, and oceans getting even warmer – hence pushing the problem around through the norward movement of fishing activity towards cooler waters in Iceland, Norway, and the North Sea. While other people hear fishing stories on newscasts, we decided to go for a fishing trip, involving even diving to the sea bottom. We saw for ourselves murky and dirty sea waters, high degree of plastic contamination which forms part of what fish eat, and depleted fish stocks (mainly due to overfishing). We noted that the fishing business is a huge industry using massive trawlers and ships, taking large amounts of fish from the sea at astonishing overfishing rates. For instance, a recent report states that by now (July 2019) which is past mid-year, the EU has already reached and exhausted the required annual fishing quota for 2019…and what does this mean? It means fishing companies will have to move their overfishing activities elsewhere in the world…may be Senegal…may be Sierra Leone…and what will this mean to an average Sierra Leonian or Senegalese who depends on fish for livelihoods and family incomes? This will actually result in a fall of fish stocks in their waters, rise in prices at local markets, fall in protein intakes, poor health and quality of lives…hence continued poverty in communities." (Interviewee EU04, England/UK/EU, 2019).

Another colleague on the same fishing trip gave opinions which were far reaching in terms of what he thought was the explanation for these events:

"The UK Government, and actually the EU, are supporting the high street – the fishing businesses and the people involved, by turning a blind eye on illegal and overfishing activity. They do this because the fishing industry employs people, they pay taxes, and they stabilise prices through continued fish food supplies – though by way of illegal and unsustainable

overfishing. There is lack of strict regulations in the UK and EU for ensuring environmental conservation of marine fishing grounds. Strict adherence to sustainable fishing requirements would render closure of fishing grounds and fishing businesses, hence resulting in loss of jobs, rise in prices of fish foods, social disorder because of high fish food prices. This could ultimately threaten survival of the UK and/or even EU governments…. Most people in the UK/EU want cheaper and affordable food, and this is difficult to achieve or guarantee when stringent sustainability measures in the fishing activity are put into effect. Little has been done to enable people to know where their fish food on the table comes from, what stages they go through, what environmental conditions exist there, and what is being done to better the situation. The resolution of sustainability challenges in fisheries (e.g., overfishing, and illegal fishing) is hampered by business motives by the global fishing firms which have clout even over governments." (Interviewee EU05, England/UK/EU, 2019).

Having seen above how legal actors in the UK/EU drive Globoverfishing practices, let's now have a look at similar practices in Tanzania. The Tanzanian government carried out a crackdown on illegal fishing in 2019. Although the fisheries sector is governed by multiple government branches,[52] field interviews with regulators and fishers in Tanzania revealed that the operation against illegal fishing was primarily planned and executed by the Ministry of Fisheries – with little or no involvement of other parties. Responding to this allegation, one regional representative of the Ministry of Fisheries (and Livestock) told the researcher that:

"…for years, we had suspected that the ongoing illegal fishing activities are largely a result of sabotage by internal elements…and we recently intercepted and defused illegal fishing activities which were coordinated by one of the heads of marine police force in one of the coastal regions…" (Interviewee TZ79, Tanzania, 2019).

This was later corroborated by another response from one of the top officers at the country's main fish market at Dar es Salaam:

"…during the period prior to 2016, buyers and sellers of illegally caught fish would usually meet in evenings just close to this main market…they would transact their business comfortably

[52] These are primarily the Ministry of Fisheries (and Livestock) – the lead, the Ministry of Local Government that monitors small-scale fishers and revenue collection at local councils and markets. Others are the Ministry of Home Affairs that provides a special police force for routine surveillance and security and the Ministry of Tourism and Natural Resources that is charged with the implementation of measures to preserve the fishing natural resources.

while guarded by armed police who would roam the area throughout the time of these meetings. Eventually, everyone would disperse and leave the area without trace…" (Interviewee TZ85, Tanzania, 2019).

According to interviews, Tanzania lacks the ability to monitor and fend off these powerful intruders into its territorial waters simply due to a lack of modern surveillance and remote sensing and monitoring technologies. One interviewee at DSFA charged with surveillance of Tanzanian marine fishery resources said:

"Over the course of the past ten years, we have apprehended several foreign vessels fishing illegally in Tanzanian waters, mostly from Asian countries but also a few from European powers. Some have been fined and they paid, others who failed to pay had their vessels arrested like one fishing vessel docked now in Mtwara. About 20 Chinese registered fishing ships escaped our trap and entered the international waters after operating illegally in our waters. The main challenge is that our current surveillance system does not enable us to ascertain the nature of fishing activities [legal or illegal] instantly and remotely around a vessel. Also, the lack of marine equipment and other resources to enable us carry out frequent surveillance routines as well as respond timely and effectively whenever illegal practices are ascertained." (Interviewee TZ74, Tanzania, 2019).

Although the EU has been funding best fishing practices among small-scale fishers in southern Tanzania through Worldwide Fund for Nature (WWF), most of the fish catches – both in shallower and deep waters – end up on the European market. Despite the high margin revenues from these fish sales, the exports reduce fish supplies in the local markets, thus pushing prices higher than most can afford. This creates food security challenges in coastal developing countries like Tanzania as presented in Figure 8 below (i.e., Globoverfishing conceptual processes or stages). In line with this, one respondent gave the following interview:

"Most of development funds in the fisheries sector in Tanzania and elsewhere started soon after the fishery resources in the donor countries had been depleted thanks to overfishing practices there as funded by state subsidies. When they fund sustainable fishing programmes in Tanzania, what happens is more fish production and less fishing as donor funding includes alternative income and livelihood programmes for fishers. At the end of the day, more and more catch grade fish and juveniles escape into deeper waters, hence getting into the hands of deep-sea

fishing fleets belonging to the same donors as stationed adjacent to Tanzanian waters. The fish catches from shallower waters also get processed locally for largely same European and Asian markets, leaving little for the domestic market. This leads to undesired development: the local fish supply shortage and skyrocketing prices encourage some fishers to embark on illegal and unsustainable fishing practices to make up the resulting shortfalls…" (Interviewee TZ03, Tanzania, 2019).

Some stakeholders reported that Globoverfishing has negative but indirect consequences on fish processing factories that supply both local and export markets. The link to this is that fish processing factories depend solely on small-scale fishers for supplies of raw materials (i.e., fresh fish). As such, fish stock shortfalls worsen the ability of fishers to adequately supply these factories. This is the case because relevant authorities and fish processors in Tanzania confirmed that all fish production depends 100% on small-scale fishers who operate with no large, modern vessels. One of the managers at a fish processing factory with local and export markets said the following during the interview:

"The Tanzanian shallower waters do not have adequate supplies for a large commercial fishing vessel. The government has also been restricting usage of large vessels in these waters. We had three large vessels operating here but now one is in Mombasa [Kenya] and the other two were sent elsewhere. Our competitiveness has been eroded because while the government prohibits catches of fish below 0.5kg, porous borders have allowed illegal catches under 0.5kg to get to our Kenyan competitors in the international markets. The government has not been able to educate and monitor operational compliance among these small-scale fishers on this aspect of sustainable fishing. This transforms Tanzanian fish processors and exporters into high-cost operators, thus becoming uncompetitive on the local and international markets." (Interviewee TZ38, Tanzania, 2019).

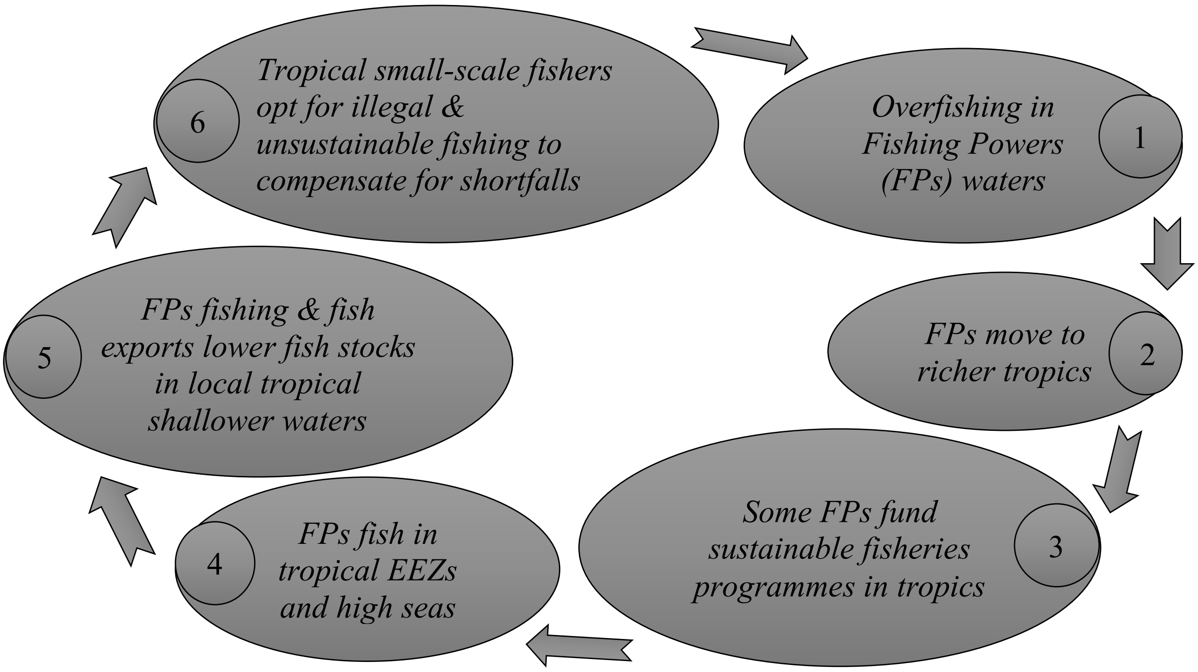


Figure 8: Six-Stage Vicious Circle of Globoverfishing Conceptualisation.

Based on Figure 8 and the narratives before it, the current study argues that illegal and unsustainable fishing in Tanzania, in all its forms and locations, is part of the Globoverfishing phenomenon. By this, Globoverfishing means ‘overfishing everywhere.’ This being the case, it may seem tautological to suggest that the Globoverfishing phenomenon, of which Tanzania is a part, is driving unsustainable fishing practices in Tanzania, both as internal and external force. Therefore, while foreign actions initiate directly or indirectly the Globoverfishing phenomenon, Tanzanian fishery practices contribute to it and are also driven by it.

Another example of indirect Globoverfishing driving unsustainable practices in local Tanzanian fisheries is the commercialisation of Nile Perch industrial processing, which began in the 1990s around Lake Victoria (in Tanzania, Uganda, and Kenya). This is primarily for fillet exports into the EU and other parts of the world. For a long time, insatiable overseas demand discouraged local consumption of Nile Perch, which led to demand instead for the less commercialised species of Tilapia. As demand for Nile Perch fillets rose in Europe, so did the drive for overfishing by fishers on Lake Victoria to constantly supply and make money from fillet processing factories. Also, policy variations among the East African partners states sharing Lake Victoria have inevitably driven fish smuggling across their borders, usually in favour of Ugandan and Kenyan processors. An interviewed leader of the fish processors and exporters in Tanzania stated:

"During the 1990s when the commercialisation of Nile Perch fish fillets commenced, business was booming with high demand and factories operated close to full capacity. This attracted new entrants or increased investments from the existing processors. There was a disregard of how long this would last in terms of the sustainability of fish supplies from Lake Victoria. As a result, demand driven overfishing has brought us to a sharp decline in fish supplies. Only 25% of industrial fish processing capacity is currently in use, rendering the remaining ¾ idle, but why this? The answer lies in the low supply of fish. Lower and fewer taxes, levies, and other regulatory measures on fisheries in Uganda and Kenya enabled smuggled Tanzanian fish to cross into these countries and fetch better prices there. This contributed to expanding our idle industrial fish processing capacity. As a result, fish processing factories in Uganda increased from 7 in 2017 to 14 in 2019 while in Tanzania the number dropped from 12 to 8 during the same period." (Interviewee TZ61, Tanzania, 2019).

Dynamite fishing is an illegal and unsustainable method of catching fish that emerges as a direct and indirect consequence of Globoverfishing. This involves the blasting of fish habitats (i.e., coral reefs) with explosive charges, allowing the fishers to harvest many dead fish at once. Fishers resort to this method following scarcity of fish catches. In its campaigns against this illegal and unsustainable practice, the government has nonetheless been discouraging fishers from doing it by imposing punitive fines for those caught in the act, or when obvious evidence points to fishers having engaged in this activity. The government has also been educating the public through the media and other channels that consuming fish killed by this method risks them ingesting carcinogens. However, interviews with fishers involved in dynamite fishing activities, as well as views given by a government-employed expert on chemical contamination suggest that this link between consumption of dynamite-contaminated fish and cancer is not believed. A fishers' group leader involved and knowledgeable about dynamite fishing said:

"We have been doing dynamite fishing way back since I was young and look now, I'm in my middle age. We have been eating these fish all this long and most of the catches have always been sold to people. Those who say that dynamite blasting contaminates fish with cancer disease are lying; if that was true many fishers including several of my colleagues and I would have caught cancer and died. Do I look sick?" (Interviewee TZ28, Tanzania, 2019).

It appeared that fishers, despite being ranked low generally in society in terms of formal education, had sufficient indigenous knowledge to counter some government-sponsored health narrative that fish killed and caught through dynamite blast method were poisonous when consumed. This narrative was proved as wrong and unscientific by an expert on food chemical contaminants, hence labelled ineffective against luring fishers away from dynamite fishing practices, when she said:

"It is true that most fish killed in dynamite blasts do not carry hazardous chemical contaminants that can develop into cancerous tumours in a consumer's body. A dynamite blast reduces all fish and coral reefs in the immediate surroundings into a heap of debris; but the energy originated from this tremor travels through water with such a powerful shockwave that fish in the nearby environment cannot cope with, hence their instant death. It is this energy, not the dynamite blast particles, that enters and destroys their tissues, turning their eyes reddish, this being a sign of internal bursting of their blood vessels." (Interviewee TZ49, Tanzania, 2019).

From the above expert point of view, two questions remain. One is whether the consumption of dynamite-contaminated fish can cause cancer; and second, whether catches from dynamite blasts contain dynamite residues. It is quite possible that these dynamite residues are carcinogenic, but also that these residues do not occur in fish harvested by this illegal means.

Petty Disguise

Some businesses in fisheries demonstrated conceptual incidental indicators (CIIs) of hiding their true size and profitability to illegitimately avoid tax obligations. These businesses are recognised by authorities including Tanzania Revenue Authority (TRA) as "informal small entrepreneurs or petty businesses." Technically, these are businesses whose annual sales should not exceed a volume or turnover threshold of TZS4.0 million (say £1,330.0). These must pay once annually for a "small entrepreneur pass ID" that was endorsed by the late President (John Pombe Magufuli) at TZS20,000.0 (say £7.0) (i.e., 0.5% of the above maximum sales volume). However, the researcher's observations of, and interviews with, some of these informal small businesses revealed that they could potentially be making far more sales and profit than officially reported. As such, sales above the TZS4.0 million could be going without paying legitimate taxes. It is on this basis the researcher coined the concept "Petty Disguise" to represent this phenomenon. One interviewed stakeholder who was a petty trader at Dar es Salaam Magogoni main fish market said:

"…We are a group of three petty traders, buying small-sized fish, usually sardines, octopus, and squids, at Dar es Salaam's Magogoni landing site. We buy these in buckets, and then fry them at the market's cooker section and thereafter walk round the streets in the city selling them as delicious, hot spiced snacks. The centres include Magogoni, Posta, Kariakoo, Keko, Congo and Mnazi Mmoja. We buy a bucket of raw fish at TZS24000.0 [£8.0] and make sales proceeds of TZS135000.0 [£45.0], thus making a profit of TZS111000 [£37] on the bucket in a single day. We pay TZS300.0 [£0.10] daily to market authorities but have not acquired "Magufuli's small entrepreneur pass ID" which will cost us an annual fee of TZS20000.0 [£7.0]. We operate freely but do not have specific or fixed business offices or address. If we worked for only one third of the year (say 120 days), our team would have made TZS13.32 million [£4440.0] in annual profits." (Interviewee TZ66, Tanzania, 2019).

The above group had not even paid the "token" tax of TZS20,000.0 and was potentially able to bring in over TZS13.3 million in annual profits. If they were to pay taxes legally at a corporate rate of 30% on profits, the government treasury coffers would have collected about TZS4.0 million (say £1330.0) in annual taxes (i.e., 20000% times what they are expected to pay legally). So, the government lost this money in 2019 from just one micro business of three members under this policy. Considering the huge number of these micro businesses in Tanzania, this gives an indication of the enormity of potential loss in tax revenues. This problem of 'Petty Disguise' was identified in Tanzania alone – not in the UK/EU (Figure 11). This Petty Disguise problem had more incidences (CIIs) of unsustainability in marine fisheries (62%) than freshwater fisheries (38%) (Table 14 & Appendix A3).

Resources Unaccountability and Resources Profiteering

The Resources Unaccountability concept means the condition where various resources, investments, or activities along the fisheries supply and value chains were mismanaged and illegitimately and recklessly wasted under the watch of rogue actors. The key motive behind this Resources Unaccountability was to drive excessive private and unsustainable gains through overexploitation of the fisheries resources at the expense of their sustainable development and commercial scaling-up. These illegal gains were conceptualised as Resources Profiteering. The researcher collected significant observational and interview data on this activity from both Tanzania and the UK/EU (Figure 11). The relevant CIIs suggest that the key stumbling block to sustainable development and commercial scaling-up of the fisheries sector did not lie in the scarcity of resources, but rather the inability to sustain and grow (including deriving lessons or learning from encountered challenges) the sector from a given level of initial investment. As for the UK/EU, overexploitation of fisheries resources was driven by food security (high demand), jobs and business interests through imports and exports of fisheries products. In both geographic settings, these findings suggest the comprehensive lack of effective institutional governance in the fisheries sector. Incidences of unsustainability (CIIs) were higher in marine fisheries than in freshwater fisheries for both concepts: Resources Unaccountability (marine 68%, freshwater 32%) and Resources Profiteering (marine 89%, freshwater 11%), (Table 14 & Appendix A3).

It emerged that some regulators or highly ranked figures were part of the illegal and unsustainable fishing network. These actors were involved in cross-border smuggling of fish that evades payment of legitimate taxes, hence making excessive gains illegally. One stakeholder observed:

"In 2019, we conducted a crackdown operation on smuggling of fishery products at one of Tanzania's busiest border posts to the south of Tanzania. We seized several vehicles full of fish and fishery products, being smuggled illegally (without legitimate permits to conduct the business, including payments of fees, royalties, etc) across the border into Zambia while others were destined further beyond to DRC and even Zimbabwe. In one case involving two fish laden vehicles, interrogation of truck drivers and customs staff revealed the cargoes belonged to highly placed influential people in the country's decision-making circles, mostly entrusted with the duty of safeguarding the country's laws and regulations on fisheries resources. These irresponsible people tried in vain to secure the release of the consignments so they could cross the border with the cargo. As we held our positions firmly, the matter escalated to high offices. Eventually, owners of these consignments paid cash into Government Revenue coffers amounting to TZS70.0 million [£23,800] in export licence, royalties plus fines. A rough conversion on fish consignments in the two vehicles would provide a value estimate of TZS4.7 billion [£1.6 million]. During the one-week operation at the border crossing, we were able to collect over TZS310.0 million [£100,000.0] in fines and penalties revenue for the government. It was also noted that some junior border customs staff were knowledgeable of the illegality of the deals but could not act to stop these practices for fear of reprisals or dismissal from work by their bosses who happen to be owners of these illicit undertakings. Furthermore, while a larger portion of the detained cargoes originated from the Lake Zone (Lake Victoria), we later

found out that most fishery products originating from Zanzibar were accompanied with fake licences and permits." (Interviewee TZ117, Tanzania, 2019).

Financial mismanagement and misappropriation are also captured by the Resources Unaccountability and Resources Profiteering concepts. To illustrate, a loan amounting to US$10.0 million[53] was advanced to Tanzania by the World Bank to fund the Marine Conservation and Environmental Management Project (MACEMP). Interviews with fisheries stakeholders revealed that instead of supporting the scaling-up and sustenance of fishing operations, the money ended up benefiting largely the coordinators of the programme and a network of rogue actors in the project implementation hierarchy. According to interviewees (fishers and experts consulted by MACEMP coordinators), the funds were meant for acquisition by existing formal/registered fisher groups of new or modern fishing boats and fishing gear. The money was also to be invested in alternative livelihoods support and income generation schemes that would have lowered pressure on fishery resources overexploitation (e.g., chicken and goat farming by fishers). One of the interviewed knowledgeable experts at Kilwa District Council who took part in the implementation of MACEMP revealed what appears to have gone wrong. He said the major mistake was the project's emphasis on immediate results (i.e., outputs) such as the creation of fisher groups to receive the funds. There appeared not to be any keenness with regards to derivable value from the project, namely short-term benefits (i.e., outcomes) as well as long-term developmental gains (i.e., impact). He said:

"Kilwa District Council received TZS800.0 million in MACEMP funds which were given to over 60 fisher groups for acquisition of modern new boats, new fishing gear, etc. As of today [October 2019] no group among those 60+ that received the money still exists in fishing operations. MACEMP failed totally, thus creating a socioeconomically non beneficial financial debt burden to the public. It was later revealed that the money was distributed to artificially created groups by well-connected local figures in political circles, comprising mostly non fishers. For those fewer fishers who received the money, it became difficult to track them down for monitoring and evaluation of the effects of the support. This is because most fishers along the marine coast are highly migratory, constantly moving and operating from one landing site to the other depending on seasonal variations in fish catches. The failure of MACEMP is largely

[53] See details at https://iwlearn.net/resolveuid/6ce243ec3e6111c219f7467d76f9c40b accessed Tuesday 13th October 2020. However, local sources in Tanzania put this figure at a higher amount of US$28.0 million. It is possible the difference relates to a separate larger tranche of another US$18.0 that went to a similar sister project of Lake Victoria Conservation and Environmental Management Project (LVCEMP) around Lake Victoria.

linked to the project's mere focus on outputs (e.g., establishing fisher groups like BMUs, purchase of boats and fishing gear, improvements in landing sites like in Mafia, Kilwa, etc – now appear like white elephants), with little involvement or consultations with key stakeholders (say beneficiaries like fishers). In short, MACEMP did not undertake any credible needs assessment process. While emphasis of the project was on outputs, there was no attention placed on outcomes (i.e., short-term results) and impact (i.e., long-term development consequences), thus resulting into a total public loss, as the government will eventually have to repay the World Bank in full inclusive of financing costs (i.e., interest charges)." (Interviewee TZ58, Tanzania, 2019).

The countrywide failure of MACEMP project was verified by the researcher while discussing the matter with fishers at landing sites in Tanga, Bagamoyo, Lindi, Mtwara, as well as Dar es Salaam.

The preceding sections present various concepts that explain what is going on in the fisheries substantive area in terms of the lack of trust and credibility among stakeholders in fisheries (i.e., Trust Loss – TL) and inadequacies in institutional public governance of the fisheries resources (i.e., Governance Loss – GL). These concepts are summarised below using cycling balloons (Figure 9) and mind map (Figure 10). Although interactive overlaps of these conceptual flows or occurrences of CIIs are possible, Figure 9 presents one such ideal possibility in five steps. To illustrate, the first step involves the TL problem, that is the lack of trust and credibility that weakens the stakeholders' spirit to collectively coordinate the pooling of resources or capital for sustainable scaling-up the fisheries sector as well as resolve existing and potential conflicts (disagreements). These resources include human and financial capital as well as technology for scaling-up fishing activities, and traceability systems for enhancing transparency and accountability for the sustainable sourcing of fisheries products to ensure consumer health safety. This lack of trust and credibility leads to next steps that depict the GL problem. Step two is about the absence of collective coordination among stakeholders in fisheries which reduces the effectiveness of data collection systems, hence the low quality and unreliability of the resulting fisheries data and the related fisheries resources governance systems.

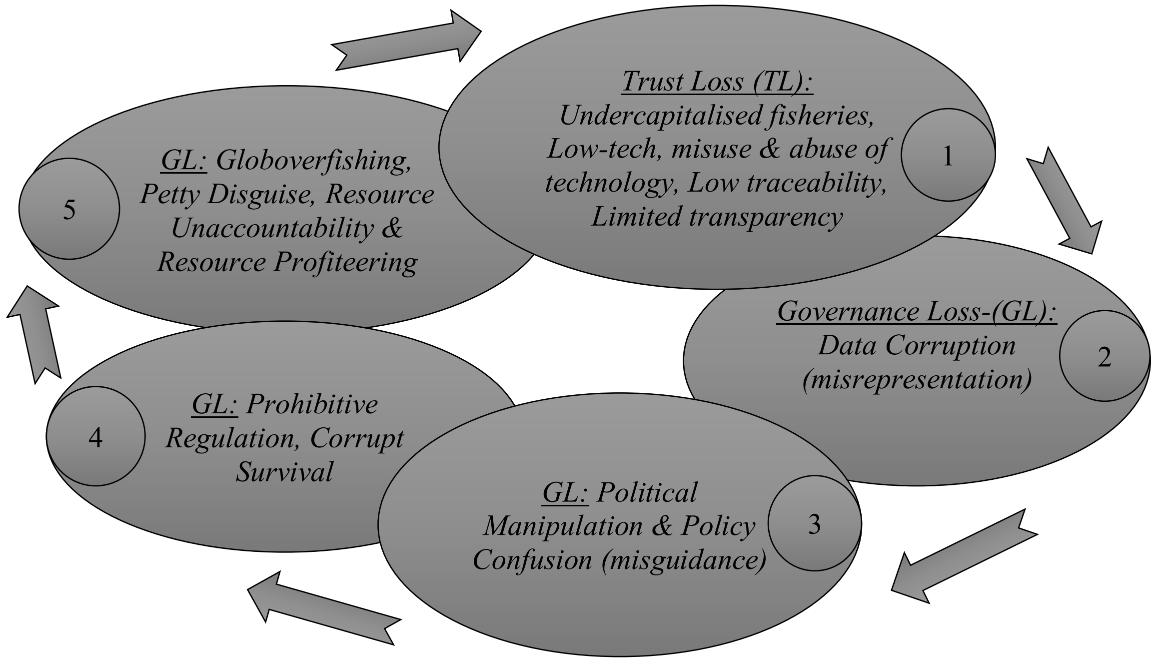


Figure 9: Illustrative Occurrence/Flow of Conceptual Incidental Indicators (CIIs) by Trust Loss (TL) and Governance Loss (GL) Categories.

This limitation in data quality creates opportunities for rogue actors to undertake and/or support plans and actions that result in unsustainable fishing practices such as overexploitation of fisheries resources for short term gains. These plans and actions include political manipulation and policy misguidance (step three), prohibitive regulations and corruption practices (step four), and finally the unsustainable over-exploitation (overfishing) of fisheries resources in Tanzanian waters by local and foreign actors (step five).

3.3.3 Merging Trust Loss (TL) and Governance Loss (GL) Problems into 'Fishmining' Core Category

3.3.3.1 The Main Concern and Emergent Core Category

The preceding sections have presented, using GT approaches, what has been going on in the fisheries sector, and this has been captured under two conceptual categories, representing problems of Trust Loss (TL) and Governance Loss (GL). Data obtained from stakeholders in Tanzania and the UK/EU presented a mix of similar and varying CIIs on unsustainability practices in fisheries, but which both fit into these two categories of TL and GL (Figure 11). Regarding TL, the lack of trust among actors, as well as the limited credibility of fishers with key resource suppliers (e.g., banks and insurance companies) and seafood buyers or importers (e.g., UK/EU) weakened the chances of developing coordinated/collective problem-solving or conflict resolution mechanisms. This included the lack of human capital resources with the qualities of being productive, credible, and trustworthy as well as inadequacies in traceability systems. The lack of effective traceability systems, which might have helped overcome these credibility problems, rendered the fisheries sector attractive to opportunistic rogue and exploitative actors. Under these circumstances, it was reasonably concluded that TL contributed qualitatively and/or quantitively to cause GL. This occurred when policies, laws, regulations, and other control measures were so ineffective that rogue actors became free to mismanage and misappropriate fisheries resources by taking advantage of extant governance inadequacies and loopholes. Because these representative conceptual categories (i.e., TL and GL) are so inter-related, it was appropriate to combine them into a higher-order concept of Fishmining, which becomes the Core Category. Fishmining brings together all the identified CIIs by which rogue actors exploit the fisheries resources for their short-term gains at the expense of sustainable long-term public benefits. The “Fishmining” concept, as explained in detail later, captures the fishers’ and other actors’ unsustainable overexploitation of fisheries resources like the extraction of non-renewable mineral resources. This Fishmining Core Category can be modelled into a more elaborate bottom-up conceptual mind map representation as shown in the next section.

Illustrating the Fishmining Core Category Bottom-Up (Pyramidic) Format

Using a bottom-up (pyramidic) mapping (see Figure 10), conceptual incidental indicators (CIIs), codes, and categories constituting the Fishmining core category are lined up thematically in a manner that overlaps and/or builds into each other. Despite these potential overlaps, concepts in Figure 10 have been presented in a way that suggests a bottom-up logical flow of events in the fisheries action scene. For instance, regarding the Trust Loss (TL) category, the problem begins with limitations in the supply of quality human resources who are lacking in productivity, credibility, and trust (i.e., human undercapitalisation). These people go on to abuse (i.e., unsustainable use of) advanced fishing technology (Technology Gap) through overfishing globally including in Tanzanian waters (Globoverfishing). Also, small-scale fishers lack satellite-GPS devices on their boats to help authorities to monitor their fishing activities at sea. Furthermore, these small-scale fishers and other actors fail to invest in modernising their fishing equipment, hence the low-tech nature of fishing operations. As fishing activities go on under these circumstances, some rogue actors undertake, and make gains from, illegal and unsustainable fishing, thanks to the lack of effective traceability mechanisms (Traceability Inadequacy) that would have identified, exposed, and even helped to prevent these illicit acts.

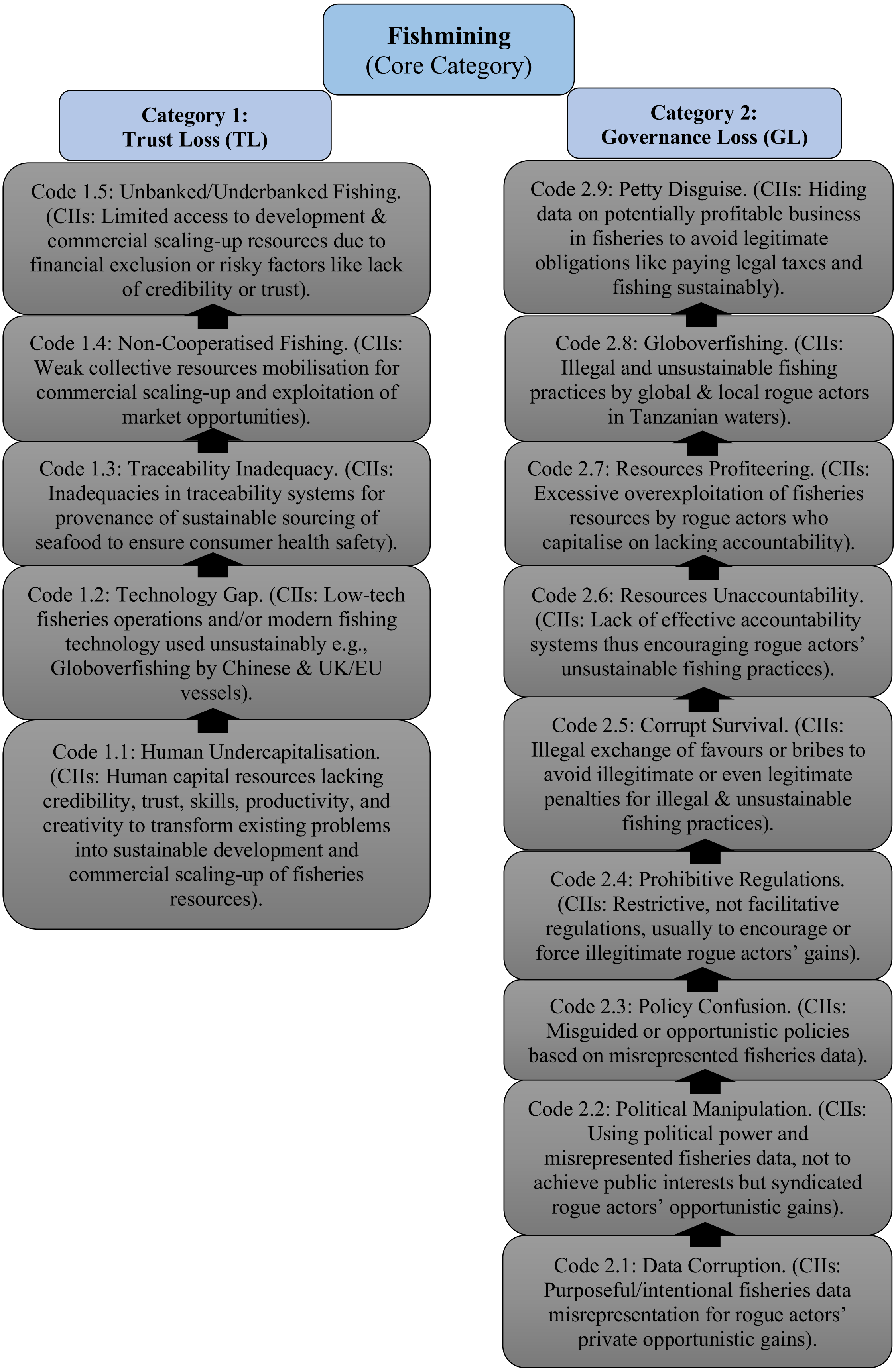


Figure 10: Bottom-up Pyramidic Fishmining Core Category Conceptual/CIIs Structure.

Source: Researcher's own Figure.

This lack of effective traceability system lowers the trust and credibility of actors in Tanzania's fisheries sector with seafood buyers or importers (e.g., UK/EU) who emphasise sustainable sourcing of fisheries products to ensure consumer health safety. However, when it happens that premium price markets exist for sustainably produced fish, most Tanzanian small-scale fishers struggle to exploit this opportunity because they largely operate in such informal and low-tech settings. These fishers do not have robust collective schemes like cooperatives that would have facilitated joint capital formation/mobilisation for investment in efficient quality production and marketing of their seafood products to access local and foreign premium price markets (hence, Non-Cooperatised Fishing). Ultimately, this lack of effective cooperative system erodes potential credibility with key resource suppliers for sustainable development and commercial scaling-up of the sector like banks and insurance firms (hence, Unbanked/Underbaked Fishing).

As for the Governance Loss (GL) category, data misrepresentation (i.e., Data Corruption) by influential actors like politicians/policy makers result in policies and regulations that contain exploitable loopholes by rogue actors who commit and gain from unsustainable fishing practices (hence, Political Manipulation, Policy Confusion, and Prohibitive Regulation). As a result of these poor policies, laws, and regulations, even those caught in acts of unsustainable fishing practices find it cheaper or more affordable to engage in practices of corruption and bribery that also result in fishers having to pay illegitimate exorbitant legal penalties (hence, Corrupt Survival). In this environment, acts of illegal and unsustainable fishing flourish as local and foreign rogue actors maximise their gains through excessive overexploitation of fisheries resources (hence Resources Unaccountability and Resources Profiteering), including through Globoverfishing and the avoidance of paying legitimate taxes (i.e., Petty Disguise).

The preceding conceptual flow diagramme (Figure 10) illustrates how isolated occurrences (i.e., CIIs) could come together to create patterns that eventually manifest into plans and actions of rogue actors to undertake unsustainable fishing practices. These unsustainability CIIs build-up into two higher-order concepts namely Trust Loss (TL) and Governance Loss (GL), both of which merge into the Core Category of Fishmining. It is important to note, however, that the CIIs used to build this Fishmining Core Category in Figure 10 were derived from participants in Tanzania and UK/EU. The geographical distribution of these CIIs between Tanzania and the UK/EU is summarised in codes and themes/categories as presented in Figure 11 below. Detailed explanations and implications of these concepts in Figure 11 were provided in the sections of GT results for TL and GL. Having seen the build-up of CIIs, codes, and categories/themes constituting the emergent Fishmining Core Category (Figures 10 and 11), the section following presents how the "Fishmining" concept was derived using GT approaches.

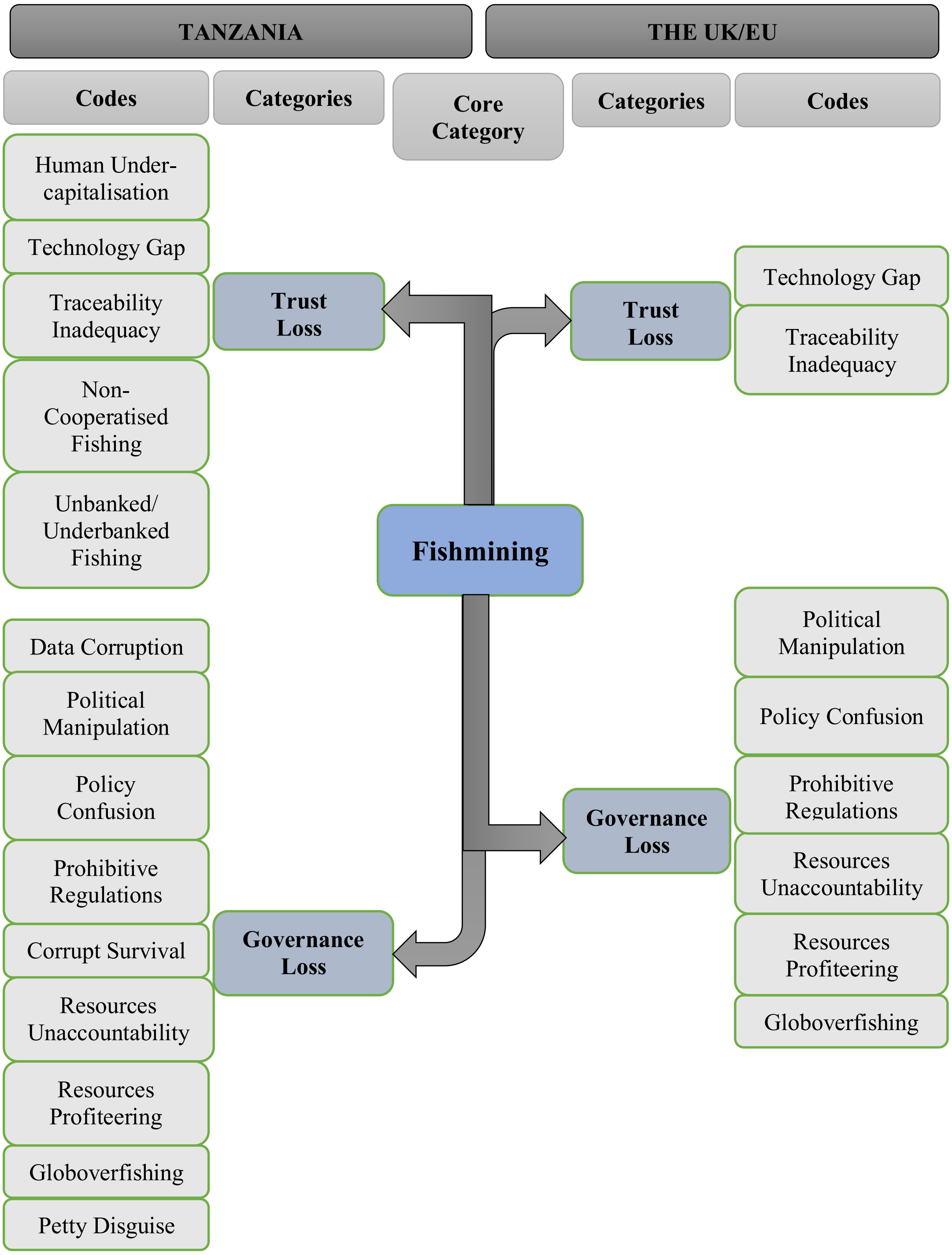


Figure 11: Mind Map of the Fishmining Core Category and its Relation to Subordinate Categories and Conceptual Codes (Tanzania & UK/EU).

Source: Researcher's own Figure.

How Fishmining Core Category was Derived Using GT Approaches

When asked what the development potential of the fisheries sector was, and how they could be part of this process, fishers gave interesting views. They suggested Tanzania was losing much more value by underinvesting in fisheries than it currently gets from the minerals sector, particularly gold mining. The view was expressed that their ongoing fishing activities were analogous to mining gold, diamonds, or Tanzanite, but where fisheries resources (e.g., Lake Victoria and the Indian Ocean to the country's east) were considered to be much more valuable than all the gold mines in the country. A member of an active fishers' group at Kunduchi landing site in Dar es Salaam responded, while flanked by fellow fishers:

"There is one thing many people don't know; this ocean is more than a gold mine. If the government knew the wealth that lies in this vast ocean, they would have made far more money than all the gold there is in Tanzania. So, to us this is our treasure of fish mine that's more valuable than what gold miners get in this country. You invest less money and time and make lots of returns within a day far much more easily than do gold or diamond miners. Even dynamite fishing operators take advantage of this. They blast and mine dead fish and go on to selling profitably. You can compare for yourself: we catch and sell fish every day, what about gold miners? They can go for weeks or months without even a speck of golden rock." (Interviewee TZ87, Tanzania, 2019).

Fishers' common catchphrase was: *"our treasure of fish mine"* suggesting conceptually that fishing operations and processes along supply and value chains are being run in a manner comparable to the unsustainable extraction of non-renewable mineral resources such as gold, diamonds, and Tanzanite. The unsustainable fishing practices by fishers and other actors in the fisheries supply and value chains as reported elsewhere in the current study appear to coalesce around this concept of *'fish mining.'* So, 'fish mining' represents unsustainable fishing practices by actors along the whole length of supply and value chains who take advantage of the absence of necessary institutional governance systems and control measures. Consistent with GT requirements (Glaser, 1978, 1992, p.45), this *'fish mining'* term is an *in vivo* conceptualisation which is found within the fisheries substantive area lexicon. Therefore, 'fish mining' transcends any analytically derived conceptualisation of the researcher that might attempt to capture the same analytic concept. As such, the 'fish mining' phrase coalesces into a single word 'Fishmining' to coin a gerund verb (with -*ing*) that signifies action (Glaser, 1978). Fishmining is therefore consistent with the GT convention of naming concepts that explain actions going on in a substantive action scene (Walsh et al., 2020, p.35). Fishmining implies the exploitation of fishery resources as if they were non-renewable, like extracting minerals such as Tanzanite, gold, diamonds, or coal. Thus, the researcher suggests a far reaching and widely encompassing meaning of the Fishmining concept: plans, actions, and/or a combination thereof by actors in the fisheries supply and value chains that stifle or limit the sustainable scaling-up, development and exploitation of fishery resources. These may include documented plans such as policies, laws, regulations, strategies, development programmes and frameworks. Additionally, Fishmining actions include activities implemented by rogue actors to cause the occurrence of and then exploit institutional governance loopholes. The overriding feature of Fishmining is that its practice allows individuals and/or syndicated rogue actors[54] to make short term gains at the expense of the wider public who lose long-term benefits in the process, the results of which are to render the fisheries sector unsustainable.

3.3.3.2 Deriving a Substantive BSP GT from the Fishmining Core Category

The next question to be addressed in this GT process is whether the Fishmining core category is a Basic Social Process (BSP). A BSP is a special core category that possesses two properties, namely: (i) processing out in two or more stages, and (ii) changing over time as observable in its stages/processes (Glaser, 1996, p.xvi; Glaser, 1978, pp.94&97). It is important to establish if the core category is a BSP or not to be able to understand the nature of the problem being investigated using the GT technique. This knowledge is important to formulate and evaluate measures to resolve the identified problems. It was found that the Fishmining core category met both BSP conditions (Figure 12). Fishmining is itself a process because, based on Glaser (1978), it has stages/processes of its own. These processes are: Deep/Invisible Fishmining, Conspiracy Space/Uncertainty Fishmining, and Surface/Visible Fishmining. These three processes can be explained as follows: (i) *hidden planning* (Deep/Invisible) process, where rogue actors in fisheries plan their unsustainable fishing practices in secrecy, to hide from the public or relevant enforcement authorities; (ii) *uncertainty or unclear* (Conspiracy Space/Uncertainty) process, whereby rogue actors act in disguise to avoid public attention if there is leakage of their plans or secrets, or to limit being monitored by relevant enforcement authorities. To achieve these goals, the rogue actors use their influence and resources to confuse the public about what is going on, including funding, and circulating misinformation to influence the public's opinion,

[54] These could be fishers acting singly or in small groups, hence low impact Fishmining. High impact Fishmining involves powerful networked individuals, usually consisting political and business elites, legal institutions like companies, or entities such as fully fledged states/countries.

for example fake news or conspiracy theories; (iii) *Visible* or *clear* (Surface/Visible) process, whereby the unsustainable fishing practices come into the open – like overfishing (Globoverfishing), dynamite fishing, poison fishing, etc. Observers may or may not realise the significance of these activities in terms of sustainability. Having discovered above that the Fishmining Core Category is a BSP, a theoretical code statement for the emergent GT can be derived as presented in the section following.

Theoretical Code/Statement for the Emergent Fishmining BSP GT

Based on the preceding GT methodological approach and analysis (Glaser, 1992; Holton, 2008; Walsh et al., 2020), a theoretical code or statement (Glaser, 1978) that predicts and explains what is going on in the fisheries sector through the emergent Fishmining BSP GT is summed up as follows:

"Whenever trust and credibility are lacking among stakeholders, and institutional public governance is inadequate, opportunistic rogue actors will transform common fisheries resources through over-exploitation from renewable (i.e., sustainable) into non-renewable (i.e., unsustainable) resources like minerals extraction for private short-term gains."

Given the BSP nature of the Fishmining Core Category, it is important to elaborate and illustrate in a more practical way the processes of the emergent Fishmining BSP GT. This is undertaken in the section following.

Illustrating the Fishmining BSP GT Processes

To demonstrate how the Fishmining BSP GT processes operate, we consider two illustrations from Japan and Tanzania. Starting with Japan, the country had a hidden plan to meet its food security needs through unsustainable whale hunting. However, when suspicion grew about the scale of their unsustainable whaling activities, Japan disguised it as a scientific research programme (Raihani & Clutton-Brock, 2009). Scientists believe that the purpose of Japan's killing of 1000 whales a year is still to source food rather than for research. This is because the current advances in technology allow for the same research to be undertaken without having to kill the whales (Raihani & Clutton-Brock, 2009). This example illustrates all three processes of the Fishmining BSP GT: first *hidden planning* (i.e., Deep/Invisible Fishmining BSP process), then when suspicions arose, they disguised their hunting as scientific in nature to create *uncertainty* or lack of clarity (i.e., the Conspiracy Space/Uncertainty Fishmining BSP process), followed finally by the *visible* killing of many whales (i.e., Surface/Visible Fishmining BSP process). The second illustration of the three Fishmining BSP processes is derived from data collected in the current study in Tanzania. During the government's crackdown on illegal fishing practices in 2019, marine police officers were among the surveillance and monitoring enforcement team. However, one of the team leaders was surprised to find out that some missions went without catching any rogue fishers or actors in the act at sea, despite tips from the local Beach Management Unit (BMU) members that unsustainable fishing practices were still going on. When the leader investigated mobile phone communications of the surveillance teams (with support from local Telecoms Companies), they found evidence of collusion with groups of fishers which helped the rogue fishers to undertake unsustainable fishing practices outside the planned surveillance times. It was highly probable that the rogue fishers would have been sharing the profits of the unsustainable fishing practices with these untrustworthy marine police officers. This story of the Tanzanian marine police officers illustrates the three processes of Fishmining BSP GT as follows: (i) marine police officers met in secrecy and *planned* with rogue fishers to collaborate to commit and gain from unsustainable fishing practices, hence the *hidden planning* (Deep/Invisible Fishmining BSP process); (ii) the marine police officers influenced their colleagues and *faked* their true intentions, hence creating *uncertainty* (i.e., the Conspiracy Space/Uncertainty Fishmining BSP process); (iii) the ongoing unsustainable fishing practices, partly or fully aided by these marine police officers, continued openly, constituting the *visible/clear* process (Surface/Visible Fishmining BSP process).

Each of the above three BSP processes traverses BSP's sub-processes (Glaser (1978). These sub-processes are: (i) the jurisdiction (local-regional-global) operational sub-process; (ii) the legal/regulatory sub-process; and (iii) management (planning, execution, and control) sub-process (see Figure 12). Glaser (1978, p.97) argues that one of the key properties of a BSP is to have far-reaching general implications beyond one substantive study or context. Glaser (1978) states further that BSPs are usually rendered as formal theories without necessarily having to undergo a further formal theory development process that captures similar problematic incidents (i.e., CIIs) across multiple substantive areas/contexts. Glaser (1978, p.97) says:

"...BSPs are ideally suited to generation by grounded theory from qualitative research which can pick up process by fieldwork continuing over time. They are a delight to discover and formulate since they give so much movement and scope to the analyst's perception of the data.

They also have clear, amazing general implications; so much so that is hard to contain them within the confines of a single substantive study. The tendency is to refer to them as a formal theory without the quite necessary comparative development of formal theory. They are labelled by a 'gerund' ('ing') which both stimulates their generation and the tendency to overgeneralise them. BSPs such as cultivating, defaulting, centring, highlighting, or becoming, give the feeling of process, change and movement over time."

According to Glaser (1978), each of the BSP processes constitutes the BSP's sub-processes (otherwise called sub-core categories). Also, each of these processes has got its specific or unique features/properties called dimensions or characteristics. For instance, one of the characteristics of the process of Deep/Invisible Fishmining is rogue actors committing unobserved unsustainable fishing practices. However, these actors do this across time and geographical jurisdictions (hence the local-global jurisdictional sub-process). This is done by manipulating and exploiting loopholes in existing legal and regulatory regimes and misrepresenting data to remain unobserved (hence the legal/regulatory sub-process). This invisibility occurs mostly at the planning stage of the Fishmining activities by fishminers (i.e., rogue actors); but it also encompasses the creation of disguises through precoordinated acts of planning, execution, and control/evaluation (hence the management sub-process). As the main process, Fishmining undergoes changes over time; and between these change transitions there are periods of stability called 'environments.' Within an environment, Fishmining activities remain unchanged; however, change in these activities leads to transition to another environment. Each of the three processes of the Fishmining BSP will now be explained in the section following, with a particular focus on their constituent sub-processes.

The Deep/Invisible (Hidden Planning) Fishmining BSP GT process

The Deep/Invisible (*hidden planning*) Fishmining brings together management, regulatory and jurisdictional sub-processes.

Management sub-process

This involves hidden planning, execution, and control (i.e., evaluation) of unsustainable fishing practices. Illustrations of this management sub-process include the examples of Japan's initial hidden planning for whale fishing and Tanzania marine police's secret involvement in supporting fishers' unsustainable fishing practices.

Regulatory sub-process

This occurs when rogue actors do research behind the scenes (i.e., hidden) to establish existing loopholes in existing laws and regulations that would offer them opportunities to undertake activities and gain, unnoticed from unsustainable fishing activities. This is usually or sometimes aided by those who are entrusted with public roles of protecting the sustainability of fisheries resources. An illustration for this sub-process is where the marine police in Tanzania, who pretended to act as defenders or protectors of fisheries resources, are secretly involved in planning and supporting illegal and unsustainable fishing practices.

Jurisdictional sub-process

This occurs when there is a hidden or secret cross-border undertaking of illegal and unsustainable fishing practices, usually involving actors across geographical boundaries. Examples of this are hidden acts of Globoverfishing involving teams of local and foreign actors. Another example was provided earlier about Tanzania's rogue actors who secretly planned to smuggle fish products across the country's southern border into Zambia and DRC.

The Conspiracy Space/Uncertainty Fishmining BSP GT process

Here, this Conspiracy Space (*Uncertainty*) Fishmining has the same sub-processes of management, regulatory, and jurisdictional as Deep/Invisible Fishmining, but where the operating environment is influenced by uncertainty, mainly through disguised plans and/or actions. As such, observers may not be able to see, discover, or understand with certainty these disguised plans or actions. While the main characteristic of Conspiracy Space Fishmining BSP process is *uncertainty* or *disguise* about what is going on, the Deep/Invisible Fishmining BSP process is characterised by a complete lack (i.e., *hidden planning*) of information about the rogue actors' plans and actions.

Management sub-process

Rogue actors undertake the planning, execution, and evaluation of their unsustainable fishing practices in a disguised way to avoid attracting attention of observers or the public. This may include instances of degrading the credibility or quality of data on fisheries activities to confuse the public about what is going on. For instance, the Japanese disguised their whaling activities as part of scientific research, when it was in fact an undertaking to meet their food security needs.

Regulatory sub-process

This is where rogue actors appear to be supporting or enforcing laws and regulations against unsustainable fishing practices while doing the opposite for personal gain. A good example is that of Tanzania marine police officers who posed or disguised as enforcers of surveillance and monitoring missions while they abused their roles by leaking vital routine surveillance and monitoring information to rogue fishers.

Jurisdictional sub-process

This happens when local and foreign rogue actors collaborate to exploit existing governance loopholes across borders or jurisdictions to undertake and gain from unsustainable fishing while disguising their actions as legal or sustainable. For instance, some foreign fishing vessels obtain permits to operate in Tanzanian waters but with some obligations, including keeping their monitoring devices on so the vessels' locations and movements could be tracked and monitored. However, there were instances of disguised intentional failures to fulfil these obligations where Tanzanian staff on duty collaborated with operators of these vessels by putting off their Vessel Monitoring Systems (VMS) devices to catch fish illegally and unmonitored in areas not granted approval for.

The Surface/Visible Fishmining BSP GT process

This illustrates the visible consequences of the actions of unsustainability in fisheries undertaken by the rogue actors in the first two processes of *hidden planning* and *uncertainty*. The three sub-processes are as follows:

Management sub-process

This involves the planning and execution of visible acts of unsustainable fishing practices. This sub-process also includes visible acts of unsustainable fishing such as Globoverfishing by European and Chinese fishing vessels in Tanzanian waters as well as dynamite fishing by local small-scale fishers.

Regulatory sub-process

This sub-process occurs when existing laws and regulations contain visible loopholes that are exploited by rogue actors to undertake and gain from illegal and unsustainable fishing practices. For instance, the fact that Tanzanian marine police were able to engage and mask their unprofessional and unsustainable fishing behaviours provides evidence that existing laws and regulations were not good enough. Even when fisheries laws and regulations provide for punitive measures against such rogue actors, there have been instances of top-ranking officials participating in illegal and unsustainable fisheries business, thus weakening the enforcement regime. An example of this are apprehended fish cargoes reportedly belonging to top government officials which were being smuggled into Zambia and DRC from Tanzania without paying legal taxes and levies.

Jurisdictional sub-process

This happens when both local and foreign actors are engaged in visible acts of unsustainable fishing practices. Examples include an instance where a Chinese vessel caught fishing illegally in Tanzanian waters ended up not paying fines/penalties because the vessel owners bribed Tanzanian members who would have testified in court against the vessel's unsustainable fishing practices. Therefore, evidence for unsustainable fishing practices was destroyed in the process.

The preceding illustrations of Fishmining BSP GT processes and sub-processes are summarised in Figure 12 below.

The next section focuses on how the identified problems of Trust Loss (TL) and Governance Loss (GL) could be resolved using the potential capabilities of a Blockchain-based traceability solution. This solution was initially suggested and presented in Chapter 2 and its features are presented in the section following (i.e., in this current Chapter 3).

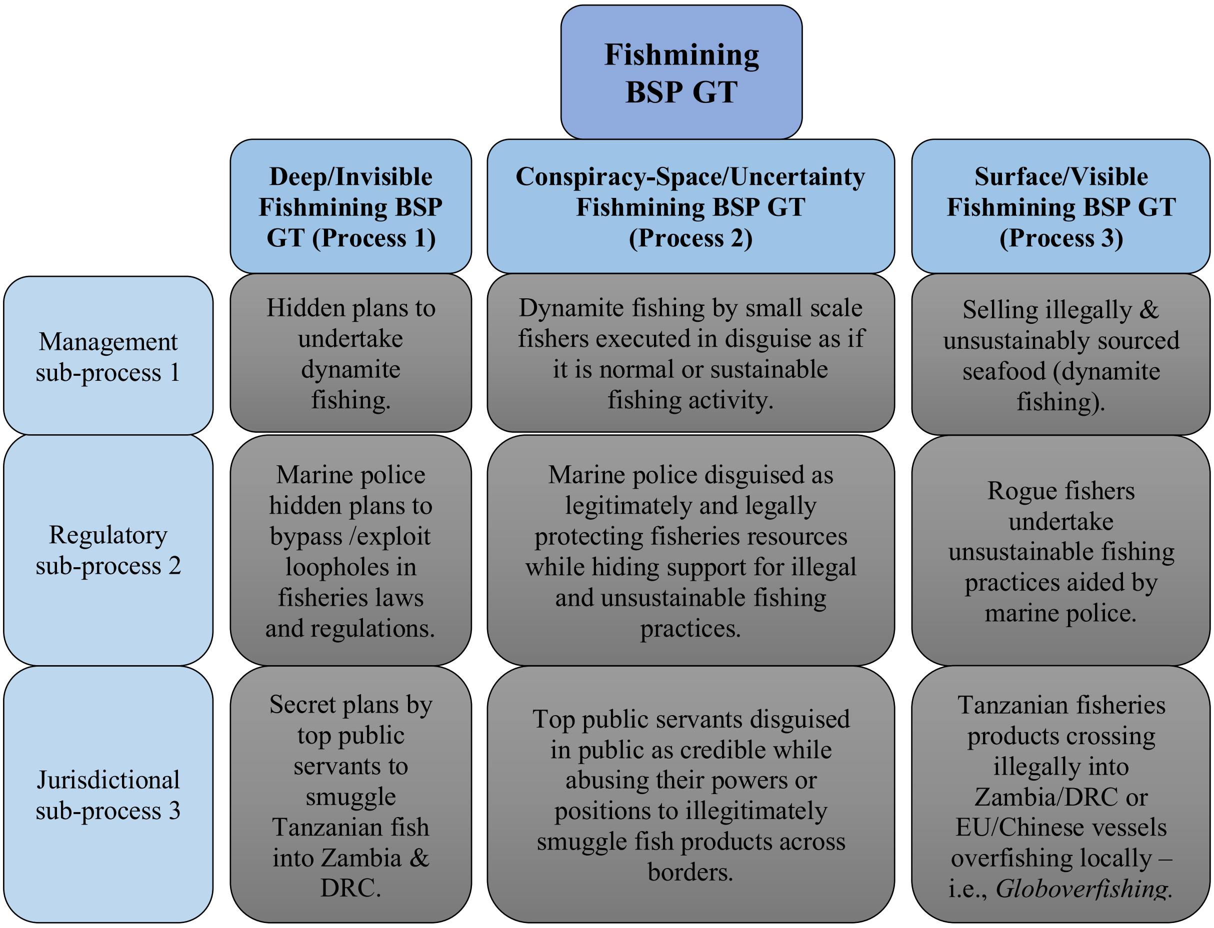


Figure 12: Bottom-up (Pyramidic) Fishmining BSP GT's Three Main Processes & Sub-processes.
Source: Researcher's own Figure.

3.4 Resolving the Identified Problems of Trust Loss (TL) & Governance Loss (GL) Using Blockchain-based Traceability Solution

In Chapter 2, there were presented various potential solutions that have been either applied or considered elsewhere in similar situations for ensuring sustainable supplies of seafood through traceability mechanisms. It was indicated that Blockchain technology offered a potentially robust seafood/fisheries traceability solution based on its key features (see below). The problems identified in the fisheries sector have been summed up as the lack of trust and credibility among fisheries stakeholders (Trust Loss, TL) and failures of the institutional public governance to ensure sustainable exploitation of fisheries resources (Governance Loss, GL). These problems are all amenable to improvement through improved traceability, which ensures transparency, thus promoting trust, while holding fisheries stakeholders accountable. Improved traceability acts to constrain the rogue actors' freedom to undertake and gain from unsustainable fishing practices. Whatever a technical solution is chosen to provide improved traceability, it must enable consumers and other actors to interrogate all sections of the supply chain, from sustainable sourcing of fish all the way to final consumer purchase/consumption. To be robust and effective against the identified problems of trust, credibility, and governance, the proposed traceability solution design will need the features of Blockchain technology for monitoring local and cross-border fisheries trade between Tanzania and premium price markets like the UK/EU (Caro et al., 2018; Jeppsson & Olsson, 2017; Kshetri, 2018; Salah et al., 2019; UNECE, 2016).

Use of Blockchain technology as the technological basis for the traceability system, with its tamper-proof data, would ensure trust, credibility, transparency, and improve the general governance of the fisheries supply and value chains by holding all actors accountable. This section explores whether Blockchain capabilities demonstrated successfully elsewhere, i.e., the use cases reviewed in Chapter 2, could be adapted, or replicated effectively in the Tanzanian fisheries environment to resolve the identified problems of TL and GL. This pursuit is of interest because Blockchain Technology use cases in fisheries have been quite rare in developing country contexts, especially in Africa, having only so far been attempted in the developed, high- and middle-income developing world (Blaha & Katafono, 2020).[55] Tanzania has some high value marine and freshwater catches namely tuna, skipjack tuna, jackfish, and Nile Perch;[56] and these high value species are ideal for adoption of Blockchain-enabled supply and value chain traceability systems (Blaha & Katafono, 2020) because they achieve price premia, against uncertified catches, of 15-25% (Sanchez, et al., 2020) and as much as double the local prices (URT, 2020b). These high premium prices are tenable in high income consumer markets (e.g., UK/EU), and the resulting profit margins can help fishers absorb extra costs associated with the new traceability technology.

However, most fish catches in Tanzania are predominantly of low value (URT, 2016), hence sold on local and neighbouring country markets (URT, 2020b; 2016). Because of their low value and therefore low price, there emerges a potential disincentive to capture these on the Blockchain network, i.e., additional costs are more difficult to absorb. Could costs or expenses of recording these on Blockchain Distribution Ledger (DL) network be subsidised by government or development partner? Would Blockchain Technology still be feasible under these varying Tanzanian conditions? Therefore, this section seeks to answer the following questions: (1) What barriers and drivers limit fishers and actors in Tanzanian fisheries from

[55] These are Indonesia, New Zealand, Australia, Thailand, Fiji, and Ecuador. Others are Chile and Panama.
[56] These are based on the researcher's field interviews with Tanzanian fishers.

adopting a Blockchain-based traceability system? (2) What are the set up and operating (i.e., adoption) costs? (3) Would the verified Blockchain Technology use cases be feasible to Tanzania's large numbers of registered and unregistered, under-educated, low capitalised, artisanal fishers? (4) Would the demonstrated Blockchain Technology capabilities be suited to addressing both Tanzania's fisheries export (premium or high value), as well as local (low value) markets? Although the identified unsustainability practices in fisheries are committed by both Tanzanian and foreign actors, controlling the behaviour of foreign fishers and their governments is beyond the scope of this study's proposed solution. Instead, this study focuses on the Blockchain-based traceability technology solution for modifying the behaviours of fishers or actors in Tanzania. As such, any potential improvements in sustainability behaviours among foreign actors would be considered as secondary (indirect) rather than direct consequences of the proposed solution.

To find out if the technology solutions from the reviewed use cases would be suitable to enhance traceability for improving the sustainability of Tanzania's fisheries, a review of their suitability and relevance is done in the section following.

3.4.1 Matching Reviewed Blockchain & Satellite-GPS Use Cases to Tanzanian Fisheries

Based on detailed use cases presented in Chapter 2, this section is intended to guide the adaptation to, and adoption of, appropriate steps to address the identified trust and credibility issues (TL) among the trading actors as well as solving government regulation problems (GL) in the fisheries sector. As such, the matching process is designed to ascertain which of the previously identified unsustainability challenges in Tanzanian fisheries could be addressed using these technologies, based on evidence from the case studies. Therefore, this section attempts to answer the following questions: (i) Whether the problems that the reviewed case studies are trying to solve are also found in Tanzania? (ii) Whether the local conditions of the reviewed case studies are like those in Tanzania (especially the level of existing technology)? (iii) If Tanzania is likely to present the same barriers to adoption as those found in the reviewed case studies? (iv) If the solutions to the barriers identified in the reviewed case studies are also applicable in Tanzania? In short, the reviewed Blockchain and Satellite-GPS use cases were found to have relevance for addressing the challenges faced by Tanzania's fisheries sector, hence the need for appropriate adaptation approaches. All the reviewed cases had improvements in traceability as their primary goal or objective for improving the quality standards of their fish products along fisheries supply and value chains. Satellite-GPS technology was used in some cases to enhance real time transmission or sharing of data among actors in the fisheries supply and value chains, especially when other means of communications (e.g., telecoms-based internet signals) appeared to be poor or unreliable. Other technologies (e.g., internet of things (IoT) and Asset Identification Methods (AIMs)) were used to help the fisheries data capture and transmission both of which need improvement in Tanzanian fisheries.

Notable challenges experienced in the case studies are also matched with local Tanzanian conditions, to identify adaptation lessons for Tanzanian actors in fisheries. Manual handling of data, limited familiarity, and the digital nature of the Blockchain technology and the lack of effective communications like satellite GPS technologies resulted in low participation and adoption by actors. Furthermore, AIMs devices (QR/RFID tags) detached from some fish products, hence leading to matching problems of digital assets (records on Blockchain platform) to physical assets (fish products) in fisheries cold supply chain. In some other cases, there was none or limited clarity regarding the nature or types of AIMs devices (e.g., mobile phones, iPads, etc) used to capture and transmit fisheries data on fish quality right from fish capture at sea, to actors along the supply and value chains down to consumers. Among the fish quality metrics collected were preservation of the seafood at low temperature and its freshness. One of the technology devices that can capture and transmit these seafood quality data seamlessly along fisheries supply and value chains is Globalstar's SmartOne Solar Satellite Asset Tracking (SOSSAT) device.[57] To illustrate, if attached to a fish container filled on a ship, the SOSSAT device has inbuilt sensor capabilities to capture and continuously relay in real time fish quality data to all actors on the supply and value chain. These data include fish weight, temperature, humidity as well as present and historical satellite-GPS location tracking. Another key strength is the device's power supply that would last over 10 years if fully charged initially. This matching of reviewed use cases to the identified problems in Tanzania's fisheries is presented in a detailed tabulation in Appendix F3.

The preceding traceability use cases in fisheries appear to have general relevance and suitability for possible adaptation to Tanzania's fisheries contexts. Based on this suitability comparison, it has been possible to identify the most propitious combination of features for a new traceability solution for Tanzania. These solution features have been adapted to addressing the identified

[57] See https://www.globalstar.com/en-gb/products/iot/smartonesolar and Chapter 2.

unsustainability problems in the Tanzanian fisheries sector namely Trust Loss (TL) and Governance Loss (GL).

3.4.2 Features of Proposed Traceability Solution Package of Blockchain-Based and Google-Enhanced Satellite Communications GPS Technologies

A satellite-based asset (e.g., fishing boat/vessel) tracking and location data sharing service that could be affordable to low-income fishers through integration with Blockchain and the Global Fishing Watch (GFW) systems is Google Maps Platform (GMP).[58] GMP offers an Application Programming Interface (API)[59] that supports tailored problem-solving applications devised by developers like GFW's tailored solutions. Such applications could be Blockchain-based for addressing the identified illegal and unsustainable fishing problems in fisheries namely data quality/integrity, transparency/accessibility, and traceability. This potential integration of Blockchain and Google technologies is technically feasible and would address the shortcomings identified in the above reviewed Blockchain use cases. These shortcomings include weak internet signals and untimely sharing of fisheries data, whereby a Blockchain application supported on the GMP would potentially benefit from data sourced from satellite GPS transmissions that are by far more reliable and much quicker in data transmission than terrestrial internet data services. The proposed Blockchain-based solution could decrease illegal fishing and increase sustainability in fisheries through limiting the access of premium local and foreign seafood markets to only those suppliers (including fishers) who adopt this traceability solution. Therefore, the potential of increased profits and/or the threat of loss of business will motivate many fishers to adopt the solution, thus addressing the illegal and unsustainable fishing problems in the process. The detailed benefits and potential limitations of adopting the proposed traceability solution are summarised in Table 16 below.

There are multiple suppliers of satellite-based GPS technology devices in the global market. Globalstar's SPOT Trace, SPOT Gen4 and SPOT X-BT GPS devices are powered by AAA batteries, or they are rechargeable from an electrical power outlet (See Figures 2, 3, and 4). These Globalstar's devices cost from US$100-300 with monthly airtime (satellite communication service) charges of US$15.00-25.00. These prices would make these devices less accessible to most artisanal fishers in low-income economies like Tanzania than the GMP-

[58] See https://cloud.google.com/maps-platform
[59] This API is defined (at www.google.com) as a set of functions and procedures allowing the creation of applications that access the features or data of an operating system, application, or other service.

or Google-enhanced satellite solutions. These high prices result from the merging of both infrastructure (the hardware and software) and tailored technological solution (the tracking capabilities) into the Globalstar's satellite-based GPS devices. Similarly, the development of a typical Blockchain- or Google satellite-based web or mobile applications requires huge investments ranging from US$50,000.00 – 250,000.00 to set up necessary infrastructure for tailoring solutions to specific problems (Blaha & Katafono, 2020; Edelson, 2014). However, despite these seemingly costly figures, monthly charges to users like fishers appear to be reasonably low, ranging from free service to US$100.00 per month (see Table 18 below). To put these cost figures into perspective, it would take an investor slightly over one year to recoup (or breakeven) a US$250,000.00 investment into the proposed traceability solution (Blockchain- and Google-enhanced mobile-/web-based satellite GPS application) if offered to ten fisher groups, each with 20 boat owners, and each boat owner paying US$100.00 per month per boat for the service. This monthly charge of US$100.00 per month per boat is justified by the researcher's field interviews[60] where a typical Tanzanian fisher reaps between US$200.00-1000.00 in weekly net profits from the catches of one fishing boat.

This proposed price package of monthly service charge of US$100.00 and the overall initial project investment cost of US$250,000.00 may significantly fall soon, especially following potential competition from other providers of satellite-based communication services in the market. For instance, Starlink Satellite Communications[61] (owned by Elon Musk, the richest man in the world in 2023) will, starting in 2024 and 2025, offer satellite-based internet of things (IoT) and other telecommunications services (i.e., text, voice, data, etc.) to mobile devices like mobile phones used globally, including by actors in Tanzanian fisheries (e.g., fishers). These Starlink's satellite-based broadband connectivity services to smartphones anywhere across the world including on global seas, lakes, and in remote places, are in early commercialisation stages following successful tests on potential customers (Shull, 2024; Zlatev, 2024). This Starlink satellite-based data and communication service potentially meets the requirements of the proposed traceability solution at a relatively cheaper package price of monthly service charge of US$250.00 and a one-off device/hardware cost of US$2,500.00 (Zlatev, 2024), preferably for the needs of one fisher/boat owner. The main price difference between the two appears to originate from the current study's proposed solution's Blockchain-based database that needs building from scratch while Starlink's service price does not include a common

[60] These were conducted among fishers (boat owners) in Tanzania from July to November 2019.
[61] See https://direct.starlink.com and https://starlink.com/business/maritime

multi-actor data storage and sharing component. Despite this limitation, Starlink's service will have a ubiquitous global coverage over land, lakes, coastal waters, and deep oceans, potentially supporting Tanzanian fishers in terms of mobile text messaging, voice communication, data streaming, and video calls while operating at sea (Zlatev, 2024). This service will also facilitate data sharing through internet of things (IoT, i.e., interconnectivity involving multiple electronic devices like satellites, mobile phones, iPads, computers, etc). This device interconnectivity will help to scale-up commercial fishing via yield optimisation by identifying best fishing grounds, facilitating weather forecasts for safe navigation, and enabling seamless communication with other actors (fishers, regulators, traders/processors, distributors, and buyers). Also, this interconnectivity will conveniently facilitate data sharing on fisheries activities by various actors mentioned above, thus helping to identify and limit the incidences of illegal and unsustainable fishing practices.

Regarding the features of the current study's proposed Blockchain-based and Google-enhanced traceability solution, Blockchain works by storing copies of data at multiple sites so that any tampering with data at one location (by a fisher or other actor) is immediately apparent through comparison with data at other locations. This data sharing approach is known as Digital Distributed Ledger (DDL). Multiple people (e.g., fishers or other actors) can have simultaneous access to the same stored data and can enter new data into the records to capture activities and transactions. Many different digital devices can be used to enter and receive data on a Blockchain platform including conventional mobile phone devices running on Google-enhanced satellite GPS. The Google-enhanced satellite technology would help to keep communications flowing reliably in situations (e.g., fishing at sea) where conventional telecoms and internet signals would be weak or non-existent. To illustrate, fitting Google-enhanced satellite GPS devices to fishing boats and linking these to a Blockchain database/platform would mean that a record is made of where each boat has obtained their catch. This data could then be monitored by regulators and fishers. Fishers could also see their own locations when at sea using their mobile phones linked to the Google-enhanced satellite GPS devices. This would help to prevent inadvertent illegal fishing in protected areas, provide buyers of assurance that fish were not caught in protected areas and give fishers a defence against false claims of them of illegal fishing.

To test fishers' willingness to adopt and pay for a package of Blockchain and Google-enhanced Satellite GPS System, an example of a combination of Google Cloud and Google Maps

Platforms has been chosen (https://www.ditoweb.com/2019/11/google-maps-expanded-cloud-and-maps/ and https://cloud.google.com/maps-platform/asset-tracking). This combination of platforms would offer limitless data storage, security, and speedy business performance. Therefore, while Google Cloud Platform could provide the foundation to build and efficiently host and run the Blockchain database application, Google Maps Platform would provide the fisheries data content and the ability for fishers using it to create powerful fishing location-based applications. The benefits and limitations, as well as features, of this proposed Blockchain-based traceability solution are summarised in Tables 16 and 17.

Table 16: Advantages and Limitations of Blockchain & Google Traceability Solution

Benefits	Shortcomings
• Provides reliable proof that fishers have not been operating illegally (e.g., in protected areas). Fish sold with this assurance may attract premium prices, e.g. 15-25% in UK/EU above normal prices.	• Would require investment in equipment for boats and possibly also periodic service subscription charges.
• Google-enabled Satellite GPS fisheries data stored on Blockchain is difficult or impossible to falsify, thus enhancing real time traceability of fisheries data, activity performance, and transparency along supply and value chains.	• It can be costly: e.g., satellite communications and user training for operating the equipment - (e.g., knowledge and skills in ICT and cryptography).
• Enables notifications on possible incidences of accidents or theft of fish and fishing gear at sea (piracy & illegal fish transshipment), thus helping fishers to seek rescue help and/or avoid the fishing area in future.	• May require multiple fishers to group together to make equipment affordable – ideally through collective scheme investments e.g., cooperatives.
• The package guides fishers away from marine protected areas, thus avoiding breaches of regulation. Also, prevention of fishing in protected areas protects fish stocks, thus making fisheries sustainable in the longer term.	• Guidance may be lost if devices on boats are turned off due to low battery or otherwise (e.g., obscured from open sky for strong satellite signals).
• The package helps to communicate environmental data visualisations at fishing locations such as sea temperature and chlorophyll. Higher chlorophyll concentrations occur generally in cold waters rich in phytoplankton organisms which are a natural food attraction for fish. This information helps fishers decide on richer locations at sea for maximising their fish catch volumes.	• Most fishers may not be competent enough to read, comprehend and interpret the data on temperature and chlorophyll. This may result in training needs that may prove costly to fishers.

Source: Adapted from https://cloud.google.com/maps-platform , https://globalfishingwatch.org/ and https://www.findmespot.com/en-us/products-services

Table 17: Basic Features of the Proposed Traceability Solution (Blockchain-Based & Google-Enhanced Satellite Communications GPS System)

1. Google Maps helps the determination of fishers' locations at sea (i.e., geocoding). This helps the tracking of potential incidences of piracy and illegal trans-shipments (e.g., fish theft), hence triggering a recovery effort and/or avoiding the location in future. The data integrity is ensured on the Blockchain platform.
2. Google's geofencing application transmits near real time information as captured on the Blockchain database when a fishing vessel enters or exits an area of interest (a geofence) like a marine protected area or an international marine border. This helps the tracking of illegal/unsustainable practices as well as fish smuggling activities. Geofencing is also applicable to traceability of fishery products as they move from one actor to another along the value chain (from producer/fisher, to distributor, to retailer until the final consumer).
3. Access to atmospheric and environmental information (e.g., humidity, temperature, and chlorophyll concentrations) at fishing locations for potential quality and quantity/volumes of fish catch. These data are stored on the Blockchain platform to ensure their integrity.
4. The Blockchain and Google traceability solution helps the estimation of optimal compass-based navigation directions; plus, distance covered on fishing activity or expedition routes for enabling resources planning and management.

Source: Adapted from https://cloud.google.com/maps-platform and other sources.

Table 18: Costing the Proposed Traceability Solution (Blockchain-Based & Google-Enhanced Satellite Communication GPS System for Asset Tracking)

Asset tracking and location data transmission services	Monthly pricing range per 1000 service requests/calls
1. Maps and routes modules	
• Mobile-based maps, accessed on devices like mobile phones (e.g., fishing area maps).	US$0.00 (free)
• Static and dynamic maps (e.g., surroundings of the fishing location)	US$2.00 – 7.00
• Static and dynamic interactive views (e.g., scenes of ongoing fishing activities at sea)	US$5.60 – 14.00
2. Places module	
• Locating/marking places (e.g., fishing grounds/areas)	US$2.27 – 2.83
• Autocomplete requests for: places (e.g., fishing locations), basic or environmental data (e.g., atmospheric humidity, temperature, etc)	US$0.00 – 17.00
3. Monthly Pricing of the Whole Traceability Solution Package	
• Blockchain enhanced Google Cloud & Maps Satellite GPS Services and Subscription for tracking and transmission of asset location data	US$100.00

Source: Adapted from https://cloud.google.com/maps-platform and other sources.

Google's Satellite GPS services on these platforms appear quite accessible (in terms of affordable costs/prices)[62] to most artisanal fishers in developing countries like Tanzania (see Table 18). Fisheries data can be stored securely on and shared from, i.e., a Blockchain application (API) hosted on Google Cloud without any dependence on the unreliable land-based telecoms and internet links. This would ensure a continuous flow of tamper-proof data that is shared in a credible, transparent, and traceable manner among the fisheries actors linked to the Blockchain platform. This package of Google-enabled Satellite GPS system and Blockchain technology potentially addresses trust issues between trading parties as well as the government regulatory challenges in the fisheries sector. This happens by identifying, monitoring, and ensuring compliance with sustainable fishing practices by vessels at sea. The Google-enhanced and Blockchain-powered fisheries data are accessible via mobile devices (e.g., mobile smart phones and iPads) as well as computers. These devices, especially the mobile smart phones, are quite accessible to most artisanal fishers in the developing world, including Tanzania. Additional options can be added to the basic services on Google Maps-based Satellite GPS services at extra cost. As such, the product/service utility rises from basic (e.g., accessing static maps on mobile devices) to advanced applications (e.g., sharing interactive panoramic scenes and places maps).

However, monthly charges may rise as high as US$17.00 for accessing and sharing high value data such as interactive maps of activity (fishing) area and environmental conditions such as atmospheric humidity and temperature. As presented in Table 18, Google's pricing (see https://cloud.google.com/maps-platform) of the full package of Blockchain and Google-enabled satellite GPS services would cost a Tanzanian boat owner (fisher) about US$100.00 per month when up to 1000 service requests are placed and executed. This monthly charge would cover both the service as well as the Blockchain and Google-enhanced satellite GPS traceability solution's hard infrastructure charges.

3.4.3 Maintenance of Fisheries Data Quality

To ensure data quality (i.e., transparent, access protected, and non-tampered fisheries data), this traceability solution would identify the activities of registered members (fishers and actors) along the fisheries supply chain and record these in a secure tamper-proof storage. To illustrate, a fisher would catch fish and pull it onto a boat. The fishers would then attach a digital sticker

[62] This is based on the findings in the current study that most Tanzanian fishers (boat owners) earn far more annual pretax profits than the suggested price for the proposed Blockchain-based Technology solution.

to the fish and measure/estimate its weight. Then, the firmly attached sticker would be scanned using the traceability solution application on the fisher's phone as enabled by the Google-enhanced satellite internet of things (IoT) network and GPS communications system. The fish temperature, humidity, water quality/contamination, satellite GPS location, and boat owner details including the registration would be captured automatically on the platform, along with the inputted fish identity and weight etc. In addition, the traceability solution application on the fisher's mobile phone would use the satellite GPS function to constantly record, store, and share on the platform the navigation routes travelled by the fishing boat at sea including the dates and times of the routes, and location and duration of stops made to pull fish nets. This functionality would help to generate fishing boat maps accessible by all actors including regulators and consumers, thus providing evidence of whether fishers made catches from restricted areas or not. Large boats could have ice storages or deep freezers onboard to help the preservation of fish quality, but small boats without reliable preservation methods could opt for landing the catches quickly before quality deteriorates. Fish buyers, both local and foreign, could place orders for the fishers' catches placed on the platform with potential price offers (i.e., spot buying), and these purchase proposals could be relayed on the platform and seen by the fishers. Fishers could also be catching to order to fulfil already existing contracts with processors, fish traders/wholesalers, hotels/restaurants, and foreign buyers. For landed catches, buyers, or their agents, would identify the fish they booked or ordered by matching the scanned tags/stickers on the solution's Blockchain platform and the physical tags on the landed fish. Before the sale or payment is made, buyers would confirm the following: remeasuring the fish to confirm their weight, checking the fish condition by laboratory or any other means, whether the captured satellite GPS location of catch is legal, and if the fishing boat is authentically registered. Once the fish catches are cleared of all these checks, payment can be made, and ownership data changed on the platform. This process would involve the new scanning by the new owner (say a fish trader, processor, or exporter). This scanning is important to enable the capture on the Blockchain platform of the new owner's details, thus building provenance history details of the traceable assets (i.e., seafood products) as they change ownership along the fisheries supply and value chain. Where value adding activities on the fish are carried out, like removal of head and internal organs, filleting, etc., this would also be recorded. If the processed fish results in multiple smaller units, say fillets and maws (swim bladders) for Lake Victoria Nile Perch, each of these products would have their digital tag/sticker. Each of these tags would be scanned and new details captured on the platform, with new weight of the products recorded. Until now, there would be a record of two owners on the platform, the first being the fisher or boat owner and the second being the current buyer. The provenance information and seafood product ownership, hence accountability, would continue to change and build up on this Blockchain platform (traceability solution) until a local or foreign final consumer buys the seafood and makes the final scanning and recording using their mobile devices (e.g., smart mobile phones, and scanners at retailers' check-out points).

3.4.4 How Will the Proposed Traceability Solution Resolve the Identified Problems for Sustainable Development and Commercial Scaling-up of the Fisheries Resources?

To justify the need for an improved traceability system for sustainable development and commercial scaling-up of the fisheries resources, this section provides an explanation in a cause (traceability)-and-effect (sustainability) relationship. Therefore, this section attempts to answer a question on the potential capabilities of the proposed traceability solution to resolve the identified problems that limit sustainable development and commercial scaling-up of the fisheries sector in Tanzania. These problems were Trust Loss (TL) and Governance Loss (GL) both of which merged into Fishmining BSP main problem. The proposed traceability solution would help to resolve, at least partially, the TL problems through its features of enhanced transparency that would in turn improve accountability by fishers and stakeholders while undertaking fisheries activities. The solution's feature to incentivise fishers to access lucrative local and foreign (e.g., UK/EU) premium price markets would encourage fishers to adopt sustainable fishing practices through collective schemes like formal groups or cooperatives, thus being able to access bank financing to scale up their operations, including the acquisition of appropriate technologies. Furthermore, the proposed traceability solution is set to resolve, at least partially, the GL problems through its ability to transparently identify the activities and transactions of fishers and other actors (i.e., fisheries data) along the fisheries supply and value chains. This identification helps to potentially suggest mitigation measures to those found undertaking illegal and unsustainable fishing practices, such as denying them access to premium price markets and/or charging them with financial or any other forms of penalties. A detailed explanation on how the proposed traceability solution would help to resolve each of the sub-problems under TL and GL is presented in Appendix D3.

3.4.5 Implementation of the Proposed Blockchain-Based Traceability Solution

3.4.5.1 Establishment of National Implementing Agency

It is important to clarify that not all the usable results from the current study (i.e., those used for drawing final conclusions) are derived only from the fishers' survey modelling results. The fishers' survey was designed to answer a very narrow set of questions around willingness to adopt the chosen technological solution. The literature review and stakeholder consultations addressed a wider set of questions, and data drawn from these exercises is also used to draw conclusions. As such, an idea of creating a voluntary professional trade body (i.e., a national implementing audit agency) comes from these sources: literature review and stakeholder consultations. As stated earlier, the proposed Blockchain-based traceability solution arrives to rectify the lack of trust and credibility among stakeholders and failures in the public governance to ensure the sustainable development and commercial scaling-up of the fisheries resources. This proposed traceability solution is purely a private sector-led initiative whose successful implementation (i.e., adoption and scaling-up) would require the involvement of various stakeholders. In the Tanzanian context, these stakeholders include fishers, traders/processors, policy makers/regulators, and resources providers (e.g., banks, industry experts, and other suppliers). According to UNECE (2016), an efficient and effective traceability system requires a competent and resourceful audit agency to be constituted by capable professionals from the private sector. To expand on this proposal to establish a credible traceability system, there is a need to set up the above stated national traceability audit agency in Tanzania in the form of a professional trade association to help with the implementation of this study's proposed traceability solution. This study informs the required functions, powers, and operationalisation of this national traceability audit agency (trade association) (see Chapter 2 and Appendix E3). Set up or fixed costs (i.e., initial outlay) for the proposed solution have been estimated earlier to be US$250,000.00. This investment appears to be sustainably feasible given the resource ability of surveyed fishers, traders, and the potential involvement of key stakeholders like financial resources providers (e.g., commercial banks, development partners, other investors, etc). A detailed account is provided in Appendix E3 about how the audit agency would obtain these financial, human capital, and other necessary resources to sustainably implement and operationalise this investment in the proposed traceability solution.

3.4.6 Traceability Solution's Relative Acceptability Between Freshwater and Marine Fishers

It has been noted elsewhere in this study that freshwater and marine fisheries have different characteristics. For instance, freshwater fishers are said to be generally more profitable and educated than marine fishers ((URT, 2020). On the other hand, marine fishers are said to operate in a more challenging fishing environment than their freshwater counterparts (URT, 2016). Based on these and other differences, it is expected that freshwater and marine fishers are going to have varying levels of willingness to accept or adopt the proposed traceability solution. Table 19 below uses the key features of the proposed traceability solution to propose different levels of relevance and acceptability of the traceability solution between freshwater and marine fishers.

Table 19: Potential Relative Acceptability of the Proposed Traceability Solution Between Freshwater and Marine Fishers

Traceability Solution Benefits or Capabilities	Relative Acceptability Levels
• Provides reliable proof that fishers have not been operating illegally (e.g., in protected areas). Fish sold with this assurance may attract premium prices, e.g. 15-25% in UK/EU above normal prices.	• Premium prices more likely to attract marine than freshwater fishers as the latter are already more profitable.
• Google-enabled Satellite GPS fisheries data stored on Blockchain is difficult or impossible to falsify, thus enhancing real time traceability of fisheries data, communication of activity performance, and transparency along supply and value chains.	• Marine fishers more likely than freshwater fishers to accept these communication and data sharing capabilities because they operate in wider, deeper, and trickier waters.
• Enables notifications on possible incidences of accidents or theft of fish and fishing gear at sea (piracy & illegal fish transshipment), thus helping fishers to seek rescue help and/or avoid the fishing area in future.	• Marine fisheries are deeper, more expansive, and challenging than freshwater fisheries. So, marine fishers more likely than freshwater fishers to accept this feature.
• The package guides fishers away from marine protected areas, thus avoiding breaches of regulation. Also, prevention of fishing in protected areas protects fish stocks, thus making fisheries sustainable in the longer term.	• Breaches of fisheries regulations have been reported in both fisheries, so this feature would be accepted equally between freshwater and marine fisheries.
• The package helps to communicate environmental data visualisations at fishing locations such as sea temperature and chlorophyll. Higher chlorophyll concentrations occur generally in cold waters rich in phytoplankton organisms which are a natural food attraction for fish. This information helps fishers decide on richer locations at sea for maximising their fish catch volumes.	• It is expected more marine fishers than freshwater fishers will accept this feature because they would want to improve their productivity and profitability, both of which are presently below those of freshwater fishers.

Source: Researcher's own Table.

3.4.7 Potential Technological Limitations of the Proposed Traceability Solution

As explained earlier in the preceding sections, the proposed traceability solution is to run or operate on some form of internet of things (IoT). In this study, this IoT network of connected devices involves smart and non-smart mobile phones, Blockchain-enabled applications (Apps), sensor embedded Asset Identification Methods (AIMs) like QR and RFID, and devices running on Google-enhanced satellite GPS communications. According to Oracle,[63] IoT is defined as a network of physical objects or devices (i.e., "things") which are embedded and connected with other tangible and intangible technological devices namely sensors, software, and other forms of technology. This is done to facilitate the connection to and exchange of data with other technological devices and systems over the internet or other communications networks. These devices range from ordinary items like smart mobile phones and other household objects like fridges and deep freezers to sector-wide or industrial sophisticated networks of devices called industrial internet of things (IIoT) (Boyes et al., 2018). An example of IIoT is smart logistics with real time notifications (i.e., digital tracking) of asset (e.g., fishery products) movements along a supply and value chain from fishers (suppliers) down to consumers and those actors in between, within country and possibly across borders (Boyes et al., 2018). The proposed traceability solution fits into this definition of IIoT. This is because the proposed traceability solution is meant to address in real time transparency and traceability issues on seafood products along the fisheries supply and value chains from the time of fish catches in Tanzanian waters to final consumers in the local market as well in export markets, especially in the UK and the EU.

Despite the preceding capabilities of IoT/IIoT, these systems appear to be heavily susceptible to cyber-attacks by rogue actors. Espinoza (2022) reports the European Union (EU) has instituted fines of up to 2.5% of annual turnover on makers of IoT/IIoT products who do not meet the minimum requirements to avert cyber-attacks for achieving cyber safety. It is noted further that only 50% of makers of the devices are presently compliant in the whole EU IoT/IIoT market of 550 billion euros (Espinoza, 2022). To illustrate what is at stake, cyber security breaches on IoT/IIoT devices have so far resulted in cyber-crime by rogue actors costing 5,500 billion euros globally in public resources by 2021 (Espinoza, 2022). Although these rules come into force in 2024, the EU has shown a good example of precautionary measures against cyber-attacks for the rest of the world to follow. It is therefore suggested that actors in the Tanzania's fisheries sector through the traceability audit agency follow suit to institute relevant cyber security measures to ensure the proposed traceability solution is continuously safe and robust. These measures should cover local markets as well as go beyond the Tanzanian borders to guarantee cyber-safety along the fisheries supply and value chains that extend into export markets – notably the UK and the EU.

[63] https://www.oracle.com/internet-of-things/what-is-iot/ accessed on Saturday 10th September 2022.

3.5 Conclusion

This Chapter set out to undertake two tasks. One was to identify the problems in the fisheries sector through consultations with multiple stakeholders in the sector, and the second was to propose a solution to resolve these problems. Regarding the first task, the study applied GT techniques to identify the main problems in the fisheries sector. There were identified two main problems (GT categories) of Trust Loss (TL) and Governance Loss (GL). TL was about the lack of trust and credibility between and among stakeholders in fisheries namely fishers, regulators, traders/distributors, and processors. This lack of collective action or coordination by the multiple stakeholders weakened existing and potential initiatives to sustainably conserve and exploit the fisheries resources. As a result, long-term collective/public benefits of conserving fisheries resources were threatened and overwhelmed by potential short-term gains derived by rogue actors committing unsustainable fishing practices. These circumstances undermined the fisheries regulatory (governance) regime as multiple stakeholders in fisheries could not comply with rules and laws for sustainable conservation and harvesting of fisheries resources. As such, the TL problem led to the inadequacies in the implementation of effective compliance with laws on the conservation and sustainable development of fisheries resources. These secondary problems in fisheries governance were coded Governance Loss (GL). These two problems were merged into Fishmining BSP overarching problem which emerged as the Fishmining BSP GT. The emerging GT's theoretical statement predicted and explained that the lack of trust and credibility among fisheries stakeholders weakens the overall institutional governance of fisheries resources such that rogue actors will take advantage of these circumstances by overexploiting fisheries resources to make short-term gains at the expense of long-term benefits to the public/society.

Regarding the second task, a Blockchain-based traceability solution appeared to be ideal to resolve the above problems of TL and GL. Based on this realisation, focus was placed on the following issues: (1) What barriers and drivers limit fishers and actors in Tanzanian fisheries from adopting Blockchain-based technologies? (2) What are set up and operating costs among these Blockchain adoption barriers? (3) How would the verified Blockchain Technology use cases be feasible to Tanzania's large numbers of registered and unregistered, under-educated, low capitalised, artisanal fishers? (4) In what ways can the demonstrated Blockchain-based Technology capabilities be suited to addressing Tanzania's fisheries export (premium or high value) as well as local (low value) market requirements? In summary, the Blockchain and other related technologies are quite modern and largely still at the testing phase, hence limited in accessibility and practical use cases (Blaha & Katafono, 2020). The limited accessibility, including user skill requirements, and unavailability to-date[64] of Blockchain technology to Tanzanian fishers constitute one set of barriers and drivers for the adoption of the proposed traceability solution. As noted elsewhere in this study, Blockchain technology adoption requires some minimum levels of skills and initial investment resources to acquire and benefit from such package of technology. Most Tanzanian fishers have either no formal education or attained low formal education levels as well as limited access to formal sources of business funding. These factors explain why Tanzanian fishers have not adopted or embraced the constructive features of Blockchain technology and Google-enhanced Satellite Communications GPS systems for sustainable development and commercial scaling-up their fishing activities. To mitigate this shortcoming, this study proposes the establishment of a market-based body as a national traceability audit agency (UNECE, 2016). This traceability audit agency would spearhead the organisation of necessary resources to create, implement, and operationalise (i.e., adoption and usage) the proposed traceability solution among fishers and other relevant actors in fisheries. This audit agency would be expected to enhance trust and credibility in the fisheries sector to improve fishers' and other actors' access to necessary skills and resources for adopting the proposed traceability solution.

The audit agency would mobilise necessary resources from participating members (as periodic fee) to oversee adoption and wider implementation of the proposed traceability solution. This would ensure all fishers and other actors along fisheries supply and value chains comply with sustainable sourcing of seafood to ensure consumer health safety and quality standards of fisheries products. The audit agency's tasks would also include collaborating with and reporting to relevant local and foreign authorities (especially in the UK/EU) about the ongoing effectiveness of the traceability system. This would include reporting instances of non-compliance to enable the relevant authorities to undertake enforcement measures against those actors not complying. This level of proven effectiveness would enable Tanzanian fisheries products to meet minimum health quality and sustainability sourcing requirements for entering premium price markets in the UK/EU. This would also address the low quality and sustainability concerns of fisheries products which are consumed in the Tanzanian local market. To achieve wider adoption of the proposed traceability solution, the audit agency should organise basic training opportunities for low skilled actors through existing formal and non-

[64] This refers roughly to the period of this study, 2018–2024.

formal fisher groups (including cooperatives). Also, fishers would be encouraged to adopt the proposed traceability solution because it would enable them to access opportunities of selling to premium local and export markets (e.g., UK/EU) with varying degrees of affordability. Furthermore, this access to more profitable premium markets in Tanzania and the UK/EU would allow fishers and fish traders to comfortably afford the cost of acquiring and operating the proposed traceability solution. Those selling at low price in the local and neighbouring countries could be supported initially with soft loans to acquire the proposed traceability solution through the audit agency's resource support mechanisms with affordable repayments over time. Under this arrangement, the proposed traceability solution would be accessible to many Tanzanian actors, especially fishers (boat owners) in their cooperatives or other forms of formal or informal groupings.

Regarding the set-up, adoption, and operating costs of the technology solution, it was found that there are two sets of solutions. A more costly option involved Globalstar's satellite-GPS devices namely SPOT Trace, SPOT Gen4 and SPOT X BT (See Figures 2, 3, and 4). These devices (hardware/handsets) cost between US$100.00-300.00 per unit while airtime service (satellite communication) is charged between US$15.00-25.00 per unit per month. A much cheaper option would be a package of Blockchain technology and Google-enhanced Satellite communications GPS system. With an initial investment of about US$250,000.00, this proposed traceability solution has some modules offered free, but the overall total price of the package to a user (i.e., a fisher/boat owner) is US$100.00 per 1000 service requests placed and executed in one given month. Based on the stakeholder interviews and field observations, it appeared most fishers earned weekly profits of more than US$200.00. It is therefore assumed that most fishers in each case of fishery type can potentially afford the above monthly acquisition and operating cost of the proposed traceability solution (i.e., US$100.00). Furthermore, this cost proposal appears attractive to potential investors to commercially scale up this technological solution. At the monthly rate of US$100.00 per fisher per boat, a potential initial investment of about US$250,000.00 would be recovered in slightly over one year if the service were extended to 10 fisher groups each with 20 members and each member with one fishing boat. This supposedly one-off investment and monthly service fee payments for the proposed traceability solution would unlock value to fishers/users through enhanced fisheries data capture on fishing boats at sea, secure data storage and near real time transmission/sharing (transparency), and effective traceability of activities along the fisheries supply and value chains from fishers/producers to intermediary actors down to consumers in Tanzania and

UK/EU export markets. These features would enable the proposed traceability solution to communicate sustainable sourcing information of seafood as well as generate the handling/processing history to help with consumer health safety. However, the proposed price of similar traceability solutions is likely to fall because of potential competition in the market. For instance, Elon Musk's Starlink Satellite Communications plans to offer in 2024 and 2025 similar traceability solution packages at a price of US$250.00 per month and a one-off investment for hardware/device of US$2,500.00 (Zlatev, 2024). Nonetheless, this Starlink's package does not offer a common multi-actor (i.e., member-based) data storage and sharing utility as provided in the current study's proposed traceability solution.

Generally, the proposed Blockchain-based traceability solution was found to potentially resolve partially the identified problems of TL and GL. Because Tanzania's fisheries products are traded on both local and export markets, it was only those fish catches landed in Tanzania where traceability data could be successfully captured and implemented on the proposed solution. Therefore, the proposed solution has a potential to effectively resolve TL and GL problems along the fisheries supply and value chains within Tanzania. Any successful implementation of this traceability solution to capture and resolve unsustainability issues in fisheries outside the country (e.g., UK/EU) is to be regarded as indirect consequences beyond the scope of this study. Lastly, it was noted that the proposed traceability solution would operate on technological devices and infrastructure (IoT/IIoT) that are prone to cyber-attacks. These attacks by rogue actors constitute serious threats that could potentially render ineffective the proposed Blockchain-based technology solution. These cyber-attacks could also cause huge costs or losses on public financial and non-financial resources. It was thus suggested that Tanzania's stakeholders in fisheries supply and value chains, as represented by the traceability audit agency, follow the EU's lead to institute procedures to avert any potential cyber-security threats posed on the proposed traceability solution.

The next chapter (Chapter 4) reports on the methodological steps leading to the testing of willingness (behavioural intention) of Tanzania's fishers (boat owners) to accept or adopt the proposed traceability solution (i.e., the package of Blockchain technology-based and Google-enhanced Satellite GPS communications system). Also, Chapter 4 provides an outline of the conceptual framework used to help explain the motivation of fishers to use the solution. From now on, this proposed solution will be labelled the "proposed traceability solution."

CHAPTER 4:
FISHERS' WILLINGNESS TO ACCEPT THE PROPOSED BLOCKCHAIN TECHNOLOGY-BASED TRACEABILITY SOLUTION

4.1 Survey methodology

A feasible traceability solution was proposed in Chapter 2 and evaluated in Chapter 3 on its potential effectiveness to overcome the identified barriers to sustainable development and commercial scaling-up of the fisheries sector in Tanzania. This solution was based on a technology package combining Blockchain technology with Google-enhanced satellite communications GPS system. It was found that this traceability solution has the potential to resolve trust/credibility and governance issues identified in the Tanzanian fisheries sector (see Chapter 3). The purpose of the current chapter (Chapter 4) is to assess the willingness of Tanzanian fishers to accept this proposed traceability solution and to identify the drivers and barriers to this acceptance. To help identify these drivers and barriers of adoption, which explain intention to adopt, an extension to the Unified Theory of Acceptance and Use of Technology (UTAUT2) (Venkatesh et al., 2012) was adopted as a testing framework. This UTAUT2 was developed in response to the emergence of multi-billion-dollar markets for consumer technology devices, applications, and services (Stofega & Llamas, 2009). As such, the UTAUT2 framework was chosen for use in the current study because fishers/boat owners in Tanzania fit into the technology consumer context with regards to the proposed traceability solution. Therefore, this survey covered a sample of 534 fishers in Tanzania (177 from freshwater, 357 from marine) who responded to an array of the survey questions (see Appendices A4 and C4). Other studies (e.g., Beza et al., 2018; Thusi & Maduku, 2020) have used UTAUT2 framework to test the willingness of agricultural smallholder farmers and millennials in Ethiopia and South Africa, respectively, to adopt new technologies. The UTAUT2 framework involved a dependent latent construct of Behavioural Intention (BI), and independent latent constructs of Complementary Technology (CT), Effort Expectancy (EE), Facilitating Conditions (FC), Habit (HT), Hedonic Motivation (HM), Performance Expectancy PE), Price Value (PV), and Social Influence (SI). BI measured the fishers' willingness or intention to adopt the proposed traceability solution. CT was about complementary technology like possession/usage of mobile phones that would facilitate adoption of the solution. EE measured the ease or convenience of using the solution while FC represented supportive resources or skills necessary to adopt the solution. HT measured fishers' automatic behavioural tendencies to use CT that were necessary to adopt the solution; and PE was about the usefulness of the solution to solve fishers' identified problems of TL and GL. HM was about fun and interesting features of the proposed solution that would encourage fishers to use it. PV measured the benefits derivable from the solution versus the financial costs of acquisition and operation of the solution. SI was about the influence exerted by third parties (e.g., colleagues, friends, family members) on fishers to adopt the solution. Also tested under this UTAUT2 framework were mediation and moderation effects. Moderation[65] occurred when a statistically interactive categorical (e.g., fishery type, gender, education class, etc) or continuous (e.g., age, profit, etc) variable indirectly influenced the direction or magnitude of the relationship between independent and dependent constructs/variables. On the other hand, mediation[66] sought to identify and explain mechanisms of indirect relationships in which third factors/variables (i.e., mediators) influenced causal effects between independent and dependent constructs. In the current study, moderators were age, experience, and gender (traditional moderators); and fishery type, education, and profitability (new/proposed moderators). Gender was ultimately excluded from the final quantitative analysis because female fishers were fewer than the minimum required sample size.

To test the veracity of this UTAUT2 as an explanatory framework, Structural Equation Modelling (SEM) (Henseler et al., 2016; Becker et al., 2013) was used. There are two forms of SEM models: Covariance Based (CB)-SEM and Partial Least Squares (PLS)-SEM (Becker et al., 2013; Henseler et al., 2009, 2016). While CB-SEM is appropriate for use in situations where changes in latent constructs influence changes in constituent measurement indicators, PLS-SEM is generally used where variations in measurement indicators cause changes in their respective latent constructs. The current study chose to use PLS-SEM because it appeared that measurement indicators influenced changes in their constituent latent constructs. This was illustrated through, for instance, the latent independent construct of Facilitating Conditions (FC) with measurement indicators of necessary resources, knowledge, compatibility, and availability of technical support to use or adopt the new technology. It was found that these measures are causal indicators the composites of which constitute latent constructs (i.e., these measures influence or cause changes in the FC latent construct and not the other way round). For instance, resources like funds or mobile phone devices are key facilitating conditions for users to acquire or use new technology. Knowledge through tailored training is also an important facilitating condition for easy adoption of technology. If new technology in question is compatible or

[65] https://en.wikipedia.org/wiki/Moderation_(statistics)
[66] https://en.wikipedia.org/wiki/Mediation_(statistics)

complementary to already existing devices, this will facilitate usage of the new technology. Finally, availability of technical support is another facilitating condition to enable users of new technology to troubleshoot through adoption challenges.

The PLS-SEM modelling provides two layers of analysis – outer and inner (see Appendix A4). Outer models constitute relationships between measurement indicators and their respective latent constructs, while inner models comprise relationships between latent constructs. In the current study, the outer model analysis involved quality checks on the measurement indicators including tests of validity and reliability of model results namely the testing for multi-collinearity, indicator weights and levels of significance. These tests generated positive results that enabled the researcher to move to the inner model analysis that involved the latent constructs, based on the just verified measurement indicators. The inner model tests involved several tests, namely the coefficient of determination (R^2), model fit, and tests of heterogeneity. These inner model procedures gave positive results too, notably on heterogeneity. Out of the five moderators, two variables, namely fishery type and education were identified through the tests as sole sources of heterogeneity in the sample.

The rationale for the adoption of these approaches and the detailed survey methodology, hypotheses (including the hypothesised framework in Figure 13), and the corresponding statistical/quantitative analyses are presented in Appendix A4. The following section presents a hypothesised UTAUT2 framework based on the preceding analysis.

4.2 Hypothesised Extended & Un-Estimated UTAUT2 Framework

Figure 13 presents the un-estimated UTAUT2 model that is to be tested for its significance and validity in explaining fishers' (boat owners') behavioural intention to adopt the proposed traceability solution. The supposed new contextual moderators (Fishery type, Education and Profitability) are included in Figure 13 to give a hypothesised picture of how they influence each of the independent latent constructs on fishers' behavioural intention to adopt the proposed traceability solution. Measurement items/indicators (i.e., questions) for each independent latent construct/variable are presented in Appendices A4 and C4. It is notable in Figure 13 that the Complementary Technology (CT) construct and the new moderators of fishery type, education, and profitability have been used to extend UTAUT2 framework as bespoke to the current study while age and experience moderators were derived from literature (Venkatesh et al., 2012). This study's UTAUT2 framework (Figure 13) has also been extended with mediation effects as derived from relevant literature.

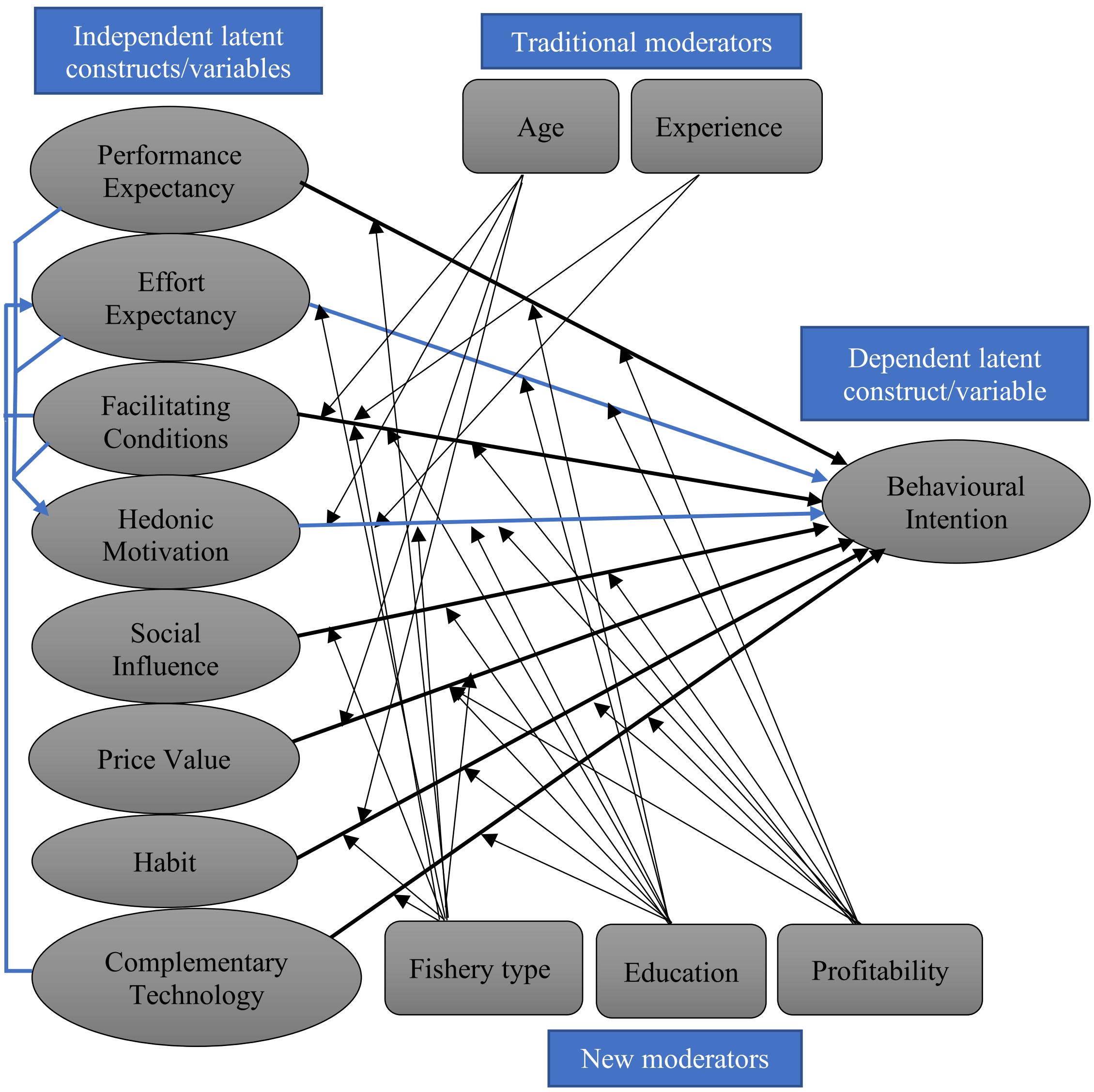


Figure 13: Hypothesised Extended and Un-Estimated UTAUT2 Framework with Direct and Indirect (Moderating and Mediating) Effects.

Note: Represent direct and moderating effects / relationships, respectively.

Represents direct and mediating effects / relationships.

Source: Researcher's Figure.

The main background problems identified in the fisheries sector by the current study (i.e., Trust Loss (TL) and Governance Loss (GL)) are not reflected in the extended UTAUT2 framework (Figure 13). This exclusion is because the constructs Performance Expectancy (PE) and Price Value (PV) (see Appendices A4 & C4) had already captured these TL and GL issues. Under PE and PV items, fishers responded to questions directly related to how the proposed traceability solution could help them to address the (identified) problems of TL and GL. This treatment of TL and GL problems mirrors the assumptions of the Theory of Planned Behaviour (TPB) (Ajzen, 1991), which assumes the background issues/problems arising from the field are already captured/modelled in one or more of its constructs/factors. Validation and testing of this UTAUT2 framework were undertaken using the PLS-SEM method to test for direct and indirect effects including moderation and mediation (Ferreira et al., 2023; Casey & Wilson-Evered, 2012; Siyal et al., 2020). To this effect, the current study tested and validated these direct and indirect effects/relationships using a bootstrapping technique, because it is well suited for the PLS-SEM method and it generates relevant results accurately and precisely (J. F. Jr. Hair et al., 2021).

4.3 Survey Results

4.3.1 Descriptive Statistics

4.3.1.1 Sample

The surveyed sample consisted of 534 boat owners/fishers, with 177 (33.1%) drawn from freshwater fisheries (Lake Victoria) and 357 (66.9%) from marine fisheries (see Table 20). All freshwater fishers were drawn from the Mwanza region, as this leads other Tanzanian regions[67] on Lake Victoria in terms of fisheries productivity, namely the value of fish caught (47%) and the number of fishing vessels (43%) (URT, 2020a). As data were unavailable for number of fishing boat owners, number of fishing boats were used as a proxy for owners. According to URT (2020), the total number of fishing vessels in Tanzania was 59,358, 54% of which were on Lake Victoria's freshwaters and 16% were in the marine fisheries. Therefore, the current study chose Lake Victoria as a representative freshwater population (31,773 vessels/boats). By adding 9,242 marine vessels/boats, the total population under this study became 41,015, being 69.1% of the national figure. The freshwater sample was drawn from Mwanza alone because the region produces close to 50% of all fisheries output on Lake Victoria (URT, 2020a). Also, more marine sampling weight was given to Coast/Pwani and Lindi as the leading marine producing regions while Dar es Salaam provided the largest market for fisheries products (URT, 2020a). However, although Lake Victoria freshwater fisheries lead marine fisheries in the number of fishing vessels and total value of annual catch (58% versus 14%), the surface area of shallow marine fisheries is almost double (i.e., 19%) that of freshwater fisheries on Lake Victoria (i.e., 10%) (URT, 2020a). Moreover, the Tanzania government report (URT, 2016)

[67] These are Kagera, Geita, Mara and Simiyu. According to URT (2020), these regions' respective shares of catch values and number of fishing vessels are: 16% and 23%; 9% and 9%; 25% and 23%; and 3% and 2%.

argues that despite its perceived huge potential, the marine fisheries resources including the deep-sea resources in the Exclusive Economic Zone (EEZ) have not been fully explored and exploited for furthering the country's sustainable development.

Table 20: Population and Sample Distributions

Region	Boat/vessel population	Representative sample
	Freshwater fisheries	
Mwanza	13,560	177
(%)	*(33.1%)*	*(33.1%)*
Other Lake Victoria regions	18,213	-
(%)	*(44.4%)*	*(0%)*
Sub-total Lake Victoria	*31,773*	*177*
(%)	*(77.6%)*	*(33.1%)*
	Marine fisheries	
Coast/Pwani	3,057	125
(%)	*(7.5%)*	*(23.4%)*
Dar es Salaam	1,240	69
(%)	*(3.0%)*	*(12.9%)*
Lindi	2,337	109
(%)	*(5.7%)*	*(20.4%)*
Mtwara	1,273	22
(%)	*(3.1%)*	(4.1%)
Tanga	1,335	32
(%)	*(3.2%)*	(6.1%)
Sub-total Marine	*9,242*	*357*
(%)	*(22.4%)*	*(66.9%)*
Total (Lake Victoria + Marine)	41,015	534
(%)	*(100%)*	*(100%)*

Source: Sample from study's field data & population data adapted from URT (2020).

4.3.1.2 Socio-Demographics

Table 21 below summarises the socio-demographic variables for the current study.

Table 21: Socio-Demographic Characteristics of Sampled Fishers (Boat Owners)

Socio-demographic characteristics	Number of sub-samples and sample totals (% proportions)		
	Freshwater (N=177)	Marine (N=357)	Total (N=534)
Gender			
Male	162 (92%)	357 (100%)	519 (97%)
Female	15 (8%)	0 (0%)	15 (3%)
Age			
18 to 33 years	35 (20%)	55 (15%)	90 (17%)
34 to 49 years	75 (42%)	173 (48%)	248 (46%)
50 to 65 years	66 (37%)	124 (35%)	190 (36%)
66 to 80 years	1 (1%)	5 (2%)	6 (1%)
Fishing experience			
0 to 1 year	9 (5%)	14 (4%)	23 (4%)
2 to 5 years	39 (22%)	67 (19%)	106 (20%)
6 to 9 years	59 (33%)	85 (24%)	144 (27%)
10+ years	70 (40%)	191 (53%)	261 (49%)
Membership to fisheries organisations			
Formal/registered	55 (31%)	152 (43%)	207 (39%)
Informal/unregistered	122 (69%)	205 (57%)	327 (61%)
Education			
Informal education	27 (15%)	159 (45%)	186 (35%)
Primary education	116 (66%)	143 (40%)	259 (49%)
Secondary education	27 (15%)	50 (14%)	77 (14%)
College/university	7 (4%)	5 (1%)	12 (2%)

Source: Researcher's own calculations.

Gender

The fishing industry in Tanzania is very heavily dominated by male fishers (see Table 21). Female fishers were only 15 (8%) out of the 177 freshwater boat owners, while marine fishers were 100% male. Overall, female fishers constituted only 15/534 = 2.8% of all sampled fishers. These figures confirm the findings of Bradford & Katikiro (2019) who report that Tanzanian women face cultural, economic and policy barriers that inhibit their participation in the fishing activities. A Chi-square test was undertaken on these gender categorical/nominal variables of male and female fishers. The results are presented in Table 23 below. These results (Table 23) suggest the observed statistical frequencies of male and female genders between freshwater and marine fishers' populations are significantly different at the 5% level ($p < 0.001 < 0.05$). The cause of this statistical result is presented in Contingency Table 22, i.e., by comparing observed with expected frequencies of male and female fishers by type of fisheries.

Table 22: Contingency Table (Extracted from Main Table 21 above)

Observed & expected values – fishers' gender	Freshwater (N=177)	Marine (N=357)	Total (N=534)
Male	162 [172]	357 [347]	519
Female	15 [5]	0 [10]	15
Total	177	357	534

Source: Adapted from observed field data and researcher's own calculations.
Chi-Square expected frequency values are in square boxes/parentheses (i.e., […]).

Table 23: Pearson's Chi-squared Test with Yates' Continuity Correction on Gender of Freshwater and Marine Fishers

Fishery type	Gender categories	Chi(X)-squared	Degree of freedom (df)	p-value
Freshwater & marine	Male & female fishers	30.8696	1	<0.001

Source: Researcher's own calculations.

Level of Fishing Experience

Based on Table 21, marine fishers appear to be relatively more experienced than freshwater fishers, with over 50% of the former having over 10 years of fishing experience, while only 40% of freshwater fishers fall into this category. This is, among other things, indicative of the fact that marine fishers are generally older than freshwater fishers (see section on age below). However, similar proportions of five years and below of fishing experience were recorded in both fishery types. Furthermore, a third of freshwater fishers and about a quarter of marine fishers had fishing experience between six and nine years. Wilcoxon's (Mann-Whitney U) test was used to test whether these differences in fishing experience between freshwater and marine fishers are statistically significant. The test was meant to provide supporting evidence that statistically significant differences exist in fishing experience between freshwater and marine fishers. These results are presented in Table 24 below:

Table 24: Wilcoxon's (Mann-Whitney U) on Fishing Experience (in years)

Fishery	Sample	Median	Average	Std Dev	Rank	W/U	Z-value	p-value
Freshwater	177	3	3.0734	0.9047	43260	35682	-2.6323	0.0085
Marine	357	4	3.2689	0.8997	99585	27507		

Source: Researcher's own calculations

The results in Table 24 confirm the alternative hypothesis assertion that statistically significant differences exist in fishing experience between freshwater and marine fishers. Therefore, the populations of freshwater and marine fishers are different in terms of the fishing experience.

Membership to Fisheries Organisations

It is shown in Table 21 that a larger proportion of marine fishers (43%) had membership in formal (registered) organisations or groups compared to only 31% in freshwater fisheries. A likely explanation for this varying degree of formal/registered membership may be the establishment of Beach Management Units (BMUs) in marine fishing areas. According to Machano (2021),[68] more government and donor sponsored BMUs were established and registered in marine than freshwater fisheries. This was the case because more illegal and unsustainable fishing practices were recorded in the marine fisheries than in freshwater fishing (Machano, 2021), hence the need for BMUs as fisheries co-management mechanisms. However, most fishers (freshwater 69%; marine 57%) are only affiliated with informal groups or organisations, thus limiting their chances of becoming part of the formal economy. To determine if the above differences in organisational memberships between freshwater and marine fishers were statistically significant, we applied a Chi-square test on these categorical/nominal variables. The results are presented in Table 26 below. Based on these results (Table 26), the observed statistical frequencies of formal/registered and informal/unregistered organisational memberships between freshwater and marine fishers' populations are significantly different at the 5% level ($p = 0.01336 < 0.05$). The cause of this statistical result is presented in Contingency Table 25, i.e., by comparing observed with expected frequencies of fishers' membership to formal/registered and informal/unregistered organisations by type of fisheries.

[68] https://blog.blueventures.org/en/the-power-of-data-for-community-co-management-in-tanzania/

Table 25: Contingency Table (Extracted from Main Table 21 above)

Observed & expected values – membership to fisheries organisations	Freshwater (N=177)	Marine (N=357)	Total (N=534)
Formal/registered	55 [69]	152 [138]	207
Informal/unregistered	122 [108]	205 [219]	327
Total	177	357	534

Source: Adapted from observed field data and researcher's own calculations.
Chi-Square expected frequency values are in square boxes/parentheses (i.e., […]).

Table 26: Pearson's Chi-squared Test with Yates' Continuity Correction on Freshwater and Marine Fishers' Organisational Membership

Fishery type	Organisational Membership categories	Chi(X)-squared	Degree of freedom (df)	p-value
Freshwater & marine	Formal/registered & informal/unregistered	6.121	1	0.01336

Source: Researcher's own calculations.

Level of Education

Table 21 shows a larger proportion of marine fishers (45%) have no formal education than freshwater fishers (15%). Also, while about two thirds of freshwater fishers attained primary education, only 40% of marine fishers attained this level of education. Very few went on to obtain secondary education or college or university qualifications in either group, with only about 15% achieving even secondary education in either group. To test these differences, the level of education was transformed into a categorical variable constituted by fishers without formal (i.e., informal) education and those with formal education (i.e., collapsing primary, secondary, and college/university education levels into formal education). Chi Square test was used (see Table 28 below) to determine if the above differences in education levels between freshwater and marine fishers were statistically significant. The results suggest that education levels between freshwater and marine fishers' populations are statistically different at the 5% level of significance ($p<0.001$). The cause of this statistical result is presented in Contingency Table 27, i.e., by comparing observed with expected frequencies for each level of education by type of fisheries.

Table 27: Contingency Table (Extracted from Main Table 21 above)

Observed & expected values – levels of education	Freshwater (N=177)	Marine (N=357)	Total (N=534)
Informal education	27 [62]	159 [124]	186
Formal education	150 [115]	198 [233]	348
Total	177	357	534

Source: Adapted from observed field data and researcher's own calculations.
Chi-Square expected frequency values are in square boxes/parentheses (i.e., […]).

Table 28: Pearson's Chi-squared Test with Yates' Continuity Correction on Freshwater and Marine Fishers' Levels of Education

Fishery type	Education levels categories	Chi(X)-squared	Degree of freedom (df)	p-value
Freshwater & marine	Informally educated & formally educated	44.70322	1	<0.001

Source: Researcher's own calculations.

Age

Table 21 shows a relatively larger proportion of freshwater fishers (20%) than marine fishers (15%) being of youngest age group (18-33 years). On the other hand, marine fishers have a higher proportion (48%) than freshwater fishers (42%) in the older age group (34-49 years) that constitutes most fishers in either case. To find out if these age differences between marine and freshwater fishers are statistically significant, a Welch Two Independent Sample t-test was used. The Null Hypothesis in this case is that the means of the two samples are not significantly different. As the results (Table 29) suggest P=0.3471>0.05, we cannot reject the Null Hypotheses and so there is no significant difference between the means. Therefore, the means of freshwater and marine fishers' age do not differ significantly at 5% level of statistical significance.

Table 29: Welch Two Sample t-test of Differences in Age Profile of Freshwater and Marine Fishers

Test data	Mean (freshwater)	Mean (marine)	Degree of freedom (df)	t-statistic	95% conf. interval (CI)	p-value
Age by fishery	44.57062	45.52661	532	-0.9412	-2.951384: 1.039405	0.3471

Source: Researcher's own calculations.

5.5.1.3 Fishing Business (Firm) Characteristics for Freshwater and Marine Fishers

A summary of characteristics of fishing business is presented in Table 30 below.

Table 30: Fishing Business (Firm) Characteristics for Freshwater and Marine Fishers

	Number of freshwater and marine sub-samples (% proportions)		
Fishing business characteristics	Freshwater (N=177)	Marine (N=357)	Total (N=534)
Nature of business organisation			
Sole proprietor	158 (89.3%)	330 (92.4%)	488 (91.5%)
Group/cooperative	8 (4.5%)	16 (4.5%)	24 (4.5%)
Limited company	0 (0.0%)	0 (0.0%)	0 (0.0%)
Family business	11 (6.2%)	11 (3.1%)	22 (4.0%)
Other	0 (0.0%)	0 (0.0%)	0 (0.0%)
Financing of fishing business			
(a) *External sources*			
Bank loans	5 (2.8%)	33 (9.2%)	38 (7.0%)
Fish buyer credit	37 (20.9%)	63 (17.6%)	100 (19.0%)
Family funding	5 (2.8%)	16 (4.5%)	21 (4.0%)
Government support/funding	0 (0.0%)	0 (0.0%)	0 (0.0%)
Member-based SACCOS & VICOBA	0 (0.0%)	0 (0.0%)	0 (0.0%)
None	130 (73.5%)	245 (68.7%)	375 (70.0%)
(b) *Usage of fishers' fee contributions*			
I don't know	1 (0.6%)	1 (0.3%)	2 (0.4%)
I don't pay fees	70 (39.5%)	118 (33.1%)	188 (35.2%)
Immediate needs–sea rescue	106 (59.9%)	238 (66.6%)	344 (64.4%)
Training on fish sustainability	0 (0.0%)	0 (0.0%)	0 (0.0%)
Getting modern fishing vessels	0 (0.0%)	0 (0.0%)	0 (0.0%)
Searching fish markets	0 (0.0%)	0 (0.0%)	0 (0.0%)
Average fish catch / boat / week			
2.5 tonnes & below	92 (52.0%)	281 (78.7%)	373 (70.0%)
2.6 to 5.0 tonnes	73 (41.2%)	73 (20.4%)	146 (27.2%)
5.1 to 7.5 tonnes	11 (6.2%)	3 (0.9%)	14 (2.6%)
7.6 tonnes & over	1 (0.6%)	0 (0.0%)	1 (0.2%)
Average fish price per kg			
TZS2500 & below	8 (4.5%)	47 (13.2%)	55 (10.0%)
TZS2501 to 5000	69 (39.0%)	222 (62.2%)	291 (54.7%)
TZS5001 to 7500	65 (36.7%)	70 (19.6%)	135 (25.3%)
TZS7501 & over	35 (19.8%)	18 (5.0%)	53 (10.0%)
Fishers employed on each boat			
1 to 20	166 (93.8%)	140 (39.2%)	306 (57.0%)
21 to 40	8 (4.5%)	70 (19.6%)	78 (15.0%)
41 to 60	3 (1.7%)	105 (29.4%)	108 (20.0%)
61 & over	0 (0.0%)	42 (11.8%)	42 (8.0%)
Annual net profits per fishing boat owner			

TZS25.0 million & below	30 (16.9%)	109 (30.5%)	139 (26.0%)
TZS25.1 to 50.0 million	36 (20.3%)	104 (29.1%)	140 (26.0%)
TZS50.1 to 75.0 million	35 (19.8%)	89 (24.9%)	124 (23.0%)
TZS75.1 million & over	76 (43.0%)	55 (15.5%)	131 (25.0%)
Other value-adding activities			
None	154 (87.0%)	298 (83.5%)	452 (85.0%)
Fish storage & transport	23 (13.0%)	59 (16.5%)	82 (15.0%)
Fish processing/value addition	0 (0.0%)	0 (0.0%)	0 (0.0%)
Trading fish locally	0 (0.0%)	0 (0.0%)	0 (0.0%)
Exporting fish	0 (0.0%)	0 (0.0%)	0 (0.0%)

Source: Researcher's own calculations.
Note: SACCOS & VICOBA are Savings and Credit Cooperative Societies; & Village Community Banks

Nature of Business Organisation

Table 32 and Figure 14 below present the nature of business organisation for both freshwater and marine fishers. Sole proprietorship dominates the Tanzanian fishing business with 89% and 92% overall business categorisation among freshwater and marine fishers, respectively. While group/cooperative and family business forms constitute relatively small proportions of the two samples, i.e., below 10%, there appears to be two family fishing businesses in freshwater fisheries for every one business in marine fisheries. The results show further that in neither type of fishery are businesses formed into limited companies or any other legal forms of business undertaking. To test if any significant statistical differences exist between freshwater and marine fishers in terms of the nature of business organisation, we applied the Chi-square test on the verified three categories of fishers' business organisation structures. The results below (Table 32) show that there are no significant differences (p=0.2287 > 5%) between freshwater and marine fisheries in terms of the distribution over business organisation structures. The cause of this statistical result is presented in Contingency Table 31, i.e., by comparing observed with expected frequencies for each nature of business.

Table 31: Contingency Table (Extracted from Main Table 30 above)

Observed & expected values - nature of business	Freshwater (N=177)	Marine (N=357)	Total (N=534)
Sole proprietor	158 [162]	330 [326]	488
Group/cooperative	8 [8]	16 [16]	24
Family business	11 [7]	11[15]	22
Total	177	357	534

Source: Adapted from observed field data and researcher's own calculations.
Chi-Square expected frequency values are in square boxes/parentheses (i.e., […]).

Table 32: Pearson's Chi-squared Test on the Nature of Freshwater and Marine Fishing Business Organisation

Fishery categories	Categories of business organisation	Chi(X)-squared	Degree of freedom (df)	p-value
Freshwater & marine	Sole proprietor, groups/coops & family business	2.9507	2	0.2287

Source: Researcher's own calculations.

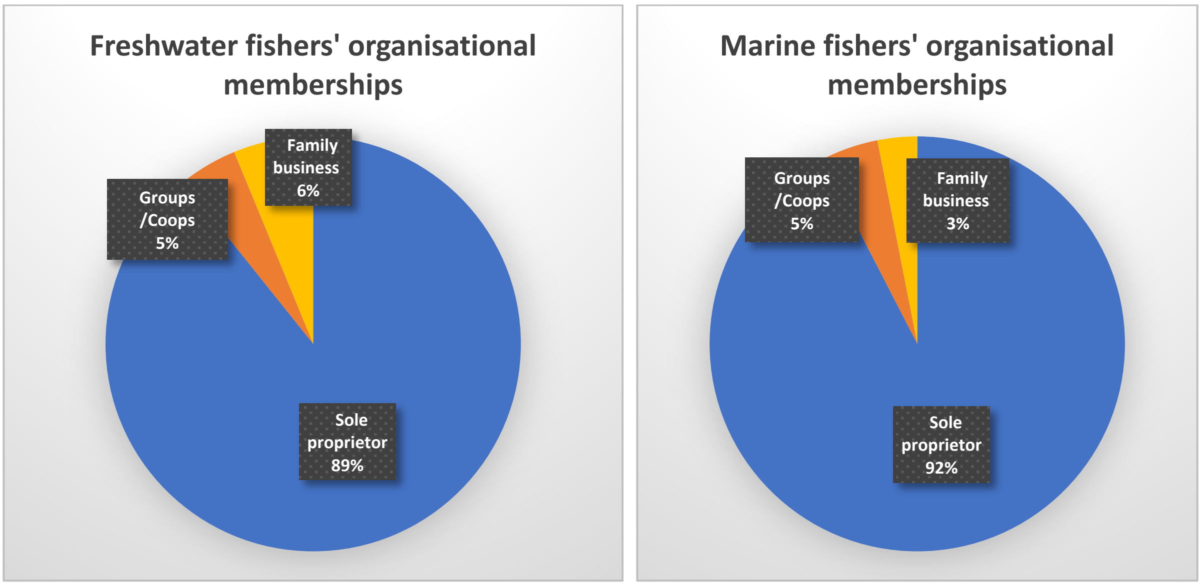


Figure 14: Nature of fishers' Organisational Structure Membership in Freshwater and Marine Fisheries.

Source: Researcher's own Figure.

External Financing of Fishing Business

Boat owners (fishers) were also asked about the major sources of external financing for their fishing business apart from their own resources. Table 30 above and Figure 15 below indicate that the leading source of funding is fish buyer credit for both freshwater and marine fisheries at 21% and 18% respectively. This buyer credit consists of loans in the form of fishing equipment and gear offered by immediate buyers, usually fish processing factories or plants. Although most fishers in both cases receive no external funding (69-73%), three times the rate of marine fishers receive commercial bank loans than freshwater fishers. At 3% and 4%, family funding is found to be the least important source of external funding in both freshwater and marine fisheries, respectively. Surprisingly, government support and member-based credit schemes (e.g., SACCOS or VICOBA) did not feature among the respondents' sources of fishing business finance. Chi Square test was used to determine if these observed differences in external financing sources were statistically significant, see Table 34 below. The results suggest that the observed frequencies of external financing modes of fishing business between freshwater and marine fisheries are statistically different at 5% level of significance (p=0.03297). The cause of this statistical result is shown in Contingency Table 33, i.e., by comparing observed with expected frequencies for each type of external funding.

Table 33: Contingency Table (Extracted from Main Table 30 above)

Observed & expected values – fishers' external financing	Freshwater (N=177)	Marine (N=357)	Total (N=534)
Bank loans	5 [13]	33 [25]	38
Fish buyer credit	37 [33]	63 [67]	100
Family funding	5 [7]	16 [14]	21
None	130 [124]	245 [251]	375
Total	177	357	534

Source: Adapted from observed field data and researcher's own calculations.
Chi-Square expected frequency values are in square boxes/parentheses (i.e., […]).

Table 34: Pearson's Chi-squared Test on External Financing of Freshwater and Marine Fishing Business

Fishery categories	Categories of fishers' external financing	Chi(X)-squared	Degree of freedom (df)	p-value
Freshwater & marine	Bank loans, buyer credit, family funding, and none	8.7389	3	0.03297

Source: Researcher's own calculations.

Usage of Fishers' Periodic Financial Contributions

Members of formal (registered) or informal (unregistered) fisher groups/organisations make periodic financial (fee) contributions that are saved and repaid to fishers when various needs arise. Table 30 above and Figure 16 below present fishers' responses regarding how these contributions are used. The results indicate most of fishers' periodic fee contributions (60% in freshwater and 67% in marine fisheries) are spent on immediate needs that include rescue at sea, death, or family support, as well as office/administration expenses.

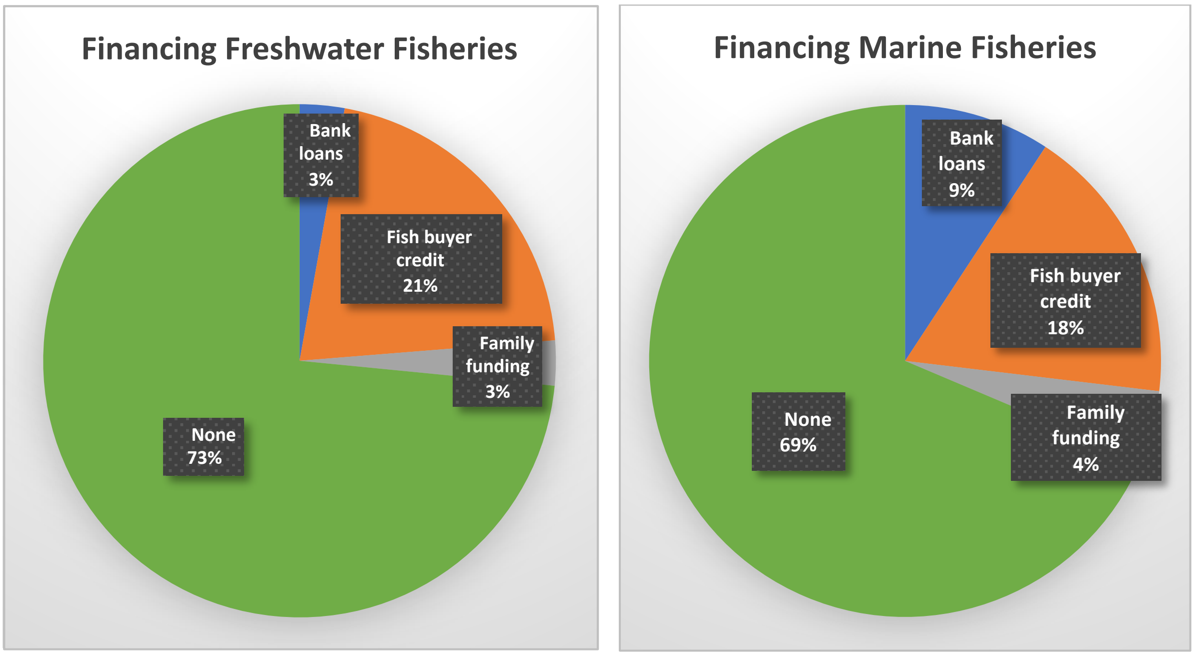


Figure 15: External Financing of Marine and Freshwater Fishing Business Structures.

Source: Researcher's own Figure.

Large sections of fishers (39% in freshwater and 33% in marine fisheries) are inactive members as they do not pay periodic fee contributions, thus weakening the socioeconomic viability and long-term survival of their member-based organisations. The striking feature of both freshwater and marine fishers' responses is that none of their periodic fee contributions went to supporting long-term development needs, namely training programmes (e.g., sustainable fishing practices), acquisition of modern fishing technology and equipment, and searching for local and foreign fish market opportunities. Chi Square test was used to test if there were any statistically significant differences between freshwater and marine fisheries in terms of use of fishers' periodic financial contributions. The results (Table 36) indicate that the fishers' use periodic financial contributions does not significantly differ between freshwater and marine fisheries $P = 0.2839 > 0.05$. The cause of this statistical result is presented in Contingency Table 35, i.e., by comparing observed with expected frequencies for the given usage of fishers' contributions.

Table 35: Contingency Table (Extracted from Main Table 30 above).

Observed & expected values – usage of fishes' contributions	Freshwater (N=177)	Marine (N=357)	Total (N=534)
I don't know	1 [1]	1 [1]	2
I don't pay fees	70 [62]	118 [126]	188
Immediate needs–e.g., sea rescue.	106 [114]	238 [230]	344
Total	177	357	534

Source: Adapted from observed field data and researcher's own calculations.
Chi-Square expected frequency values are in square boxes/parentheses (i.e., […]).

Table 36: Pearson's Chi-squared Test on Fishers' Usage of Periodic Financial Contributions Between Freshwater and Marine Fishers

Fishery categories	Categories of usage of periodic contributions	Chi(X)-squared	Degree of freedom (df)	p-value
Freshwater & marine	I don't know, I don't pay fees, usage for immediate needs-e.g., rescue at sea.	2.5185	2	0.2839

Source: Researcher's own calculations.

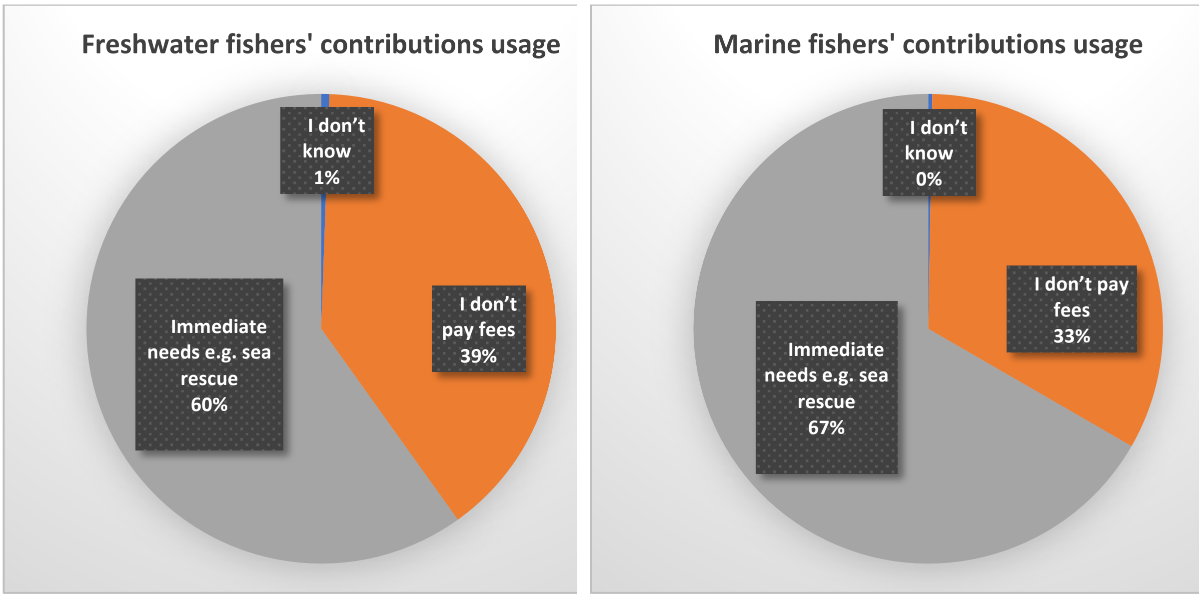


Figure 16: Usage of Fishers' Periodic Fee Contributions.

Other Value-Adding Activities

Fishers were also asked about what other value-adding activities along the fisheries supply and value chain they were involved in, apart from catching and landing fish. Table 30 above and Figure 17 below suggest that most fishers (87% freshwater, and 83% marine) do not undertake any other value-adding activities beyond selling their catch at landing sites. The major value-adding activity apart from landing their catches is storage and transport services for the landed catch. This is done by 13% of freshwater and 17% of marine fishers. Moreover, responses suggested that both freshwater and marine fishers do not engage in higher value-adding activities such as fish processing and exporting to more lucrative foreign markets like those in the UK and EU. To determine if there were any significant statistical differences in undertaking other value-adding activities between freshwater and marine fisheries, a Chi-squared test was conducted. The results (Table 38) indicate that the observed frequencies of fishers' other value-adding activities between freshwater and marine fisheries are not statistically different (P>0.05). The cause of this statistical result is shown in Contingency Table 37, i.e., by comparing observed with expected frequencies for each of other value-adding activities.

Table 37: Contingency Table (Extracted from Main Table 30 above).

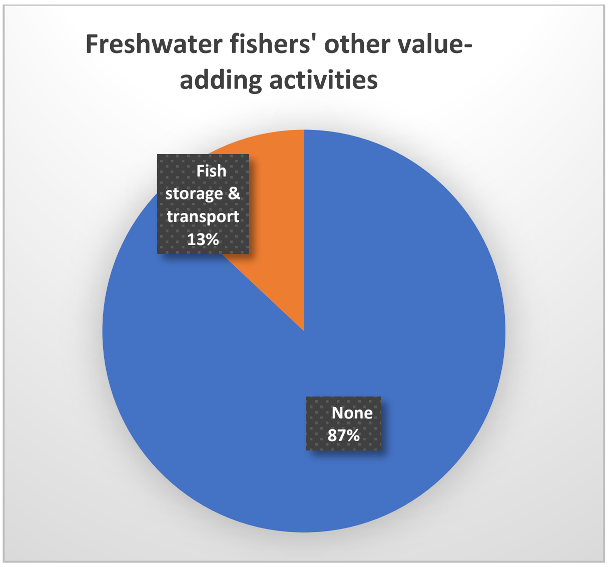
Observed & expected values – other value-adding activities	Freshwater (N=177)	Marine (N=357)	Total (N=534)
None	154 [150]	298 [302]	452
Fish storage & transport	23 [27]	59 [55]	82
Total	177	357	534

Source: Adapted from observed field data and researcher's own calculations.
Chi-Square expected frequency values are in square boxes/parentheses (i.e., […]).

Table 38: Pearson's Chi-squared Test with Yates' Continuity Correction on Freshwater and Marine Fishers' Other Value-Adding Activities.

Fishery categories	Categories of other value-adding activities	Chi(X)-squared	Degree of freedom (df)	p-value
Freshwater & marine	None and fish storage & transport	0.88038	1	0.3481

Source: Researcher's own calculations.



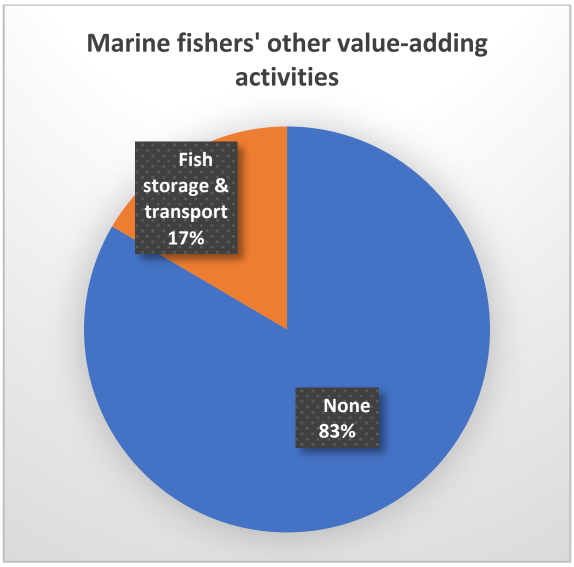


Figure 17: Freshwater and Marine Fishers' Value-Adding Activities.

Source: Researcher's own Figure.

Average Weekly Fish Catch per Boat

The survey collected data from fishers about their average fish catch weight in tonnes per week per boat under each motorisation type: inboard, outboard and without engine boats. Catch weights were classified into four ordinal categories. As seen in Table 30, the results show that the most frequently cited catch category per boat per week was < 2.5 tonnes (marine 78.7%, freshwater 52%) followed by the range 2.6 - 5.0 tonnes (marine 20.4%, freshwater 41.2%). Welch Two Sample t-test was used to determine whether average weights in tonnes for these catches were significantly different between the fisheries type. The results (Table 39) show that the observed differences between the freshwater and marine fisheries type were statistically significant (P<0.001).

Table 39: Welch Two Sample t-test on Freshwater and Marine Fishers' Average Weekly Fish Catch Weights (Tonnes) per Boat.

Test data	Mean (freshwater)	Mean (marine)	Degree of freedom (df)	t-statistic	p-value
Weekly fish catches per boat	2.65141	1.81387	263	6.27378	<0.001

Source: Researcher's own calculations.

Average Fish Price per Kilogramme

There were obvious differences in price per kilogramme between the freshwater and marine fish species (Table 30), suggesting a modest tendency for higher prices for freshwater over marine fish (possibly from high value fish species like Nile Perch). Wilcoxon's (Mann-Whitney U) test (Table 40) revealed that significant differences exist between freshwater and marine fisheries in terms of average prices per kilogramme of different fish species (P<0.001).

Table 40: Wilcoxon's (Mann-Whitney U) on Average Category Numbers of Fish Price per Kilogramme for Freshwater and Marine Fisheries.

Fishery	Sample	Median	Average	Std Dev	Rank	W/U	Z-value	p-value
Freshwater	177	3	2.7175	0.8322	58783	20159	7.5238	<0.001
Marine	357	2	2.1653	0.7096	84062	43030		

Source: Researcher's own calculations.

Number of Fishers Employed on Each Boat

Fishers (boat owners) were also asked about their fishing manpower in terms of the number of workers/fishers employed on their boats. The results (Table 30) suggest that almost all freshwater fishing boats (i.e., 94%) and close to 40% of marine fishers employ a maximum of 20 fishers on each boat. About half of all marine boats have between 21 and 60 fishers. These results are consistent with the recent government fisheries statistics report (URT, 2020a) that suggests that a typical marine fishing boat employs 1.7 times more fishers than a typical freshwater fishing vessel on Lake Victoria. Wilcoxon's (Mann-Whitney U) test (Table 41) showed that the observed differences in number of boat workers between freshwater and marine fisheries were statistically significant at 5% level of significance (P<0.0001).

Table 41: Wilcoxon's (Mann-Whitney U) on Average of Category Numbers for Number of Fishers on a Typical Freshwater and Marine Fishing Boat.

Fishery	Sample	Median	Average	Std Dev	Rank	W/U	Z-value	p-value
Freshwater	177	1	1.0791	0.3276	29560.5	49381.5	-11.8481	0.000
Marine	357	2	2.1373	1.0683	113284.5	13807.5		

Source: Researcher's own calculations.

Profitability per Fishing Boat Owner

The survey asked the fishers (boat owners) to provide their most accurate estimate of annual profits for their fishing business before tax. Table 30 above suggests that about 63% of freshwater fishers earn over TZS50.1 million in annual pre-tax profits, while a similar proportion (60%) of marine fishers report earnings below TZS50.1 million annually. This higher level of profitability among freshwater than marine fishers is likely due to the former's involvement in high value species like Nile Perch, plus premia obtained from exports to lucrative (premium price) European markets as well as the lower number of workers employed on freshwater relative to marine boats. Wilcoxon's (Mann-Whitney U) test (Table 42) showed that these differences were statistically significant (P<0.001).

Table 42: Wilcoxon's (Mann-Whitney U) on Estimated Annual Pretax Profits per Freshwater and Marine Boat Owner's Fishing Business

Fishery	Sample	Median	Average	Std Dev	Rank	W/U	Z-value	p-value
Freshwater	177	3	2.8870	1.1425	57238.5	21703.5	6.0873	<0.001
Marine	357	2	2.2521	1.0538	85606.5	41485.5		

Source: Researcher's own calculations.

Fishers' Average Period (Number of Months) of Active Fishing

The survey also sought to establish the average number of months in each year that the two different types of fisheries engaged in active fishing (Table 30). Freshwater fishers reported fishing for 6.8 months of the year and marine fishers 6.4. Welch Two-Independent Sample t-test (Table 43) indicated that significant differences exist (p=0.001 < 5%) between freshwater and marine fisheries' average number of months of active fishing.

Table 43: Welch Two Sample t-test on Number of Months of Freshwater and Marine Fishers' Active Fishing.

Test data	Mean (freshwater)	Mean (marine)	Degree of freedom (df)	t-statistic	95% conf. interval (CI)	p-value
Fishing months by fishery	6.796610	6.422969	532	3.3025	0.1513880: 0.5958939	0.001

Source: Researcher's own calculations.

4.3.1.4 On-Board Fishing Vessel Technology & Sustainability Requirements

Fish Preservation Technology

Fish and fish products are highly perishable. Therefore, their quality (hence their value) depends on the technology used to preserve them right from the time of capture at sea to landing and eventual sale. Table 44 and Figure 18 below summarise fishers' responses with regards to technologies used on fishing boats to preserve and retain fish quality from the time of catch at sea to landing.

Table 44: On-board Fishing Vessel Technology for Preserving Fish Condition & Sustainability Requirements Observed.

Fish preservation technology, marketing & sustainability	Number of freshwater and marine sub-samples (% proportions)		
	Freshwater (N=177)	Marine (N=357)	Total (N=534)
Fish preservation technology used			
No technology	144 (81.4%)	280 (78.4%)	424 (79%)
Ice buckets/chambers	33 (18.6%)	77 (21.6%)	110 (21%)
Cold storage facilities	0 (0%)	0 (0%)	0 (0%)
Deep freezers or fridges	0 (0%)	0 (0%)	0 (0%)
Gutting or salting	0 (0%)	0 (0%)	0 (0%)
Other technology	0 (0%)	0 (0%)	0 (0%)
Modes of marketing of fish catch			
Sales at landing sites	177 (100%)	357 (100%)	534 (100%)
Mobile communications	177 (100%)	357 (100%)	534 (100%)
Satellite GPS communications	0 (0%)	0 (0%)	0 (0%)
Email & internet means	0 (0%)	0 (0%)	0 (0%)
Other means	0 (0%)	0 (0%)	0 (0%)
Sustainability requirements observed			
None/not applicable	177 (100%)	357 (100%)	534 (100%)
Not fishing in protected areas	0 (0%)	0 (0%)	0 (0%)
Laboratory fish quality tests	0 (0%)	0 (0%)	0 (0%)
Fish quota per period	0 (0%)	0 (0%)	0 (0%)
Reliable fisheries catch data	0 (0%)	0 (0%)	0 (0%)
GPS locator devices on boats	0 (0%)	0 (0%)	0 (0%)
Others	0 (0%)	0 (0%)	0 (0%)

Source: Researcher's own calculations.

Both freshwater and marine fishers are predominantly undertaking their fishing activities without any onboard vessel fish preservation technology (freshwater 81%; marine 78%). The only onboard vessel fish preservation technology used by fishers is ice buckets or chambers (freshwater 19%; marine 22%). There was no evidential record of other listed technologies being used by either category of freshwater or marine fishers. A Chi-squared test (Table 46) revealed that there were no significant differences between freshwater and marine fishers in the use of ice buckets or chambers fish preservation technology (P>0.05). The cause of this statistical result is presented in Contingency Table 45, i.e., by comparing observed with expected frequencies for each of fish preservation technology used.

Table 45: Contingency Table (Extracted from Main Table 44 above)

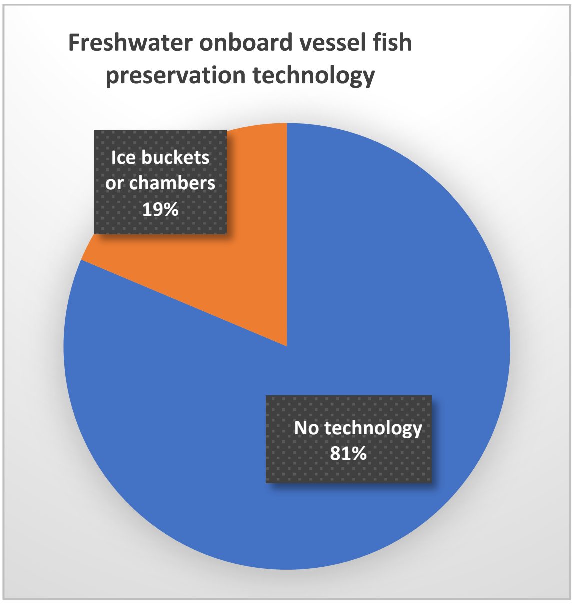
Observed & expected values – fish preservation technology used	Freshwater (N=177)	Marine (N=357)	Total (N=534)
No technology	144 [141]	280 [283]	424
Ice buckets/chambers	33 [36]	77 [74]	110
Total	177	357	534

Source: Adapted from observed field data and researcher's own calculations.
Chi-Square expected frequency values are in square boxes/parentheses (i.e., […]).

Table 46: Pearson's Chi-squared Test with Yates' Continuity Correction on Fishers' Usage of Fish Preservation Technology on Freshwater and Marine Fisheries.

Fishery categories	Categories of fishers' fish preservation technology	Chi(X)-squared	Degree of freedom (df)	p-value
Freshwater & marine	No technology & ice buckets/chambers	0.4529	1	0.5010

Source: Researcher's own calculations.



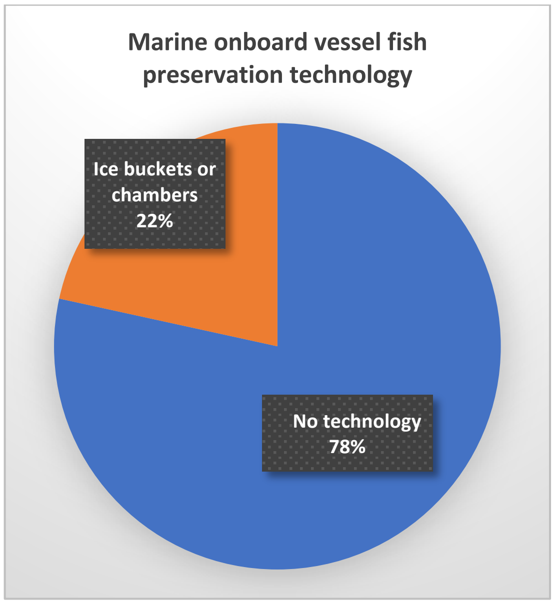


Figure 18: Onboard Vessel Fish Preservation Technology for Freshwater and Marine Fisheries.

Source: Researcher's own Figure.

Fish Marketing and Compliance with Sustainability Requirements

Table 44 and Figure 19 show that all fishers from freshwater and marine fisheries use two approaches to marketing their catches: (i) direct sales at landing sites and (ii) mobile communications. None of these fishers used satellite GPS communications or internet to market their catches.

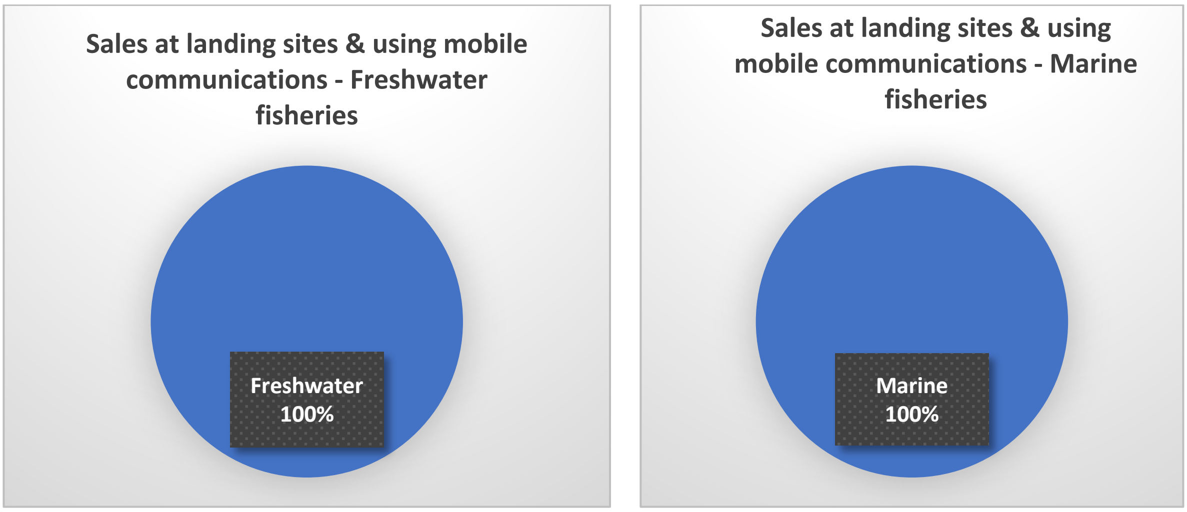


Figure 19: Fish Marketing Approaches for Freshwater and Marine Fisheries.

Source: Researcher's own Figure.

Survey responses suggested further that although regulations existed to ensure sustainable fishing practices (e.g., URT, 2009), both freshwater and marine fishers did not fulfil these sustainability requirements as they were not enforced by authorities when fishers landed and marketed their fish catches (Figure 20).

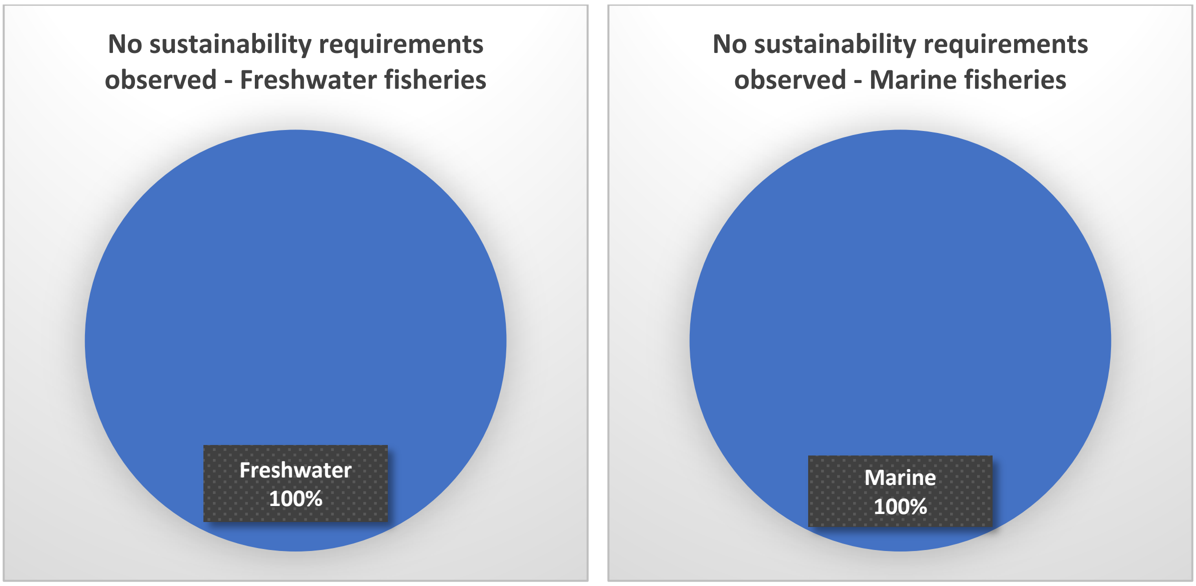


Figure 20: Observance of Sustainability Requirements by Freshwater and Marine Fisheries.

Source: Researcher's own Figure.

4.3.1.5 Willingness (Behavioural Intention) to Accept the Proposed Traceability Solution

An analysis was made on questionnaire responses to find out the proportions of freshwater and marine fishers who expressed willingness (i.e., behavioural intention) to adopt the proposed Blockchain-based traceability solution. It was found (Table 47) that marine fishers had a higher proportion (89.1%) than freshwater fishers (84.2%) of willingness to adopt the proposed traceability solution. On the other hand, freshwater fishers had a higher proportion (15.2%) than marine fishers (10.6%) of being undecided to adopt the proposed traceability solution.

Table 47: Proportions of Freshwater and Marine Fishers Who are Willing to Adopt the Proposed Blockchain-based Traceability Solution.

Likelihood of technology adoption	Freshwater fishers	Marine fishers	Total fishers
Likely to adopt	149	318	467
(%)	*(84.2%)*	*(89.1%)*	*(87.5%)*
Undecided	27	38	65
(%)	*(15.2%)*	*(10.6%)*	*(12.1%)*
Unlikely to adopt	1	1	2
(%)	*(0.6%)*	(0.3%)	*(0.4%)*
Total	177	357	534
(%)	*(100%)*	*(100%)*	*(100%)*

Source: Researcher's own calculations.

A Welch Two Independent Sample t-test was conducted to establish if these differences in Table 47 between freshwater and marine fishers were statistically significant. The results (Table 48) suggest that there is no significant difference (P=0.1917) between freshwater and marine fishers in their willingness or behavioural intention to adopt the proposed Blockchain-based traceability solution.

Table 48: Welch Two Independent Sample t-test on Freshwater and Marine Fishers' Willingness (Behavioural Intention, BI).

Test data	Mean (freshwater)	Mean (marine)	Degree of freedom (df)	t-statistic	95% conf. interval (CI)	p-value
Behavioural intention (BI)	4.352166	4.423903	532	-1.307	-0.17953491: 0.03606057	0.1917

Source: Researcher's own calculations.

4.3.2 Inferential Statistics

4.3.2.1 SEM Outer Model Results

Multicollinearity

To identify the determinants of the fishers' willingness to adopt the proposed traceability technology/solution, an SEM model was run. When this SEM model was run for the first time, a "Singular Matrix error" resulted. This error was caused by the repetition of a single value across 12 of the 21 measurement indicators contributing to the composite Complementary Technology (CT) independent latent construct, leading to variance scores of zero for these measurement indicators (not the composite CT construct itself). Based on Cenfetelli et al. (2009), this problem was resolved by deleting the twelve (12) repetitive measurement indicators, leaving nine (9) measurement indicators on which to subject the CT construct for further testing (see Table 53 in Appendix B4).

Tests for multicollinearity were undertaken using the Variance Inflation Factor (VIF) approach,[69] whereby construct indicators with VIF values of 5 and higher were eliminated. This was done in two steps. First, VIF values were computed between measurement indicators within each of the latent constructs (outer model). When the threshold of VIF<5 was attained at the measurement indicator level in each latent construct, there followed the second step. In this

[69] Variance Inflation Factor (VIF) estimates the amount of multicollinearity between independent variables (predictors) in a regression model. The VIF detects and measures the extent to which the variance of a regression coefficient is inflated because of existence of multicollinearity in the model. For more details see https://www.statisticshowto.com/variance-inflation-factor/

second step, VIF values were calculated to test for multicollinearity between the independent latent constructs (inner model) (See Tables 54 and 55 in Appendix B4). As shown in Table 54, the following indicators have initial VIF values of 5 and above: EE1, EE2, FC1, FC2, FC3, and FC4. Cenfetelli et al. (2009) suggest that where multicollinearity is found, the relevant indicators should be examined to identify causes, for example in the form of overlaps in the wording or meaning of respective measurement indicators. Upon examination, it was found that the wording for the questions underlying indicators EE1, FC2 and FC3 overlapped with the meanings of other measurement indicators in their respective constructs (Effort Expectancy, EE, and Facilitating Conditions, FC), making them redundant. For instance, both knowledge and compatibility (FC2 and FC3) constitute necessary human resources (FC1) for adoption of the proposed traceability solution. Where such overlaps have been identified, Cenfetelli et al. (2009) contend that removal or deletion of all but one of the overlapping set of indicators would not alter the original conceptual meaning of the respective construct. To illustrate, FC2 and FC3 can be removed because the remaining indicator, FC1, has a meaning that encompasses the removed items (i.e., FC2 and FC3). Table 54 shows the effect of deletion of these redundant measurement indicators (i.e., final VIF column), with VIF scores for all remaining indicators being <=5. Table 55 in Appendix B4 shows the test for multicollinearity between the latent constructs (inner model) after addressing multicollinearity issues in constituent measurement indicators (Table 54). Table 55 shows no multicollinearity problems, i.e., VIF < 5 in all cases.

Contribution (Coefficient Weights & Significance) of Measurement Indicators to Latent Constructs

As explained in the methodology section, measurement indicators in the current study are formative (not reflective). This assumes that the latent constructs are constituted and influenced by an array of observable phenomena, i.e., the measurement indicators. The use of latent constructs helps the analysis of causes and effects of a construct, through observance of the rule of parsimony, by the bundling of multiple indicators, representing different construct facets, into single coherent constructs (Barki et al., 2007; Mathieson et al., 2001). To ensure the quality and robustness of these constructs, their constituent measurement indicators were assessed individually through an evaluation of their specific contributions to their respective latent constructs, using path weights and significance (Cenfetelli et al., 2009). This was achieved through bootstrapping the remaining measurement indicators, i.e., those that passed the multicollinearity test, to test their effect on these respective latent constructs in terms of effect size, sign, and significance of each. Where outer model indicator weights (coefficients) were not significant at 5%, these indicators were deleted (Cenfetelli et al., 2009). While Ghasemy et al. (2020) suggest that non-significant indicators need not be discarded if their outer model loadings were found to be 0.5 or higher, other researchers, such as Becker et al. (2013); and Henseler et al. (2016) have pointed out that these loadings are values for computing Average Variance Extracted (AVE) which falls under reflective-based factor (CB-SEM) models, and so, are not appropriate in the current study (i.e., PLS-SEM). These weights for measurement indicators are presented in Table 56, Appendix B4, whereby all indicators for the Complementary Technology (CT) construct, plus some for other constructs, appear to be non-significant.

Following Cenfetelli et al. (2009), these levels of non-significance were improved by first removing/deleting non-significant measurement indicators, starting with the most non-significant, and then running the model again. For instance, the most non-significant measurement indicators for the Complementary Technology (CT) construct (i.e., CT10, CT4, CT11, CT7, CT9) were deleted first and the model run again. This improved the significance of the results whereby the remaining indicators contributing to the CT latent construct, i.e., CT14 and CT17 became significant. These results with improved levels of significance are presented in Table 57, Appendix B4. Having validated the observed measurement indicators, attention now moved to the significance of the independent latent constructs as derived from these measurement indicators. This test of significance involved testing the extent to which the independent latent constructs explained variance in the Behavioural Intention (BI) dependent latent construct/variable. However, this was aimed not at testing the significance of the specified independent latent constructs, but rather for identifying the drivers of intention to adopt the proposed traceability solution, hence an explanatory model. The results of this testing are presented in Table 49 and Figure 21 below. These results show that four independent latent contracts namely Complementary Technology (CT=synergy-enhancing technology combinations), Effort Expectancy (EE=perceived ease of use of technology), Performance Expectancy (PE=belief in the utility or usefulness of proposed technology), and Facilitating Conditions (FC=belief in the existence of supportive resources/environment to adopt/use technology) had significant and positive direct influence on variation in fishers' Behavioural Intention (BI) to adopt, or willingness to accept, the proposed traceability solution.

Table 49: Regression of Independent Latent Constructs on Behavioural Intention (BI) - Bootstrapping Results.

Direction of construct relationships	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (O/STDEV)	P values
Complementary Technology → Behavioural Intention	0.150*	0.152	0.059	2.552	0.011
Effort Expectancy → Behavioural Intention	0.138*	0.138	0.057	2.398	0.017
Facilitating Conditions → Behavioural Intention	0.143*	0.137	0.056	2.567	0.010
Habit → Behavioural Intention	0.090	0.098	0.053	1.704	0.088
Hedonic Motivation → Behavioural Intention	0.071	0.067	0.052	1.364	0.172
Performance Expectancy → Behavioural Intention	0.141*	0.140	0.057	2.474	0.013
Price Value → Behavioural Intention	0.091	0.094	0.050	1.812	0.070
Social Influence → Behavioural Intention	0.021	0.037	0.045	0.456	0.648

Notes: The SmartPLS data analysis settings were: 5,000 resamples, Parallel Processing, Two-tailed test, Complete Bootstrapping and Bias-Corrected and Accelerated (BCa) Bootstrap, Weighting Scheme: Path; Maximum Iterations: 300; Stop Criterion: $1x10^{-7}$. * = significant at 5% level.
Source: researcher's own calculations.

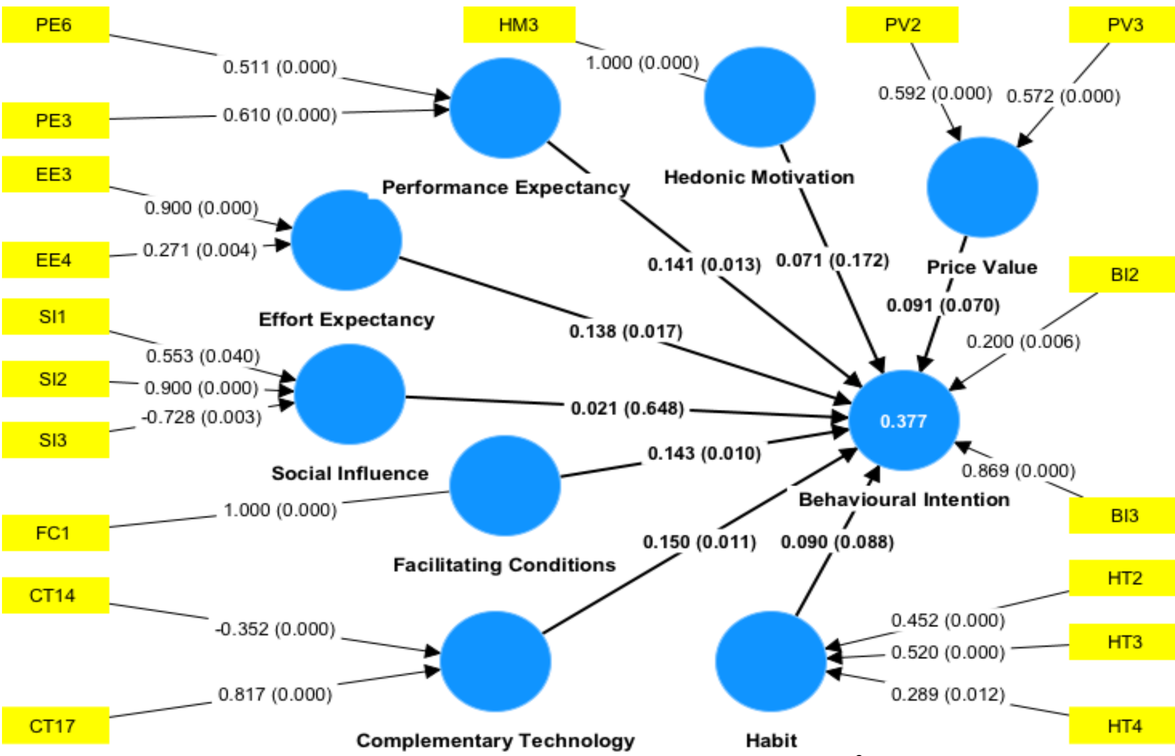


Figure 21: Estimated Parsimonious Model with an Adjusted R^2=37.7% (Behavioural Intention, BI).

Note: Other values in Figure 21 are regression path coefficient weights and corresponding p-values in brackets

4.3.2.2 Inner Model Results

Testing Model Fit - Coefficient of Determination (R^2)

As stated in the methodology section, the primary statistic used for the inner model fit testing is the coefficient of determination (R^2) (Chin, 2010; Henseler et al., 2009), this being the amount of variance in the dependent or outcome variable explained by the independent latent variables contained in the model. Figures 23 (Appendix B4) and 21 above, present, respectively, the estimated unadjusted and adjusted measures of R^2 in the SEM model. Figure 21 (adjusted R^2) suggests that the eight independent latent constructs/variables explain 37.7% of variation in the BI to adopt the proposed traceability solution. This result is classified or categorised as moderately strong (Ghasemy et al., 2020).[70]

Testing model fit - Standardised Root Mean Square Residual (SRMR)

As explained in the methodology section, values of Standardised Root Mean Square Residual (SRMR) of 0.08 or less would confirm that data are suitable for a composite-based (formative) SEM model (Henseler et al., 2016; Hu & Bentler, 1999; 1998). In this case the SRMR values were 0.037 (saturated or observed) and 0.038 (estimated). These values suggest that if all correlations or relationships in the current study's data were equally misfitted, the SEM model used would still be approximately well fitted if the estimated and observed/saturated values or correlations differed by only 0.037. This suggests that the current study's SEM model is more robust and accurate due to its smaller variance fit than the maximum acceptable standard SRMR value of 0.08. For more details see Table 58 in Appendix B4.

Testing for Observable and Unobservable Heterogeneity

Subgroups within the sample may differ in terms of how latent variables impact on intention to adopt the traceability technology solution package. For example, Facilitating Conditions may have a significant effect on intention in the case of women, but not men. This would mean that there is heterogeneity within the sample in terms of the effect of the latent variable. There are two types of this heterogeneity, observable and unobserved. Observable heterogeneity simply

[70] R^2 values of 0 to 25%, 26% to 50%, 51% to 90% and over 90% are respectively considered weak, moderate, significant, and undesirable overfit.

means that data has been collected on the socio-demographic dimension causing the heterogeneity, while unobserved heterogeneity means that data have not been captured for the socio-demographic dimension causing effect. As explained above, the current study tested for observable heterogeneity using five contextual moderating variables, which were anticipated, *a priori,* to have some possible effect on the way latent variables operate, and for which data were collected (Lubke & Muthén, 2005). This testing was done using the Multi-Group Analysis (MGA) tool on SmartPLS software (Ringle et al., 2015). As heterogeneity was tested on collected/captured socio-demographic data, unobserved heterogeneity was not expected, and this was confirmed with FIMIX-PLS test (Hair, et al., 2016; Matthews et al., 2016). The results for observable heterogeneity are presented below.

Segmentation Dimension 1: Fishery type (Freshwater versus Marine Fisheries Segments)

It was found that fishery type has a significant moderating effect on Price Value (PV), i.e., net benefits over acquisition and operational costs of adopting the proposed technology. Therefore, PV had a greater effect on Behavioural Intention (BI) in the case of freshwater fishers than marine fishers. See detailed results in Table 59 in Appendix B4.

Segmentation Dimension 2: Age (Young and Mid-Old Fishers' Segments)

The results showed that there were no significant moderating effects of fishers age group (young and mid-old groups) on the influence of exogenous latent constructs at 5% level of significance. This suggested that the aggregate sample of fishers was fully homogeneous (had no observable heterogeneity) for analysis purposes with respect of age. See detailed results in Table 60 in Appendix B4.

Segmentation Dimension 3: Experience (Up to 10 Years Fishing Experience; and Over 10 Years' Experience)

Results showed that there were no significant moderating effects of level of experience on any of the exogenous latent variables at the 5% level of significance. As such, these two groups exhibited a high degree of homogeneity. See detailed results in Table 61 in Appendix B4.

Segmentation Dimension 4: Education (Formally Educated Fishers; and Fishers Without Formal Education)

The results indicated the existence of heterogeneity on this dimension, whereby level of education had a significant moderating effect on Facilitating Conditions (FC) which had a smaller effect on Behavioural Intention (BI) in the case of informally educated fishers than the formally educated fishers. See detailed results in Table 62 in Appendix B4.

Segmentation Dimension 5: Profitability (Fishers with Profit up to TZS50.0 Million; and Fishers With Profit Over TZS50.0 Million)

There were no significant moderating effects of the level of business profit on any of the exogenous latent variables at 5% level of significance. Therefore, the two segments of size of profit (potential proxy for business scale) exhibited a high degree of homogeneity, and the data can be pooled on this dimension. See detailed results in Table 63 in Appendix B4.

Based on the preceding MGA testing, two conclusions can be drawn. First, in terms of moderating effects on the latent independent variables the fisheries data appear to be largely homogeneous, i.e., with respect of the age, experience, and profitability segments. Second, the data suggest some limited heterogeneity within two moderators: fishery type (freshwater and marine fishers) and education (fishers without and with formal education).

Final SEM Model Results (Integrating Direct, Moderating, and Mediating Effects)

Having identified through MGA tests that fishery type and education segments have potential moderating effects on independent latent constructs/variables, it is important to integrate these two moderators into the final model. Also integrated in this final model are potential mediators as derived from literature (see Figure 13). Running this finally revised model established the extent to which these indirect (moderating and mediating) effects affected the results already presented in Figure 23 (Appendix B4), Figure 21 and Table 49 above. Preliminary results for this final SEM model are presented in Table 64 and Figure 24 (both in Appendix B4). Two conclusions can be drawn from these results in Table 64 and Figure 24. First, by comparing these results with those in Table 49 and Figure 21 above, the highly insignificant moderation effects of fishery and education segments in Table 64 and Figure 24 have also rendered insignificant the direct and indirect (including mediating) effects or influence of most independent latent constructs (except Price Value, PV) on fishers' Behavioural Intention (BI). Second, the moderation effects of fishery and education segments have improved the explanatory power of the model (i.e., adjusted R^2) from 37.7% (Figure 21) to 39.5% (Figure 24). These highly non-significant effects in the first instance could be a result of the specified moderating variables (fishery type and education) being irrelevant to moderate some of the independent latent constructs' influence on fishers' intention or being collinear with each other or among themselves (Kraemer, 2013). To resolve this general non-significance problem, the researcher followed the footsteps of Cenfetelli et al. (2009). The insignificance of these independent latent constructs and indirect (moderating and mediating) effects (Table 64 and Figure 24) were improved by systematically deleting the most non-significant variables/relationships and running the model again (Cenfetelli et al., 2009). This procedure produced an improved and parsimonious final SEM model as presented in Table 50 and Figure 22 below. It is seen here that the adjusted R^2 has improved from 37.7% before the indirect (moderation and mediation) effects (Figure 21) to 38.5% thereafter (Figure 22).

As presented in Table 50 and Figure 22, four independent latent constructs had a direct positive influence on fishers' intention (BI) to adopt the proposed traceability solution. These are (use of) Complementary Technology (CT=synergistic complementary technology for enhancing adoption of proposed solution like smart mobile phones), Effort Expectancy (EE=ease or convenience of using the solution), Performance Expectancy (PE=usefulness or utility of the solution to resolve the identified problems), and Price Value (PV=net benefits of the solution over costs of its acquisition and operation). While PV had both direct and indirect influence on fishers' Behavioural Intention (BI) through the fishery type moderator, Facilitating Conditions (FC) and Habit (HT) influenced BI indirectly through education and fishery type moderators, respectively. It was found that there were non-significant differences in direct effects between the fishery type segments (freshwater and marine fishers) and education segments (fishers without formal and with formal education) on fishers' intention (BI) to adopt the proposed traceability solution. On the other hand, the influence of PV on BI was found to be stronger among freshwater fishers than marine fishers. Moreover, the influence of HT on BI was found to be stronger among marine fishers than freshwater fishers. Finally, the influence of FC on BI was found to be stronger among the formally educated fishers than those without formal education. These results have been summarised in Table 65 (Appendix B4) that compares the study's hypotheses presented in the survey methodology section and the empirical results.

Table 50: Final Parsimonious SEM-Model Results for Direct and Indirect (i.e., Moderation and Mediation) Effects/Relationships

Hypothesised Effects (Relationships)	Original coefficient (p_3)	Sample mean (M)	Standard deviation	T statistics	P values
Direct (main) effects					
Complementary Technology → Behavioural Intention	0.146*	0.147	0.060	2.419	0.016
Complementary Technology → Effort Expectancy	0.462**	0.462	0.055	8.335	0.000
Education moderator → Behavioural Intention	0.018	0.016	0.073	0.247	0.805
Effort Expectancy → Behavioural Intention	0.153*	0.148	0.060	2.537	0.011
Effort Expectancy → Hedonic Motivation	0.159**	0.160	0.054	2.946	0.003
Facilitating Conditions → Behavioural Intention	0.048	0.046	0.072	0.660	0.509
Facilitating Conditions → Effort Expectancy	0.288**	0.289	0.048	6.067	0.000
Facilitating Conditions → Hedonic Motivation	0.344**	0.343	0.053	6.514	0.000
Fishery moderator → Behavioural Intention	0.016	0.020	0.078	0.210	0.834
Habit → Behavioural Intention	-0.026	-0.014	0.072	0.362	0.717
Hedonic Motivation → Behavioural Intention	0.062	0.059	0.052	1.190	0.234
Performance Expectancy → Behavioural Intention	0.131*	0.130	0.059	2.234	0.026
Performance Expectancy → Hedonic Motivation	0.118**	0.119	0.045	2.610	0.009
Price Value → Behavioural Intention	0.216**	0.219	0.076	2.824	0.005
Social Influence → Behavioural Intention	0.009	0.026	0.045	0.189	0.850
Indirect (moderating) effects					
Fishery moderator x Habit → Behavioural Intention	0.202*	0.193	0.093	2.163	0.031
Fishery moderator x Price Value → Behavioural Intention	-0.192*	-0.191	0.095	2.028	0.043
Education moderator x Facilitating Conditions → Behavioural Intention	0.152*	0.147	0.069	2.192	0.028

Indirect (mediating) effects

Hypothesised mediation effects	Coefficient ($p_1 \times p_2$)	T-statistics	P values	Is ($p_1 \times p_2$) significant? Y/N	Is p_3 significant? Y/N	Mediation Outcome (results)
PE→HM→BI	0.007	1.038	0.300	N	Y	Direct Only (No mediation)

EE→HM→BI	0.010	1.008	0.313	N	Y	Direct Only (No mediation)
FC→HM→BI	0.021	1.179	0.239	N	N	No Effect (No mediation)
CT→EE→BI	0.071*	2.393	0.017	Y	Y	Complementary (Partial mediation)
FC→EE→BI	0.044*	2.367	0.018	Y	N	Indirect Only (Full mediation)

Note:
p_1 = a coefficient of the relationship between an independent construct to a mediator construct.
p_2 = a coefficient of the relationship between a mediator construct and a dependent construct.
p_3 = a coefficient of the (direct) relationship between an independent and a dependent construct.
The SmartPLS data analysis settings to capture both direct and indirect (moderating and mediating) effects were: 5,000 resamples, Parallel Processing, Two-tailed test, Complete Bootstrapping and Bias-Corrected and Accelerated (BCa) Bootstrap, Weighting Scheme: Path; Maximum Iterations: 300; Stop Criterion: $1x10^{-7}$. * and ** = significant at 5% and 1% levels, respectively.
Source: Researcher's own calculations.

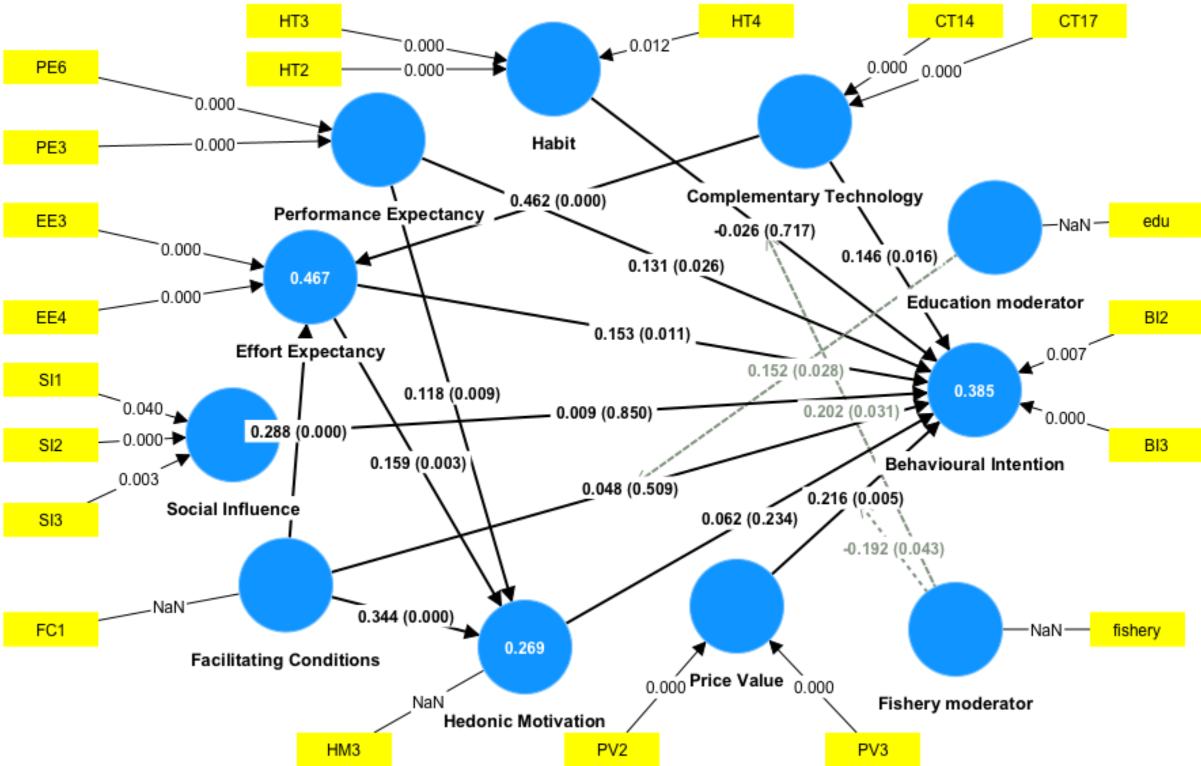


Figure 22: Final Parsimonious SEM-Model with Direct and Indirect (Moderating and Mediating) Effects.

Note: Adjusted R^2 = 38.5% (Behavioural Intention). Other values in the figure are regression path coefficient weights and corresponding p-values in brackets. The SmartPLS data analysis settings were: 5,000 resamples, Parallel Processing, Two-tailed test, Complete Bootstrapping and Bias-Corrected and Accelerated (BCa) Bootstrap, Weighting Scheme: Path; Maximum Iterations: 300; Stop Criterion: 1×10^{-7}; NaN=Not a Number.

Source: Researcher's own Figure.

In terms of main (i.e., direct) effects, Table 50 shows a non-significant relationship between Habit (HT) and fishers' intention (BI) (HT → BI, p>0.05). However, Table 50 also shows a significant moderating effect of fisheries type (FT) on HT (FT → HT, p<0.05). This means FT changes the way that HT impacts BI. To explain these significant moderating results while the main effects were insignificant, analyses on the sub-groups were undertaken. The multi-group analysis (MGA) test (see Table 59, Appendix B4) shows no significant differences between the marine and freshwater fisheries type in terms of the way HT impacts BI (p>0.05). However, the finite mixture partial least square (FIMIX-PLS) test (Hair, et al., 2016; Matthews et al., 2016) as presented in Table 66 (Appendix B4) shows that there is a significant statistical relationship between HT and BI for marine fishers (P<0.05), but not freshwater fishers (P>0.05). These last two results suggest that the impact of HT on BI for marine fishers is only borderline significant.

Furthermore, the main (i.e., direct) effects in Table 50 show the Facilitating Conditions (FC) → Behavioural Intention (BI) relationship to be non-significant (p>0.05), suggesting FC does not have direct effects on fishers' intention (BI). On the other hand, however, Table 50 also shows education as having significant moderating effects on the FC → BI relationship. This suggests education moderator changes the way that FC impacts BI. To explain these significant moderating results while the main effects were found to be insignificant, the researcher undertook an analysis of education segments. The multi-group analysis (MGA) test (see Table 62, Appendix B4) shows fishers with formal education having a significant influence on the FC → BI relationship (p<0.05) while fishers without formal education having no significant effects (p>0.05). These results are confirmed by the finite mixture partial least square (FIMIX-PLS) test (Hair, et al., 2016; Matthews et al., 2016) (Table 67, Appendix B4). It is found that formally educated fishers influence the way FC impacts on BI (p<0.05) while those fishers without formal education have insignificant influence (p>0.05).

Regarding the mediating effects, the results in Table 50 and Figure 22 show that Hedonic Motivation (HM) does not mediate the effects (relationships) between the following constructs (i.e., P-values>0.05 for p_1xp_2 coefficients): Performance Expectancy (PE) and Behavioural Intention (BI), Effort Expectancy (EE) and BI, and Facilitating Conditions (FC) and BI. These results suggest that fun and interesting features of the proposed traceability solution do not influence the effect of its utility/usefulness (i.e., PE), ease/convenience of use (i.e., EE), and technical support services and infrastructural resources (i.e., FC) to drive fishers' motivation and intention (BI) to adopt the solution. On the other hand, EE was found to mediate (i.e., P<0.05) the relationship between Complementary Technology (CT) and BI. This happened when the direct relationship between CT and BI (CT→BI) was significant. As the coefficients in both these direct (p_3=0.146) and indirect (i.e., mediated, p_1xp_2=0.071) relationships are pointing in one direction (i.e., positive), this mediation type is called complementary partial mediation. This means the ongoing usage of complementary technologies like mobile phones (i.e., CT) drives the fishers' intention (BI) both directly and indirectly (i.e., mediated) through the ease/convenience of use (i.e., EE) of the proposed traceability solution. Finally, EE is found to mediate (i.e., P<0.05) the relationship between FC and BI in a way that the direct effect (i.e., FC→BI) is insignificant. This type of 'indirect (i.e., mediated) only' mediation is called full mediation. This suggests that the effect of existing infrastructural resources and technical support (i.e., FC) on fishers' intention (i.e., BI) to adopt the proposed traceability solution can be achieved only when the solution has features of ease and convenience of use (i.e., EE).

Differences Between Whole Sample, Freshwater, and Marine Fishers

As noted earlier, there exist significant differences between freshwater and marine fisheries regarding the influence of Habit (HT), Price Value (PV), and Facilitating Conditions (FC) on the fishers' intention (BI) to adopt the proposed traceability solution. Therefore, the current study sought to undertake separate PLS-SEM analyses by running the hypothesised framework/model (Figure 13) on each of these sub-group samples (i.e., freshwater, and marine fishers) to uncover the extent of these differences. Table 51 presents a summary of these results, with detailed results in Appendix B4 (Tables 68 and 69; and Figures 25 and 26).

Table 51: Testing and Comparing Direct and Indirect Effects Between Whole Sample, Freshwater, and Marine Fisheries

Hypothesised and Tested Relationships (Effects)	Overall fisheries sample (N=534)		Freshwater fisheries (N=177)		Marine fisheries (N=357)	
	Coefficient	P-values	Coefficient	P-values	Coefficient	P-values
Direct effects						
CT→BI	0.146*	0.016	0.137*	0.019	0.092	0.209
EE→BI	0.153*	0.011	0.146*	0.012	0.215**	0.005
FC→BI	0.048	0.509	-0.038	0.625	-0.022	0.809
HT→BI	-0.026	0.717	0.258**	0.003	0.277**	0.004
HM→BI	0.062	0.234	0.066	0.209	0.064	0.332
PE→BI	0.131*	0.026	0.146*	0.012	0.261**	0.000
PV→BI	0.216**	0.005	0.090	0.065	0.014	0.817
SI→BI	0.009	0.850	0.013	0.773	-0.028	0.640
Adjusted R^2	38.5%		38.8%		43.6%	
Indirect effects						
Moderating effects						
Fishery moderator x HT→BI	0.202*	0.031	-	-	-	-
Fishery moderator x PV→ BI	-0.192*	0.043	-	-	-	-
Education moderator x FC → BI	0.152*	0.028	0.280**	0.001	0.209*	0.043
Education moderator x HT→ BI	-	-	-0.244*	0.012	-0.231*	0.046

Mediating effects

Hypothesised mediation effects	Coefficient $(p_1 \times p_2)$	T-statistics	P values	Is $(p_1 \times p_2)$ significant? Y/N	Is p_3 significant? Y/N	Mediation Outcome (results)
Whole sample (N=534)						
PE→HM→BI	0.007	1.038	0.300	N	Y	Direct Only (No mediation)
EE→HM→BI	0.010	1.008	0.313	N	Y	Direct Only (No mediation)

FC→HM→BI	0.021	1.179	0.239	N	N	No Effect (No mediation)
CT→EE→BI	0.071*	2.393	0.017	Y	Y	Complementary (Partial mediation)
FC→EE→BI	0.044*	2.367	0.018	Y	N	Indirect Only (Full mediation)
Freshwater fisheries (N=177)						
PE→HM→BI	0.008	1.081	0.280	N	Y	Direct Only (No mediation)
EE→HM→BI	0.010	1.057	0.291	N	Y	Direct Only (No mediation)
FC→HM→BI	0.023	1.247	0.213	N	N	No Effect (No mediation)
CT→EE→BI	0.068*	2.370	0.018	Y	Y	Complementary (Partial mediation)
FC→EE→BI	0.042*	2.328	0.020	Y	N	Indirect Only (Full mediation)
Marine fisheries (N=357)						
PE→HM→BI	0.007	0.789	0.430	N	Y	Direct Only (No mediation)
EE→HM→BI	0.013	0.855	0.392	N	Y	Direct Only (No mediation)
FC→HM→BI	0.021	0.954	0.340	N	N	No Effect (No mediation)
CT→EE→BI	0.096*	2.509	0.012	Y	N	Indirect Only (Full mediation)
FC→EE→BI	0.063*	2.392	0.017	Y	N	Indirect Only (Full mediation)

Note:
p_1 = a coefficient of the relationship between an independent construct to a mediator construct.
p_2 = a coefficient of the relationship between a mediator construct and a dependent construct.
p_3 = a coefficient of the (direct) relationship between an independent and a dependent construct.
The SmartPLS data analysis settings to capture mediation effects were: 5,000 resamples, Parallel Processing, Two-tailed test, Complete Bootstrapping and Bias-Corrected and Accelerated (BCa) Bootstrap, Weighting Scheme: Path; * and **= significant at 5% and 1% levels, respectively.
Source: Researcher's own calculations.

Regarding the main (i.e., direct) effects, Table 51 shows similar significant results across all three samples (i.e., whole sample, freshwater, and marine fisheries) with regards to EE→BI and PE→BI relationships. This suggests that the influence of ease or convenience of use (i.e., EE) and utility or usefulness (i.e., PE) on the intention (i.e., BI) of fishers to adopt the proposed traceability solution is homogeneous (i.e., the same) across the freshwater and marine fishers' populations. Also, the results for the CT→BI relationship were similar and significant for the whole sample and freshwater fishers while the same relationship (i.e., CT→BI) was non-significant for marine fishers. This suggests that the synergistic effect of complementary technologies such as usage of smart mobile phones (i.e., CT) would influence the intention (i.e., BI) of freshwater (not marine) fishers to adopt the proposed traceability solution. While the HT→BI relationship was non-significant in the whole sample, this relationship became strongly significant (i.e., $p<0.01$) when tested separately in sub-samples of freshwater and marine fisheries. This suggests the existence of significant differences in automatic habitual tendencies (HT) between freshwater and marine fisheries to use complementary technology (i.e., CT) that influence the fishers' intention (i.e., BI) to adopt the proposed traceability solution. These differences tend to be obscured or hidden when the sub-samples are pooled (i.e., whole sample) and tested together. Furthermore, the relationship PV→BI was significant for the whole sample but became non-significant when tested under each of the sub-samples of freshwater and marine fisheries. This suggests that the net benefits of adopting the proposed solution over its acquisition and operational costs (i.e., PV) become significant when the number of fishers with intention (i.e., BI) (i.e., sample size) is sufficiently large enough to command adequate statistical power (Serdar et al., 2021). Overall, the eight independent (i.e., exogenous) latent constructs explain 38.5%, 38.8%, and 43.6% of variations in intention (i.e., BI) among the whole population, freshwater, and marine fishers respectively, to adopt the proposed traceability solution. As all these three levels of explained variation in fishers' intention fall within the range of 26-50%, they are labelled as moderately strong (Ghasemy et al., 2020). This suggests that separation or breaking of the whole sample into respective sub-samples of freshwater and marine fisheries improves the explanatory power of the specified framework/model in Figure 13. However, this improvement is only really meaningful in the marine fisheries case. This means, pooling the whole sample together obscures/hides significant differences between freshwater and marine fisheries, thus eroding/weakening the explanatory power of the specified model. Therefore, the above results indicate that the specified eight independent latent constructs influence more variations/changes among the marine fishers' than the freshwater fishers' intention to adopt the proposed traceability solution.

As for the moderating effects, the results in Table 51 show that education moderates the FC→BI relationship across all three samples: the whole sample, freshwater, and marine fisheries. This means the influence of infrastructural resources and other necessary support services (i.e., FC) on intention (i.e., BI) is higher among fishers with formal education than those without formal education across both freshwater and marine fisheries. Moreover, education was also found to moderate the relationship HT→BI in both sub-samples of freshwater and marine fisheries. This suggests that the influence of automatic habitual tendencies (i.e., HT) on intention (i.e., BI) is higher among fishers without formal education than those with formal education across both freshwater and marine fisheries.

Table 51 indicates further that the freshwater fisheries sub-sample results exactly mirror the mediation results of the whole sample as presented in Table 50 and explained earlier. Moreover, the mediation results of the marine fisheries sub-sample appear to be like those of the freshwater sub-sample, except for the CT→EE→BI relationship. For freshwater fisheries, EE mediates (i.e., $p<0.05$) the relationship between CT and BI when the direct relationship between CT and BI (i.e., CT→BI) is significant, hence the complementary partial mediation. This is because the coefficients in both these direct (p_3=0.137) and indirect (i.e., mediated, p_1xp_2=0.068) relationships are positive (i.e., pointing in one direction). These results suggest that the ongoing usage of synergistic complementary technologies like mobile phones (i.e., CT) drives the freshwater fishers' intention (BI) both directly and indirectly (i.e., mediated) through the ease/convenience of use (i.e., EE) of the proposed traceability solution. However, for marine fisheries, the relationship CT→EE→BI appears to be mediated only (i.e., $p<0.05$, coefficient p_1xp_2=0.096), where the direct (i.e., the CT→BI) relationship is non-significant (i.e., $p>0.05$). These results indicate that usage of synergistic complementary technologies like mobile phones (i.e., CT) influences marine fishers' intention (BI) indirectly only (i.e., mediated) through the ease/convenience of use (i.e., EE) of the proposed traceability solution.

The next chapter (Chapter 5) discusses these results, provides policy implications and recommendations, and finally concludes the current study.

CHAPTER 5:
DISCUSSION, POLICY IMPLICATIONS, AND CONCLUSIONS

5.1 Discussion

5.1.1 Research Problem and Questions

The main research problem addressed in this dissertation was the identification of barriers and drivers to the sustainable development and commercial scaling-up of the fisheries resources sector in Tanzania and then to evaluate potential approaches to overcoming these barriers. These solutions had to satisfy two objectives: (i) improvement in the sustainability of the relevant fisheries resources, i.e., preventing over-exploitation; and (ii) ensuring fair distribution of opportunity for those who rely on fisheries to meet their food and income needs. To achieve these objectives the following research questions were proposed: (i) What are the drivers of, and barriers to, the sustainable development and commercial scaling-up of Tanzania's fisheries supply and value chains? (ii) To which extent do governance and traceability failures act as barriers? (iii) How might governance and traceability in fisheries be improved/guaranteed through use of technology to increase traceability? (iv) Would fishers adopt new traceability-enhancing technologies?

5.1.2 Identification of Barriers to Fisheries Sustainable Development

Two main barriers to fisheries sustainable development were identified, which were termed Trust Loss (TL) and Governance Loss (GL). While TL captures deficiencies in human capital qualities, namely trust, credibility, and productivity, GL captures the overexploitation, by opportunistic rogue actors, by taking advantage of inadequacies in governance presented by TL. These unsustainability problems (TL & GL) were found to be more prevalent in marine fisheries (i.e., 68%) than in freshwater fisheries (i.e., 32%). This unsustainable overexploitation of fisheries resources was conceptualised in the current study as Globoverfishing, which means overfishing everywhere by local and foreign actors, especially in Tanzanian waters. This Globoverfishing was recently illustrated in Ghana whereby two government officials disappeared in mysterious circumstances while on duty as compliance enforcers/observers onboard foreign marine fishing vessels (Nyarko, 2023). It is alleged that these two officials had collected evidence (one in 2019, another in 2023) that would implicate foreign fishing vessels that they observed, including a Chinese one, for undertaking illegal and unsustainable fishing practices in Ghanaian waters (Nyarko, 2023). This evidence would potentially have formed a basis to charge owners of respective vessels fines amounting to US$1.0 million each (Nyarko, 2023). These unsustainability problems in fisheries resources (i.e., TL and GL), including those that are potentially life-threatening to advocates of sustainable fishing practices (e.g., Nyarko, 2023), were collectively coined in the current study as Fishmining Basic Social Process (BSP) Grounded Theory (GT). This Fishmining BSP GT concept represents the undertaking (in Tanzania waters) of illegal and unsustainable fishing practices by rogue opportunistic actors in a manner like extraction of non-renewable mineral resources. This prompted the need to enhance the sustainability of the fisheries sector through improved trust and credibility among fisheries stakeholders and robust institutional governance structures. The conceptualised Fishmining BSP GT relates, in a meaningful way, to an already tested natural resource governance framework (Schmeier et al., 2016) (see Appendix B3). This framework suggests that sustainable use and development of common, or public, resources requires that stakeholders meet two basic conditions: first is having guiding rules and principles that spell out the rights and obligations of each actor/stakeholder (i.e., resource governance). The second condition is the existence, among stakeholders/actors, of a collectively agreed mechanism to evaluate, from time to time, the resource exploitation status, as well as conflict resolution procedures (which are dependent on the level of trust and credibility among stakeholders). Moreover, Wang et al. (2020) found that the problem of foodborne illnesses can be addressed through improvements in food handling behaviours driven by use of consumer self-protection measures and food safety knowledge. This notion of putting the responsibility for maintaining food safety onto consumers is consistent with the current study’s proposition that the lack of trust and credibility among fishery stakeholders and failures in public governance of fisheries, can be circumvented by alternative private sector food safety mechanisms. Wang et al.’s (2020) research focused on consumers in a leading economy (i.e., China) while the current study addresses fisheries sustainability problems and potential solutions in a developing country (Tanzania) context. However, both studies appear to converge on the growing global trend to move away from public, towards private or consumer-centred, food safety and sustainability mechanisms (Leal et al., 2015).

Achieving the sustainable development of any resources including fisheries resources requires a concerted collective effort by a range of actors (Andriesse et al., 2022; Plotnek et al., 2016; Schmeier et al., 2016). However, in the current study, only limited collaboration between actors in the Tanzanian fisheries sector was reported which contributed much of the ongoing unsustainability problems. A similar problem was reported by Plotnek et al. (2016) for an overfished fishery in Chile that failed to meet Marine Stewardship Council's (MSC)[71] certification standards for sustainability and traceability. This Chilean fishery failed to get all actors/fishers to collectively agree on and enforce sustainability compliance requirements among all members. These failures were worsened by the existing local regulatory environment (i.e., laws and regulations) which did not prioritise and enforce sustainability requirements on fishers and other actors involved in fisheries resources' exploitation. However, the current study's results differ from those of Plotnek et al. (2016) who focused on the local market with limited or lower prospects for seafood premium prices compared to the current study involving both the local Tanzanian market and potential foreign buyers in the UK/EU. The cross-border component of the current study is crucial, as it is this type of trade that offers a potential opportunity for actors in both Tanzania and the UK/EU to jointly invest in a credible traceability system that would help to address the identified unsustainability challenges. Such a traceability system would help to ensure the sustainable sourcing of seafood products and compliance with higher health safety quality standards, thus attracting premium price consumers (Leal et al., 2015). Also, such a traceability system would encourage sustainable fishing practices as this compliance would be rewarded with a guarantee of continued business, especially the access to lucrative premium price markets in the UK/EU. This way, the sustainable development and commercial scaling-up of fisheries resources in Tanzania would be achieved through the above compliance measures that limit or remove the access of rogue actors to lucrative premium price markets.

5.1.3 Testing Drivers of Fishers' Acceptance of a Blockchain-Based Technology Solution

5.1.3.1 Proposed Traceability Solution and its Potential Levels of Uptake

The current study has proposed a Blockchain-based and Google-enhanced satellite communications system with features of enhancing transparency and accountability to limit illegal and unsustainable fishing practices along Tanzania's fisheries supply and value chains. This proposed traceability solution will, among others, help fishers to access richer fishing grounds, avoid prohibited or conserved fishing areas (e.g., marine protected areas), communicate seamlessly with their potential local and foreign fish buyers (i.e., fish markets) and suppliers of key goods and services while at sea, as well as be able to report emergency situations like accidents while at sea, thus enabling timely arrival of rescue services. Equally

[71] MSC is a market-based certification organisation that certifies fisheries after they meet minimum sustainability and traceability requirements, thus granting them a wider access to premium seafood markets. See https://www.msc.org/

important, the current study's proposed traceability solution is going to help its operators (i.e., the audit agency) and relevant authorities to identify and hold accountable through prosecution, those rogue actors who undertake illegal and unsustainable fishing practices, including denying them access to lucrative local and foreign premium price fish markets. This current study's proposed traceability solution resembles Starlink's satellite broadband communications (data streaming/internet, video/audio calls, messaging, etc) which is presently being commercialised following successful tests with potential users (Shull, 2024; Zlatev, 2024). However, Starlink's package appears to be relatively cheaper (at US$250.00 monthly charge and US$2,500.00 one-off hardware cost (Zlatev, 2024), compared to the current study's US$100.00 monthly charge and the initial fixed cost outlay of US$250,000.00 for database server equipment and infrastructure. Nonetheless, the current study's proposed traceability solution offers a functionality for common multi-actor (member-based) storage and real time sharing of fisheries data and activities. This feature is not present in the Starlink's satellite communications package, hence the main reason for the significant initial price difference relating to fixed costs.

The current study found a higher rate of potential uptake among marine relative to freshwater fishers, although both are more than 80%. This was expected because the features of the proposed traceability solution appear to address challenges that are more severe for marine than freshwater fishing environments. For instance, the feature providing access to environmental data suggesting richer fishing grounds would help improve fishers' productivity through higher catch volumes. Also, adoption of the traceability solution could potentially improve access to premium price markets in the UK/EU. These two features would appear more attractive to marine fishers, whose current productivity and profitability lag those of freshwater fishers. In addition, the traceability solution feature of satellite GPS communications would potentially help fishers to report incidences of piracy at sea, also to avoid areas protected or prohibited for fishing activities. These features appear to be of more value in the more challenging marine fishing environments (e.g., wider/expansive, and deeper) than freshwater environments.

The above traceability solution uptake rates are consistent with rates found in previous studies (for example, see, Damba et al., 2020; Ouédraogo et al., 2019). While assessing the effects of technology dissemination approaches on agricultural technology uptake among rice, maize, and soybeans farmers in Northern Ghana, Damba et al. (2020) found the rate of technology uptake among farmers to vary between 68% and 75%. These technology uptake variations were driven by the quality of the technology dissemination approach design, notably radio dissemination, case studies, and field trials. On the other hand, Ouédraogo et al. (2019) evaluated the rates of uptake of Climate Smart Agricultural Technologies among farmers in Mali and found them to vary between 21% (intercropping) and 89% (organic manure). These uptake rates were driven by variations in farmers' education levels, number of workers on farms, access to government or donor subsidies, and training with the technology. The uptake rate for organic manure (i.e., 89%) is quite comparable to the current study's findings, because manure from domesticated livestock was readily available and accessible to farmers in the same way that the possession of Complementary Technology (e.g., mobile phones) drove potential uptake rates among Tanzanian fishers. Another similarity of the current study with that of Ouédraogo et al. (2019) is that both had objectives of technology adoption to achieve sustainability by limiting unsustainable practices by actors in fisheries and agriculture, respectively. Although the technology uptake rates for these two studies (Damba et al., 2020; Ouédraogo et al., 2019) appear to be like those of the current study, there remain some differences. While the two studies in Ghana and Mali tested actual rates of uptakes of available technologies by farmers, the current study just tested the fishers' potential uptake (i.e., willingness to accept/adopt) of a notional (not yet available) technology solution. Therefore, there are chances that actual rates of adoption of the current study's proposed solution might be different. To illustrate, Domician (2018) found that most small-scale farmers in Tanzania use their mobile phones on social (non-business related) interactions rather than for advancing business or commercial activities. This mirrored Tanzania's general trends whereby most public and private investable resources go to addressing short-term social causes rather than building and scaling up long-term productive capacities and economic development (Domician, 2006). Therefore, to enhance the uptake of the proposed traceability solution, Domician (2018) suggests that fishers should be incentivised to increase the usage of their mobile phones to maximise the potential commercial benefits of this solution. Another difference between the current study and the above-listed past studies is that these past studies tested technology adoption in agricultural crops and settings while the current study focuses on the fisheries sector. Other studies produced technology uptake rates which were significantly different from the current study's results. Dzanku et al. (2020) determined the level of technology uptake among farmers in Ghana for plant inoculants and improved seeds and found the actual uptake rates to be 22.0% and 23.7%, respectively. These uptake rates were so low because the technologies were not available at the time the farmers were trained or exposed to trials, due to supply limitations arising from importation and distribution logistical issues. The actual technologies were made available to the farmers later, hence the low actual uptakes. The other difference is that fishers in the current study perceive that there would be no supply limitations, while in the Dzanku et al.'s study the farmers are aware that supply problems already existed. In Table 52 below, Obiero et al.'s (2019) study is used as a comparator to highlight the importance, for rate of technology uptake, of fishers' familiarity and existence of complementary technology with the user technology platform.

Table 52: Obiero et al.'s (2019) Study as a Comparator to the Current Study's Technology Uptake Rate

Factor	This current Study (2024)	Obiero et al.'s (2019)	Remarks
Country	Tanzania	Kenya	Comparable developing countries
Main research subject and context	Traceability technology solution for commercial sustainability in smallholder marine and freshwater fisheries.	Aquaculture technologies uptake level among smallholder fish farmers.	The two studies share similar main actors in supply and value chains: (i) smallholder fishers in Tanzanian capture fisheries and Kenyan fish farmers in aquaculture; and (ii) both largely dependent on local markets including fish processors.
Level of initial awareness or familiarity with the technology.	None – researcher had to introduce technology features (this being new or notional technology).	Aquaculture technology awareness by 63% of fish farmers	Kenya fish farmers aware of hormonal sex reversed fingerlings and supplementary feeds aquaculture technologies. Fishers in Tanzania have complementary technology (mobile phones) to drive adoption of the proposed/notional technology.
Uptake rates	87.5% (overall) – notional adoption	30% – actual adoption	Low actual uptake rate in Kenya due to limited skills and acquisition resources. Aquaculture projects are more expensive than capture fisheries due to costly fish feeds and farm management (Villasante et al., 2013). Despite being notional, over 75% of Tanzanian fishers had enough incomes for potential acquisition of proposed technology and would have no skills issues as they possess mobile phones needed to adopt the traceability solution.
Drivers of uptake	Key driver: Access to premium price markets (e.g., UK/EU). Other drivers: Ease of use (EE), usefulness or utility to solve traceability problem (PE), benefits/price value ratio (PV), availability of complementary technology (e.g., mobile phones, GPS/Google maps).	Ease of use (EE), technology affordability (PV), and accessible language communication materials (including short video presentations, and radio features).	Apart from the current study's incentive to access lucrative local and export markets, other drivers are similar between the two studies. The language barrier challenge was not highlighted in the Tanzanian case because the solution was communicated in the well understood Swahili language. However, this language barrier may arise in the actual testing environment if the solution's instructions are predominantly presented in English.

Source: Adapted from Obiero et al. (2019) and current study's literature & data analysis.

This Obiero et al. (2019) study predicted the actual uptake rate of aquaculture technologies among smallholder fish farmers in Kenya and found the uptake rate to be 30.0%. The major barriers that caused this low rate of uptake in Obiero et al.'s (2019) study were identified as low technical skills and limitations in resource base among the majority fish farmers. Again, these two studies in Ghana and Kenya tested actual rates of technology uptake in the real environment which is different from the current study's testing of potential uptake rates in a notional environment. In addition, the fishers' income levels as presented elsewhere in the current study can comfortably afford the solution's proposed price, and these fishers already use existing Complementary Technology (e.g., mobile phones with embedded applications like text messaging, Google Maps & Cloud). These complementary technologies would reduce the initial adoption costs of the proposed traceability solution.

5.1.3.2 Factors/Drivers of Fishers' Willingness to Adopt the Proposed Traceability Solution

To summarise, results in the current study showed four main drivers of willingness to adopt the technology solution, namely Complementary Technology (CT), Effort Expectancy (EE), Performance Expectancy (PE), and Price Value (PV). In addition, the effect of PV on Behavioural Intention (BI) (adoption intention) was found to be moderated by fishery type, whereby the influence of PV on BI was found to be stronger among freshwater fishers than marine fishers. Although the main effects of Habit (HT) and Facilitating Conditions (FC) on BI were insignificant, fishery type was found to significantly moderate the HT → BI relationship as education was found to significantly moderate the FC → BI relationship. While the effect of HT on BI was found to be stronger among marine fishers than freshwater fishers, the effect of FC on BI was found to be stronger among the more formally educated fishers than those without formal education. These results are unpacked in detail in the following paragraphs.

The CT's significance and positive influence on fishers' intention to adopt the proposed traceability solution was anticipated ($\beta=0.146$, $P=0.016<0.05$). This is because CT represents the already existing infrastructural support that is necessary for fishers' adoption of this traceability solution. The key infrastructure here is fishers being in possession and operation of internet-capable smart mobile phones on which an application for the proposed traceability solution would run. Also, these fishers' mobile phones have relevant applications already embedded in them like text messaging and satellite enabled Google Maps and Cloud features which are necessary for the functioning of the proposed traceability solution. Therefore, this

CT would reduce the overall initial cost for fishers' adoption of this traceability solution, and thus lower the learning requirement. This finding that CT has a significant and positive effect on fishers' intention to adopt the proposed traceability technology solution confirms the findings of Mezei et al. (2022) who found that the similar concept of technology readiness (TR) influences the adoption and continued usage of digital mobile technologies among a group of young elderly Finnish consumers. This TR is defined as users' willingness and ability to use technology solutions presented to them to resolve their existing problems (Mezei et al., 2022). Nevertheless, while Mezei et al.'s (2022) research was conducted in a developed world context (i.e., Finland) involving elderly consumers, this study was undertaken in the developing world context (i.e., Tanzania) involving a mix of young and middle-aged fishers. Therefore, this study's results have advanced and generalised Mezei et al.'s (2022) research findings into more contexts and wider consumer attributes.

In another study, Sukarno et al. (2022) attempt to measure the readiness (TR/CT) of Agricultural Extension Officers (AEOs) to adopt the digitisation needed to solve the food security problem through urban farming. This study tested AEOs readiness to adopt a notional digital technology (information and communication technology, ICT) to provide agricultural extension services to agricultural producers in urban centres (cities) in Indonesia. It was found that the majority of AEOs (i.e., 62.5%) were willing to adopt the notional technology (adopters and pioneers). As Sukarno et al. used Technology Readiness Index (TRI) framework to test AEOs' notional uptake rate and obtained a medium value[72] of 2.90 to 3.51, it can be reasonably assumed that this significant proportion of AEOs (i.e., 62.5%) possessed some form of complementary technology (e.g., electronic gadgets like mobile phones, iPads, computers, etc). These results suggested that future technological transformation involving AEOs was possible and key to achieving food security and agricultural development. This high level of readiness to adopt the technology was based on AEOs' anticipation of benefits including government-sponsored training programmes to enhance their competency. This motive to adopt the new technology is like the current study's results where fishers expressed high notional adoption rates due to already existing infrastructure (mobile phones) which could lower initial adoption costs, plus a potential to access premium price markets. A study by Schukat & Heise (2021), which explored the factors that influence adoption and actual usage of smart agricultural technology solutions among German farmers, found that TR's influence on farmers' intention

[72] According to Sukarno et al. (2022), TRI framework can generate 3 categories of results with the following values: low readiness (TRI<=2.89), medium readiness (TRI=2.90-3.51), high readiness (TRI>3.51).

to adopt and use the technology was significant. These results confirmed the importance of CT/TR in influencing technology users' intention across the developing (e.g., Tanzania) and the developed (e.g., Finland and Germany) worlds.

On the other hand, Dyerson et al. (2016) offer scenarios of the influence of Complementary Technology (CT)/Technology Readiness (TR), on the intention of actors to adopt new technologies. While assessing the readiness of small business firms in the UK to adopt new technologies, Dyerson et al. (2016) noted that limited investments in strategic and operational capabilities (CT and TR dimensions) would lower the chances of achieving this goal. These capabilities were identified as acquisition of necessary hard and soft technological infrastructure, conducting training and skills development programmes for users, and undertaking continuous improvements depending on new developments. Extending this principle, it can be assumed that for the proposed traceability solution to succeed in the long term in Tanzania, there needs to be adequate advance investments in these factors from fishers/users and other actors along the fisheries supply and value chains. Fishers have already done this by being in possession of the most important piece of technology required to adopt the traceability solution service (i.e., smart mobile phones).

The result in the current study that EE significantly and positively influences the fishers' intention to adopt the proposed traceability solution was expected (β=0.153, P=0.011<0.05). This means, Tanzanian fishers perceived the proposed traceability solution to be easy and convenient to use with minimal effort and resources because the solution application would be downloaded on their already existing mobile phones and operated on familiar applications such as text messaging and Google Maps. The findings of this study are consistent with the studies of several other researchers, such as Beza et al. (2018 who, while studying Ethiopian smallholder farmers' intentions to adopt the mobile Short Messages Service (SMS), found EE to be a key influencing factor. Also, Khan et al. (2019) found that EE influenced the acceptance of electronic banking in rural Pakistan. However, not all past studies have shown this same effect. For instance, Septiani et al. (2020) used UTAUT2 and SEM to conclude that EE had no significant effect on farmers behavioural intention to adopt peer-to-peer lending technology among smallholder farmers in Indonesia. Additionally, Thusi & Maduku (2020) used similar approaches and found that EE had no significant influence on South African millennials' intention to adopt banking applications. Nonetheless, Thusi & Maduku (2020) suggest that the insignificance of EE was because all or most respondents perceived the use of the technologies to be widespread, easy, and quick to learn or use them, thus lacking novelty and making the EE variable non-discriminatory between the respondents, hence lacking explanatory power. Finally, a study by Schukat & Heise (2021) explored the factors that influence adoption and actual usage of smart agricultural technology solutions among German farmers and found that EE had insignificant effects on the farmers' intention and actual use of the technology. These authors blame this insignificance of EE on increased demands on the farmers to constantly enhance their knowledge and skills to be able to keep up with the ever-changing complexity of the technology and the related management tasks. These demands were perceived by farmers as additional costs and other resource requirements to adopt and use the technology, hence failing on the ease-of-use test. However, if the farmers perceived that there would be large effort requirements to using the technology as is supposed, then this is more likely to cause the variable to be significant but negatively signed, rather than non-significant. What might cause this is if all farmers felt the same way and so there was no significant variation on this perception between those who would and those who would not adopt the said technology.

As expected, PE was found in the current study to significantly and positively influence fishers' intention to adopt the proposed traceability solution ($\beta=0.131$, $P=0.026<0.05$). This means that Tanzanian fishers would be much more likely to adopt and use the proposed traceability solution where they perceived it to be useful for the operation or profitability of their business, for example by enabling them to avoid restricted fishing grounds, improve access to richer fish stocks, and sell into lucrative premium price markets. These results are consistent with some previous studies. For instance, Septiani et al. (2020), Beza et al. (2018), Thusi & Maduku (2020), and Khan et al. (2019) used UTAUT2 and SEM to find that technology usefulness or utility (i.e., PE) had a positive impact on users' behavioural intentions to adopt new technologies, i.e., peer-to-peer lending technologies in Indonesia; mobile-based short text message (SMS) communications among Ethiopian farmers; banking applications among South African millennials; and electronic banking (e-banking) technology among rural Pakistani customers, respectively. Moreover, a study by Schukat & Heise (2021) on the factors that influenced adoption and actual usage of smart agricultural technology solutions among German farmers found that PE influenced the farmers' intention to adopt the technology. However, when Shi et al. (2022) examined the factors that influence Bangladeshi premium fruit farmers' willingness to adopt and pay for Internet of Things (IoT) technology, they found that PE influenced the farmers' willingness to adopt IoT but it (i.e., PE) had insignificant influence on farmers' willingness to pay for this IoT technology. This suggests technology benefits (i.e., price value) become more important in deciding what the technology users would be willing to pay once its performance has been assured. Generally, PE is among the factors that influence most users' intention to adopt new technologies (Venkatesh et al., 2003, 2012). The above difference (Shi et al., 2022) can be explained as users or consumers wanting to test a new technology first in terms of its usefulness or effectiveness in solving their problem (Alalwan et al., 2014; Rahi et al., 2019) before they would consider paying for it. It is also possible for potential adopters to recognise that the technology delivers in performance terms, but it is simply too expensive. This scenario would be revealed by a significant and positively signed PE and a significant and negatively signed PV.

Tanzanian fishers perceived the net benefits of adopting the proposed traceability solution (i.e., PV) to be significant and positive ($\beta=0.216$, $P=0.005<0.05$). This suggests that derivable benefits of the proposed traceability solution are higher than the potential financial costs of acquiring and using it. Congruent with this, PV was a significant influencing factor for fishers' BI. Because the price offered to the fishers for the proposed traceability solution was US$100.00 per month, the significant PV means most fishers' perceived benefits were higher than this price. This result is not surprising because the general monthly incomes of the surveyed fishers appeared to be several times higher than this proposed price. As stated earlier, most fishers already have smart mobile phones capable of downloading the application for the proposed traceability solution, thereby eliminating part of the start-up cost of acquiring the desired function. The importance of PV's influence on the adoption of new technology was recorded in other studies. For instance, Septiani et al. (2020) & Beza et al. (2018) found that PV predicted users' behavioural intentions to adopt peer-to-peer lending technology in Indonesia and mobile-based communication technologies among Ethiopian smallholder farmers, respectively. Also, Shi et al. (2022) examined Bangladeshi premium fruit farmers' willingness to adopt and pay for Internet of Things (IoT) technology. Although the authors did not clarify the benefits of IoT adoption, it would be reasonable to assume it was meant to address rural producer challenges such as access to premium markets and optimal sources of key farming inputs. Their results suggest that PV influenced the farmers' willingness to adopt the IoT but its (i.e., PV's) effects on the farmers' willingness to pay for this IoT technology were insignificant. This is perhaps because all farmers who did not have a positive PV would indicate a zero (i.e., the lack of) willingness to pay and so would be excluded from the sample in the price estimation. However, Schukat & Heise (2021) found that PV had insignificant effects on the farmers' intention to adopt and use the new technology. This result was attributable to the nature of the precision agriculture technology whereby farmers would experience uncertainties while operating the technology that involved a mix of data- and experience-based decisions. This was a surprise because these uncertainties were not indicated by the farmers when expressing their expectation of technology performance. This impacted unfavourably the farmers' perceptions on the net benefits of adopting the technology. Also, Schukat & Heise (2021) argue that the German farmers perceived the smart farming technologies as too highly priced relative to their potential derivable benefits, hence conflicting or diverging from published expectations by agricultural experts. These results differ from the current study in that they relate to the real technology while the current study is about a notional technology. Furthermore, fishers in the current study appeared to trust the performance of the traceability solution and they expressed high adoption rates, suggesting their being ready to pay the proposed price of US$100.00.

Regarding the indirect (moderating) effects, it was found that PV influence on fishers' intention was stronger among freshwater fishers than marine fishers, i.e., fishery type moderates the effect of PV. These results suggest PV is more influential for freshwater fishers in terms of greater price sensitivity than marine fishers. This is the case despite the evidence that freshwater fishers earn higher incomes than marine fishers. Because freshwater fishers receive higher fish prices, and incur less labour cost per fishing boat, they are likely to be more profitable than marine fishers. Therefore, if freshwater fishers perceive fewer benefits (e.g., reduced profitability following a potential price fall), then they would be more price sensitive than marine fishers despite earning more money. This favourable position of freshwater fishers is largely supported by their supply of high-priced Nile Perch fish from Lake Victoria that account for most fish fillet exports into the lucrative UK/EU and other global premium price markets. This moderation of PV by a sub-group within the population is consistent with the findings of several previous studies. For instance, Beza et al.'s (2018) study on Ethiopian farmers' intention to adopt Short Message Services (SMS) found that PV's influence on intention was stronger among non-SMS using farmers than those using the SMS to share/communicate their farming activities. These results suggested that non-users (i.e., non-SMS farmers) are more price sensitive because they would incur higher costs in adopting the SMS technology (Beza et al., 2018). In a study of German farmers' adoption of smart technologies, Schukat & Heise (2021) found that PV was moderated by level of work experience, i.e., the influence of PV was stronger among the farmers with over 30 years' experience. Kwateng et al. (2019) examined the factors influencing the adoption of mobile banking services in Ghana and found that PV had both direct and indirect (i.e., moderated) positive effects. This finding in Kwateng et al. is consistent with the results of the current study which found PV to have both direct and indirect (moderated) significant and positive effects on fishers' intention to adopt the proposed traceability solution.

It was also found that although FC had insignificant direct or main effects on fishers' intention (BI) for the whole sample, for the subgroup of fishers with formal education FC did have a significant effect on BI, i.e., level of education moderated the effects of FC. The main possible reason for these results is that the formally educated fishers are likely to have more of the necessary knowledge and skills to conveniently adopt and use the proposed traceability solution than fishers without formal education. These skills and knowledge would include the ease and familiarity of using smart mobile phones. It was found that freshwater fishers exhibit higher levels of formal education than marine fishers. The fact that education level moderates FC and that FC was more influential on BI for fishers with higher education levels is consistent with general expectation that fishers with formal education are likely to have better knowledge, skills, and accessibility to relevant supportive environments than do those fishers without formal education. These results are consistent with Fares et al. (2012) who explored the factors for adoption of mobile banking in Jordan and found the level of education to moderate the influence of FC on users' intention to adopt.

Although there was no significant effect of Habit (HT) on fishers' intention (BI), fishery type was found to significantly moderate this HT→BI relationship; and for the marine sub-sample, this relationship was significant. It is concluded that for marine fishers who have developed continuous habits of using similar or complementary technologies, this would increase their willingness to adopt. This HT appears to affect intention in marine and not in freshwater fisheries possibly because marine fishers are more dominant in the sample compared to the freshwater fishers. Also, as previously explained, the levels of potential uptake of the proposed traceability solution appeared to be higher among marine fishers than freshwater fishers. With limited access to studies in which fishery type moderated the influence of HT on BI, the researcher obtained supporting evidence to demonstrate that socio-demographic characteristics moderate HT. For instance, Kwateng et al. (2019) found that HT's influence on users' intention to adopt and use mobile banking services in Ghana was stronger among highly educated users than the less educated. The study (Kwateng et al., 2019) suggests that highly educated people are more likely to develop habits (i.e., repeated, or continuous experience) of adopting and using new technologies than the less educated counterparts. However, Schukat & Heise (2021) explored the determinants of intention to adopt and use smart agricultural technology solutions among German farmers and found that HT was insignificant and had no moderating effects to influence the farmers' intention. Therefore, Schukat & Heise (2021) confirm the results of Tamilmani et al. (2018) who undertake a meta-analysis of UTAUT2 empirical studies that incorporated the HT latent independent construct to report that all studies had insignificant moderated HT influence on technology users' intention.

Also, the current study tested indirect (mediating) effects. It was found in the current study that Effort Expectancy (EE) mediated, through complementary partial mediation, the relationship between Complementary Technology (CT) and fishers' intention (BI) to adopt the proposed traceability solution. This result suggested that the fishers' current use of compatible technologies such as mobile phones (i.e., CT) enhances their intention (BI) both directly and indirectly (i.e., mediated) through the ease/convenience of use (i.e., EE) of the proposed traceability solution. This finding is consistent with Casey & Wilson-Evered (2012) who used UTAUT framework and PLS-SEM technique to predict that EE mediates the effect of trusted technologies (e.g., CT) on users'/consumers' intention (BI) to adopt the technologies. Also, the results of this current study showed that EE mediated the effect of FC on BI while the direct relationship (i.e., FC→BI) was not significant (i.e., full mediation). This meant that it was only through the proposed traceability solution having features of ease and convenience of usage (i.e., EE) that the effect of existing infrastructural resources and technical support (i.e., FC) would drive the fishers' intention (i.e., BI) to adopt the solution. This result is redolent of Venkatesh et al. (2003) who found through their famous UTAUT framework that EE fully mediated the effect of FC on BI.

Given the preceding differences between freshwater and marine fisheries, this current study undertook further separate testing of these fishery type sub-samples. However, there was limited access to similar studies/literature that compared the two fisheries type sub-populations. As such, the current study used logical arguments to explain the results. The analysis showed that the convenience/ease of use (i.e., EE) and usefulness/utility (i.e., PE) influenced the fishers' intention (i.e., BI) to adopt the proposed traceability solution across both the freshwater and marine fishers' populations. This result suggests that the features of convenience of use (i.e., EE) and usefulness (i.e., PE) are equally important to enhance the uptake of the of the proposed traceability solution among both populations of freshwater and marine fishers. Also, while the use of complementary technologies (i.e., CT) influenced the freshwater fishers' intention, this relationship (i.e., CT→BI) was non-significant among marine fishers. This result can be explained by the fact that marine fishers have higher rates of uptake of CT than freshwater fishers, and therefore this factor (i.e., CT) is not discriminating between marine fishers as a determinant of BI.

Moreover, the study found that despite being non-significant at the whole sample level (i.e., $\beta=-0.026$, $P=0.717>0.05$), the fishers' automatic habitual tendencies' influence on intention (i.e., HT→BI) was found to be strongly significant and positive in both freshwater ($\beta=0.258$, $P=0.003<0.05$) and marine fisheries ($\beta=0.277$, $P=0.004<0.05$). The above result of non-significance at whole sample level would suggest that pooling together for analysis of freshwater and marine fisheries sub-samples tends to obscure or hide significant differences between these two fishery types such that the differences become significant and visible when the sub-samples are tested separately. This result of non-significance at whole sample level was not expected. This is because if both freshwater and marine fisheries show significant and positive relationships between HT and BI (i.e., HT→BI) when tested individually, each with smaller samples, then it would logically follow that the two should show a significant HT→BI relationship when combined/pooled into one larger whole sample. If the whole (larger) sample is non-significant in the HT→BI relationship, it would be justifiable to expect that at least one of the fishery types is significant and the other non-significant, thus cancelling out when pooled/combined. Therefore, the possible way to justify this result of non-significant whole sample would be if the two sub-samples had differently signed significant results which cancelled each other out in the combined whole sample. However, contrary to these expectations, the beta (β) values of the two sub-samples are both positively signed and significant as indicated above. Two possibilities can be suggested following this occurrence of the two betas not being differently signed between freshwater and marine sub-samples. First, for the combined (larger) sample, an explanatory variable either becomes significant or increases its explanatory power such that the HT→BI relationship becomes non-significant at the whole (combined) sample level. For this to happen, the explanatory factor (i.e., BI) must be collinear with HT to explain better the variance that HT presents in the sub-samples (i.e., being non-significant at the whole sample and significant at the sub-samples of marine and freshwater fisheries). This is because collinearity within or among variables tends to obscure significance or significant relationships between variables, thus rendering them non-significant (Kraemer, 2013). The second possibility is that the combined (whole) sample of non-significant HT→BI result is an artefact – a random effect that defies explanation. Furthermore, while the analysis at the whole sample level found the net benefits of adopting the proposed solution over its acquisition and operational costs (i.e., PV) to influence the fishers' intention, this relationship (i.e., PV→BI) became non-significant when tested separately at each of the sub-sample levels of freshwater and marine fisheries. This could be explained by the possibility that smaller sub-samples of freshwater and marine fisheries lost some statistical power to command sufficient significance, as suggested in Serdar et al. (2021).

In summary, the results for the main (i.e., direct) effects indicate that the eight independent (i.e., exogenous) latent constructs explained higher proportion of variation in fishers' intention in both freshwater and marine fisheries sub-populations (i.e., 38.8% and 43.6%, respectively) when tested separately than the overall fisheries population variation of 38.5%. This improvement appears to be more meaningful in the marine fisheries case. This means the specified eight independent latent constructs would more strongly influence intention to adopt the proposed traceability solution among the marine fishers than the freshwater fishers. These results are consistent with the current study findings which suggest that the features of the proposed traceability solution appear to address more challenges in the marine fisheries environment than those in freshwater fisheries. As a result, the level of notional uptake of the proposed traceability solution was higher among marine fishers than freshwater fishers.

Regarding the indirect (i.e., moderating) effects, it was found that education moderates the influence of infrastructural resources and other necessary support services (i.e., FC) on fishers' intention (i.e., BI) in both fisheries type sub-populations. The influence of FC on intention was found to be higher among fishers with formal education than those without formal education across both freshwater and marine fisheries. This finding is consistent with the results of the current study that suggest that fishers with formal education are more likely to have more skills and knowledge than fishers without formal (i.e., informal) education. These skills and knowledge would help these fishers with formal education to better understand relevant instructions and therefore be able to apply them to effectively use the proposed traceability solution than those fishers without formal education. Also, education was found to moderate the influence of automatic habitual tendencies (i.e., HT) on intention (i.e., BI), and HT's influence on intention was found to be higher among fishers without formal (i.e., informal) education than those with formal education across both freshwater and marine fisheries. This result is consistent with the preceding findings in the current study where marine fishers who constitute the bulk of those without formal (i.e., informal) education are the ones experiencing more fisheries challenges than freshwater fishers. As a result, these marine fishers expressed higher habitual tendencies than freshwater fishers with higher notional uptake rate to adopt the proposed traceability solution. This result would imply that education co-varies with fisheries type and that this education effect is actually just a fisheries type effect.

In the case of indirect (i.e., mediation) effects, there were noted differences between freshwater and marine sub-populations. For freshwater fisheries, it was found that the continued usage of synergistic complementary technologies like mobile phones (i.e., CT) drives the fishers' intention (BI) both directly and indirectly (i.e., mediated) through the ease/convenience of use (i.e., EE) of the proposed traceability solution. On the other hand, however, the usage of these synergistic complementary technologies (i.e., CT) appeared to influence marine fishers' intention (BI) indirectly only, (i.e., mediated) through the ease/convenience of use (i.e., EE) of the proposed traceability solution. These results were expected because, relative to freshwater fishers, marine fishers are less educated (i.e., being more informally educated), and thus less skilled, and less knowledgeable. Therefore, these marine fishers are more likely than freshwater fishers to need the features of ease and convenience of use to be able to effectively use the proposed traceability solution.

5.1.3.3 Supply Chain Coverage and Maximising the Technical Solution's Uptake

Data Capture and Optimising Supply Chain Coverage

The preceding findings suggest that to minimise illegal and unsustainable fishing practices, the fisheries supply and value chain in Tanzania would require data capture from marine and freshwater fishing boats on the water to final purchase by consumers buying fish products. Also, given that Tanzania's fisheries output is consumed both locally and in export markets (including the main premium price destination of UK/EU), data capture would need to cover both local and cross-border trade in fish products. The proposed Blockchain-based traceability solution would mean that fisheries data captured on this platform would be secure and tamper-proof.

Regarding the issue of supply chain coverage, there are two 'coverage' dimensions to consider here. First, is upwards along the fisheries supply and value chain, and second, is laterally across practitioners in fisheries. Regarding the first dimension, fishers, buyers, processors, retailers, and exporters would need to adopt various aspects of the proposed traceability solution. Fishers would use the solution to help them with identifying and avoiding marine protected areas, thus being able to prove to buyers and relevant authorities that they follow sustainable fishing practices. Other beneficial aspects of the solution to fishers include the identification of richer fishing grounds for maximising catch volumes, as well as satellite communications to enhance marketing of fish catches and rescue effort while at sea. It is also expected that processors, retailers/distributors, and exporters would like to adopt the solution to be able to prove to their customers/buyers and relevant authorities that they are dealing with suppliers (i.e., fishers) who fish sustainably. This would include the ability to prove the provenance of the fish using the GPS locator history service embedded in the proposed traceability solution.

On the second dimension, what proportion of fishers would need to adopt the solution to achieve the various objectives? Would some objectives, such as access to premium markets still be achievable at relatively low rates of uptake? Would resource protection (i.e., sustainability) be achieved at low levels of uptake? The current study attempts to answer these questions. Because private benefits can accrue to individuals taking up the solution, if enough fishers adopt the proposed traceability system to cover establishment and operating costs, the system will be sustainable and some benefits to the fishing community will accrue. This means, the more fishers that adopt the solution, the lower will be adoption cost per head/fisher. However, there will be a certain threshold of adoption below which no public sustainability benefits would accrue. Therefore, for public benefits to accrue, most fishers would need to adopt the solution. For instance, how would sustainability be improved if only 20% of fishers adopted, obeyed, and met all the solution's compliance requirements and all other sustainability regulations, while 80% did not and went on fishing illegally and unsustainably? First, it is assumed that voluntary adopters are less likely to be currently engaged in illegal and unsustainable fishing. As such, these voluntary adopters will have no negative effect on sustainability. To enhance this sustainability, current illegal and unsustainable fishers need persuading to join. This will mean that there will not be any significant arithmetic increase in public sustainability benefits with these initial increases of adopters. Instead, there will be a threshold of uptake that must be reached before any significant benefits are found, followed by an exponential increase with increased uptake, before levelling off over time. To maximise or get majority uptake it needs to be made a requirement to adopt the system to access the local market as well as the premium-price export market. This would mean lobbying buyers to ensure that they insist on this certification.

However, it is notable that the audit agency would operate on a voluntary membership basis without any legal basis of enforcement. So, what if the solution's uptake levels remained low under these voluntary mechanisms? Also, what about those fishers who would opt to supply non-premium local and regional markets because of low or non-existent fisheries sustainability requirements in these markets, hence achieving high profitability due to non-compliance? These questions lead to the second option to drive the solution's uptake. The audit agency would attempt to lobby the government and development partners to set up a fund (like WYDDF for women, youth, and disabled) that would extend credit to fishers who would make losses in non-premium markets (locally and regionally) following the adoption of the traceability solution. This fund would help these fishers to cover the key costs of adopting the traceability solution at low or interest-free credit terms, including flexible repayments of these funds over a reasonable period. It is important to note, however, that adoption of this traceability solution in regional markets beyond the borders of Tanzania would be more consequential than primarily intended within the scope of this current study. But what if a significant proportion of fishers in Tanzania still refused to embrace these adoption opportunities without justifiable reasons, thus undermining the solution's intended goals of enhancing sustainability and commercial scaling-up of the fisheries sector? Under these conditions, the researcher proposes some form of limited government involvement or enforcement based on specific requests by the audit agency. This approach would ensure the implementation of the proposed traceability solution remained primarily private sector led. Because the adopters' fishing data and activities will be transparently recorded and shared on the solution's Blockchain, this would make the audit trail or clarity of direct and indirect derivable benefits of adoption to the public. This transparency would involve mandating that the audit agency reports to relevant public/government authorities about incidences of illegal and unsustainable fishing practices by rogue actors as captured on the solution's Blockchain for possible financial penalties and/or prosecution. These benefits, which would be expected to be higher the greater the level of adoption, would include increased payments of legal taxes and levies, improved sustainability in fisheries, and expanded business profits and jobs. Faced with this kind of evidence, the government would most likely be inclined to support this solution's obvious development initiative. It is through this linkage that the audit agency would influence or lobby the government for such support measures as making the adoption mandatory to all fishers and actors in fisheries, hence improving the solution's uptake to even higher rates.

Maximising the Uptake Levels of the Traceability Solution

To encourage adoption and avoid scaring away fishers and other users, the scheme operators (the national traceability audit agency) would have to reassure these actors that their data will not be shared with third parties, especially the government regulatory bodies if they are not found to be in breach of government regulation. This audit agency was suggested in the current study as an envisaged implementor of the proposed traceability solution (UNECE, 2016). As explained elsewhere, those actors identified on the Blockchain to be involved in illegal and unsustainable fishing practices would have their membership terminated by the audit agency and reported immediately to relevant authorities for possible prosecution. This would mean an instant loss of business, especially the lucrative local and foreign premium price markets like the UK/EU. An unerasable blacklisting record for their involvement in unsustainable fishing practices would remain on the solution's Blockchain platform for all actors to see, especially buyers/consumers and prosecuting authorities. This blacklisting would lapse after some specified time, especially following past offenders' proof that they have taken steps to prevent reoccurrence of illegal and unsustainable fishing practices. These breaches by fishers and other actors would be identified by the audit agency when these actors fail to prove their compliance to sustainable fishing practices on the traceability solution's platform. Also, buyers/consumers of the fish products are expected to check the provenance information (e.g., to ensure that fish were not caught in protection zones) on a purchase-by-purchase basis. This will guarantee that sustainability compliance has been achieved, thus leading to accepting the system's accreditation. Other sources of data to prove breaches by these actors would be based on credible third parties such as court records of prosecution. However, the audit agency is ultimately responsible to hold all its members accountable to ensure the fish and fisheries products supplied to fisheries supply and value chains meet the minimum sustainability requirements. The audit agency is better suited for this task than consumers/buyers because these consumers/buyers may not have the required technical skills and/or the costs would potentially be more prohibitive to them. To meet these monitoring and operational costs, the audit agency would use members' periodic financial contributions as well as other resources such as commercial borrowing or grants from government to invest in the implementation and day-to-day operations of the proposed traceability solution. This way, the audit agency would, through the implementation of the traceability solution, become an independent private certifying organisation for sustainably sourced fish products destined to lucrative local and foreign premium price markets. This certification scheme would financially benefit those fishers and actors who comply with the solution's sustainability requirements through continued access to lucrative premium price markets. It is based on this business continuity that fishers and other actors would sustainably accrue profits to reinvest in the commercial scaling-up of their fishing businesses.

5.1.4 Practical Implications and Future Research Directions

5.1.4.1 Practical Implications

As a market-based response to the unsustainable use of fisheries resources, the adoption of the proposed traceability solution would be voluntary, but with sufficient incentives to entice fishers and other actors to adopt. This solution would exploit the rising trends of consumers in the premium price markets like the UK/EU demanding provenance of sustainable sourcing of seafood. Therefore, when fishers and other actors adopt this solution to derive business profits by pursuing premium prices, they would concurrently be implementing the desired initiative to ensure sustainable fishing practices, especially the sustainable sourcing of seafood. Although uptake levels projected by this study are notional, it is assumed the actual uptake would still be high due to obvious benefits that the solution would offer, especially the access to premium price markets.

5.1.4.2 Future Research Directions

This study has revealed some research gaps that require further work. The success of the proposed traceability solution would depend on its acceptability and levels of trust and credibility in the perception of users (fishers, consumers, and other actors). While the current study has shown high potential uptake rates by fishers, further research is needed to demonstrate whether both local and international consumers would trust accreditation schemes supported by the proposed traceability solution. Also, future research needs to test consumers' willingness to pay for accredited sustainability and enhanced food safety credence values as provided in the current study. This would entail opportunities to receive even higher prices in premium markets (e.g., UK/EU) as well as lucrative local markets in Tanzania (e.g., in top hotels and recreation spots that serve tourists and other affluent elites). Moreover, further research is needed to establish the extent to which trust between different actors in the fisheries supply and value chain would be enhanced. Finally, this solution has been designed to capture fisheries data from fishing boats registered by Tanzanian authorities that land catches on Tanzanian beaches/sites. More research is needed on how the proposed traceability solution could be scaled up or improved to address the extant challenge of over-exploitation of fisheries stocks in Tanzanian coastal waters by rogue actors from the international community (i.e., transshipment).

5.2 Policy Implications/Recommendations and Conclusions

5.2.1 Policy Implications/Recommendations

It was found in the current study that existence of relevant complementary technologies such as smart mobile phones already possessed and used by fishers was a potential factor for driving the uptake of the proposed traceability solution. In this regard, the envisaged national audit agency should collaborate with commercial banks and other lending institutions to offer guarantees for fishers to access soft loans with affordable repayments to enable them to acquire appropriate mobile phones for adoption of the solution. Also, because ease and convenience of use of the proposed traceability solution was found to enhance adoption, the audit agency should ensure this solution is designed and implemented in a manner that requires minimal time and other resource commitments from fishers or users. Furthermore, fishers expressed as equally important the delivery of net benefits from adopting the solution and that these should be greater than the financial costs of acquiring and operating it. In this regard, the audit agency should assist fishers in maximising the listed benefits of the solution, with special priority given to establishing the sustainability provenance of fish products, so that fishers can derive higher market returns from these credence values. This would be achieved first by constant maintenance and upgrading of the traceability solution services. Next, it would also require the audit agency to convince buyers in lucrative local and foreign markets to encourage the use of the proposed traceability solution through offers of premium prices for seafood/fisheries products with this traceability provenance. In addition, the audit agency should consider establishing the credibility of certification schemes based on the sustainability-enhancing functions of this proposed traceability system.

Also, the current study found that freshwater fishers appeared to be more sensitive to price/benefit (PV) ratio than marine fishers for adopting the proposed traceability solution. For this, the audit agency should work to encourage more of the freshwater products to be marketed into premium price markets. This would help to lower the PV sensitivity of freshwater fisheries. This higher sensitivity is likely because of fewer perceived benefits of the solution to freshwater fishers than marine fishers. For instance, due to the smaller size of fisheries resources (e.g., Lake Victoria) compared to an expansive Indian Ocean, freshwater fishers are likely to derive fewer benefits from GPS communications, identification of rich fishing grounds, and satellite communications, than marine fishers. Additionally, it was noted that supportive resources like training or specialised education programmes would result in more adoption of the solution among formally educated fishers than those without formal education. Therefore, the audit agency should use part of members' periodic contributions and/or any other relevant sources to arrange training and knowledge enhancement programmes among the fishers without formal education to improve their uptake rates. In addition, the audit agency should lobby relevant authorities in Tanzania to implement policies that would make formal education accessible and affordable to unprivileged fisher communities with low rates of formal education. Attaining more formal education would improve fishers' uptake levels of the traceability solution. Moreover, continuous/automatic habitual tendencies to use complementary technology (e.g., smart mobile phones) were found to be higher among marine than freshwater fishers. This could be attributable to the fact that freshwater fishers are already benefiting from lucrative premium price markets in the UK/EU through Nile Perch exports, hence the lower incentive than marine fishers. However, the audit agency should devise incentives to uplift habits of adoption among freshwater fishers by emphasising the potential additional returns or profits derivable from adopting the proposed traceability solution.

Regarding the mediation effects, the current study's results suggest that a successful uptake of the proposed traceability solution among fishers requires the solution to have ease and convenience of use features. These features would enhance the effect of fishers' complementary/compatible technologies such as mobile phones and other necessary infrastructural and support resources and services to drive the fishers' intention to adopt the solution. To maximise the uptake of the proposed traceability solution among fishers, the envisaged national traceability audit agency in Tanzania needs to ensure the solution to be implemented entails these features. Furthermore, industry buyers/importers of seafood, especially in lucrative local and export (e.g., UK/EU) markets, could help the adoption of the proposed traceability solution by offering premium prices for fisheries products with the solution's provenance data. These buyers would do this by requiring that all fisheries products from Tanzania into the UK/EU market have the audit agency's label to certify that the seafood items are compliant with the proposed traceability solution requirements. Alternatively, if buyers in lucrative export markets like UK/EU require the use of certification schemes from their local markets where the products will be sold (e.g., UK/EU, because these consumers know and trust these suppliers already), then the Tanzanian audit agency would need to forge a strategic working relationship with these foreign certification entities. This working relationship would entail ensuring that the audit agency in Tanzania meets all the quality and sustainability requirements in those export markets. As hinted earlier, another possibility would be developing local premium price markets targeting affluent buyers like major hotels and tourist attractions. These lucrative local markets would place a requirement for fishers to prove the sustainable sourcing of their fish supplies to be able to access these premium price buyers. Because most Tanzanian fishers would be attracted by high margins or profits, so would be their adoption rates of the solution. This way, the seafood market would help to influence sustainability in fishing practices by encouraging the solution's usage/uptake.

Because the proposed traceability solution is for the good of the public, especially the consumers, a Fisheries Development Support Fund (FDSF) could be set up or adapted to scale up the initiative, in addition to the private funding mechanisms already explained elsewhere in the current study. Resources into this fund could come from various sources, including relevant development sources like government and development partners depending on the lobbying effort of the audit agency. A good example of potential development funding for this purpose would be Tanzania's Women, Youth, and Disabled Development Fund (WYDDF) and the World Bank funds which were inaccessible, misused, or not managed properly in the fisheries sector as evidenced in the current study. This money could otherwise be used, among others, to support the establishment and adoption or offer soft loans or subsidies to offset operational costs of the proposed traceability solution (e.g., infrastructural set up and commissioning, acquisition of smart mobile phones, training, etc.). The repayment of soft loans with affordable interests would make the FDSF sustainable and scalable through a revolving mechanism, thus perpetuating and widening the adoption of the proposed traceability solution. This FDSF would set interest rates low enough to be affordable by struggling fishers, yet high enough to meet its administrative and operational expenses.

5.2.2 Conclusions

This study set out to identify barriers and drivers for sustainable development and commercial scaling-up of Tanzania's fisheries resources and suggest a means to overcoming these barriers. It was found that the lack of trust and credibility among stakeholders and ineffective governance systems in the fisheries sector created opportunities for a few, powerful local and global rogue actors to undertake and profit from unsustainable fishing practices in Tanzanian waters. The ontology of these illegal and unsustainable fishing activities was explained by the emergent Fishmining BSP GT. The GT statement predicted and explained that whenever trust and credibility are lacking among stakeholders and there exist inadequacies in the governance of fisheries resources, local and foreign rogue actors will undertake and gain from overexploitation (overfishing) of the fisheries resources, thus transforming them into finite resources like minerals. The involvement of both local and foreign actors in unsustainable fishing practices in Tanzanian waters was dubbed the Globoverfishing problem. This term was extended to capture over-fishing globally, including in Tanzanian waters, by technologically advanced fishing powers from Europe and China. This Globoverfishing leads to pressure to engage in unsustainable fishing practices by locals in their own local waters due to depletion of the fish stocks that might be harvested by legal means. In some cases, these unsustainable fishing practices (i.e., Globoverfishing) were supported, covertly, through official policy measures like subsidies in these developed fishing powers to safeguard their food security, fisheries sector employment opportunities and industry revenues.

Following the identification of unsustainable fishing problems, the study devised and tested the acceptability of a tailored, market-based, traceability solution among Tanzanian fishers (fishing boat owners). The observed high levels of willingness to adopt of the solution are attributable, in part, to largely already existing supportive infrastructure, such as mobile phones on which the solution's application would be downloaded and operated (i.e., a positive Complementary Technology, CT). Another key factor encouraging fishers to adopt is ease and convenience in the use of the proposed solution with minimal time and other resource commitments (i.e., a positive Effort Expectancy, EE). Fishers also emphasised the need for the solution's usefulness or ability to effectively resolve the ongoing unsustainability problems and the need to commercially scale up their fishing activities (i.e., a positive Performance Expectancy, PE). This implies that fishers are basing their decisions on perceived public goods benefits, when in actuality they are more likely to be influenced by perceived private goods benefits. The solution would help with this performance by identifying and recording fishing locations as a potential proof of sustainable sourcing of seafood, thus enabling fishers to meet one of the conditions of accessing lucrative premium price markets in the UK/EU. Also important for fishers' adoption were derivable benefits from the solution relative to financial costs of acquiring and operating it (i.e., a favourable Price Value, PV). In addition to the preceding, other benefits of adopting the solution included secure storage or non-tampered fisheries data, transparency, and accountability in fishing activities, using the solution's satellite GPS communications service to avoid restricted/protected fishing areas, communicating rescue emergency needs and fish catch marketing information while still at sea. These benefits, in the minds of most fishers surveyed, outweighed the solution's proposed price/cost of US$100.00 per month per 1000 requests (following an initial fixed cost of US$250,000.00), especially among fishers who already had existing infrastructure like smart mobile phones which are necessary for implementing the solution. The results also showed that freshwater fishers were more sensitive to the price/benefit (PV) ratio of adopting the proposed traceability solution than marine fishers. This is likely due to fewer perceived benefits of the solution for them. In addition, the availability of supportive resources like training or accessible/affordable mobile phones (i.e., existence of Facilitating Conditions, FC) would result in more adoption of the solution among formally educated fishers than those without formal education. Furthermore, the automatic habitual tendency (Habit, HT) to adopt and continue using complementary technologies (i.e., CT) was found to be much higher among marine than freshwater fishers. Generally, marine fishers were found to be more likely to adopt and use the proposed traceability solution than freshwater fishers because the solution appeared to be more useful (offer more benefits) in marine than freshwater environment. For instance, the solution helps fishers to identify richer fishing grounds for improving catch volumes. It also helps with satellite Google-enhanced GPS communications for marketing and rescue purposes. Moreover, the solution's feature of establishing the provenance of fish labelled 'sustainably sourced' would help fishers to access lucrative price markets like the UK/EU. In all these benefits, the marine fishers are presently lagging freshwater fishers, especially in terms of exports into the EU premium price market. Also, with the Indian Ocean being more expansive than Lake Victoria, the satellite GPS communication links are likely to be more useful in this marine than freshwater environment.

To implement this solution, the study proposes the establishment of an independent and voluntary private sector-led professional trade association (i.e., the national traceability audit agency) that would mobilise all necessary resources from members and third parties. This audit agency would have monitoring, and compliance roles, to ensure all participating actors (members) on the fisheries supply and value chains comply with all sustainability requirements for sustainable sourcing of seafood to meet consumer health safety needs. This means, being a market-based solution, buyers would stop buying if data on provenance were not supplied. As Tanzania's fisheries output is consumed locally and in export markets, the audit agency would have to convince relevant authorities in Tanzania and in export markets (e.g., UK/EU) that the traceability solution is effective in protecting the sustainability of fisheries resources as well as food safety. For instance, the audit agency would be required by these authorities to prove the veracity of the solution, in terms of demonstrable identification and reporting for elimination of the identified unsustainable fishing practices, the benefits of transparency in fishing activities, and secure data storage and sharing following access to lucrative premium price markets. Achieving this milestone by demonstrating the solution's relevant abilities would expand the recognition of the audit agency's certification scheme in Tanzania and in the UK/EU export markets regarding the sustainable sourcing of seafood to ensure health safety of consumers. It is through this recognition by relevant authorities that the audit agency would be able to convince more fishers and other actors along the fisheries supply and value chains to adopt it, thus maximising the potential public and private benefits of the traceability solution through driving its uptake rate.

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APPENDICES

Appendix A3: Detailed Frequency Distribution of Conceptual Incidental Indicators (CIIs) Between Freshwater and Marine Fisheries Concepts (Codes & Categories)

Trust Loss (TL) Category

Code/concept	CIIs	Freshwater CIIs	Marine CIIs	Conceptual memos with highlighted CIIs
Human Undercapitalisation	40	4	36	*"…during the late 1980s up until the 1990s, TAFICO was operational with a couple of seagoing fishing vessels and ready local and foreign fish markets, especially in Japan. Around the 1990s, the government ordered the cessation of TAFICO fishing operations following the directives of the IMF not to use public funds to support TAFICO. Even the World Bank pressured the government to get TAFICO privatised. This happened even though TAFICO was making profits; and so it was not being a burden to the public resources. Eventually, TAFICO did not get a buyer, and so the government has decided lately to take it back and recapitalise it for commercial deep-sea fishing. This happens after a loss of over 20 years based on badly thought decision to privatise it."* (Interviewee TZ101, Tanzania, 2019). Freshwater & marine *"This [Mbegani] facility has now lost the following: it used to be a national centre of excellence in marine fishing knowledge and practice. It was able to deliver consistently and effectively a weekly minimum of ten tons of fish using its marine vessel [MV Mafunzo] over 20 years of its*

				operations. These were subsequently kept in cold storage facilities, processed right there, and sold to the public. In other words, the MV Mafunzo has over the last 20 years lost sales of seafood, lost jobs for potential employees, lost tax payments for the government, lost businesses for suppliers of goods and services in the general economy. Our engineering section built quality boats which were also sold locally and across the border into east Africa. The fall began when internal power struggles to control the money from these investments started and intensified. Following the lack of trust among internal members, the [MV Mafunzo] ship was later commissioned to third parties [investors] through bidding procedures. Aware of internal friction, these investors started to take advantage of the situation. They initially negotiated to give low offers to hire the MV Mafunzo for fishing. Over time, what they offered was not enough to cover the operational costs of the vessel. The administration decided eventually to end the MV Mafunzo agreement with the investors. As we speak now, the ship is docked out there for three years to-date in need of very expensive overhauls. The engineering section is now also like a museum of what happened then. Nothing is left of anything after 20 years of glory, just buildings, scrap metal and wood leftovers.” (Interviewee TZ126, Tanzania, 2019). Marine *“We have a collective total of 72 boats and 3,222 fishers, say 45 fishers per boat. In 2019, we made monthly fish gross sales of about TZS250.0 million among us [UK£83,000 or US$107,500]. Despite these huge sums, members are unwilling to contribute more than TZS5,000.00 [UK£1.66 or US$2.15] per daily catch landings. These contributions are too small for achieving the modernisation of our fishing activities. Because of negative experiences of theft or misuse of group funds, most of our members are scared to give much in contributions. There are no mechanisms now to help to regain members’ trust and credibility. As a result, members prioritise spending more on social matters than investing on fishing gear. They have limited ideas for expanding their fishing business. Even the government has not come up with support to encourage fishers to expand their fishing operations. We always keep our daily records intact, especially the sales levy that we pay to government agents at every morning fish landings. However, the government keeps harassing us, they do not take us seriously in terms of modernising our fishing activities. It appears the government promotes other producers in agriculture and livestock than fishing. We try many times to seek assistance from government, but it is not coming up fast enough.”*

				Interviewee TZ02, Tanzania, 2019 Marine
Technology Gap	44	12	32	*"The ongoing underdevelopment of the fisheries sector in Tanzania is a result of several complex challenges. In the past, our fishers used to get adequate catch volumes without much effort, just in adjacent shallower waters. This was possible even with the poor fishing gear, including wooden boats and even traditional canoes. But when the leading nations of the world came to our oceans to fish with advanced ships or through exports, our local fishers no longer catch enough fish. The problem is worsened by the fact that these small boats cannot make a catch in deeper waters."* Interviewee TZ43, Tanzania, 2019. Freshwater & marine *"We have a vast ocean rich in marine resources but as a country we have not been able to exploit even a tiny bit of it. DSFA has a limited routine of surveillance operations due to lack of adequate budgetary resources. But even these few budgetary resources have yielded good results as many foreign vessels have been caught in our waters and fined. One of [the] shortcomings in our work is the use of an outdated surveillance system called Vessel Monitoring System (VMS). This VMS helps with ascertainment of marine vessel's sailing speed, direction, and position of vessels. The system does not help with instant discovery of ongoing illegal, unregulated, and unreported (IUUs) practices being committed by the vessels at sea. This offers loopholes to foreign vessels to continue to commit IUUs unnoticed. Modern surveillance technology would help us very much to secure and sustainably exploit the country's deep-sea resources."* (Interviewee TZ67, Tanzania, 2019). Marine *"There is no Tanzanian publicly or privately-owned vessel operating in the country's deep-sea waters. Therefore, the Tanzania's exclusive economic zone (EEZ) waters have always been dominated by foreign vessels which from time to time enter and fish illegally in the sea. In 2009 a vessel manned by the Chinese crew was apprehended in Tanzania's EEZ for carrying out illegal fishing activities. Currently in 2019, twenty Chinese vessels have been reported internationally for*

				purposes of being blacklisted for fishing illegally in Tanzania's EEZ waters and running away into high seas. These are supposed to pay TZS1.0 billion each in fines (say US$435,000/-). There is another vessel owned by a Malaysian tycoon that was caught fishing illegally in Tanzania's EEZ waters, and now it is docked at Mtwara pending a TZS1.0 billion in fines." (Interviewee TZ129, Tanzania, 2019). Marine *"While cephalopods and crustaceans are regarded as high value, they possess higher socioeconomic potential and lower investment requirements as well, relative to bone fish. Octopus for instance, are harvested in shallow marine waters with significant involvement of not only men, but women. Therefore, small-scale fishing of cephalopods and crustaceans can be modelled to fight poverty through widening job opportunities to disadvantaged groups in society – especially women. On the other hand, bone fish are always in deeper waters, hence the need for more investments in fishing vessels and technology, thus a more costly endeavour that may delay socioeconomic exploitation of fishery resources in Tanzania. The major challenge facing the Tanzanian fisheries industry is the fact that fishing effort is by far higher than the rate of available fish supplies, hence the unsustainable fishing trend."* (Interviewee TZ171, Tanzania, 2019). Marine *"The fishing sector lags in development because of limited access to capital. This affects both small-scale and large-scale fishing operations. However, policies are not clear on the definition of small or large fish enterprises: is the distinction based on size of fish gear? If yes, then it would attract a dispute because many small-scale boats may possibly produce relatively larger fish catches than bigger vessels, thus registering more revenues and more capital base through accumulation of ensuing profits. The lack of capital denies fishers the means to access modern fishing technology, hence a characteristic or property of primitive fishing methods – kokolo, ndoano, etc – which basically help only trial and error fishing. With this low and primitive technology, fishers are not capable of determining where to fish for larger catches, they therefore go for a cheaper and unsustainable dynamite fishing. It also renders the activity to seasonal*

				fishing, doing so when the seas are calmer. Even marine parks harbouring fish breeding grounds in shallow waters become easy targets by low tech fishers, despite the critical importance of preserving these breeding grounds. All this low productivity is due to poor fishing technology of the fishing equipment and gear. Modern technology would make it possible to undertake continuous fishing irrespective of weather conditions and sea depths." (Interviewee TZ08, Tanzania, 2019). Freshwater & marine
Traceability Inadequacy	42	22	20	*"Ensuring fish and other perishable food quality for consumer safety is really a challenge in Tanzania. We conduct frequent surveys on this aspect and come up with many instances of chemical contamination during preservation to such a high degree that if we acted stringently, many fish and food businesses would be forced to close. This is where the traceability mechanism is needed, but the difficulty to act boldly would still render it ineffective. So, lenience in food safety measures puts local and foreign consumers' health at risk, except for fish destined to Europe who require certified food safety tests before granting fish cargo entry permits."* (Interviewee TZ05, Tanzania, 2019). Freshwater & marine *"Today, traceability is still a buzzword in academic circles that has not gotten enough traction in the real business world. What the seafood industry emphasises is quality that meets all the necessary health safety standards for the consumer. While the illegally sourced catches may struggle to clear border checks into the EU as they lack credible papers on sourcing legitimacy, the same consignment could still get a good price in the black market if it met all quality tests, thus getting to EU consumers through other means."* (Interviewee EU02, UK/EU, 2020). Freshwater & marine *"As for traceability, tests on atomic energy radiation are not performed appropriately, especially on Nile Perch fish consignments for export. To track possible sources of this, regulators or inspectors should have required maintenance of fish consignments by processors or suppliers per source or origin to allow sample-based tests. Instead of this procedure, no samples are taken but*

				charges for this test is a lumpsum based on invoice value – ignoring the fact that the whole consignment could be made up of a mix of fish form all three states sharing Lake Victoria, with a possibility that a consignment or two from any of these countries may contaminate the whole cargo. Because the charge is based on the whole cargo and not a sample, then more is paid than would be the case on sampling. It turns out the scheme is not service delivery as labelled but revenue enhancement." (Interviewee TZ57, Tanzania, 2019). Freshwater *"Another challenge facing the fisheries sector is about imported stringent quality requirements. Most fishers are not capable to invest in traceability systems and facilities that ensure quality standards which are usually of the developed world – like the EU. Practically speaking, it is easier and cheaper for most fishers to meet for instance standard quality requirements for DRC sardine importers (i.e., relatively less stringent) while they could struggle to supply to Australian buyers (with more stringent requirements). The standards in Tanzania are stringent and uniform with no flexibility to accommodate the varying spectrum of quality requirements in the real market. This denies Tanzanian small-scale fishers lots of revenues as the regulatory regime is largely not export enhancing to disadvantaged small-scale operators."* (Interviewee TZ70, Tanzania, 2019). Freshwater & marine *"Tanzania has one major laboratory at Nyegezi Mwanza for testing quality and safety of fishery products. The facility is accredited internationally by Southern African Development Community Accreditation Service (SADCAS); and it carries out biological, chemical, and physical analyses on fish food samples. All fishery products exports, mainly to the EU, get tested and passed here. However, these tests are only driven by foreign demand or buyers – they are undertaken thanks to the EU requirements that all fishery imports into the EU should meet some specific safety and quality standards as a measure to protect European consumers. Almost all fishery products consumed locally and those destined to most African neighbouring countries (say Rwanda, DRC, Zambia, etc) do not undergo these safety tests, and business goes on normally without cases of*

				health hazards. This is an area requiring improvement, given recent cases of chemical and/or poison contamination of two fish consignments – one being imports from China with heavy mercury contamination, some of which had been distributed and consumed locally, and the second being potential local fish exports to DRC." (Interviewee TZ15, Tanzania, 2019). Freshwater & marine *"Dar es Salaam is the country's main fish market for both freshwater and marine fish. When the fish are transported from these places to the Dar es Salaam market, there are no certification documentation to indicate the places the catches were made. This is indicative of potential practices of illegal fishing cannot be detected or cross-checked easily. These could be unauthorised fishing methods like poison fishing usually in freshwater fisheries or dynamite fishing in both marine and freshwater fisheries. Other fishers could catch such fish in prohibited areas like marine protected areas. Sometimes also the means of preparation of the fish like sun drying, frying, salting and others are not hygienic, thus posing a health risk to consumers. Furthermore, means of transportation from landing sites to local markets and even further to the country's main market in Dar es Salaam are not specialised or hygienic, thus causing another threat to consumer health. Overall, there is no effective traceability system to enable one to get a history of where, when, how, and who produced or transported fish found on a particular market in Tanzania."* (Interviewee TZ31, Tanzania, 2019). Freshwater & marine *"To facilitate traceability in fisheries supply and value chains, AlphaKrust has three EU approved fish buying centres, particularly for fishing of exportable cephalopods (octopuses, squids and cuttlefish) and crustaceans (crabs, lobsters and prawns/shrimps). They are Kilwa (01), Mtwara (02) and Tanga (03). These centres are located on rocky shallow waters which provide conducive environment for octopus breeding and fishing. To help traceability, each fish box sent into the EU has code showing production date, expiry date and batch number. For instance, a code of 19J18A01 means the following: 19 stands for year 2019; J stands for production month, say*

				January; 18 stands for the specific production date – 18th January; A stands for a shift responsible for production of a certain fish box/batch, say one of three 24-hour shifts A, B, C; 01 stands for an EU approved centre with sufficient competent quality control staff, equipment and laboratory facilities. In this code, 01 stands for Kilwa. Information on this code enables traceability or tracking of truck used to transport the fish from approved centre to factory or laboratory, the owner and driver of the truck, fishers who supplied the fish as well as staff who processed/produced the batch – thus be able to ascertain sources of any health threatening contaminants that may spoil the whole or part of the consignment. However, fish caught in other waters around Dar es Salaam are suspected to be contaminated because of the industrial wastes draining into the surrounding marine waters. These end up in the local and neighbouring countries markets. Therefore, available systems are in favour of ensuring consumer health safety for foreign consumers while ignoring to guarantee the local consumer health. This could negatively affect the health conditions of Tanzanians and other consumers in the neighbouring countries." (Interviewee TZ154, Tanzania, 2019). Marine
Non-Cooperatised Fishing	52	20	32	*"Since this country's independence and the time prior to that, many schools and learning centres were built in the north, north-west (lake zone) and the south-west (the southern highlands). This followed the colonial inherited cooperative systems in those areas where economically important agricultural commodities and livestock with high export potential were grown and farmed. These cooperatives enabled farmers and livestock keepers in those areas to build schools and educate their children. Later, these children occupied most decision-making positions in government, thus maintaining the skewed allocation of national developmental resources towards their home regions. The fisheries resources which are our main socioeconomic sector did not get this privilege during the colonial era and the government did not correct this imbalance after independence. Until today, the fisheries sector lacks a robust government supported cooperative system. As a result, there are no guaranteed fisheries product quality levels and marketing systems. We have been left out on our own. This will continue as we have fewer political and technical representatives in key areas of allocating national development resources because these are historically dominated by children of farmers and livestock keepers."*

				(Interviewee TZ11, Tanzania, 2019). Marine *"As processors and exporters of fish products, we face numerous problems which appear to worsen by the day. Among these, is the unreliability of fishers who cannot formulate themselves as credible formal groups. Therefore, we pay more to buy most of our raw materials from specialised agents near the EU approved centres in Mafia, Kilwa and Rufiji. Small-scale fishers work mostly individually rather than in coordinated teams or groups. Some fisher groups would rather divide fish among themselves, and each go out to find buyers than market and sell their catches collectively. AlphaKrust tried in vain to advise the formation of formal fisher groups whereby the former was ready to supply the latter with fishing equipment and gear so that their catches could be sold automatically to AlphaKrust."* (Interviewee TZ52, Tanzania, 2019). Marine *"The challenges facing the Tanzanian fisheries sector include low levels of mechanisation. There is no adequate investment at both national and sectoral levels. Other sectors like agriculture have specific support measures, such as the establishment of Tanzania Agricultural Development Bank (TADB), while none exists for fishers. The agricultural crop sector has got government supported formal cooperatives along which sorts of collective production and marketing of produce are enhanced – again, none exist in the fisheries sector. In fisheries, groups of fishers are fewer, …informal, …disorganised and as such not institutionalised as is the case for other sectors. Generally, the government favours other sectors like agriculture tourism and energy much more than the fisheries sector, and this largely explains the underdevelopment of the fishing industry relative to other socioeconomic sectors."* (Interviewee TZ107, Tanzania, 2019). Freshwater & Marine *"Lack of collective dialogue or communication for joint action between and among fishers has been a major problem facing fishers. One way to address this would be to formalise their weak*

				fisher groups into cooperatives or registered groups. This would further help to promote dialogue and delivery of training/extension services, marketing, and distribution of fishery products. Unfortunately, the current disorganisation of fishers and the loose cooperation with other actors in fisheries, coupled with unfavourable policies and punitive regulations against fishers like confiscation of our fishing gear, unfair/unreasonable penalties, limited financial/bank support, extreme government crackdown under the guise of illegal fishing, and unreliable markets. These problems are responsible for the current governance vacuum and irresponsibility leading to fisheries resources mismanagement. This results in loss of opportunities for disadvantaged small-scale fishers while indirectly promoting unsustainable fishing." (Interviewee TZ183, Tanzania, 2019). Freshwater & Marine *"Tanzania's small-scale fishers lack of modern fishing equipment and gear and unreliable marketing systems. There is need at a national level to enhance investments in modern fishing port facilities to attract local and foreign fleets which would in turn raise local demand for seafood, thus a hike in local prices as well as purchases by local operators like hotels and restaurants. This would have benefited small scale fishers. However, because these fishers are largely operating as individuals and not in formal businesses or registered groups/cooperatives, there would be little chances of exploiting these potentials. This way, fishers would not easily access lucrative supply/sales contracts with hotels or restaurants. This would still limit the fishers from accessing vital financial resources for supporting their fishing operations. Even more reliable buyers like hotels and restaurants would be lost as they prefer to deal with businesses well established with banks."* (Interviewee TZ139, Tanzania, 2019). Freshwater & Marine *"As small-scale fishers in Tanzania, we do not have access to reliable markets, and this makes us fetch low prices from middlemen in the market who go on to make higher margins from well established businesses. The other problem is that we fishers do not have active formal cooperative movements, and as a result, we are denied a lot of benefits. We therefore miss out on reliable*

				markets, resulting in low and unreliable prices. Our colleagues in agriculture who produce crops like coffee, cotton and cashew nuts enjoy government extension services and guarantees of minimum prices. It is time we small scale fishers lobbied to get similar support from government. If we do not do this, the fisheries sector will remain in dire circumstances." (Interviewee TZ41, Tanzania, 2019). Freshwater *"Another key challenge that we fishers face is that our Beach Management Units (BMUs) are not well supported and so our members in BMUs cannot undertake routine surveillance trips to ensure compliance of sustainable fishing plus collection of fisheries data. These BMUs do not get cordial support from local government authorities, save for any meaningful help from the Ministry of Fisheries. These BMUs were meant to work as fishers' and other fisheries stakeholders' collective mechanism to cooperate at local or fishing ground level to tackle illegal and unsustainable fishing practices. Therefore, weak BMUs result in the growing unsustainable fishing practices."* (Interviewee TZ177, Tanzania, 2019). Freshwater *"Supplying fish products to formal sectors including hotels and restaurants would require fishers to first and foremost achieve formality in their fishing operations. This is where they fail. Most fishers are not in formal organisational settings, and a few registered fisher cooperatives are practically dysfunctional and other fisher groups do not have strong active memberships. Some of these are truly registered but not carrying out fishing or not actively organised commercially as fisher groups. This lack of coordination among fishers is another form of governance vacuum which is instantly taken advantage of by ruthless middlemen and vendors/traders. Therefore, being disorganised internally weakens fishers' prospects for achieving sustainable fishing business through access to reliable markets (say hotels and restaurants), thus leaving ample room for others (say middlemen and vendors/traders) to scramble for the occasion. The ongoing efforts by fishers at Minazi-Mikinda in Dar es Salaam to coordinate their fellows along the Tanga-Mtwara marine coast to form an umbrella representation (national cooperative body) for all marine*

				fishers could prove critical in unlocking the formalisation of market access and other sectoral challenges involving fishers and other relevant actors."- (Interviewee TZ19, Tanzania, 2019).Marine
Unbanked/Underbanked Fishing	36	16	20	*"Banks have always been there to support other sectors especially agriculture but not fishing. Even the government prioritises loan guarantees for agricultural and livestock-based activities – not fishing. I recently approached a bank for a loan to acquire one more fishing boat. When they visited to verify and assess my business potential, they said they wouldn't accept my two boats which were currently operational as collateral, but they wanted an immovable and marketable house. I eventually failed to secure the loan. I gave up."* (Interviewee TZ02, Tanzania, 2019). Marine *"Bank lending to the fishing sector, particularly small-scale fishers, is quite low at present. The main reasons for this poor bank-borrower relationship are (i) credit mismanagement, (ii) lack of business knowledge and embedded risks, (iii) lack of bank's proper consultancy to borrowers, (iv) lack of financial discipline - diversion of funds to unplanned causes; (v) lack of proper market research by both bank and borrower. Eventually, any lending to most fisheries activities is regarded as extremely risky, which could potentially threaten banking operations and sustainability. So far, there has been no assuring mechanism that would enable the banking industry to limit the risks posed by the fisheries sector."* (Interviewee TZ13, Tanzania, 2019). Freshwater & Marine *"Lending to fishing and agriculture generally poses significant risks mainly due to the unpredictable nature of the activities – i.e., high dependence of natural conditions rather than predictable human performance. Therefore, most loans extended to this industry end up becoming*

				unrecoverable debts, thus causing heavy losses to banks. The bank has been incurring costly expenditure trying to engage third parties, usually auctioneers / debt collectors to help, although they are expensive. If there arose a solution to address this problem in a simple and cheaper mechanism, it would be advisable for the banks to adopt it. The bank has not had a good business footing with the fisheries sector, especially small-scale fishers. The sector is generally considered risky because it is always on the news especially in terms of government bans and destruction of fishing gear and equipment due to frequent illegal fishing activity. What if a fisher or a group of fishers take up the loan and end up in jail due to illegal fishing practices, or their fishing boat gets seized in the crackdown?" (Interviewee TZ18, Tanzania, 2019). Freshwater & Marine *"[There is] a culture of not depositing sales proceeds with banks for fear of them being seized and estimated for higher tax payments by Tanzania Revenue Authority (TRA). Fishers and other small-scale operators should organise themselves and establish a culture of building trust with third parties, especially banks. It should begin with doing away with informal and outdated practices of operating without business bank accounts. This is an area a bank would evaluate a client in terms of trust in their financial discipline. Fishers and small-scale operators should be able to tell how they spend their own money from daily cash flows before seeking extra funds in bank loans for furthering their fishing operations."* (Interviewee TZ25, Tanzania, 2019). Freshwater & Marine *"The fishing business in Tanzania is largely uninsured; and this is obvious with regards to small scale fishers. The insurance industry sees a problem in the nature, quality and standard of fishing vessels used by these fishers. They are all low-tech and wooden. We are giving cover to vessels with obvious risk of going under; and this certainty of risk disqualifies any offering of insurance policy. Uncertainty of risk, which could open fishers' access to insurance products and services would require the fishers to operate modern or hi-tech fishing boats or vessels. The working model would be for them to get reliable fishing vessels through bank guarantees or facilities, and then, as*

				insurers we would cover these assets in the names of the lending banks. Cover policies in fisher group names would follow ownership transfer after the loans are fully repaid." (Interviewee TZ29, Tanzania, 2019). Freshwater & Marine

Governance Loss (GL) Category

Code/concept	CIIs	Freshwater CIIs	Marine CIIs	Conceptual memos with highlighted CIIs
Data Corruption	31	7	24	*"…when the Government of Japan handed this main fish market over to the Government of Tanzania in 2000s, it was a fully-fledged facility, with functioning weighing scales for incoming/inbound and outgoing/outbound fish cargoes. However, it was not long before these scales were dismounted and kept in store. As we speak, nothing is measured and recorded here, whether the landed catches or fish coming in from Mwanza or Kilwa by road…"* (Interviewee TZ33, Tanzania, 2019). Marine *"…that room over there had a weighing scale installed for measuring weights for fish catches here before they could go out to the market. However, the equipment became unusable later and needed repairs that were offered intermittently. Eventually, officers from the district council came over and dismounted it and carried it away. It had never been returned to-date and no weighing of fish catches is done currently."* (Interviewee TZ37, Tanzania, 2019). Marine

				"…Charles, where did you get that figure? We have never seen any government official come to us the way you have done and introduce themselves as collectors of fish catch statistics or volumes; and we are the most active and productive fishers here in Dar es Salaam. Can you tell me any agricultural commodity that generates more money for the government daily than levies on our landed fish catches at every site? Maybe you need to visit the Dar es Salaam [Magogoni] fish market one early morning so you can see for yourself. Our fishing activities contribute far more to the economy…. than what you are telling us." (Interviewee TZ01, in Tanzania, 2019). Marine *"…when you go to any typical fishing site across the country you will find it full of people…possibly more people than you would find at other agricultural market gatherings. What are they doing there every day? They are buying and selling fish…and cash is changing hands constantly. If they made losses, they wouldn't be there every morning…and they are paying government revenues every day as well. I have not seen a sector as vibrant as the fishing sector, yet TBS [Tanzania Bureau of Statistics] would keep reporting the fisheries as insignificant contributors to the national economy."* (Interviewee TZ78, Zanzibar, Tanzania, 2019). Freshwater & Marine *"…we had a couple of disagreements with one of the levy collectors who had a habit of harassing us to pay more than necessary. One day we decided to go to his boss so we could report him at the local authority. We were armed with records from our daily register. On arrival, we requested the boss to cross-check our levy payment records against the local government's database. To our surprise, we found that for one day when we recorded in our register to have paid TZS345,000/- in levy payments, the records at the local government showed it to have received TZS26,000/- only. The boss' reaction in*

				the days that followed was to switch the responsible levy collection officer to other duties and replace him with another staff. He was not suspended at all." (Interviewee TZ81, Tanzania, 2019). Marine *"…I don't do what my boss doesn't ask me to do; he only wants me to send him daily figures of levy collections. I understand that some things here are not proper regarding data, but I cannot go beyond what my bosses require me to do. Periodic fisheries data are compiled and reported based on estimates rather than real daily catches. Maybe I will be able to undertake this task when I write my master's dissertation…"* (Interviewee TZ102, Tanzania, 2019). Marine
Political Manipulation	34	11	23	*"These people [the government] are unpredictable. Their decisions are always impractical. You can't catch dagaa [sardines] with a 10mm net as its holes are too wide, so the small fish could escape easily. We had always been ready to go fishing with these officials so they show us how their prescribed fishing methods can be done practically but they don't invite us, they do it themselves and dictate to us what we cannot realistically implement. Whenever they need our votes, our political representatives always come to us with politically reassuring gestures or promises saying that bans on prohibited fishing gear including small-hole nets have been lifted. Once in power, they change their previous positions and start punitive crackdowns on us, thus inflicting heavy losses on our fishing businesses."* (Interviewee TZ94, Tanzania, 2019). Freshwater & Marine *"A lot of the money from this fund is lent out and not repaid, thus turning bad and/or irrecoverable. Political figures at these councils have been blamed on the dysfunctional*

				nature of the scheme, as most loans are issued on political lines rather than on commercial terms, thus resulting by design into mass defaults and non-recoverability." (Interviewee TZ59, Tanzania, 2019). Marine *"It is true that we had advised the government to ban 8mm nets and those below for catching sardine species (dagaa) as they lead to overfishing, particularly the catching of juveniles. However, as a public institution, we must follow the government directives as issued to us from time to time. These do sometimes result into reviewing and changing previous positions…. We also do not invite fishers as we undertake marine research because our scientific approach does not require them to be there to render more credibility to its results. My experience engaging with these small-scale fishers has not been good…they usually behave and present themselves as being so knowledgeable about fishing, even more so than us marine scientists. This behaviour puts me off when it comes to working together with them."* (Interviewee TZ127, Tanzania, 2019). Freshwater & Marine *"You know, we're the bravest and most successful fishers because we learned the skill from our ancestors. We come from Pemba and some of us are in Unguja [Zanzibar] and we have no other major socioeconomic activity than fishing. The government has never been serious to develop or support our fishing activities…so we chose to support opposition politics with every little resource we have. I think this punitive crackdown and targeted destruction of our fishing gear is a hidden government reprisal against our political orientation. If not the case, why fishers in Dar es Salaam and other ruling party strongholds did not suffer a similar fate while their fishing activities are larger in scale than us?"* (Interviewee TZ132, Tanzania, 2019).

				Marine
Policy Confusion	45	19	26	*"The UK government has once again betrayed us…the new export custom procedures take longer [since the Brexit Deal] as checks cover the whole consignments and not samples as done previously… Documentation, especially export health certificates, constitute other time consuming and costly financial challenges, especially when multiple fish species and several [EU] destination ports are involved. We are now required to complete up to 71 pages of paperwork for every truck of fish entering the EU."* (Analysed media interviews, UK/EU, 2021). Freshwater & Marine *"Unfortunately, TAMISEMI focuses on revenue collection from fisheries activities, but they are not obliged by law to utilise the collected money to undertake fisheries resources protection, development as well as quality control, standards and marketing. As a result, the fisheries sector remains underdeveloped – poor landing sites and untidy fish auctioning/marketing buildings, inappropriate revenue collection mechanisms, lack of necessary infrastructures such as fish ports. In addition to these shortcomings, there is no formal coordination between the two ministries in which case TAMISEMI would be communicating, at least periodically, to account for the revenue collections and how they were spent and on which activities."* (Interviewee TZ73, Tanzania, 2019). Freshwater & Marine *"In the past, the Ministry of Fisheries employed statisticians as data collectors, but later the government removed these staff and reallocated them elsewhere, thus exacerbating the data quality problem. There followed a period of about two years when no official collection of fisheries data was made."* (Interviewee TZ64, Tanzania, 2019).

				Freshwater & Marine *"In Tanzania, local policy on food safety does not encourage investments into food safety testing systems and instead these infrastructures are prioritising safety and quality of fisheries exports, especially to Europe. This creates a confusion where the country appears to care more about foreigners and not the health safety of its own people. As such, the fishery sector is buyer driven, meaning buyers especially those in the developed world like the EU are dictate prices and other terms, whereby sellers or suppliers especially those in developing countries follow the terms of buyers – including price setting. This would explain why governments (in upstream = supply side) would prioritise to have conditions for food safety met as stipulated by buyers (in downstream = demand side) and for the safety and benefit of buyers only – not local populations."* (Interviewee TZ97, Tanzania, 2019). Freshwater & Marine *"Tanzania has to improve its competitiveness in the deep-sea fishing industry as managed through DSFA by doing away with investment threatening measures. Fuel levy should be eliminated for sea vessels or deep-sea vessels so they could refuel at Tanzanian ports. No foreign fishing vessels dock at Tanzanian ports, mostly because fuel levy makes refuelling in Tanzania expensive relative to Mauritius and Seychelles which have abandoned the charge. The US$0.40/- charge for every kilogram of target fish species was another aspect that drove foreign fishing vessels away from the country's EEZ – some of these being spotted recently in Somalia waters. Tanzania must purposefully invest in its national fishing fleet if it wants to take charge and advantage of the EEZ fishery resources."* (Interviewee TZ118, Tanzania, 2019). Marine

				"The fisheries sector is governed by some public institutions which tend to perform similar tasks, thus creating a confusion in terms of a duplication of effort leading to unnecessary costs on the part of served stakeholders (mainly fish processing plants). For instance, while the Occupational, Safety and Health Agency (OSHA) examines fish processing staff on these standards at a fee, Municipal councils have been repeating the same procedures and requiring payments. Tanzania Bureau of Standards (TBS) does calibration tests on fish processing plant equipment and gets paid; and the same tests are repeated and billed by another government entity: Weighing and Measurement Agency (WMA). Early this year (2019), a consignment of fish was imported from China but was not cleared from the Dar es Salaam port. Later the Tanzania Revenue Authority (TRA) turned up to auction the fish and recover taxes. A 90-day announcement through public media was made inviting all relevant government institutions to come over and test the quality and safety of the fish to see if they are fit for human consumption. During these 90 days, the competent authority (Fish Quality Control section at the Ministry of Livestock and Fisheries) did not turn up. Instead, Tanzania Foods and Drugs Authority (TFDA) came up with a clean bill – the fish consignment was fit for human consumption. Based on this TFDA clean health report, TRA went ahead with auctioning procedures. No sooner had some trader at Kigamboni bought the fish container and started public distribution than the competent authority came along and confiscated the then unsold lot which was still significantly over three quarters. They quickly took samples and did their version of the tests – only to come up eventually with a negative report: the fish were actually not fit for human consumption. The apprehended fish cargo was destroyed in public. The questions then lingered: why all this coordination mess and professional incompetence with these seemingly capable government institutions? Assuming the last test by the competent authority was right, it is important to note that their delay to turn up in the 90 days had rendered some fish into the distribution chains – possibly already consumed by humans. One also asks, what was wrong with TFDA? Do government agencies have different places or equipment to get their tests done? All in all, no entity assumed

				responsibility to compensate the trader who had invested a lot of his money and time at the time of the confiscation. Possibly because of this mix-up, it has been observed lately that TFDA has been stripped of its food portfolio, with its name changing to Tanzania Medicine & Medical Devices Authority (TMDA).” (Interviewee TZ109, Tanzania, 2019). Freshwater & Marine
Prohibitive Regulation	33	9	24	*“Also, a marine safety regulator (TASAC, formerly SUMATRA) would require that each boat have on board no more than 30 fishers – all above this number are to be fined TZS2.0 million each. In most of these cases, fishers are apprehended and penalised when found with illegal fishing gear on board while they are coming back from sea about to land their catches – usually not necessarily on the spot red handed fishing. Enforcers assume and are most of the time quite sure based on experience rather than hard evidence that the fishers should have used these illegal gears in their fishing.”* (Interviewee TZ88, Tanzania, 2019). Marine *“The number of foreign fishing vessels registered in the Tanzania’s EEZ waters has been fluctuating unfavourably since 2009. A fall in number of vessels around 2012/2013 is associated to the risk of piracy while a rise that comes subsequently is thanks to a subsidy offered by vessel flag nations that offset the perceived piracy risk. From 2015 onwards, there was news of a pending change in Tanzanian laws and regulations to implement a charge of US$0.40/- per kilogram of target fish species. This was passed late in 2016, thus chasing all vessels away from the country’s EEZ waters. In 2017 there was a temporary 6-month waiver of the US$0.40/- charge, but it was not extended on expiry, sealing the fate of foreign fishing ships. In 2011, there seems to have been a small number of reported catch volume (544 tonnes) while purse sein vessels were close to 40 – casting doubts on correctness of the figure given the large number of vessels.”*

				(Interviewee TZ104, Tanzania, 2019). Marine *"Regarding the lack of clarity about allowable fishing depths, we usually advise fishers verbally that they must carry out fishing operations at sea locations with such depths one cannot see the sea floor. This is usually 50 metres and above, as interpreted from the laws and regulations – but also with some flexibility from bylaws set by implementing local governments. This is meant to ensure fishing nets are hung in the water without touching the seabed, which could endanger coral reefs and other marine natural habitats. But they must do this without the use of diving gear [oxygen cylinders, eye protector-masks, swimming flaps/shoes] as they may use it to commit illegal fishing activities. To limit this possibility, we only allow them 2 to 3 cylinders of oxygen for emergencies only on a boat of 30 fishers maximum; but we understand they are practically in a range of 50 to 80 fishers per boat when fishing out there. The law allows us to penalise them TZS2.0 million [UK£650] for any extra gas cylinder found with them and TZS2.0 [UK£650] for any extra fisher found on the fishing boat. However, although it is generally public knowledge that many fishing boats carry between 70 and 80 fishers, there hasn't been much received by TASAC in penalty fines revenue."* (Interviewee TZ135, Tanzania, 2019). Freshwater & Marine *"One morning we were returning to land our catch. As we passed that mini-island with a navy base, we were quickly surrounded with their armed boats and ordered to change course and move towards their camp. Our catches were abandoned rotting in the sun as we were interrogated as if we were illegal fishers. It later became unbearable, and we decided to forcefully break loose and leave with our boats. Gunshots ensued, …one of us died and a couple more fishers sustained injuries from these gunshots. As we speak now, there is an ongoing court case relating to this incident which we consider as*

				unsubstantiated fabrication case of illegal fishing. Other similar incidents in the past that involved surveillance officials would usually be settled unnoticed by people as we offered them baskets of fish and some cash." (Interviewee TZ22, Tanzania, 2019). Marine
Corrupt Survival	20	8	12	*"These fisheries officers would usually wait until we fishers are coming back to land our catches. That is when they impound our vessels and fish consignments followed by fabrication of wrong offences against us – especially when we have nothing to offer them (bribes). Giveaways are generally in the form of cash commissions or bags of fish. This scenario builds on the discretional powers that fisheries officers and accompanying regulators have over fishers. The fishers are usually cornered to choose between their apparent fishing rights which would take them through a lengthy and dubious yet unguaranteed path or a shorter and instant route of offering kickbacks. Being cost conscious, fishers in their majorities find themselves forced to join the network of corruption ridden illegal fishing, thus stifling further the prospects of running the sector on the principles of transparency and good governance. They have to bribe their way for survival unless they are ready to pay the heavy price. These practices of corruption have also been reported recently where officials receive bribes from fishers to access richer waters in Mozambique. This opens doors for illegal fishing and smuggling of fisheries products across the Tanzania-Mozambique border as facilitated by a network of corrupt actors – regulators, traders, border customs officers, etc.`"* (Interviewee TZ121, Tanzania, 2019). Marine *"Fisheries regulators and police officers from Mwanza occasionally undertake surveillance activities in the lake while we are out there fishing. There are instances when some of us get caught up with illegal fishing gear, usually fishing nets with illegal*

				specifications – e.g., those that catch juveniles. These fishers caught in the act would usually get their fishing equipment impounded, pending court cases and/or fines or penalties. Based on experience, these charges and financial penalties tend to be too punitive to be affordable by most fishers, and this usually results in fishers losing their fishing assets. However, these officials usually do these acts on purpose and creatively to attract informal negotiations with the corresponding fishers, and this is where opportunities to pay bribes arise. Fishers who are capable to meet these corrupt demands are the ones who get their equipment back, those who do not end up being charged in court and/or their equipment confiscated.” (Interviewee TZ113, Tanzania, 2019). Freshwater
Resource Unaccountability	25	8	17	*“In 2019, we conducted a crackdown operation on smuggling of fishery products at one of Tanzania’s busiest border posts to the south of Tanzania. We seized several vehicles full of fish and fishery products, being smuggled illegally (without legitimate permits to conduct the business, including payments of fees, royalties, etc) across the border into Zambia while others were destined further beyond to DRC and even Zimbabwe. In one case involving two fish laden vehicles, interrogation of truck drivers and customs staff revealed the cargoes belonged to highly placed influential people in the country’s decision-making circles, mostly entrusted with the duty of safeguarding the country’s laws and regulations on fisheries resources. These irresponsible people..... tried in vain to secure the release of the consignments so they could cross the border with the cargo. As we held our positions firmly, the matter escalated to high offices. Eventually, owners of these consignments paid cash into Government Revenue coffers amounting to TZS70.0 million [£23.0 million] in export licence, royalties plus fines. A rough conversion on fish consignments in the two vehicles would provide a value estimate of TZS4.7 billion [£1.6 million]. During the one-week operation at the border crossing, we were able to collect over TZS310.0 million [£100,000.0] in fines and penalties revenue for the government. It*

				was also noted that some junior border customs staff were knowledgeable of the illegality of the deals but could not act to stop these practices for fear of reprisals or dismissal from work by their bosses who happen to be owners of these illicit undertakings. Furthermore, while a larger portion of the detained cargoes originated from the Lake Zone (Lake Victoria), we later found out that most fishery products originating from Zanzibar were accompanied with fake licences and permits." (Interviewee TZ117, Tanzania, 2019). Freshwater & Marine *"Kilwa District Council received TZS800.0 million in MACEMP funds which were given to over 60 fisher groups for acquisition of modern new boats, new fishing gear, etc. As of today [October 2019] no group among those 60+ that received the money still exists in fishing operations. MACEMP failed totally, thus creating a socioeconomically non beneficial financial debt burden to the public. It was later revealed that the money was distributed to artificially created groups by well-connected local figures in political circles, comprising mostly non fishers. For those fewer fishers who received the money, it became difficult to track them down for monitoring and evaluation of the effects of the support. This is because most fishers along the marine coast are highly migratory, constantly moving and operating from one landing site to the other depending on seasonal variations in fish catches. The failure of MACEMP is largely linked to the project's mere focus on outputs (e.g., establishing fisher groups like BMUs, purchase of boats and fishing gear, improvements in landing sites like in Mafia, Kilwa, etc – now appear like white elephants), with little involvement or consultations with key stakeholders (say beneficiaries like fishers). In short, MACEMP did not undertake any credible needs assessment process. While emphasis of the project was on outputs, there was no attention placed on outcomes (i.e., short-term results) and not on impact (i.e., long-term development consequences), thus resulting into a total public loss, as the government will*

				eventually have to repay the World Bank in full inclusive of financing costs (i.e., interest charges)." (Interviewee TZ58, Tanzania, 2019). Marine
Resource Profiteering	35	4	31	*"Our [UK] fish suppliers have been telling us that fishing is getting more costly, fish have been declining in the sea, and oceans getting even warmer – hence pushing the problem around through the norward movement of fishing activity towards cooler waters in Iceland, Norway, and the North Sea. While other people hear fishing stories on newscasts, we decided to go for a fishing trip, involving even diving to the sea bottom. We saw for ourselves murky and dirty sea waters, high degree of plastic contamination …which forms part of what fish eat, and depleted fish stocks (mainly due to overfishing). We noted that the fishing business is a huge industry using massive trawlers and ships, taking large amounts of fish from the sea at astonishing overfishing rates. For instance, a recent report states that by now (July 2019) which is past mid-year, the EU has already reached and exhausted the required annual fishing quota for 2019…and what does this mean? It means fishing companies will have to move their overfishing activities elsewhere in the world…may be Senegal…may be Sierra Leone…and what will this mean to an average Sierra Leonian or Senegalese who depends on fish for livelihoods and family incomes? This will actually result in a fall of fish stocks in their waters,….. rise in prices at local markets,…. fall in protein intakes,…. poor health and quality of lives…hence continued poverty in communities."* - (Interviewee EU04, England/UK/EU, 2019).Marine *"The UK Government, and actually the EU are supporting the high street – the fishing businesses and the people involved, by turning a blind eye on illegal and overfishing activity. They do this because the fishing industry employs people, they pay taxes, and they stabilise prices through continued fish food supplies – though by way of illegal and unsustainable overfishing. There is lack of strict regulations in the UK and EU for*

				ensuring environmental conservation of marine fishing grounds. Strict adherence to sustainable fishing requirements would render closure of fishing grounds and fishing businesses, hence resulting in loss of jobs, ….rise in prices of seafood, ….social disorder. This could ultimately threaten survival of the UK and/or even EU governments…. Most people in the UK/EU want cheaper and affordable food, and this is difficult to achieve or guarantee when stringent sustainability measures in the fishing activity are put into effect. Little has been done to enable people to know where their fish food on the table comes from, ….what stages they go through, ….what environmental conditions exist there, …and what is being done to better the situation. The resolution of sustainability challenges in fisheries (e.g., overfishing, and illegal fishing) is hampered by business motives by the global fishing firms which have clout even over governments." (Interviewee EU05, England/UK/EU, 2019). Marine *"The question of ensuring the sustainable development of fisheries resources in Tanzania and around the world brings one key dilemma. How do you balance the business interests and sustainable fishing levels? Many times, sustainable fishing would require a degree of reduction in fishing operations, and this comes at a loss to fishing businesses because they are faced with ever-rising demand for seafood. In the developed world where demand for seafood is highest, fishing businesses are quite influential of government policy making, hence resulting in failed efforts to attain sustainable fishing levels. There are documented and reported incidences of Chinese and European fishing fleets that were found overfishing illegally in developing country waters including here in Tanzania. These fleets receive state financial support to undertake overfishing in the rest of the world to drive their business profits at unsustainable levels."* (Interviewee TZ134, Tanzania, 2019). Freshwater & marine

				"…during the period prior to 2016, buyers and sellers of illegally caught fish would usually meet in evenings just close to this main market…they would transact their business comfortably while guarded by armed police who would roam the area throughout the time of these meetings. Eventually, everyone would disperse and leave the area without trace…" (Interviewee TZ85, Tanzania, 2019). Marine
Globoverfishing	29	7	22	*"Despite the resource challenges faced by DSFA, we have been able to identify and sometimes catch foreign fishing vessels especially from European countries and China that overfished illegally in Tanzanian marine waters. These activities have been driven by the rising demand for seafood in these countries, hence going out to overfish in global oceans. When these large global fishing vessels operate in Tanzanian waters, they reduce fish supplies for local fishers who operate in shallower waters, thus encouraging them to commit unsustainable fishing practices like dynamite fishing to fulfil their normal catch requirements."* (Interviewee TZ76, Tanzania, 2019). Marine *"Over the course of the past ten years, we have apprehended several foreign vessels…. fishing illegally in Tanzanian waters,…. mostly from Asian countries but also a few from European powers. Some have been fined and they paid, others who failed to pay had their vessels arrested like one fishing vessel docked now in Mtwara. About 20 Chinese registered fishing ships escaped our trap and entered the international waters after operating illegally in our waters. The main challenge is that our current surveillance system does not enable us to ascertain the nature of fishing activities [legal or illegal] instantly and remotely around a vessel. Also, there is lack of marine equipment and*

				inadequate supply of other resources to enable us carry out frequent surveillance routines as well as respond timely and effectively whenever illegal practices are ascertained." (Interviewee TZ74, Tanzania, 2019). Marine *"Most of development funds in the fisheries sector in Tanzania and elsewhere started soon after the fishery resources in the donor countries had been depleted thanks to overfishing practices there as funded by state subsidies. When they fund sustainable fishing programmes in Tanzania, what happens is more fish production and less fishing activities because donor funding includes alternative income and livelihood programmes for fishers. At the end of the day, more and more catch grade fish and juveniles escape into deeper waters, hence getting into the hands of deep-sea fishing fleets belonging to the same donor countries as stationed adjacent to Tanzanian waters. The fish catches from shallower waters also get processed locally for largely same European and Asian markets, leaving little for the domestic market. This leads to undesired development: the local fish supply shortage and skyrocketing prices encourage some fishers to embark on illegal and unsustainable fishing practices to make up for the resulting shortfalls…"* (Interviewee TZ03, Tanzania, 2019). Freshwater & Marine *"During the 1990s when the commercialisation of Nile Perch fish fillets commenced to feed mainly the European market, business was booming with high demand and factories operated close to full capacity. This attracted new entrants or increased investments from the existing processors. There was a disregard of how long this would last in terms of the sustainability of fish supplies from Lake Victoria. As a result, demand driven overfishing has brought us to a sharp decline in fish supplies. Only 25% of industrial fish processing capacity is currently in use, ….rendering the remaining ¾ idle, but why this? The answer lies in the low supply of fish. Lower and fewer taxes, levies, and other regulatory*

				measures on fisheries in Uganda and Kenya enabled smuggled Tanzanian fish to cross into these countries and fetch better prices there. This contributed to expanding our idle industrial fish processing capacity. As a result, fish processing factories in Uganda increased from 7 in 2017 to 14 in 2019 while in Tanzania the number dropped from 12 to 8 during the same period." (Interviewee TZ61, Tanzania, 2019). Freshwater
Petty Disguise	16	6	10	*"…We are a group of three petty traders, buying small-sized fish, usually sardines, octopus, and squids, at Dar es Salaam's Magogoni landing site. We buy these in buckets, and then fry them at the market's cooker section and thereafter walk round the streets in the city selling them as delicious, hot spiced snacks. The centres include Magogoni, Posta, Kariakoo, Keko, Congo and Mnazi Mmoja. We buy a bucket of raw fish at TZS24000.0 [£8.0] and make sales proceeds of TZS135000.0 [£45.0], thus making a profit of TZS111000 [£37] on the bucket in a single day. We pay TZS300.0 [£0.10] daily to market authorities but have not acquired "Magufuli's small entrepreneur pass ID" which will cost us a small annual fee of TZS20000.0 [£7.0]. There are many of us in town who do similar business and make a lot of money but pay little or nothing to government. This is because they cannot find us easily. We operate freely but do not have specific or fixed business offices or address. Sometimes if government officers at the fish market are friendly you could pay little to them or nothing at all and they allow you to pass freely and go to do business and make good money. If we worked for only one third of the year (say 120 days), our team would have made TZS13.32 million [£4440.0] in annual profits. There are larger or more formal businesses that cannot make this profit."* (Interviewee TZ66, Tanzania, 2019). Marine

				"We usually buy small fish "dagaa" and some large ones that were not sold instantly to buyers. We fry and salt them with some spices to make them delicious and pack in large transparent bags to attract customers. We then start walking around selling. We do not have lots of expenses, we only rely on walking around business places, bus stops, bars, and entertainment houses where people buy our fish snacks that appear to go down very well along with their drinks. We make good profits sometimes beating formal businesses like corner shops. This is because we do not incur much in terms of costs associated with business premises or taxes to pay to government." (Interviewee TZ142, Tanzania, 2019). Freshwater

Appendix B3: How Schmeier et al's Resource Governance Framework Relates to Fishmining

Schmeier et al. (2016) state that resource governance has got four components, namely principles, norms, rules, and mechanisms. Principles relate to collective or joint consent of actors on laws and obligations for governing and sharing the resource benefits. Regarding the Tanzanian fisheries sector, fishers complained during the interviews that they were never consulted adequately by authorities when new laws/regulations were proposed or when changes to existing laws/regulations were made. This lack of fishers' consent or involvement resulted in difficulties to achieve full compliance or enforcement of the laws by relevant authorities, hence the GL problem. Norms, on the other hand, relate to expected behavioural standards of actors in terms of their rights and obligations towards the exploitation of the joint resource. Therefore, norms would spell fishers' and other stakeholders' rights and obligations in relation to joint or collective actions to protect fisheries against unsustainable fishing practices (e.g., establishment of effective Beach Management Units, BMUs). Norms would also involve joint or collective action to reverse damages that have already occurred due to unsustainable fishing practices. Unfortunately, most fishers said regulators did not engage in dialogue with them to spell out and discuss rights and obligations for the collective exploitation and safeguarding of the fisheries resources. This lack of dialogue between the parties added to the difficulties of enforcing the existing laws and regulations due to the fishers' limited participation, hence the continuation of the GL problem. Rules are put in place to operationalize principles and norms, including the shared allocation of resource for use in a sustainable manner. This was not achieved in the Tanzanian fisheries environment for the reasons explained above under the principles and norms components.

The fourth and final component of resource governance are mechanisms. These are ways meant to guide corrective actions to achieve delivery of the first three components of resource governance principles, norms, and rules. These mechanisms include dispute resolution and enforcement of compliance through collective and cooperative means. While the principles, norms, and rules are about the implementation of a resource governance system, mechanisms do something more: offering an opportunity to review the implementation and make corrections or improvements, if any. For dispute resolution and enforcement of compliance to occur, parties need to have an initial sense of trust or good faith in each other, and this depends very much on their interactions in the first three components of resource governance (Schmeier et al., 2016). Tanzanian fishers said during the interviews that they had never been involved in serious mechanisms with regulators to resolve differences or conflicts and compliance enforcement issues on the collective governance of the fisheries resources. Even if these mechanisms existed, fishers said they were hesitant to cooperate with regulators on fisheries governance issues because they were skeptical that regulators had good intentions to ensure the sustainable development of the fisheries sector. This skepticism was due to regulators not having engaged the fishers adequately in prior steps of the fisheries resources governance such as the formulation of policies and regulations or laws. So, the fishers viewed regulators as not credible and untrustworthy partners in relation to ensuring a sustainable collective fisheries resource governance system. Therefore, these limitations in fisheries governance mechanisms resulted in the lack of trust, good faith, coordination, and cooperation among various actors for resolving differences to ensure a collective governance of fisheries resources. This constituted our second problem of Trust Loss (TL). While GL is about failures of actors to collectively draft and enforce regulations/laws to implement principles, norms, and rules in the collective fisheries resources governance system, TL relates to failures of the actors to resolve conflicts or compliance issues arising in GL. Because both TL and GL originated from limitations in the public governance of fisheries resources, the two were combined into a higher order problem (core category) as antecedents of ‘lacking trust and credibility among stakeholders and inadequacies in public fisheries resource governance.’ This higher order core category was called Fishmining BSP.

Appendix C3: Stakeholders' Interviews Questions Checklist

STAKEHOLDER INTERVIEWS (2019)

PARTICIPANT INFORMATION SHEET

Dear Sir/Madam,

I am Charles Domician, a PhD candidate at the University of Reading. I am undertaking research which seeks to identify barriers and drivers in the fisheries supply and value chains from regulators, producers, traders, processors, and exporters in developing countries (represented by Tanzania case study) to regulators, importers, and distributors in the developed world markets (represented by relevant stakeholders in the UK and EU). The study also intends to explore the stakeholders' current uptake levels and/or willingness to adopt available solutions for addressing the identified obstacles.

This note is intended to ask for your consent to answer questions about my research. This interview is meant to record your perspective towards the general fisheries sector issues, but particularly those relating to fisheries trade linkages and associated challenges (barriers and drivers) between the developing world (represented by Tanzania) and the developed economies (represented by the UK and the EU). You have been selected to participate in this research because you/your organisation is an important player in this sector.

My research is supervised by Philip Jones and Daniele Asioli of the University of Reading School of Agriculture, Policy and Development. The interview would take place at a location where you feel comfortable and will last for a maximum of one hour. Depending on your consent and approval, this interview will be audio recorded and will be used solely for this research. Your participation in this research will be voluntary, and I will treat any information you provide confidentially. All the information will be kept anonymously, meaning that no one will be able to work out what you have said. If you have any comments or questions about this research, please feel free to contact my supervisor, Mr. Philip Jones by telephone +44 118 378 8186 or by email p.j.jones@reading.ac.uk

If you feel uncomfortable and unwilling to continue with the interviews, please feel free to opt out at any time. You are also free to opt out of this research by contacting me before the 30th of September 2019, after which I will start processing the data. I will, however, like to know your reasons for opting out of the discussion if you do not mind. If you need further information about my research, please let me know.

The University of Readings Ethics Committee has approved this research. Many thanks in advance for your consideration.

If you agree to carry on with the interview, kindly tick the consent box below.

Regards,
Charles Domician, PhD Candidate, School of Agriculture, Policy and Development, University of Reading, Email: c.domician@pgr.reading.ac.uk,
Phone:…………………………Mobile:+44 7342 877 501 Skype: docharlz18

INTERVIEW PROTOCOLS

No.	Procedure or protocol aspect	What to be done
1.	What to say to interviewees when setting up the interview	• Greetings and introducing myself (My name and University of Reading, College of Agriculture, Policy and Development) • Briefly explaining why I have invited or requested meeting the interviewee (purpose and value of the research work) • Asking the interviewee to briefly introduce him/her-self
2.	What to say to interviewees when beginning the interview	• Reminding the interviewees of the importance of their consent to participate • Insisting that I will ensure confidentiality of his/her identity
3.	What to do during the interview	• Asking questions • Taking notes on interviewee responses • Audio taping the interview • Asking follow-up (probing) questions
4.	What to say to interviewees in concluding the interview	• Asking interviewees if they have final comments or opinions on the discussed issues or any other related and relevant aspects • Thanking participants for their time
5.	What to do following the interview	• Proper summarisation of interview notes following Grounded Theory (GT) approaches • Listening to audiotape and using it to ensure completeness of interview notes • Carrying out open coding of the interview notes to establish empirical codes and categories and thematic patterns • Establishing theoretical underpinnings of observed empirical data • Summarising an initial draft of the evolving GT

DATA COLLECTION INSTRUMENTS (INTERVIEW QUESTIONS)

A1: REGULATORS, RESEARCHERS AND EXPERTS (TANZANIA)

The following questions are meant for interviewees in relevant Government positions. These include:

- Ministry of livestock and fisheries – fisheries section
- Ministry of Local Government – that oversees Local Councils, fisheries departments
- National Director of Fisheries
- Tanzania Fishing Company (TAFICO)
- District Councils – fisheries departments, beach management units (BMUs) – Ilala, Temeke, Kinondoni -Dar, Kilwa, Mafia -Coast, - Tanga, - Mtwara (Marine part); and Mwanza, Mara, Geita and Kagera (Lake Victoria inland fisheries).
- Researchers and consultants in fisheries – e.g., UDSM-CoAF, TAFIRI, Ilala MC, etc….
- Local/international institutions and NGOs in fisheries –WWF (Mr Paul Mafia, representatives of fishers/BMUs, etc)

No.	Interview topic	Topical question or objective
1.	Introduction	1.1 Briefly describe your organisation (role, mission, strategy). 1.2 What is your role and position in the organisation? 1.3 How would you briefly describe the state of Tanzania's local fisheries in relation to regional and global developments?
2.	Fishery policy and regulatory environment	2.1 Describe the policy and regulatory environment regarding the marine, inland water fisheries. *2.2* Describe how the policy and regulatory environment relates to undertaking periodic fish stock assessments.
3.	Fishery production, distribution, and trade (local and exports)	3.1 Describe the governance structure or power relations between the regulators and the regulated – involving all value chain actors in the fisheries sectors. *3.2* How would you describe the dynamics in Tanzania's fishery and production, distribution, and trade (local and exports)? Where are the sectors headed to in terms of prospects? 3.3 Describe the adequacy level of surveillance operations on Tanzania's marine, inland and other territorial waters for protection of fishery resources. 3.4 How does Tanzania manage to enforce contractual terms (e.g., sustainable fishing, quality and quantity aspects,

		etc) with foreign fishing fleets operating in its territorial sea and inland waters? Request for official narrative and quantitative reports on trends.
4.	Challenges	4.1 Describe the policy, regulatory and implementation or operational challenges (barriers and drivers) that limit commercial scaling-up in marine, inland water fisheries and fish farming.
5.	Potential solutions	5.1 Given all the preceding challenges (barriers and drivers) in fisheries (both marine and inland wild catch), describe what you would propose as possible solutions 5.2 Describe your willingness/readiness to cooperate in the development and subsequent use of technological or other solutions meant to enhance trust/credibility, compliance, traceability, and sustainability in fishing activities, thus improving, and sustaining safety, quality, and quantity of fish food supplies as well as revenues derived from the sector? 5.3 How do you view or perceive Blockchain's or any other distributed ledger technology (DLT) applications as a potential solution to credibility and traceability challenges (barriers and drivers) in the fisheries sector?
6.	Concluding remarks	6.1 What would you like to comment further on Tanzanian fisheries in addition to the details you have provided? 6.2 Thank you so much for your time.

A2: REGULATORS, RESEARCHERS AND EXPERTS (UK/EU)

1. Regulators of imports

The following stakeholders form part of the intended sample of interviewees:

- UK foreign trade office in charge of customs (fisheries) imports

No.	Interview topic	Topical question or objective
1.	Introduction	1.1 Briefly describe your organisation (role, mission, strategy). 1.2 What is your role and position in the organisation? 1.3 How would you briefly describe the state of joint or collaborative efforts between the UK/EU and Tanzania regarding sustainable fishing activities development projects?

2.	Fishery policy and regulatory environment	2.1 Describe the UK/EU policy and regulatory environment regarding the marine, inland water fisheries. 2.2 Describe how the UK/EU policy and regulatory environment relates to influencing the undertaking periodic sustainability measures in Tanzania such as fish stock assessments as a guide to levels of fishing effort/activities.
3.	Fishery production, distribution, and trade (local and exports)	3.1 Describe the governance structure or power relations between the UK/EU regulators and the regulated – involving all fisheries value chain actors from developing countries (e.g., Tanzania) and UK/EU importers/distributors. *3.2* Describe the levels of trade in fisheries between the UK/EU and developing world, say Tanzania. Where are the sectors headed to in terms of prospects? *3.3* Describe the UK/EU position or initiatives regarding the adequacy of surveillance operations on Tanzania's or EAC's marine, inland, and other territorial waters for protection of fishery resources sustainability. *(Potential follow up questions based on literature: How has UK/EU supported the enforcement of sustainable fishing in Tanzania waters foreign fishing fleets (e.g., from China and EU states) operating in Tanzania territorial marine (sea) waters?* 3.4 Describe the terms and conditions under which, if fulfilled, you would be ready and willing to start/up-scale imports of fish products from Tanzania?
4.	Challenges	4.1 Describe the policy, regulatory and implementation or operational challenges (barriers and drivers) that limit commercial scaling-up of production and trade in fisheries products between Tanzania and UK/EU. 4.2 Based on your experience and knowledge, how would you describe commercial scaling-up problems in the Tanzanian fisheries sector?
5.	Potential solutions	5.1 Given all the preceding challenges (barriers and drivers) in fisheries (both marine and inland wild catch), describe what you would propose as possible solutions 5.2 Describe your willingness/readiness to cooperate in the development and subsequent use of technological or other solutions meant to enhance trust/credibility, compliance, traceability, and sustainability in fishing activities, thus improving, and sustaining safety, quality and quantity of fish food supplies as well as revenues derived from the sector?

		5.3 How do you view or perceive Blockchain's or any other distributed ledger technology (DLT) applications as a potential solution to credibility and traceability challenges (barriers and drivers) in the fisheries sector?
6.	Concluding remarks	6.1 What would you like to comment further on Tanzanian fisheries in addition to the details you have provided? 6.2 Thank you so much for your time.

B: ARTISANAL FISHERS/SMALL-SCALE FISHING ASSOCIATIONS AND TRADERS

- Association of small-scale fishers on Lake Victoria (Mwanza, Geita, Kagera and Mara regions)
- Association of small-scale fishers on marine fishing (Dar es Salaam main fish market in Ilala Municipality)
- Beach management units (BMUs) leaders and members in ward and village local structures in Dar es Salaam region - Kigamboni, Temeke; Coast region – Mafia, Rufiji and Bagamoyo; Lindi region – Kilwa Masoko and Kilwa Kivinje landing sites; Tanga region – largely affected by illegal fishing activities; Mtwara region
- Small scale buyers, processors, and traders of fish

No.	Interview topic	Topical question or objective
1.	Introduction	1.1 Briefly describe your organisation (role, mission, strategy). 1.2 What is your role and position in the organisation? 1.3 How would you briefly describe the state of Tanzania's local fisheries in relation to regional and global developments?
2.	Fishery policy and regulatory environment	2.1 Describe the policy and regulatory environment aspects that are relevant to your marine, inland water fisheries activities. *2.2* Describe the extent to which the policy and regulatory environment together with its implementation has fulfilled your expectations. *(Potential follow up question(s) based on literature: to what extent are your fishing activities guided by official levels of available fish stocks assessments undertaken and reported or provided to you periodically?*
3.	Fishery production, distribution, and trade (local and exports)	3.1 Describe the governance structure or power relations between the regulators and you fishers (the regulated) – involving all value chain actors in the fisheries sector. *3.2* How would you describe the dynamics in Tanzania's fishery production, distribution, and trade (local and exports)? Where are the sectors headed to in terms of prospects?

		3.3 Describe the adequacy level of surveillance operations on Tanzania's marine, inland and other territorial waters for protection of fishery resources. In what ways are you involved in these initiatives? 3.4 By giving qualitative and quantitative examples, in what ways have foreign fishing fleets operating in Tanzanian territorial sea and inland waters improved or worsened your fishing activities? *3.5* To what extent are your fishing activities integrated in local and foreign fish supply and value chains *(e.g. artisanal fishers catching fish, processing them and supplying to larger buyers or factories who sell retail or whole sale locally or abroad through exports; OR large buyers supplying modern fishing gear and equipment to artisanal fishers, buying their fish catch, processing and supplying to larger buyers or factories who sell retail or whole sale locally or abroad through exports)….what limits your current level of backward and forward integration…?* 3.6 How do you ensure that reported quantities by colleagues on fishing shifts are correct (especially those group teams working in rotations).
4.	Challenges	4.1 Describe the policy, regulatory and implementation or operational challenges (barriers and drivers) that limit commercial scaling-up your activities in marine, inland water fisheries. 4.2 Describe your experience or knowledge of any cases of misreporting or mistrust regarding fish quality and quantity among your suppliers of fish? Explain mitigation approaches…. 4.3 To what extent is access to and ownership of modern fishing gear and equipment a hurdle to commercial scaling-up problem? How would you suggest a solution for this?
5.	Potential solutions	5.1 Given all the preceding challenges (barriers and drivers) in fisheries (both marine and inland wild catch), describe what you would propose as possible solutions 5.2 Describe your willingness/readiness to cooperate in the development and subsequent use of technological or other solutions meant to enhance trust/credibility, compliance, traceability, and sustainability in fishing activities, thus improving, and sustaining safety, quality and quantity of fish food supplies as well as revenues derived from the sector?

		5.3 How do you view or perceive Blockchain's or any other distributed ledger technology (DLT) applications as a potential solution to credibility and traceability challenges (barriers and drivers) in the fisheries sector?
6.	Concluding remarks	6.1 What would you like to comment further on Tanzanian fisheries in addition to the details you have provided? 6.2 Thank you so much for your time.

C: LARGE SCALE FISHERS, PROCESSORS, LOCAL TRADERS, AND EXPORTERS (TANZANIA)

- Operators of large boats and trawlers (details to be sought locally)
- Fish processing factory owners in Dar es Salaam, Mwanza, Kagera and Mara regions (e.g., through vertical integration schemes)
- Tanzania Industrial Fishers and Processors Association (TIFPA)
- Processors of fish for local distribution or sales, usually through sun drying, smoking, salting, oil frying, etc – in Mwanza on Lake Victoria and in Dar es Salaam on Magogoni main fish market (These will be identified at local fish markets, especially in Mwanza and Dar es Salaam)
- Major processors of fish for export markets in Europe, China, Hong Kong, Japan, etc usually through deep freezing, chilling, icing, etc – these are fish processing factories on Lake Victoria in Mwanza, Kagera and Mara; but also in Dar es Salaam
- Processors of fish for regional markets like Rwanda, Burundi, DRC, etc commonly use sun drying, smoking, salting and oil frying – usually in Mwanza on Lake Victoria
- 15 Members of Tanzania Industrial Fish Processors Association (TIFPA) – on both marine and inland water fisheries (see table below)

No.	Interview topic	Topical question or objective
1.	Introduction	1.1 Briefly describe your organisation (role, mission, strategy). 1.2 What is your role and position in the organisation? 1.3 How would you briefly describe the state of Tanzania's local fisheries in relation to regional and global developments?
2.	Fishery policy and regulatory environment	2.1 Describe the policy and regulatory environment aspects that are relevant to your marine, inland water fisheries activities. *2.2* Describe the extent to which the policy and regulatory environment together with its implementation has fulfilled your expectations.

3.	Fishery production, distribution, and trade (local and exports)	3.1 Describe the governance structure or power relations between the regulators and you fishers (the regulated) – involving all value chain actors in the fisheries sectors. *3.2* How would you describe the dynamics in Tanzania's fishery production, distribution, and trade (local and exports)? Where is the sector headed to in terms of prospects? 3.3 Why did UK fish imports from Tanzania vanish especially after or around mid 1990s? 3.4 Describe the adequacy level of surveillance operations on Tanzania's marine, inland and other territorial waters for protection of fishery resources. In what ways are you involved in these initiatives? 3.5 By giving qualitative and quantitative examples, in what ways have foreign fishing fleets operating in Tanzanian territorial sea and inland waters improved or worsened your fishing activity levels? 3.6 To what extent are your fishing activities integrated in local and foreign fish supply and value chains (e.g. artisanal fishers catching fish, processing them and supplying to larger buyers or factories who sell retail or whole sale locally or abroad through exports; OR large buyers supplying modern fishing gear and equipment to artisanal fishers, buying their fish catch, processing and supplying to larger buyers or factories who sell retail or whole sale locally or abroad through exports)….what limits your current level of backward and forward integration…?
4.	Challenges	4.1 Describe the policy, regulatory and implementation or operational challenges (barriers and drivers) that limit commercial scaling-up of your activities in marine, inland water fisheries. 4.2 Describe your experience or knowledge of any cases of misreporting or mistrust regarding fish quality and quantity among your suppliers of fish? Explain mitigation approaches…. 4.3 To what extent is access to and ownership of modern fishing gear and equipment a hurdle to commercial scaling-up problem? How would you suggest a solution for this?
5.	Potential solutions	5.1 Given all the preceding challenges (barriers and drivers) in fisheries (both marine and inland wild catch), describe what you would propose as possible solutions

		5.2 Describe your willingness/readiness to cooperate in the development and subsequent use of technological or other solutions meant to enhance trust/credibility, compliance, traceability, and sustainability in fishing activities, thus improving, and sustaining safety, quality, and quantity of fish food supplies as well as revenues derived from the sector? 5.3 How do you view or perceive Blockchain's or any other distributed ledger technology (DLT) applications as a potential solution to credibility and traceability challenges (barriers and drivers) in the fisheries sector?
6.	Concluding remarks	6.1 What would you like to comment further on Tanzanian fisheries in addition to the details you have provided? 6.2 Thank you so much for your time.

D: LARGE FISH PRODUCERS, IMPORTERS, WHOLESALERS AND DISTRIBUTORS/SUPERMARKETS (UK/EU)

7 Large producers, importers and/or wholesalers & retailers

Stakeholders intended for interviews include:

- London Billingsgate, ……, (UK)
- Tesco, ILDI, ASDA, Sainsbury's, The Smelly Fish, Reading Fresh Fish…..(UK)
- Other individual operators

No.	Interview topic	Topical question or objective
1.	Introduction	1.1 Briefly describe your organisation (role, mission, strategy). 1.2 What is your role and position in the organisation? 1.3 How would you briefly describe the state of sustainability regarding trade in fisheries products between the UK/EU and Tanzania?
2.	Fishery policy and regulatory environment	2.1 Describe the UK/EU policy and regulatory provisions relevant to your marine, inland water fisheries activities. 2.2 Describe in what ways does the UK/EU policy and regulatory environment favour and/or hinder your involvement in fishing production and trade activities in Tanzania/EAC.

3.	Fishery production, distribution, and trade (local and exports)	3.1 Describe the governance structure or power relations between the UK/EU regulators and the regulated (i.e., all fisheries value chain actors in the UK/EU). How does this governance structure affect producers in developing countries (e.g., Tanzania) who aim to export into the UK/EU? *3.2* Describe the levels of trade in fisheries between the UK/EU and Tanzania. Where is the sector headed to in terms of prospects? 3.3 Describe your experience about importing and trading in fish from the developing world, say Tanzania? 3.4 Describe the UK/EU fishing businesses' position or initiatives regarding the adequacy of surveillance operations on Tanzania's marine, inland and other territorial waters for protection of fishery resources sustainability. 3.5 Describe the terms and conditions under which, if fulfilled, you would be ready and willing to start/scale up imports of fish products from Tanzania?
4.	Challenges	4.1 Describe the policy, regulatory and implementation or operational challenges (barriers and drivers) that limit commercial scaling-up of production and trade in fisheries products between Tanzania and UK/EU. 4.2 Describe your experience or knowledge about scenarios where unsafe food or fish were supplied for human consumption through normal public distribution channels …. thus jeopardising consumer health 4.3 Based on your experience and knowledge, how would you describe commercial scaling-up problems in the Tanzanian fisheries sector?
5.	Potential solutions	5.1 Given all the preceding challenges (barriers and drivers) in fisheries (both marine and inland wild catch), describe what you would propose as possible solutions 5.2 Describe your willingness/readiness to cooperate in the development and subsequent use of technological or other solutions meant to enhance trust/credibility, compliance, traceability, and sustainability in fishing activities, thus improving, and sustaining safety, quality, and quantity of fish food supplies as well as revenues derived from the sector? 5.3 How do you view or perceive Blockchain's or any other distributed ledger technology (DLT) applications as a potential

		solution to credibility and traceability challenges (barriers and drivers) in the fisheries sector?
6.	Concluding remarks	6.1 What would you like to comment further on Tanzanian fisheries in addition to the details you have provided? 6.2 Thank you so much for your time.

Appendix D3: How the Proposed Traceability Solution Helps to Resolve the Identified Problems of Trust Loss (TL) and Governance Loss (GL)

As explained elsewhere in the current study, the results on fisheries resources unsustainability appear to relate in a meaningful way with an already tested resource governance framework (Schmeier et al., 2016) (see Appendix B3). As suggested by UNECE (2016), some of the identified problems under TL and GL in the fisheries supply and value chains could be resolved by a specially designed cross-border traceability system. Because the current study focuses on Tanzanian fishers as producers of fisheries products and insights on UK/EU as a potential premium price market or buyers, this cross-border traceability system appears to be a plausible solution. To make it more robust, the cross-border traceability system would be designed and built on a Blockchain platform to ensure data transparency (sharing), and security (Amit Ganeriwalla, Michael Casey, Prema Shrikrishna, Jan Philipp Bender, 2018; Salah et al., 2019; Shahid et al., 2020). The identified problems of TL and GL are represented below to establish the extent to which the proposed Blockchain-based traceability solution could address them.

How the Proposed Solution Resolves Trust Loss (TL) Problems

Human Undercapitalisation

This problem is about limitations in the quality of human capital resources (e.g., lack of trust, credibility, competency, creativity, productivity, innovation, etc.) that causes responsible actors to fail, either intentionally or unintentionally, to transform the fisheries resources into sustainable and commercially scalable opportunities. The proposed Blockchain-based traceability solution may not be able to directly ensure, cause, or enhance these qualities in actors/stakeholders along the fisheries supply and value chains. However, the traceability solution does deal directly with the lack of trust issue, by ensuring the transparency, non-tampering, and sharing/communication of fisheries data and activities as well as actors' accountability along the fisheries supply and value chains. This way, dubious transactions, and activities by untrustworthy rogue actors (human capital resources) could be identified and penalised, hence discouraging their being repeated. The penalties may include denial of access to local and foreign (e.g., UK/EU) lucrative premium price markets.

Technology Gap

This problem is about the abuse of fishing technology usually by foreign vessels overfishing in Tanzanian waters as well as unsustainability due to low-tech fishers. The proposed traceability solution would not be able to address this problem of overfishing (Globoverfishing) by Chinese and European high-tech vessels because the catches would not normally be landed in Tanzania but exported directly while at sea through transshipment. Therefore, fisheries data for these catches wouldn't be captured by the proposed traceability solution as they wouldn't usually be landed in Tanzania. However, as most (up to 95%) of Tanzanian producers in fisheries are low-tech artisanal fishers who also undertake fishing unsustainably (Jiddawi & Öhman, 2002; Robertson, 2018), the proposed solution would help to resolve this second form of Technology Gap. For these small-scale fishers, Technology Gap is lack of appropriate technology, such as satellite-based Global Positioning System (GPS) and abuse of technology, such as explosives. The proposed traceability solution addresses the Technology Gap by preventing misuse of technologies among artisanal fishers and provides higher incomes (access to price premia), making more money available to them for investment. Capturing the data for artisanal fishers is possible because the fishers would land their catches locally, hence entering the supply chain covered by the proposed traceability solution. This would enable the identification of unsustainably fished catches, so they are excluded from accessing local and foreign (i.e., UK/EU) premium price markets. Therefore, incentives to access premium price markets through the proposed traceability solution would tend to dissuade these local fishers and other actors from committing illegal and unsustainable fishing practices.

Traceability Inadequacy

This problem is about the inability or failure to track seafood items at any physical point and time along the fisheries supply and value chains to ascertain their sustainable sourcing credentials for ensuring consumer health safety. The proposed traceability solution will address this problem because it targets improvements in traceability directly. This will be achieved using Blockchain technology and Google-enhanced satellite GPS communications capabilities of secure, and non-tampering of data to share transparently and seamlessly actors' activities along the fisheries supply and value chain. As an incentive for adoption or usage, the traceability solution will help fishers and other actors to access premium price markets like the UK/EU that emphasise the provenance of sustainable sourcing of fisheries data. However, the solution will be able to trace and capture data and transactions along the fisheries supply and value chains in Tanzania, while access or capturing of those activities occurring across the border (e.g., in UK/EU) would possibly depend on jurisdictional interventions beyond the scope of this study.

Non-Cooperatised Fishing

This problem relates to the lack of strong fisher groups or cooperatives that could take advantage of existing local and export market opportunities through coordinated collective production and marketing schemes. The proposed traceability solution is unlikely to solve this problem directly.

However, the improvements in transparency that the proposed technology solution brings would increase trust among groups of fishers and this would facilitate their co-operation. It is through this indirect linkage the fishers would form strong groups or cooperatives to be able to exploit these local and foreign premium price markets which would generally require larger volumes of fish to be profitable than what one or a few fishers could manage to accumulate.

Unbanked/Underbanked Fishing

This problem is about the limited access of fishers and other fisheries stakeholders to financial services offered by commercial banks and insurance firms. This is largely due to the perception that fishers and other actors in fisheries are untrustworthy and lack credibility to do business with, thus considered risky to lend money to, or deal with businesswise. The proposed traceability solution cannot solve these issues directly. However, if a group or cooperative of fishers adopted the traceability solution and were able to access premium price markets like UK/EU, then their commercially scaled up businesses would need and likely qualify for bank products including local and export trade finance as well as business expansion loans. This way, the fishers' credibility, and trustworthiness with the providers of the financial services would grow naturally.

How the Proposed Solution Resolves Governance Loss (GL) Problems

Data Corruption

This problem is about the misrepresentation of fisheries data that results in sub-optimal decisions and/or unsustainability in fisheries exploitation by rogue actors. The proposed traceability solution would help to solve this problem directly for catches landed in Tanzania. If all or most fishers were registered on this solution's Blockchain platform, then transparency and non-tampering of fisheries data along the fisheries supply and value chains would help to avoid revenue loss and other fisheries data misreporting/misrepresentation. However, this proposed solution cannot guarantee capturing and ensuring the quality of data on activities and transactions happening on the fisheries supply and value chains beyond the borders of Tanzania.

Political Manipulation, Policy Confusion, Prohibitive Regulation & Corrupt Survival

These problems occur when data misrepresentations are committed by rogue political elites in Tanzania to influence sub-optimal policy decisions which in turn lead to prohibitive rather than facilitative laws and regulations in fisheries. These actions result in short term gains by these rogue actors including through corrupt behaviours and unsustainable fishing practices. The proposed traceability solution cannot solve this problem directly. However, by enhancing accountability through transparency and non-tampering of fisheries data and activities along the supply and value chains, the freedom of these rogue politicians, regulators, and enforcers of compliance to make gains illegally and unsustainably through misrepresentation of fisheries data could be limited or ended.

Globoverfishing

This problem means overfishing anywhere globally including in Tanzanian waters by foreign and/or local actors. As explained under Technology Gap problem, the proposed traceability solution will not be able to resolve this problem directly, especially if over-fishing is being undertaken by foreign vessels in deep sea waters and the catches exported directly before landing them first in Tanzania. However, the solution may help to identify the actions of small-scale and other actors who commit Globoverfishing and land their catches locally, so their fisheries data and activities could be captured on the solution's Blockchain platform, allowing government agencies and international fisheries NGOs to monitor the scales of catches and act when set thresholds are reached.

Petty Disguise, Resources Unaccountability, and Resources Profiteering

Petty Disguise is about the purposeful misrepresentation of business profits or performance in fisheries to illegitimately pay less taxes or levies to relevant authorities. On the other hand, Resources Unaccountability and Resources Profiteering are respectively the failure to manage fisheries responsibly and the resulting excessive overexploitation, both of which lead to unsustainability in fisheries resources. These three problems cannot be resolved directly by the proposed traceability solution. However, the solution's capabilities of enhancing accountability through transparency and non-tampering of fisheries data could help with the identification of the activities of these rogue actors along the fisheries supply and value chains. This identification would help further steps including denying the responsible rogue actors the opportunities to access premium price seafood markets in Tanzania and abroad (like UK/EU). The identification of these rogue actors could also be used as evidence to take legal measures against them including penalties or prosecution by relevant authorities.

Appendix E3: Implementation of the Proposed Traceability Solution

Functions of the Audit Agency

The current study's suggested implementer of the proposed solution (i.e., the audit agency) would undertake the standard functions of a cross-border traceability regime for sustainable trade in fisheries as provided in UNECE (2016). This audit agency would in addition seek voluntary members who would be the ultimate or primary funders and owners of the trade association. Third parties like commercial banks, other private investors, and/or development partners could potentially give additional business financing based on the commercial soundness of the proposed traceability solution. More importantly, the audit agency would be expected to monitor and ensure compliance of sustainable fishing practices along the fisheries supply and value chains within Tanzania and those destined to the UK/EU markets. The audit agency would also need to win the support of relevant authorities in Tanzania and the UK/EU by proving its ability to protect seafood consumers through the identification and reporting for denial of market access and prosecution of those rogue actors committing unsustainable fishing practices along the supply and value chains. One way to win the trust of these relevant authorities would be for the traceability solution to be designed in a manner that enables it to synchronise with existing credible databases to verify the authenticity of boat/vessel registration, licencing, ownership, owner's membership to BMUs, and other legitimate legalities. Further to this, the tentatively detailed tasks of the audit agency are listed in Chapter 2, and they include mobilising necessary resources from members (fishers, traders, processors, exporters, etc) for establishing the traceability system. Other tasks include overseeing the actors' compliance to safeguarding seafood consumer health quality and ensuring the sustainable sourcing of fish and fishery products. From time to time, the audit agency would report to and collaborate with relevant authorities in Tanzania and the UK/EU regarding the veracity of its activities, including the identification of those shipments and their owners that should be denied local and foreign premium price market access due to their non-compliance with sustainable fishing practices. This identification of the rogue actors would also enable the enforcement authorities to act against them, including imposing financial charges and/or prosecution in courts of law.

Investments in & Governance Operations of the Proposed Traceability Solution

As stated earlier, the traceability solution would require an initial investment of about US$250,000 to build its digital application and its associated hardware such as hosting servers. How might such an investment be funded? To illustrate, this amount could readily be collected from a one-off levy paid by the most capable 1,000 out of the 59,358 fishing boat owners countrywide (i.e., 1.7%), each contributing US$250.00. Thereafter, these 1,000 fishers would pay US$100.00 monthly, hence a total of US$100,000.00, towards the operational maintenance costs of the solution's infrastructure and service. These figures are presented illustratively to prove the viability and affordability of the proposed traceability solution. More fishers or members would be expected to use the solution, thus lowering the tentative amount each would have to contribute. The researcher believes this is a reasonably achievable goal, given that about 75% of surveyed fishers/boat owners make over US$900.00 in monthly pretax profits.[73] The money would be contributed voluntarily as share purchases by fishers and other actors (e.g., fish traders, processors, exporters, importers, retailers, etc.). The main funding through the traceability audit agency for the continuity of the traceability solution service would be fixed periodic or annual fees, and variable fees based on trading volumes (e.g., % of profits or sales revenues). Other potential sources of financing would be commercial loans, and development funding from government or donors.

Once the traceability solution application is operational, these actors would have to download it on their mobile phones. Next, they would register themselves voluntarily by inputting details according to their categories and roles along the fisheries supply and value chain. For instance, fishers would include names of boat owner, address, contacts, boat registration, fishery type, tax and business certifications, and uploads of key photo IDs and relevant business certificates. After submitting these details, they would be reviewed and passed/approved by a responsible member of the audit agency. Before this approval, the audit agency would verify the credibility and authenticity of the documents and details submitted by applicants by synchronising with existing databases or relevant authorities with regards to the authenticity of boat/vessel registration, licencing, ownership, owner's membership to BMUs, and other legitimate legalities. This would require the design of the traceability solution to have a mechanism of accessing other databases to ensure operational efficiency. This mechanism should have both digitally automated and manual modes of operation to allow business continuity in cases where the automated database access mode goes offline. The audit agency would be a newly registered entity for this purpose (UNECE, 2016), and it would be a voluntary organisation for the purposes of membership, and would be owned by participating private actors in fisheries – fishers, traders, processors, exporters, importers, retailers, etc. This audit agency would be staffed and managed by an independent team of professionals drawn from within and/or outside the membership based on their relevant competencies. There would be a number of committees to ensure the smooth governance of the audit agency – like on issues of traceability and sustainability compliance, business continuity,

[73] This assumes the exchange rate of US$1.00 = TZS2,320.00.

planning and finance, etc. The ultimate decision-making body of the audit agency would be the board comprising representatives from all constituting members. It is expected that fishers and actors in Tanzania fisheries would be attracted to join the audit agency and comply with sustainable fishing practices to be able to access lucrative premium price markets like in the UK/EU, as importers there require this as part of their own efforts to comply with rising provenance demands of consumers. Non-compliance would result in a potential loss of business, including a denial to access these premium price markets.

Appendix F3: Matching Reviewed Blockchain & Satellite-GPS Use Cases to Fisheries Problems Identified in Tanzania

The Indonesian Provenance Case Study	
Demonstrable Case Study Metrics/Factors	Relevance for Tanzanian Fisheries
• *Data capture and storage* Fisheries data captured and securely stored across all fisheries supply and value chain activities (i.e., fish catch, landing, factory processing, to retail outlets and consumer points) using Ethereum Blockchain technology, potentially improving traceability of seafood. • *Interoperability with existing system(s)* The Ethereum Blockchain technology application worked on users'/fishers' mobile smart phones, and on smart tags (QR & RFID). This technology was also interoperable with existing data capture and management systems in fisheries namely financial, stock, and procurement management functions. *Limitations* The case study suffered from weak telecoms-based internet connectivity. It was also difficult to link and digitise ownership of physical assets (i.e., the tuna fish) to the digital assets (i.e., records or tokens on the Blockchain) along supply and value chains using smart asset identification methods (AIMs) – e.g., 2D, QR, RFID, NFC tags. Other experienced difficulties related to data sharing as most data were collected privately by actor groups and not shared publicly in Indonesia, namely vessel registration and tracking, self-reporting of catch and effort, independent port sampling programs, Fair Trade data capture, fish tagging, internal traceability systems and Apps for fishermen and suppliers.	• This technology could potentially help to resolve problems with fisheries data quality and secure storage in Tanzania as evidenced earlier in the literature. • By being interoperable, this technology's application could potentially work on Tanzanian fishers' mobile phones and/or improve BMUs largely manual fisheries data collection and storage systems. • Tanzanian fisheries need to investigate alternative ways other than this case study to resolve such problems as weak telecoms-based internet signal and digitisation/linking of physical assets (e.g., Nile Perch fish fillets) to digital assets (e.g., traceable and scannable tags like QR codes). Also, important is to find other ways of digitising for convenient and secure sharing of such fisheries data as fishers' vessel registration and tracking of their fishing activities. This enhanced tracking (or traceability) will help to monitor compliance with environmental and seafood health quality standards.

WWF-New Zealand/WWF-Australia & WWF-Fiji, ConsenSys, Sea Quest (Fiji) Ltd, and TraSeable Solutions	
Demonstrable Case Study Metrics/Factors	Relevance for Tanzanian Fisheries
• *Data capture application* During the case study, tuna supply chain was mapped into the Blockchain App with data entry interfaces and permissions or rules for data capture. Then, smart AIMs (RFID & QR) tags/devices on tuna products were used to capture and relay data automatically at sea. At port/landing site, each unloaded tuna was tracked by scanning its RFID or QR tag. The tuna products were tracked, and key data collected along the tuna supply and value chains (processing facility, distribution points down to consumers). If a whole	• These factors/challenges that the WWF and other organisations' case studies were trying to overcome (e.g., fisheries data capture, data quality, weak internet signal, digitisation of physical tuna and other fish products, and fishers' unfamiliarity with the App based on Blockchain technology) are like those faced by Tanzania's fisheries resources.

tuna was transformed into other products such as loins, then each new product (loin) was given a new identity on the Blockchain platform and tracked separately. • *Internet-based data transmission* Data transmission to Blockchain database depended on internet quality. • *Limitations* Digitisation problem as all value chain stages relied on manual data collection/capture. Limited local supply of smart AIMs devices (RFID tags), hence the costly importation. Cheaper QR codes used to limit the negative impact of costly RFID tags. The newness of or limited familiarity with Blockchain technology led to hesitancy by many actors (fishers, fish retailers and buyers) to participate in the mapping exercise. Detached RFID and QR code tags along tuna supply and value chains affected the precise matching of digital data on the Blockchain to the physical assets (i.e., the tuna fish).	

OpenSC - WWF-Australia and BCG Digital Ventures - Patagonian Toothfish	
Demonstrable Case Study Metrics/Factors	Relevance for Tanzanian Fisheries
• *Data capture & traceability-based technologies* Fish tagged with AIMs devices (RFID) and their fisheries data captured as they moved throughout the cold supply chain. Integration achieved between Blockchain platform and other technologies, thus enabling interoperability. These technologies are machine learning (i.e., Artificial Intelligence-AI), internet of things (IoT) and satellite-GPS data to further determine whether the fish were caught in legal locations (away from marine protected areas). Traceability of Patagonian toothfish fillets was done from catch at sea to retailers, down to customers/consumers in Asia, Europe and the Americas using internet of things (IoT) and Blockchain Technology. When the Patagonian toothfish were filleted, the attached RFID tags were converted into unique QR codes for each fillet on a packaging. The exact Patagonian toothfish origin was established through an RFID tag put on each fish on board fishing vessel immediately after capture at sea. This was followed by taking the exact satellite-enabled GPS location of the vessel and feeding this data into the fish RFID tag. Temperature for individual Patagonian toothfish was monitored and tracked throughout the cold supply and value chain using	• Tanzania's fisheries face similar data capture and timely transmission problems. Also, Tanzania's traceability systems in fisheries are either non-existent or very underdeveloped, hence failing to identify and help to end illegal fishing, including in marine protected areas (MPAs). As a result, the suggested modern traceability-based technologies (i.e., Blockchain, AIMs/RFID & satellite-GPS devices, machine learning/AI, and IoT) appear to be quite new and unfamiliar among Tanzania's fisheries actors, thus requiring adaptation means to maximise adoption in Tanzania's context. • Most Tanzanian fishers and other stakeholders own and operate smart mobile phones which could potentially be interoperable with the above traceability-based technologies (e.g., through Apps downloadable on the phones). • To ensure the constant monitoring of fish quality, the recording and timely transmission of temperature

RFID devices attached to the fish. This ensured fish quality was communicated constantly and timely along the fisheries supply and value chain. • *Limitations* There was no mention of the technology or devices used by fishers and other actors to record and transmit the temperature of the fish along the supply chain (e.g., mobile phones? iPads? Etc). No clarity on method used to avoid the problem of RFID/QR code tags detaching from the fish or fish fillets as observed in other use cases. The detachment caused a problem of matching digital assets to physical fish products.	of fish and fish products along the fisheries supply and value chains in Tanzania can be resolved with Globalstar's SmartOne Solar Satellite Asset Tracking (SOSSAT) technology.

Fishcoin	
Demonstrable Case Study Metrics/Factors	Relevance for Tanzanian Fisheries
• *Incentivising fisheries data capture/collection on Blockchain technology ecosystem* Fishers caught fish, collected data about their catch, entered this data on the Blockchain and thus earned Fishcoin stablecoin tokens or points in the process. These Fishcoin tokens were exchanged for airtime from a local mobile network operator that participated in the ecosystem. As fish products changed hands along the fisheries supply and value chains, and data for such exchanges got entered on the Blockchain, so actors (fishers, retailers/distributors, and consumers) earned Fishcoin tokens. This approach incentivised the creation of digital assets (i.e., ownership records) on Blockchain platform, thus easing the matching of ownership or custodianship of physical assets (real fish products). • *Limitations* Hesitancy to participate by many value chain actors in fisheries sector due to their limited familiarity with Blockchain-based Fishcoin stablecoin tokens technology. As Fishcoin tokens system is highly digitised, there happened efficiency problems in data capture with most fisheries that operated on manual data handling systems.	• The Blockchain-based Fishcoin stablecoin tokens (i.e., incentives) are likely to be quite unfamiliar to fishers and other actors in Tanzania's fisheries. However, there is a need to devise ways to motivate/incentivise actors in Tanzania's fisheries to willingly cooperate to capture fisheries data on any potentially established Blockchain-based traceability system. This enhanced traceability would result in the ease to match digital assets or record on Blockchain to ownership of physical fish products in custody. This would in turn help the identification of responsible rogue actors to ensure accountability whenever fish quality is compromised along Tanzania's fisheries supply and value chains. • Most actors in Tanzania's fisheries supply and value chains, especially fishers, are still relying heavily on manual systems of data capture. This may delay adoption of highly digitised Fishcoin token system, hence the need for adaptation and adoption incentives like training and access to higher fish prices.

Sustainable Shrimp Partnership (SSP) Case Study	
Demonstrable Case Study Metrics/Factors	Relevance for Tanzanian Fisheries

• *Sustainable farming of shrimps with full traceability of quality compliance* Following food fraud and poor-quality food entering the market, the Ecuadorian Sustainable Shrimp Partnership (SSP) developed strict protocols for shrimp production, guided by its credible advisory board members (WWF, Sustainable Trade Initiative, Aquaculture Stewardship Council, and Colombian Institute of Technical Standards & Certification). SSP producers were subjected to constant verification at each stage of shrimp production to ensure compliance to best quality production practices (zero use of antibiotics, full traceability, and no negative impact on the local environment). SSP shrimp producers in Ecuador recorded data on the IBM Food Trust sponsored Blockchain Platform App about how the shrimps are produced, which was then accessible to retailers and consumers through scanning of QR codes. This scanning enabled them to view the provenance data as shrimp supplies moved along the value chains around the world. • *Limitations* No clarity on how consumers or retailers scanned QR codes on shrimp blue packs (whether they used mobile phones or other devices). To lead the world in sustainable shrimp production, SSP had to overcome barriers related to members adopting a completely new technology for transparency and traceability (Blockchain) and the adoption of strict consumer health quality standards for shrimps.	• Tanzanian shrimps are largely wild catches (prawns) rather than farmed. These prawns and other fish species are highly overfished (illegally and unsustainably), hence the need for adopting legal and sustainable fishing approaches. Therefore, the traceability mechanisms proposed in this SSP Case Study and the engagement of credible experts (advisory board members) to scale up fish quality standards and traceability mechanisms locally and globally are quite relevant in the context of Tanzania to improve the fish quality and sustainability of fisheries. • As most fishers and actors in Tanzania's fisheries own and operate smart mobile phones, it would be possible for them to capture and transmit fisheries data from a Blockchain-based App like that used in the SSP Case Study. This suggests Tanzanian actors in fisheries need to engage relevant third parties to build similar Blockchain tools for enhancing sustainability and quality compliance through the traceability of their fishery products. • As the Blockchain technology-based traceability systems are new to Tanzanian fishers and other stakeholders in fisheries, there is a possibility of facing similar low adoption speed due to this unfamiliarity with the technology.

Global Fishing Watch (GFW) Initiative	
Demonstrable Case Study Metrics/Factors	Relevance for Tanzanian Fisheries
• *Achieving sustainable exploitation of fisheries by using satellite-GPS devices to identify and report illegal fishing practices.* This involved using modern satellite-based technology (e.g., GPS devices) to collect data, analyse it and report transparently/publicly about fishing activities in the oceans around the world. This is meant to ensure sustainable exploitation of fisheries resources by informing and supporting responsible governments to act on illegal and unsustainable fishing practices. The case	• GFW initiative is an opportunity for the Tanzanian actors in fisheries including the government to improve policies and regulations that promote sustainable fisheries management including the enhancement of the traceability mechanisms through satellite-based GPS technology for the fisheries

study took place in Indonesia, Peru, Ecuador, Chile, and Panama. All these countries have been able to link up their national fisheries databases with GFW's satellite-GPS technology, thus benefiting from transparency and efficiency in sustainable fisheries resources management. This has included training on the effective use of the technology, the identification and limitation of incidences of unsustainable, illegal, unreported, and unregulated (IUUs) fishing practices. As a result, these countries were able to improve the effectiveness of their policies and regulations with regards to the sustainable conservation and exploitation of their fisheries resources. In Indonesia, GFW bought small-scale tracking devices from various developers including Globalstar's SPOT X, SPOT Gen4 and SPOT Trace and evaluated them in the real fishing environment in Indonesia. These devices used satellite-based GPS locator technology to track and monitor movements of assets at sea including fishing vessels. This was done by sending instant SMS text messages notifications or email alerts on the fish boat owner's mobile phones, computers, or any other internet-linked electronic gadget. In so doing, these SPOT X/Trace devices helped boat skippers to navigate their fishing vessels safely in legal locations thus avoiding marine protected areas. Also important, SMS text messages and email notifications transmitted by these satellite technology-enabled SPOT X/Trace devices helped fishers send fisheries data in real time along fisheries supply and value chains even when internet networks were low or never existed at sea. In addition, Peru benefited from GFW's technology to track vessels using night-time imagery, especially useful for monitoring squid fisheries, for which vessels use bright lights at night. Also, Chile's additional benefits from GFW collaboration have been effective control, monitoring and protection of its enormous marine wealth and high-value fisheries such as anchovy, sardines, and hake through, among others, the creation and safeguarding of marine protected areas (MPAs). To illustrate Panama's benefits from the GFW collaboration, Indonesia apprehended in 2019 the Panamanian-flagged vessel MV NIKA, which was wanted in several jurisdictions for committing IUUs previously. This rogue vessel's capture was achieved thanks to international cooperation between INTERPOL, Indonesia, the authorities of South Georgia and the South Sandwich Islands, the United Kingdom, Korea, and Panama. All these countries have had the experience in satellite-based vessel monitoring technology from GFW.

- *Limitations*

sector. This would mirror the benefits gained by other countries namely Indonesia, Peru, Ecuador, Chile, and Panama. Being member to GFW would boost Tanzania's efforts to improve traceability to limit the presently ongoing illegal and unsustainable fishing practices.

- Globalstar's satellite-based GPS devices, namely SPOT Trace, SPOT Gen4, and SPOT X were evaluated and found to be effective in traceability by being able to relay fisheries data (text/SMS messages and emails) on handy electronic devices such as mobile phones and computers. These Globalstar devices are thus suitable for use in Tanzanian fisheries because most actors in the sector use mobile phones. Also, the devices' satellite-based GPS communications technology is quite useful when fishers are at sea where terrestrial telecoms internet signals are weak or ineffective.

Despite their clear benefits to country members, GFW has not had any African beneficiaries, not least in Tanzania. Also, GFW has not been able to win the support of China whose vessels are blamed for committing illegal and unsustainable fishing practices on a global scale.	

Source: Researcher's own Table.

Appendix A4: Survey Methodology & Statistical/Quantitative Approaches

Survey Methodology

Conceptual Frameworks Explaining Technology Acceptance

Information technology presents an array of products for users to select from. Researchers have generated a range of conceptual models to help the assessment of users' willingness to adopt such technological products. The best of these models in the information systems, psychology, and sociology fields have been able to explain over 40% of intention, or willingness, to adopt various forms of these technologies (for example, see Taylor & Todd, 1995a, 1995b; Venkatesh et al., 2003). Venkatesh et al. (2003) identify these models as: the Technology Acceptance Model (TAM), Social Cognitive Theory (SCT), Theory of Reasoned Action (TRA), Theory of Planned Behaviour (TPB), Combined Theory of Planned Behaviour and Technology Acceptance ((TPB/TAM), Motivational Model (MM), Diffusion of Innovations Theory (DIT), and Model of Personal Computer Use (MPCU). For each of these eight models, there were identified between two and seven significant determinants (independent latent constructs) of user acceptance of technology, for a total of 32 determinants across the eight alternative models and their extensions (Venkatesh et al., 2003).These authors (Venkatesh et al., 2003) point to significant variation in the ability of these eight models to predict behavioural intention and usage of new technologies among different user contexts, namely consumers and organisational employees. This wide range of constructs identified by these frameworks makes it difficult to identify the core set of constructs that explain technology adoption. There is therefore a risk that choosing one or a few representative models could result in the loss of positive contributions from constructs and models not included from the excluded models. Furthermore, as explained above, it was critical to disentangle the extent and nature of technology acceptance among the different categories of users. As a way of overcoming these weaknesses, in 2003 Venkatesh et al. published their Framework for Unified Theory of Acceptance and Use of Technology (UTAUT) as an all-inclusive framework for explaining the divers and barriers to user acceptance of new technologies.

Unified Theory of Acceptance and Use of Technology (UTAUT)

Venkatesh et al. (2003) reviewed and synthesised the eight prominent extant user acceptance models to assess their similarities and differences. Data on employee acceptance and use of technology at four organisations was used by the authors to empirically compare the efficacy of the eight models against the new UTAUT framework. The analysis found that the eight models individually explained between 17% and 53% of variance in users' behavioural intentions to use new technologies. By comparison, UTAUT outperformed the eight individual models by explaining 69% of variations in users' behavioural intentions to use technology. A cross validation involving a sample of employees from six organisations (including the original four) yielded similar results of 70% of variation in user's behavioural intentions and 50% of variation in the actual use of new technologies being explained by UTAUT. Therefore, UTAUT was confirmed as a better tool for business managers, or decision makers, to predict the acceptance of new technologies based on user demographic and other differences. Also, UTAUT helped business decision makers to assess the determinants or drivers of user's acceptance of such new technologies for a timely design of appropriate interventions (e.g., specific training needs, sales and marketing strategies, business financing routes, etc).

According to Venkatesh et al. (2003) there are four key determinants (factors or latent constructs) of behavioural intention and usage of technology: (i) Performance Expectancy (PE), (ii) Effort Expectancy (EE), (iii) Social Influence (SI), and (iv) Facilitating Conditions (FC). While (i), (ii) and (iii) influence Behavioural Intention (BI) to use technology, the last construct of FC and the BI itself, together predict actual Technology-Usage behaviour (TU) (Venkatesh et al., 2003). The authors postulate further that the impact of the four constructs on intention to use and actual use of technology varies depending on certain moderators, namely: level of experience with target technology, gender, age of users, and voluntariness of the target technology use.

However, despite its noted success above, UTAUT has not been without its critics. First, UTAUT has been applied generally in both organisational (e.g., employee-based) and non-organisational (e.g., non-employee consumers/users) contexts (Neufeld et al., 2007). However, the UTAUT framework is more suitable for use in organisational employee settings, and thus lacks generalisability (Venkatesh et al., 2003). Also, UTAUT was tested using just four moderators including voluntariness of technology usage which is only relevant and applicable in the organisational employee setting where technology use can vary from being absolutely prohibited or mandatory to being absolutely voluntary while for consumers the decision is almost always fully volitional (Venkatesh et al., 2012). These limitations highlighted the need for comprehensive research to determine the factors relevant to the consumer technology use context. This task was accomplished in Venkatesh et al. (2012) whereby UTAUT was reviewed and extended to make it more suitable for predicting behavioural intentions and use of technology in consumer contexts, the resulting framework being known UTAUT2. In the next section, the UTAUT2 framework is introduced, and an explanation is provided of how it works, plus its validation and relevance to the current study.

UTAUT2 Framework: Its Nature, Relevance to the Current Study, and Functional Constructs

What is UTAUT2?

Extended Unified Theory of Acceptance and Use of Technology (UTAUT2) is a framework for testing acceptance of (or behavioural intention to adopt) new technologies (Venkatesh et al., 2012). UTAUT2 is an improvement to the original UTAUT framework to make it suitable for consumer contexts, where the original UTAUT was suited for organisational employee settings (Venkatesh et al., 2012); Venkatesh et al., 2003). This limited application to organisational employee contexts constituted a key shortcoming of UTAUT which prompted the authors to work on its improvement in 2012. In UTAUT, the behavioural intention and actual usage of new technologies were influenced by four independent latent constructs namely Effort Expectancy, Facilitating Conditions, Performance Expectancy, and Social Influence. On the other hand, the influence of these four latent constructs on behavioural intention and actual usage of technology was moderated by gender, voluntariness to use technology, age, and level of experience. To transform UTAUT into UTAUT2, the authors implemented changes such that elements irrelevant to retail consumer technology (e.g., the moderator of voluntariness to adopt technology) were dropped while new constructs fitting the consumer technology experience (e.g., Hedonic Motivation (HM), Price Value (PV) and Habit (HT)) were added. As such, while UTAUT was originally constituted by four determinants or latent constructs (factors),[74] the number of UTAUT2 constituting latent constructs (factors) rose to seven. According to empirical research, e.g., (Venkatesh et al., 2012; Neufeld et al., 2007), the original four latent constructs (factors) in UTAUT serve a varying degree of both organisational employee and consumer technology contexts, hence their retention and retailoring in the emergent UTAUT2.

Relevance of UTAUT2 to the Current Study

The development of UTAUT2 was prompted by the emergence of multi-billion-dollar markets for consumer technology devices, applications, and services (Stofega & Llamas, 2009). Fishers/boat owners in Tanzania fit into the technology consumer context, rather than the organisational employee setting. Moreover, while Venkatesh et al. (2012) developed and tested UTAUT2 using

[74] These are performance expectancy (PE), effort expectancy (EE), social influence (SI) and facilitating conditions (FC).

technology consumer data from a largely developed world context (i.e., Hong Kong), it is interesting to find out in the current study how the UTAUT2 framework would play out in the developing world context (i.e., Tanzania). Furthermore, many other UTAUT2 studies have tested behavioural intention and use of technology in other sectoral settings than fisheries hence the uniqueness of the current study. For instance, Beza et al. (2018 and Septiani et al. (2020) used UTAUT2 on agricultural smallholder farmers, Thusi & Maduku (2020) applied the UTAUT2 framework on South African millennials. The extension of UTAUT into UTAUT2 involved the collection and testing of data from consumers of mobile internet technological products and services (Venkatesh et al., 2012).

Following the footsteps of Venkatesh et al. (2012) (i.e., dropping irrelevant moderators) and Beh et al. (2021) and Baptista & Oliveira (2015) (i.e., incorporating new and relevant moderators) in UTAUT2, we proposed new moderators for inclusion in the current study's UTAUT2 testing framework. These are fishery type, education level, and profitability or business revenue generation potential. These new moderators helped the testing for identification of multi-group differences in the surveyed sample of marine and freshwater fishers in Tanzania. Results of initial interviews of fishery stakeholders and the review of relevant literature (see Chapter 3; and URT, (2020)) had suggested existence of education-level and business revenue or profitability differences between these two fisher groups. The current study's latent endogenous (i.e., dependent) variable (construct or factor) is fishers' Behavioural Intention (BI) or willingness to adopt the proposed traceability solution. Testing of the effect of current technology use is captured by inclusion of a latent exogenous (i.e., independent) construct called Complementary Technology (CT) usage. Based on the work in Chapter 3, the proposed traceability solution would run on and be transmissible through already existing fishers' mobile phone devices and applications (e.g., text messages, mobile internet, camera, other inbuilt or downloadable applications like location tracking, maps, and cloud data storage). In this regard, the potential consumers/users of technology (i.e., fishers) already have some infrastructure in place (i.e., Complementary Technology) which is necessary and appropriate for adoption of the proposed traceability solution. The inclusion of CT raised to eight the number of independent constructs in this UTAUT2 study.

As stated earlier, the purpose of this section was to lay down the methodological steps used to predict fishers' (boat owners') willingness to accept (i.e., behavioural intention to adopt) the proposed traceability solution presented to them in Tanzania (see Chapter 4). The current study had one justifiable methodological similarity with Venkatesh et al. (2012) who generated

UTAUT2 from UTAUT. Respondents in both studies (i.e., the current study and UTAUT2) are potential and actual consumers, respectively, of technology and not organisational employees. As the two studies focus on technology usage or consumption, Venkatesh et al. (2012) tested both behavioural intention and actual technology use while the current study tests only behavioural intention to adopt the proposed technology. This contrast is because respondents had already experienced using the technology in Venkatesh et al. (2012) while the proposed traceability solution is still notional and quite new to fishers in the current study. Thus, we employed UTAUT2 in this large-scale survey by applying the framework's constructs and influencing factors to gauge fishers' drivers of and barriers to their intention to adopt and use the suggested package of technology.

In the next sub-sections, we demonstrate how UTAUT2 works and validate it through a review of past empirical studies. Additionally. we demonstrate this through presenting theoretical and hypothesised explanations linking UTAUT2's constructs to drivers of, and barriers to, fishers' potential adoption and usage of the proposed traceability solution. These will be followed by a proposal and testing of three traditional moderating variables as adapted from UTAUT2, and thereafter by the new proposed additions of latent construct and moderators for the current study. It is hoped, based on literature, that these variables are going to directly and/or indirectly impact on the fishers' intention.

UTAUT2 Traditional Constructs

Presented and explained below are the UTAUT2 latent constructs, starting with the eight traditional constructs adapted from UTAUT2. The eight traditional latent constructs include one dependent and seven independent latent constructs. The independent constructs are Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), Facilitating C (FC), Habit (HT), Hedonic Motivation (HM), and Price Value (PV). The dependent construct is Behavioural Intention (BI). Traditional moderators are age, gender, and experience. The proposed new additions include a latent construct of Complementary Technology (CT), and moderators of fishery type, education, and profitability. These newly added variables were devised by the current study based on literature review and the nature of the research design. Complementary Technology was added because the proposed traceability solution would be expected to run on existing technological devices already in use by fishers like smart mobile phones and embedded user mobile applications like text (SMS) messages, camera, and Google maps. As such, the inclusion of these new moderators was based on the literature review and/or stakeholder consultation which led to a conclusion that these moderators will impact fishers' intention to take up the new technology/traceability solution, either directly or indirectly (i.e., acting via other constructs). For both traditional and new variable explanations, hypothesised statements are presented on the nature of the expected direct and indirect influence of the latent constructs and the moderators, respectively, on fishers' behavioural intention to adopt the proposed traceability solution.

Performance Expectancy (PE)

PE is the level of belief or perception by technology users that the technology in question will perform in a way as to meet their expectations (Rahi et al., 2019; Venkatesh et al., 2003). Similarly, Alalwan et al. (2014) and Rahi et al. (2019) see PE in terms of a perceived usefulness, or outcome expectancy, meaning the utility derivable by using the technology. PE has been found to be a significant determinant of intention to adopt technologies in a number of past context-relevant studies. Purwanto et al. (2021) built a framework combining UTAUT and Innovation Resistance Theory (IRT) (Ram, 1987) and used the UTAUT-IRT framework to test fish buyers' intention to adopt a digital fishery platform (DFP) to link fishers and buyers directly in Jakarta (Indonesia). This direct linkage of fishers and buyers was meant to limit costs associated with middlemen as well as to minimise unnecessary physical interactions to control the spread of the COVID-19 pandemic. IRT explains various factors that contribute to resistance by individuals and/or organisations to adopt new innovations. These factors include perceived threats to current ways of life, being wary or unfamiliar with the innovations, being nervous due to perceived innovation risks/uncertainty and high adoption costs, and limited potential benefits. It was found that PE influenced the fish buyers' intention to adopt the DFP. Also, during their empirical study using UTAUT2 and SEM methods, Septiani et al. (2020) found that performance expectancy had a positive impact on smallholder farmers' behavioural intentions to adopt a peer-to-peer lending technology in Indonesia. Beza et al. (2018) explored Ethiopian smallholder farmers' intentions to adopt mobile-based communication technologies in agricultural activities and found that farmers' intentions were predicted by PE. Similar results were obtained by Thusi & Maduku (2020), who found that performance expectancy predicts behavioural intention to adopt banking applications among South African millennials. However, results in Chapter 4 suggest that some fishers are engaged in illegal and unsustainable fishing, and these are unlikely to adopt the proposed traceability solution, at least in the short-term, as they may perceive it as potentially limiting their activities. Nonetheless, as the Tanzanian government is presently instituting policies against illegal, unreported, and unregulated (IUU) fishing practices, it is believed most fishers and other actors would hold positive expectations on technology performance, hence potentially accepting the proposed traceability solution. Therefore, by following the footsteps of Beza et al. (2018) and Septiani et al. (2020), it is expected that the proposed traceability solution will be perceived as having utility and value-adding capabilities. Therefore, most fishers' acceptance of this traceability solution will be positively influenced by this perceived utility (i.e., PE). From this, we therefore hypothesise (H1) about PE that:

H1: Performance Expectancy (PE) positively influences fishers' Behavioural Intention (BI) to adopt the proposed traceability solution.

Effort Expectancy (EE)

EE captures the extent or degree of ease, or convenience, by which a given technology can be put into use (Venkatesh et al., 2003). The users' intention to adopt the technology is positively related to the ease of use (Rahi et al., 2019). In their study, Purwanto et al. (2021) combined UTAUT and Innovation Resistance Theory (IRT) (Ram, 1987) to test fish buyers' intention to adopt a digital fishery platform (DFP) in Jakarta (Indonesia) to enhance direct dealings between fishers and buyers. They found that EE had a positive influence on fish buyers' intention to adopt the DFP. Beza et al. (2018) applied UTAUT2 to explore smallholder farmers' intentions to adopt agricultural mobile-based communication technologies and found this was significantly predicted by the perceived effort or ease of using the technology (Effort Expectancy). Fishers are expected to be willing to accept the proposed package of technology only when its adoption does not exceed some maximum requirement for effort or resources (Venkatesh et al., 2003, 2012). In contrast, Septiani et al. (2020) used UTAUT2 and found that effort expectancy had no significant effect on farmers behavioural intention to adopt peer-to-peer lending technology among smallholder farmers in Indonesia. Similar results were recorded by Thusi & Maduku (2020) who found that effort expectancy had no significant influence on South African millennials' behavioural intention to adopt banking applications. However, because the current study's proposed traceability solution involves mobile-based communications, it draws some resemblance to the Beza et al. (2018) study of farmers' adoption of mobile-based technology. As such, we expect EE to positively influence fishers' behavioural intention to adopt the proposed package of technology. This means there is expected a positive relationship such that a high EE score means a potential ease to use the proposed technology solution. Therefore, we hypothesise that (H2):

H2: Effort Expectancy (EE) positively influences fishers' Behavioural Intention (BI) to adopt the proposed traceability solution.

Social Influence (SI)

SI captures the collective effect of social and environmental factors on the perception of users towards a given technology (Venkatesh et al., 2003). As such, users' acceptance and adoption of technology is significantly influenced by the opinions of their relatives, close friends, and work colleagues (Chaouali et al., 2016; Rahi et al., 2019). Purwanto et al. (2021) used a framework that combined UTAUT and Innovation Resistance Theory (IRT) (Ram, 1987) to test fish buyers' intention to adopt a digital fishery platform (DFP) to drive fish sales in Jakarta, Indonesia. It was found that SI influenced fish buyers' intention to adopt the DFP. However, some studies have not found SI to be a significant determinant of intention to adopt new technologies. Beza et al. (2018) and Septiani et al. (2020), for example, conclude that social influence does not have a significant influence on smallholder farmers' behavioural intention to adopt new technologies. Preliminary results in the current study (see Chapter 3) suggest that powerful rogue actors make gains from syndicated illegal and unsustainable fishing practices in Tanzania. As the proposed traceability solution is likely to enhance transparency and traceability for accountability in fisheries activities, those fishers and other actors benefiting from illegal and unsustainable fishing will likely oppose its adoption. To the extent that these rogue actors influence the majority, this may lead to social pressure to refuse such technologies. As such, this may potentially result in a negative relationship of social influence on behavioural intention. However, with influential actors (for example policy makers, regulators, and environmental researchers/scientists)[75] pushing for favourable policies like training and other education programmes on sustainability in fisheries, it is expected most of these fishers (boat owners) are going to be socially influenced to adhere to sustainable fishing practices. This will increase the likelihood that SI will positively influence fishers to adopt any new technologies that might help achieve this aim. Therefore, we hypothesise (H3) on SI as follows:

H3: Social Influence (SI) positively influences fishers' Behavioural Intention (BI) to adopt the proposed traceability solution.

Facilitating Conditions (FCs)

FCs capture available organisational, financial, and technical support infrastructure as well as the users' relevant acquired knowledge, ability, and resources necessary to enable adoption of technology (Rahi et al., 2019; Venkatesh et al., 2012). In support of the role of this construct, Thusi & Maduku (2020) found that facilitating conditions had a positive influence on South African

[75] This was implied during the researcher's data collection in Tanzania in 2019, see details in Chapter 3.

millennials' behavioural intention to adopt banking applications. However, two empirical studies by Beza et al. (2018) and Septiani et al. (2020) concluded that facilitating conditions did not have a significant influence on smallholder farmers' behavioural intention to adopt new technologies. The current study has shown through literature that many Tanzanian fishers have only limited access to the factors that would constitute FC, such as, finance, education/training, quality enhancing technologies, and markets for their fisheries products. On this basis it might be assumed that FC would have a negative impact on intention to adopt the traceability solution in Tanzanian fisheries. However, the proposed traceability solution is potentially very much accessible to Tanzanian fishers, as it would run on mobile phones already owned and operated by many fishers. Given these circumstances, it is expected that despite the above challenges, FC is likely to positively influence most fishers' behavioural intention to adopt the proposed traceability solution. As such, we hypothesise (H4) that:

H4: Facilitating Conditions (FC) positively influence the fishers' Behavioural Intention (BI) to adopt the proposed traceability solution.

Hedonic Motivation (HM)

HM captures the pleasure or enjoyment (i.e., fun) that users expect to get from using new technologies, and the role of this in influencing their intention to adopt them (Venkatesh et al., 2012). Schomakers et al. (2022) noted that in addition to being influenced by utilitarian factors like usefulness, technology adoption is also impacted by emotional factors such as hedonic motivation. An empirical study by Septiani et al. (2020) found that hedonic motivation had a positive impact on farmers' behavioural intention to adopt peer-to-peer lending technology among Indonesian smallholder farmers. However, another study (Beza et al., 2018), using the same methodology, concluded that hedonic motivation has no significant impact on smallholder farmers' intentions to adopt agricultural mobile-based communication technologies. The proposed traceability solution in view of the current study would require users (fishers) to download and work from a Blockchain-based mobile application on their smart 'phones. Most fishers surveyed in the current study already owned and operated these phones and had mobile applications running on them, and so they were already very familiar with the use of similar mobile application-based technologies. As such, we believe the fishers are going to build on this base of already existing familiarity with complementary technology to derive fun or enjoyment in using the mobile application of the proposed traceability solution. It is therefore predicted that HM is going to positively influence the fishers' behavioural intention to adopt the proposed traceability solution. Thus, we hypothesise (H5) for HM as follows:

H5: Hedonic Motivation (HM) positively influences fishers' Behavioural Intention (BI) to adopt the proposed traceability solution.

Price Value (PV)

PV relates to technology users' cognitive trade-off between the derivable utility/benefits of using a new technology and the potential financial costs of acquiring and operating it (Venkatesh et al., 2012). Whenever the utility or benefits are perceived to be higher than the perceived costs, PV is positive. Two empirical studies (Beza et al., 2018; Septiani et al., 2020) concluded that price value positively predicts smallholder farmers' behavioural intentions to adopt a peer-to-peer lending technology and mobile-based communication technologies in agricultural activities, respectively. In Chapter 3, it was shown that the proposed traceability solution would have a selling price of US$100.00 per month that would be affordable by most fishers in Tanzania, while providing tangible benefits. Also, most fishers already have smart mobile phones capable of downloading the application for the proposed traceability solution, thereby eliminating part of the start-up cost of acquiring the desired function. As such, we therefore hypothesise (H6) for PV that:

H6: Price Value (PV) positively influences the fishers' Behavioural Intention (BI) to adopt the proposed traceability solution.

Habit (HT)

Habit (HT) captures automatic behaviours derived from experience or learning over time (Limayem et al., 2007). Although conceptualised rather similarly, habit differs from experience in the following ways. Experience, being the use of a technology over a passage of time, can result in varying levels of habit depending on the degree of interaction and familiarity developed (Venkatesh et al., 2012). Despite this overlap, HT has been found to be an important influencing factor in technology adoption and use (Venkatesh et al., 2012). In support of this view, Thusi & Maduku (2020) found that automatic habitual tendency to use similar or complementary technology was among the factors that were significantly associated with millennials' behavioural intention to adopt a new technology. It is expected that fishers' prior use (i.e., experience) of hardware platforms such as smart 'phones, these being complementary technologies, may have resulted in automatic habitual use (i.e., habit) and this may potentially increase the likelihood of intention to adopt the novel technology application. To illustrate, Thusi & Maduku (2020) used UTAUT2 to investigate South African millennials' behavioural intention and actual use of mobile banking applications. They concluded that habit significantly predicts the millennials' behavioural intention to adopt new technology. As such, we hypothesise (H7) on HT that:

H7: Habit (HT) positively influences the fishers' Behavioural Intention (BI) to adopt the proposed traceability solution.

Behavioural Intention (BI)

BI captures the fishers' behavioural intention to use the proposed traceability solution within some future timeframe. This is the dependent construct for the current study. As such, the preceding seven constructs are independent constructs to be regressed on BI. This will help to determine their respective significance and influence on fishers' behavioural intention (BI) to adopt the proposed traceability solution.

Having explained and hypothesised about how the eight traditional latent constructs connect to the current study, next are explanations and linkages for the traditional moderators – age, experience, and gender.

Impact of Traditional Moderators–Age, Gender, & Experience on UTAUT2 Constructs

In their development of UTAUT2, Venkatesh et al. (2012) argued that independent latent constructs of Facilitating Conditions, Hedonic Motivation, Price Value, and Habit were moderated by age, gender, and experience in a consumer context. A moderator is a variable that works indirectly to impact users'/consumers' behavioural intention to adopt a new technology through an influence on an independent latent construct. For instance, let us assume that adoption of new technology is influenced by the available level of support like training or other incentive (say, Facilitating Conditions construct) to potential users, and that there are variations in the intensity of this support based on the consumer's age group. Assuming further that young technology consumers are eager and faster learners than their old peers, one could say: young consumers are potentially cheaper customers to acquire as they require less resources support (Facilitating Conditions) than old peers to adopt the new technology. In this case, age (young versus old groups or segments) is termed as a moderator that moderates the influence of Facilitating Conditions construct on Behavioural Intention to adopt the new technology. Presented below are instances in which the traditional moderators of age, gender, and experience have moderated the influence of the four independent latent constructs on consumer behavioural intention to adopt new technologies.

Moderation of Facilitating Conditions (FC) on Age, Gender, and Experience

According to Venkatesh et al. (2003, 2012), FC captures all necessary material and knowledge/skill resources that are key to enabling a smooth adoption of new technology by consumers. Furthermore, Morris & Ward (2004), Plude & Hoyer (1985), and Venkatesh et al. (2012) note that low cognitive and memory capabilities limit older or aging consumers from quick learning and adoption of new technologies relative to younger users. Moreover, men demonstrate higher resilience in the face of difficulties encountered while pursuing their goals. They therefore require less support, or facilitating conditions, than women in adoption of new technologies (Henning & Jardim, 1977; Rotter & Portugal, 1969; Venkatesh & Morris, 2000). As for experience, Alba & Hutchinson (1987) note that greater experience may lead to higher familiarity with and knowledge of technology that in turn result in facilitating learning of a potential technology user. This reduces dependence on external support in the process of technology adoption. Also, Schomakers et al. (2022) found that level of education influenced likelihood of use of mobile health application technology through the enhancement of users' knowledge and cognitive abilities. Moreover, while studying strategies to support Malaysian entrepreneurs through adoption of ICT-related innovations, Ibrahim (2018) found that age, gender, and experience were significant moderators of facilitating conditions. In another study, however, it was noted that some African cultures favour male fishers to dominate Tanzanian fisheries activities and the resulting wealth (Bradford & Katikiro, 2019). This means Tanzanian male fishers' control almost all means that facilitate adoption of new technology among fishers. It is therefore proposed that only age and experience may moderate FC's influence on fishers' behavioural intention. We therefore hypothesise (H8) and (H9) that:

H8: One or both age and experience will moderate the effect of Facilitating Conditions (FC) on fishers' behavioural intention (BI) to adopt the proposed traceability solution.

H9: One or both age and experience will moderate the effect of Facilitating Conditions (FC) on fishers' Behavioural Intention (BI) such that the positive effect will be stronger among highly experienced and older fishers.

Moderation of Age, Gender, and Experience on Hedonic Motivation (HM)

Venkatesh et al. (2012) found that age, gender, and experience all moderated the effect of HM on behavioural intention. According to these authors, this is because of heterogeneity in consumers' levels of innovativeness, novelty seeking, and perception of novelty of a target technology. In this regard, Midgley & Dowling (1978) define innovativeness as the extent of an individual's receptiveness to new ideas leading to their independent decisions on innovation. On the other hand, novelty seeking involves a purposeful search for novel information or stimuli (Hirschman, 1980). As such, a combination of innovativeness and novelty seeking would underlie users' HM to adopt or use some new technology (Holbrook & Hirschman, 1982). These authors argue that when first starting to use a new technology, consumers are usually attracted more by the product novelty (e.g., some new utility or functionality of a mobile application or a unique interface of a mobile 'phone). Over time, as consumers get used to the new technology (i.e., experience) and novelty, the influence of hedonic motivation will also decline, thus giving the product more pragmatic use values, such as gains in efficiency or effectiveness (Venkatesh et al., 2012). Therefore, with increased experience, the influence of HM on technology use diminishes. Also, technology innovation seeking behaviour in consumers has been linked to age and gender (Lee et al., 2010) with younger males more attracted by novelty and innovativeness during their early days of technology adoption. This means any moderating effect of HM on fishers' behavioural intention will vary across age and gender. This means any moderating effect of HM on fishers' behavioural intention will vary across age and gender. However, Bradford & Katikiro (2019) find that cultural norms influence male domination of fisheries activities in Tanzania. This limits the role women play in fishing and fisheries operations. Based on the preceding analysis, it is hypothesised (H10) and (H11) that:

H10: Age and experience will moderate the effect of Hedonic Motivation (HM) on fishers' Behavioural Intention (BI) to adopt the proposed traceability solution.

H11: Age and experience will moderate the effect of Hedonic Motivation (HM) on fishers' Behavioural Intention (BI) such that the effect of HM will be stronger among young fishers with less experience.

Moderation of Age, Gender, and Experience on Price Value (PV)

PV is defined as a difference between the consumers' perceived benefits and potential costs associated with adopting and using a new technology (Venkatesh et al., 2012). According to Deaux

& Lewis (1984) and Venkatesh et al. (2012), the importance of PV as a determinant of intention varies with age and gender. This conclusion is supported by studies on social roles theories (Hindin, 2007; Sunstein, 1996; Yang, 2013). These theories argue that various categories of people in society perform their activities in a predictable way according to predefined social roles. For instance, based on these theories, women are generally expected to occupy more childcare roles than men. Regarding pricing decision behaviours, men tend to be more independent, competitive, and undertake decisions based on selective data/information and heuristics, whereas women are usually more interdependent, social, cooperative, and consider broader details in their decision making (Deaux & Kite, 1987). Therefore, in a consumer context, women are likely to pay more attention to prices of products and services and are consequently more cost conscious than men (Venkatesh et al., 2012). Moreover, Slama & Tashchian (1985) find that women undertake more purchasing responsibilities and are thus more careful with money than men. These gender-based attitudinal differences will therefore, in most cases, lead men to value technological products or services in monetary terms more highly than women (Venkatesh et al., 2012).

These gender differences, in terms of social roles, also interact with age. This is because older women tend to engage more in caring for their families (Deaux & Lewis, 1984). As such, there is a societal expectation that older women are more price sensitive than men due to the pressure exerted on them by the burden of their social roles. As noted by Bradford & Katikiro (2019), men dominate both the marine and freshwater fishing activities in Tanzania; and the nature of fishing roles suggests those working there to be of active working age (say, 18 to 65 years in the Tanzanian context). Therefore, it is expected the male-dominated fishing community, lacking distinction in social roles, will be relatively insensitive to the price of the proposed traceability solution and so it is not expected that either gender or age will moderate PV. Finally, Owusu Kwateng et al. (2019) note that consumer experience moderates the influence of PV on behavioural intention. It follows that, the longer consumers use similar or complementary technology, the more they become familiar with its benefits as well as ways to mitigate associated usage costs, hence more PV. Based on the preceding, it is therefore hypothesised (H12) that:

H12: Experience will moderate the effect of Price Value (PV) on fishers' Behavioural Intention (BI) to adopt the proposed traceability solution such that the impact will be higher in the case of more experienced fishers.

Moderation of Age, Gender, and Experience on Habit (HT)

If performance of a particular behaviour is frequent, there can result established attitudes and behavioural intentions activated by environmental objects or cues (Fishbein & Adjen, 2010). These activated attitudes and intentions lead further to automatic behaviours whose execution requires no conscious mental awareness (Fazio, 1990). Experience and HT relate strongly through repeated behaviour. This happens after HT is sufficiently practiced over a longer passage of time (i.e., experience) enough for it to be stored in long-term memory, thus overriding other unwanted pre-existing behavioural patterns (Lustig et al., 2004). The extent of activation of this behaviour, however, is dependent on how sensitive a consumer is to environmental or contextual changes (Verplanken & Wood, 2006), with the automatic habitual behaviour more likely to be disrupted by environmental changes in people who are sensitive to such things. Based on the preceding relationships, Venkatesh et al. (2012) note that responses to environmental/contextual cues/signals and behavioural intention, are strongly influenced by experience. It can therefore be surmised that habit will have stronger effect on intention to adopt new technologies the more experienced the consumers are with similar or underpinning technologies. Regarding age and gender, older consumers have a greater tendency to rely more on automatic information processing (Jennings & Jacoby, 1993) such that their rigid habits limit or suppress their uptake of new knowledge (Lustig et al., 2004). Therefore, environmental, or contextual cues are more likely to affect younger than older consumers/users of technology. As for gender, women have a tendency of paying more attention to details as well as being more elaborate in their messages than men (Gilligan, 1982). Also, women have been found to demonstrate higher sensitivity to details than men in the context of consumer decision making (Meyers-Levy & Tybout, 1989). This happens because women process information in a piece-meal and more detailed manner while men have a behaviour of processing information in a wholesale format thus ignoring some relevant details (Meyers-Levy & Maheswaran, 1991). Therefore, women are expected to be more sensitive and conscious than men to environmental or contextual cue changes, thus weakening the effect of their overall habit on behavioural intention or actual behaviour (Venkatesh et al., 2012).

The above analysis suggests that experience, age, and gender may all moderate the effect of habit on behavioural intention, sometimes in interaction with each other. As Tanzanian fisheries are dominated by men (Bradford & Katikiro, 2019), stable habits are expected to be exhibited by older and experienced male fishers. As old men rely more on experience or habits than new knowledge, then it is likely that age will moderate the impact of habit on intention. Gender will have no moderating effect due to the total and extreme predominance of males in the respective marine and freshwater sub-samples. Based on the preceding, we hypothesise (H13) that:

H13: Age and experience will moderate the effect of Habit (HT) on fishers' Behavioural Intention (BI) such that the impact will be stronger with older experienced fishers.

Proposed/New Latent Independent Construct, Moderators, and Mediators

Complementary Technology (CT) Latent Construct

In Venkatesh et al. (2012, p.158), a suggestion was made about possible extensions/integrations to the original UTAUT variables. These advancements included contextual adaptations and latent independent constructs. Prior research has advanced in this direction. For instance, Beza et al. (2018) and Thusi & Maduku (2020) added new latent constructs, namely trust and personal innovativeness; and institutional trust and perceived risk, respectively. They found that (institutional) trust and perceived risk were significantly associated with behavioural intention of users to adopt new technologies. Therefore, CT is being proposed in the current study as an additional independent latent construct. It has been argued that some form of experience of then use of similar or complementary technology is a good predictor of future behavioural intention to use new technologies (De Schepper et al., 2015; Limayem et al., 2007; Venkatesh et al., 2012). In this regard, experience in using a complementary technology is viewed as a potential opportunity to adopt and use a target or proposed technology, and this experience is measured by the consumer's passage of time over which the complementary technology is in use (S. S. Kim & Malhotra, 2005). However, other researchers have tested this experience with the usage of target/proposed rather than complementary technologies. While Kim et al. (2005) measured experience with target technology usage in five time periods, Venkatesh et al. (2003) operationalised experience with target technology usage over three phases of time: post training (when proposed technology was available for use), one month later, and 3 months later. The operationalisation of experience with technology in the context of the current study is somehow different from the preceding studies. Fishers have had no prior experience in using the proposed traceability solution. However, the applications of this traceability solution are expected to run on fishers' mobile phones and other electronic gadgets which are by and large already owned and operated by them (i.e., with varying degrees of experience). Given the circumstances, de Schepper et al. (2015) and Venkatesh et al. (2012) argue that some technologies are best evaluated for deriving maximum benefits to users if they are considered as a package or a combination rather than assessing them individually. Therefore, mobile 'phones and their embedded applications are considered here as complementary technologies because it is on these that the proposed traceability solution application would run. Based on the preceding analysis, we can predict that usage of similar or complementary technology influences the users' behavioural intention to adopt a new technology. As such we hypothesise (H14) that:

H14: Usage of similar or Complementary Technology (CT) will positively influence the fishers' Behavioural Intention (BI) to adopt the proposed traceability solution.

Moderators of Fishery Type, Education, and Profitability

In their development of UTAUT2, Venkatesh et al. (2012) argued that the five latent constructs of Facilitating Conditions, Hedonic Motivation, Price Value, Habit, and Behavioural Intention were moderated by age, gender, and experience. In addition to these moderators, Venkatesh et al. (2012, p.158) suggested a list of possible extensions/integrations to the original UTAUT framework, and these included changes in contextual settings as well as additions of latent dependent and independent constructs. Previous studies have also added to the list of moderators proposed by Venkatesh et al. (2012). Research has, in addition to age, gender, and experience, included more moderators depending on the nature of those studies. For instance, Beh et al. (2021) incorporated perceived vulnerability and perceived severity as moderators in their UTAUT2 study while Baptista & Oliveira (2015) used cultural moderators namely collectivism and uncertainty avoidance in a similar UTAUT2 framework research. In both cases, these new moderators were found to significantly and indirectly predict users' behavioural intentions to adopt proposed technologies. Based on these trends, it is proposed to expand the list of moderators in the current study to include contextual moderators namely fishery type, fishers' education, and fishers' profitability levels. The Tanzanian fisheries sector is composed by both marine and freshwater fishers. This research was designed in a manner that data were collected from both segments of marine and freshwater fishers. Therefore, it is important to add this fishery type moderator to be able to identify any significant moderating effects from this variable's segments. Moreover, it was noted in Chapter 3 (analysis of fishers' interview responses) that there are significant differences in levels of education between marine and freshwater fishers. Finally, freshwater fishers were found in URT (2020) to be more profitable than their marine peers. To establish if these moderating differences were significant, it is justifiable to add to the current study the new moderators of fishery type, education level, and profitability. It is therefore hypothesised (H15) that:

H15: Fishery type, education, and profitability will moderate the influence of all or some independent latent constructs on the fishers' Behavioural Intention (BI) to adopt the proposed traceability solution.

Mediation Effects

The relationship between independent and dependent constructs (i.e., X → Y) is called direct (i.e., main) effect. An indirect effect represents a sequence of relationships involving at least one mediator construct between the independent and the dependent constructs, i.e., X → Z → Y (J. F. Jr. Hair et al., 2021). This indirect effect is what constitutes a 'mediating effect', and therefore the total effect is a sum of the direct effect and indirect (i.e., mediating) effect (J. F. Jr. Hair et al., 2021). According to Hair et al. (2021), mediation happens when a variable or construct called 'a mediator' alters the way an independent (exogeneous) construct relates to a dependent (endogenous) construct. Mediation analysis is a statistical procedure that tests whether the effect of an independent construct X on a dependent construct Y (that is: X → Y) is at least partly explained by the effect of another independent construct Z that is: X → Z → Y) (Fiedler et al., 2011). However, Fiedler et al. (2011) caution that most results of mediation analysis represent a necessary, but not necessarily sufficient, condition to guarantee that all mediation in the statistical model is captured. This is because, as research (e.g., Fiedler et al., 2011) has demonstrated through multiple simulations, the significance criteria fulfilled in a mediation model can potentially be caused by one or a few factors/variables specified in the model, leaving out other unspecified real mediators (e.g., Z_1, Z_2, Z_3, …, Z_n). This means existing mediation analysis approaches are designed to only measure/estimate the strength and significance levels of specified causal models, but not to distinguish real mediating factors/variables from non-real mediators (i.e., real causal versus non-real causal factors/variables) (Fiedler et al., 2011). This has led to the possibility of some non-real mediators producing significant mediation results while not necessarily making sense as mediators in empirical terms (Fiedler et al., 2011). This is because, according to simulations by Fiedler et al. (2011), significant mediation effects not only result from real mediators, but also from (i) correlates of dependent variables (Y), and (ii) correlates of real mediators with completely different theoretical meanings.

To identify real mediating factors, Fiedler et al. (2011) suggest that researchers need to employ clever theorising that involves validation analysis of theoretically identified mediation causal factors, as well as undertaking experimental tests of antecedent–consequence relationships. Fiedler et al. (2011) used this approach to differentiate mediator from moderator models in the X → Z →

Y relationship. In the Friedler et al. model, X is a male mating strategy (direct or indirect), Z represents females' reaction, and Y stands for mating response results (positive or negative). It was found that the direct strategy was more successful resulting in more positive female responses. However, when the females were identified as being constituted of two distinct groups of cool or emotional, it was found that there were more positive responses by emotional women, who constituted most responses to the direct strategy. Based on the preceding, the women type (i.e., cool, or emotional) could potentially represent a moderator (an exogenous factor, i.e., pre-existing condition, that determines the response) or a mediator (an endogenous condition caused by the mating strategy) variable (Fiedler et al., 2011). If the differences of cool or emotional women pre-existed and were visible to male agents, as a moderating factor, before the males' determined their mating strategy, then the success of the direct strategy could be explained by the advantage gained from by the prior knowledge of female status. However, if these female differences were unknown a priori, whereby female type was framed as a mediator, this could only be differentiable as cool or emotional women after the males' mating strategy had been implemented, based on a posteriori analysis of the women responses. The success of the 'direct' mating approach (X) could then be interpreted as causing an emotional female reaction (Z), which in turn caused a positive response (Y), hence suggesting that direct male mating strategies result in higher success rates when mediated by female emotion than indirect strategies. The study also found that success rates of direct strategies were higher in the meditator condition than in the moderator condition (Fiedler et al., 2011). Therefore, to conclude, similar correlation patterns can be interpreted as a mediation effect if Z followed X in close sequence (i.e., identified/known a posteriori) or as a moderator effect if Z was predetermined (i.e., identified/known a priori) (Fiedler et al., 2011; J. F. Jr. Hair et al., 2021).

Theoretical hypothesis and empirical testing are two key steps in undertaking meaningful mediation analysis (J. F. Jr. Hair et al., 2021). There are three types of mediation and two types of non-mediation (J. F. Jr. Hair et al., 2021). The three mediation types are complementary, competitive, and indirect-only. Complementary mediation (also called partial mediation) occurs when both direct and indirect effects are significant and have the same sign (i.e., point to the same direction). Competitive mediation (also called inconsistent mediation or suppressor effect) is when direct and indirect effects are significant and signed in opposite directions. Indirect-only mediation (also called full-mediation) means only the indirect effect is significant (i.e., the direct effect is not significant). Non-mediation occurs in the forms of direct-only and no-effect. Direct-only mediation is when only the direct effect is significant (i.e., indirect effect is not significant). No-effect mediation is when neither the direct nor the indirect effect is significant).

The current study's overall testing framework is based on UTAUT2 (Venkatesh et al., 2012). Although Venkatesh et al. (2012) reported no mediation results in their landmark UTAUT2 study, Casey & Wilson-Evered (2012) and Siyal et al. (2020) used the UTAUT (not UTAUT2) framework and PLS-SEM method to identify mediating effects in their studies. It was found that Hedonic Motivation (HM) mediates the effect/relationship between Performance Expectancy (EE) and Behavioural Intention (BI), suggesting that when consumers/users find the proposed technology to be useful and efficient, those that adopt tend to derive pleasure and enjoyment while using it (Siyal et al., 2020). It was also found that HM mediates the effect/relationship between Effort Expectancy (EE) and BI, meaning that consumers/users of technology look for and are interested in easy, convenient, and efficient solutions that enable them to derive fun/enjoyment, thus driving their intention to use the technological solution (Siyal et al., 2020). Furthermore, it was found that HM mediates the effect/relationship between Facilitating Conditions (FC) and BI (Siyal et al., 2020). This suggests that the availability of technological infrastructure coupled with uninterrupted access increases enjoyment and so enhances consumers'/users' intention to use the technological solution (Siyal et al., 2020). In summary, consumers are more likely to adopt if: PE is favourable; EE is favourable; FC is favourable, and HM is favourable (i.e., pleasure is derived). Adoption would be unlikely, in the absence of enjoyment, even if these three exogenous factors (i.e., PE, EE, and FC) were favourable. This equates to a 'Complementary' mediation requirement. On the other hand, it was found that EE mediates the effect/relationship between Trust in Technology (TT) and BI (Casey & Wilson-Evered, 2012). This means for users/consumers to trust in the technology solution, it needs to be convenient and easy to apply, thus enhancing the users'/consumers' intention to use it. In this regard, trust is defined, among others, as being derived from the ability of the technological solution to resolve the intended problem(s) as anticipated by users/consumers (Casey & Wilson-Evered, 2012). This definition has similarity to Performance Expectancy (PE), one of the UTAUT2 constructs in the current study. Moreover, this definition of trust aligns with Complementary Technology (CT), another construct in the current study. As the proposed traceability solution application will be downloaded and operated on fishers' mobile phones (i.e., CT), this would drive trust in the proposed solution as the fishers are already familiar with similar applications on their mobile phones. As such, the current study will use CT as interchangeable with TT to undertake the mediation testing. Finally, Venkatesh et al. (2003) present mediation conceptualisation in their UTAUT conceptual model to find out that the Effort

Expectancy (EE) construct (i.e., ease/convenience of use) fully mediates the effect of the Facilitating Conditions (FC) construct (i.e., supportive infrastructure/resources) on Behavioural Intention (BI) to adopt the technology.

The current study builds on the preceding research (Fiedler et al., 2011;Venkatesh et al., 2003, 2012; Casey & Wilson-Evered, 2012; Siyal et al., 2020) to identify, hypothesise, and conceptualise the mediation effects in its conceptual model (see Figure 13). Theorising around potential mediating factors is done through the already tested models in the relevant literature (Fiedler et al., 2011), including the above studies. This model (Figure 13) is designed to capture and reveal both direct and indirect (i.e., moderating and mediating) relationships/effects. It is important, however, to explain that these variables being analysed in this section are mediators and not moderators. To do this, a priori logic is used such that the exogenous variable states are not determined by these factors (HM and EE) and so they cannot be moderators, only mediators. For instance, PE does not change based on pre-understanding of HM, but rather PE remains fixed, and is only influential on BI if HM is favourable. Based on the preceding literature, it was theorised and hypothesised in the current study's conceptual model (Figure 13) that:

(i) HM mediates the effect/relationship between PE and BI (PE → HM → BI).
(ii) HM mediates the effect/relationship between EE and BI (EE → HM → BI).
(iii) HM mediates the effect/relationship between FC and BI (FC → HM → BI).
(iv) EE mediates the effect/relationship between CT and BI (CT → EE → BI).
(v) EE mediates the effect/relationship between FC and BI (FC → EE → BI).

Statistical Approaches

Sample Size

Literature is largely inconclusive on the appropriate minimum sample size for SEM studies. While Schreiber et al. (2006) suggest that at least 10 participants should be sampled for each latent variable (construct), Kline (2015) recommends 20 respondents per construct. However, based on other factors such as impact size,[76] a minimum sample of 200 has been recommended for any SEM analysis (Kline, 2015; Weston & Gore, 2006). In this regard, sample size constitutes one among many SEM evaluation criteria. Studies (e.g., Barroso et al., 2010; Hair, Sarstedt, Pieper, et al., 2012; Hair, Sarstedt, Ringle, et al., 2012) have indicated that small sample sizes, i.e., 100, 159 or 176 observations can produce reliable results under PLS-SEM. Also, Barclay et al. (1995) provide a popular rule of thumb for minimum samples needed to achieve robust PLS-SEM estimations.

76 See Soper's Sample size calculator at http://www.danielsoper.com/statcalc/calculator.aspx?id=89

The rule requires a minimum of ten times the maximum number of constructs in the un-estimated SEM model. In our case, there were nine constructs which would require the minimum sample of 90 observations (i.e., fishers/boat owners). To measure the significance of the identified moderating effects, the fisheries data were split into moderator variable segments. To obtain valid results, these segments had each to meet the minimum sample size for SEM analysis. The current study met all the above sample size requirements, including the consideration of two segments (sub-populations or analytical units). Therefore, both freshwater fishers (N=177) and marine fishers (N=357) meet all the above SEM minimum sample size requirements. Also, the sizes of other segments within the overall sample meet this requirement. These segments include age (young group of 48 years and under, N=311; and the mid-old group of over 48 years, N=223) and experience (fishers with experience of 10 years and under, N=273; and fishers with over 10 years' fishing experience, N=261). Other segments are education (fishers without formal education, N=186; and fishers with formal education, N=348); and profitability (i.e., fishers making TZS50.0 million and under in annual pretax profits, N=279; and those making over TZS50.0 million in annual pretax profits, N=255).

As reliable data on freshwater and marine fishing boat owners were unavailable, the current study used the number of fishing vessels as a proxy for number of boat owners. Therefore, the marine fishers sample represented 4% of all 9,242 marine boat owners in Tanzania; and the freshwater fishers sample made up 0.2% of the total 31,773 Tanzanian fishing boat owners on Lake Victoria (URT, 2020). The marine sample was drawn from all marine regions of Tanzania, namely Tanga, Pwani/Coast, Dar es Salaam, Lindi, and Mtwara. The sample of freshwater fishers was drawn from Mwanza only because the region contributes almost half (i.e., 47%) of the annual fish catch, by value, on the Tanzanian side of Lake Victoria (URT, 2020). Although there are more boats on Lake Victoria (freshwater) than in the marine fisheries, a larger sub-sample of marine fishers (N=357) was drawn than freshwater fishers (N=177). This was so because marine fisheries appeared to have varying characteristics across the five regions, hence the need to have representative sub-samples from each region (see more details under Descriptive Statistics section).

Survey Data Collection Instrument

A survey questionnaire (see Appendix C4) was developed to capture data in the current study. Data were collected from fishers (owners of boats/fishing businesses), i.e., those able to make final decisions regarding the adoption of the proposed traceability solution. The questionnaire was designed to capture, in addition to demographic information, the boat owners' perceptions, experiences, and any potential barriers to their intention to adopt the proposed traceability solution. This questionnaire was 29 pages long, comprising 45 questions that focused on four topics/sections which reflected on demographic and socioeconomic data of boat owners, a description of the proposed traceability solution, as well as the UTAUT2 dependent and independent latent constructs. The independent constructs were Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), Facilitating Conditions (FC), Hedonic Motivation (HM), Price Value (PV), Habit (HT), Complementary Technology (CT); and the dependent construct of Behavioural Intention (BI). Having met all the University ethical requirements for this research and to overcome delays caused by COVID-19 travel restrictions, the researcher recruited, trained, and paid a Tanzanian agent to collect and deliver the data using Qualtrics,[77] an electronic quantitative data collection and management tool. This contracted agent was Tanzania Fishers Union Organisation (FUO)[78], represented by its chairperson, based in Mwanza City, on the southern shores of Lake Victoria. The data collection exercise lasted 29 days (from 27 October to 24 November 2021).

Demographic and Socioeconomic Data

Collected under this header were data on area of residence in Tanzania, type of fishing (freshwater or marine), gender, age, fishing experience, education level, and overall fishing business success characteristics (e.g., profitability).

Description of Proposed Traceability Solution

The traceability solution tested on fishers was quite new and likely unfamiliar to them (i.e., a web and mobile-based application of Blockchain technology and Google-enhanced satellite communications GPS system). Therefore, to enhance their basic understanding of the key features of the traceability solution, the fishers were presented with a brief description of the traceability solution's relevant working functions and benefits, shortcomings, and an indicative acquisition and use price. Also explained was the integration potential of the proposed traceability solution to fishers' existing (complementary) technologies and applications – e.g., (smart) mobile phones, text messages, internet access, mobile-phone-based camera, and maps.

[77] https://www.qualtrics.com/support/survey-platform/getting-started/survey-platform-overview/?utm_lp=homepage+tile
[78] https://fishersunion.blogspot.com/

Construction of UTAUT2 Constructs

The measurement items/indicators used in this current UTAUT2 study were adapted from Venkatesh et al. (2012) because both studies focus on testing user intention to adopt technology in a consumer context. As explained elsewhere in this study (see Figure 13), the current study's UTAUT2 framework also incorporated traditional and new moderating factors, also in line with Venkatesh et al. (2012). Presented below are a description of the measurement items/indicators for each latent construct in the current UTAUT2 framework.

Performance Expectancy (PE)

With PE, fishers were asked questions about their level of belief or perception that the traceability solution in question would meet their expectations in terms of their perceived usefulness or derivable utility. In Venkatesh et al. (2012), PE was measured by four items focusing on productivity and the usefulness of the technology to accomplish or achieve intended goals (i.e., resolve existing problems). These items were extended and adapted in the current study to capture resolution of problems in the fisheries sector, hence resulting in eight items. Therefore, PE was formed by the following eight questions/items in the questionnaire:

Question or measurement indicator	Statistical analysis label
This traceability solution will enhance my fishing catch volumes.	PE1
This traceability solution will enhance my fishing growth and scaling-up.	PE2
This traceability solution will enhance my fishing cost reduction.	PE3
This traceability solution will enhance my fishing productivity.	PE4
This traceability solution will enhance my profitability in fishing.	PE5
This traceability solution will enhance higher local fish prices.	PE6
This traceability solution will enhance higher fish export prices in the UK & EU.	PE7
This traceability solution will limit illegal & unsustainable fishing practices.	PE8

Effort Expectancy (EE)

Here, fishers were asked questions about the extent, or degree of ease, or convenience, to which the proposed traceability solution could be put into use by them. In this regard, the following four questions/items were adapted in the questionnaire for EE from Venkatesh et al. (2012):

Question or measurement indicator	Statistical analysis label
Effort to use this traceability solution in fishing is acceptable.	EE1
This traceability solution is easy to use in fishing activities.	EE2

It is easy to learn skills needed to use this traceability solution in fishing.	EE3
Interaction with this traceability solution is clear and understandable to me.	EE4

Social Influence (SI)

Under SI, fishers were asked about the potential collective effect of social and environmental factors on their willingness to adopt the proposed traceability solution. As such, the following three questions/items were adapted and included in the questionnaire based on Venkatesh et al. (2012):

Question or measurement indicator	Statistical analysis label
Other fishers that I respect will be using this traceability solution in their fishing operations	SI1
People who are important to me would encourage me to use this traceability solution in my fishing activities	SI2
People who influence my behaviour would approve of my using this traceability solution in fishing.	SI3

Facilitating Conditions (FC)

Here, fishers were asked questions about available organisational, financial, and technical support infrastructure as well as their relevant acquired knowledge, ability, and resources necessary to enable their adoption of the proposed traceability solution. Therefore, the following four questions/items were adapted and included in the questionnaire as in Venkatesh et al. (2012):

Question or measurement indicator	Statistical analysis label
I have the resources necessary to use this traceability solution in fishing.	FC1
I have the knowledge necessary to adopt and use this traceability solution in fishing.	FC2
This traceability solution is compatible with other technologies I use in fishing.	FC3
Others can help me when I have difficulties using this traceability solution in fishing.	FC4

Hedonic Motivation (HM)

Under HM, fishers were asked questions about the pleasure, motivation, or enjoyment that they expected to get from using the proposed traceability solution. To do this, the following three questions/items were adapted and included in the questionnaire based on Venkatesh et al. (2012):

Question or measurement indicator	Statistical analysis label
I am motivated to use this traceability solution in future fishing.	HM1
I am motivated to use this traceability solution in present fishing.	HM2
Experience of using this traceability solution in fishing would be rewarding to me.	HM3

Price Value (PV)

Questions in this sub-section related to fishers' cognitive trade-off between the proposed traceability solution's derivable utility/benefits and the potential financial costs of acquiring and operating the proposed traceability solution. To measure this, the following three questions/items were adapted and included in the questionnaire as in Venkatesh et al. (2012):

Question or measurement indicator	Statistical analysis label
This traceability solution is reasonably priced for benefits it would provide.	PV1
This traceability solution is good value for money in fishing.	PV2
This traceability solution has value and would address the problems I experience in fishing.	PV3

Habit (HT)

Fishers were asked about having habits of using similar or complementary technologies which would give an indication of possible adoption of the proposed traceability solution. To capture their responses, the following four questions/items were adapted and included in the questionnaire based on Venkatesh et al. (2012):

Question or measurement indicator	Statistical analysis label
Using this traceability solution in fishing would become a habit for me.	HT1
I will be addicted to using this traceability solution in fishing.	HT2
I will definitely have to use this traceability solution in fishing.	HT3
Using this traceability solution in fishing will become natural.	HT4

Complementary Technology (CT)

As explained elsewhere in the current study, CT was a new construct derived from relevant literature (e.g., De Schepper et al., 2015) and proposed for addition to the UTAUT2 framework as suggested in Venkatesh et al. (2012). Here, fishers were asked questions about their experience in usage of a provided list of similar or complementary technologies as this might be a good predictor of their future behavioural intention to use the proposed traceability solution. Based on Tanzania's fisheries context, the following list of technological items was presented to fishers in the questionnaire:

Question or measurement indicator	Statistical analysis label
Computers.	CT1
iPads.	CT2
Digital cameras.	CT3
Internet browsing on a mobile phone/device.	CT4
Internet browsing on a computer.	CT5
Internet of Things (IoT)	CT6
E-mail on mobile phone/device.	CT7
E-mail on computer.	CT8
Smart mobile phones.	CT9
Non smart mobile phones.	CT10
Mobile Text Messages.	CT11
Barcodes.	CT12
Quick Response (QR) codes.	CT13
Radio frequency identification (RFID) sensors.	CT14
Mobile money.	CT15
Bank account.	CT16
Fish ice storage.	CT17
Fish deep cold storage facilities.	CT18
Blockchain.	CT19
Google Maps Platform Services.	CT20
Google Cloud Platform Services	CT21

Behavioural Intention (BI)

BI expressed or captured fishers' intention to adopt the new traceability solution within the next 12 months. While the preceding eight constructs were modelled as latent independent constructs/variables, BI was a latent dependent construct/variable. To capture this fishers' intention, the following three questions/items were adapted and included in the questionnaire as in Venkatesh et al. (2012):

Question or measurement indicator	Statistical analysis label
I intend to pay for and use this traceability solution in future fishing.	BI1
I will definitely pay for and use this traceability solution in my daily fishing.	BI2
I am planning to pay for and use this traceability solution in future fishing.	BI3

The above behavioural intention (BI) is measured in each of the three items by two questions (i.e., intention/willingness to pay and adoption) asked at once which may have needed separating in the questionnaire. However, while this seems to be a clear limitation, it was addressed with fishers/respondents during the fieldwork. Prior to and during the data collection phase, fishers were taken through various aspects of the proposed traceability solution, including its problem-solving features and adoption price. It was thus assumed that fishers had this background understanding of the 'price requirement' before deciding on adoption. Therefore, while responding to the above questions, fishers were already aware of the need to pay for the proposed traceability solution, thus making 'intention to use/adopt' the only remaining key question seeking responses under BI.

Quantitative Measurement of Responses

To collect fishers' (boat owners') responses to the UTAUT2 questions, questions were constructed using Likert scales. Many authors support the use of a seven-point Likert scale based on its provision of more options for capturing participants' objective reality (Joshi & Ganjiwale, 2015). However, other researchers contend that a choice between a five-point or seven-point Likert scale must be guided by the perceived cognitive state of respondents (Weijters et al., 2010). These authors argue that seven-point Likert scales be administered to generally educated populations, who have higher cognitive abilities, while the five-point Likert scales be reserved for the lesser educated, namely the rest of the public (Weijters et al., 2010). As fishers constitute one of the less educated groups in Tanzania (URT, 2018), it made sense therefore that questions for Tanzanian fishers/boat owners be prepared using a five-point Likert scale. The questionnaire was originally prepared in English but administered to fishers/boat owners in their native Swahili language, due to generally weak English language communication skills in this group.

Choice of Regression Modelling Approach

The current study set out to model the drivers of behavioural intention of Tanzanian fishers (boat owners) to adopt the proposed traceability solution. Because Tanzanian fishers have varied interests and operate in a complex environment, the chosen regression model must be able to capture direct and indirect effects of multi-directional statistical relationships involving latent constructs, their moderators, and mediators. As elaborated in Chapter 3, Tanzanian fishers operate in unpredictable natural marine and freshwater environments with low-tech equipment in challenging depths, including deep marine waters. These fishers also face varying unfavourable business environments including the unreasonably punitive actions of regulators, unreliable markets for their fish products, and limitations in fisheries traceability systems. Given these complexities in the Tanzanian fishing environment, the study employed the Structural Equation Modelling (SEM) technique (Becker et al., 2013; Henseler et al., 2016). SEM permits the modelling of complex relationships between dependent and independent constructs, i.e., where there are possibilities of both indirect (i.e., mediated, and/or moderated), and direct relationships, as well as correlation between independent constructs caused by the existence of difficult to measure latent constructs (Becker et al., 2013; Henseler et al., 2009, 2016). These latent constructs, such as trust in a technology, cannot be measured directly, but can be inferred from multiple directly measured, and self-reported metrics, as derived from perceptions, or experiences, of respondents (Suhr, 2006). Therefore, SEM is employed because the chosen analytical framework of UTAUT2 is based on latent constructs formulated from measurement indicators (Venkatesh et al., 2012).

What Type of SEM was Used?

According to Becker et al. (2013) and Henseler et al. (2016), there are two types of SEM models. The first is called the Common Factor Model, or Covariance-Based SEM (CB-SEM). A CB-SEM employs reflective measurements (i.e., effect indicators), which are themselves impacted by changes in unobserved latent constructs. To put it more concisely, the unobserved constructs determine the observed indicators or variables. These observed reflective indicators are usually assessed or evaluated in terms of their correlation with, or loadings upon, the unobserved construct, for example via Factor Analysis. These correlations are represented in model diagrammes by arrow pointers running from the latent constructs towards the observed indicators. The second type of SEM model is the 'Composite' or 'Variance-Based' Partial Least Squares SEM (PLS-SEM). The PLS-SEM makes use of formative measurements (either causal, or composite indicators), i.e., the observed measurement indicators are assumed to determine the unobserved constructs. When combined, these observed formative measures are assumed to form latent (unobserved) constructs. The act of combining these formative measures is undertaken without regard to any interrelationships (intercorrelation patterns) among the indicators. In SEM diagrammes, this direction of causality is represented by arrows running from the observed measurement indicators to the latent (unobserved) constructs. To sum up the differences between these two SEM typologies, reflective measurement models (CB-SEM) assume that changes in latent constructs drive changes in the observed indicator variables, while in formative measurements models (PLS-SEM) the reverse is assumed.

The CB-SEM estimates model parameters to minimise the discrepancy between the estimated and sample covariance matrices; while PLS-SEM ensures that the variance explained (R^2) by the latent dependent construct is maximised, by estimating partial model relationships or regressions (Cheah et al., 2020; Fornell & Bookstein, 1982; Hair, 2020; Hwang et al., 2020). Generally, therefore, the PLS-SEM algorithm generates more reliable and robust results than CB-SEM in situations of non-normal (skewed) data (and where measures are assumed to be formative) (Dijkstra, 2010; Henseler et al., 2009). Therefore, the choice between CB-SEM and PLS-SEM can be resolved as follows: CB-SEM is best used in confirmatory studies testing prior strong theory and where observed indicator variables are assumed to be reflective (Barroso et al., 2010). PLS-SEM, on the other hand, is primarily intended for causal-predictive analysis with complex problems being explored (many constructs, indicators, and interrelationships) with limited prior theoretical knowledge and where observed indicator variables are assumed to be formative (Barclay et al., 1995; Wold, 1980). Generally, PLS-SEM appears to be a relatively more robust and reliable analytical tool than CB-SEM, mainly due to its minimal demands on sample size, and less requirement for normality of residuals and measurement scales (Fornell & Bookstein, 1982).

To demonstrate the superiority of PLS-SEM over CB-SEM, Henseler et al. (2016) ran a series of SEM model estimations using CB-SEM and PLS-SEM comparing results for bias. The authors concluded that PLS-SEM generates better (unbiased) results using both common factor- and composite-based model structures compared to CB-SEM. This happens especially if it is not known whether the measures are common factor (reflective) or formative (formative). To confirm this choice, Hu & Bentler (1998) and (Henseler et al., 2016) provide an alternative way to decide between PLS-SEM and CB-SEM. The authors argue that if researchers ran a quick test on the data and found Standardised Root Mean-square Residual (SRMR) to be less or equal to 0.08 (i.e., SRMR <= 0.08), then the nature of the data would be suitable for the PLS-SEM formative measurement model. Otherwise, the data would be suitable for CB-SEM factor-based measurement model. In this regard, a test was conducted on the current study's data using PLS-SEM analysis software called SmartPLS (Ringle, et al., 2015). The results (see Results Section) showed SRMR <= 0.08. This hinted on the choice of PLS-SEM over CB-SEM. Another test was undertaken to confirm this choice. As indicated earlier, the key selection criterion of PLS-SEM or CB-SEM is the determination of whether changes in unobserved latent constructs lead to changes in observed measurement indicators (i.e., CB-SEM) or whether changes in measurement indicators result in changes in constructs (i.e., PLS-SEM). The choice of PLS-SEM appeared confirmed when illustrated through the latent independent construct of Facilitating Conditions (FC) and its corresponding measurement indicators. Based on the field questionnaire items, the measurement indicators (i.e., the measures) in FC included necessary resources, knowledge, compatibility, and availability of technical support to use or adopt the new technology. It could be shown here that these items are causal indicators (i.e., they influence or cause changes in the FC construct and not the other way round). Resources like funds or devices are key facilitating conditions for users to acquire or use new technology. Knowledge through tailored training is also an important facilitating condition for easy adoption of technology. If technology in question is compatible or complementary to already existing devices, this will facilitate usage of new technology. Finally, availability of technical support is another facilitating condition to enable users of new technology to troubleshoot through adoption challenges.

PLS-SEM Model Analysis

Because the composite model (PLS-SEM) was adopted to identify the influences of intention to adopt the proposed traceability solution, there is accordingly a formative treatment of measurement indicators. For instance, while Cronbach's alpha and reliability tests are generally used to evaluate reflective measures, such internal consistency or reliability tests are irrelevant for quality assessment of formative measures (Diamantopoulos, 2006; Diamantopoulos & Winklhofer, 2001). Furthermore, Hair et al. (2011) note that convergent and discriminant validities for formative measurement indicators cannot be established empirically. Where reflective measures are involved, because they are all reflective of an underlying construct, they must necessarily be highly correlated with each other, such that one indicator can be removed without causing any significant change in the value or meaning of the construct (Edwards & Bagozzi, 2000; Jarvis et al., 2003). Therefore, in CB-SEM models, reflective measurement indicators have high covariance values due to their being highly correlated. This makes the testing of internal consistency of measures relevant. However, covariance or correlation between formative measurement indicators is not a requirement in PLS-SEM based formative composite measurement models (Henseler et al., 2016). This means, measurement indicators in formative composite models can be highly correlated or not (i.e., high, or low covariance) without significantly altering the value or meaning of their respective constructs (Hair, Sarstedt, Pieper, et al., 2012; Henseler et al., 2016). This is the main reason why tests of consistency/covariance/coherence (e.g., Cronbach's Alpha) are not usually undertaken in PLS-SEM based formative composite measurement models. This may explain why SmartPLS results tables for Cronbach's Alpha test for the current study were blank.

Outer and Inner PLS-SEM Model Analysis

Outer Model Evaluation

Formative Evaluation Approach

The PLS-SEM model was evaluated formatively to gauge its quality in terms of reliability and validity of the resulting composite regressions (Hair, Sarstedt, Pieper, et al., 2012). Formative composite evaluation assumes latent constructs are constituted, but not necessarily caused by, a combination of composite indicators (Bollen & Bauldry, 2011). Therefore, several tests of validity and reliability of model results were undertaken, including the testing for multi-collinearity, indicator weights, and significance. These are explained in detail in the sections below.

Multicollinearity

Tests were run first for multicollinearity to assess the weight stability[79] of measurement indicators within each of the independent latent constructs. This is in accordance with Cenfetelli et al. (2009) who recommend that evaluation of variance inflation factor (VIF) values between indicators and their respective constructs must precede the evaluation of VIF values between independent constructs. This is because in composite-based models, formative measurement indicators influence latent constructs. As such, there cannot be stable latent constructs until the stability or quality of the formative measurement indicators from which they are derived is assured. Multicollinearity was assessed based on tolerance and VIF values (Hair et al., 2011). Unfortunately, the literature provides no real consensus on the acceptable threshold of VIF values for determining whether unacceptable multi-collinearity exists. For instance, Kim (2019) and Hair et al. (2019) suggest that multicollinearity becomes problematic with VIF values at 5 or higher, while Hair et al. (1995) argue that VIF values below 10 do not cause model instability. The current study took a safer position by retaining only those formative measurement indicators with VIF < 5. Indicators with VIF values of 5 and above were dropped immediately to ensure the stability of the model.

[79] Regression weight stability is a quality measure of a quantitative model that ideally looks to minimise the level of randomness and variations in the model performance, hence enhancing its predictive robustness. See more details at: https://aclanthology.org/K19-1087/

Measurement Indicator Weights and Significance

The other quality evaluation approach was indicator measurement/regression weights. The evaluation of formative indicator regression weights also included the assessment of their significance through bootstrapping resampling procedures using SmartPLS analysis software (Ringle et al., 2015). This provided weights' corresponding to t- and p-values. Evidence of reliability and validity was confirmed in this outer model using these statistics (see Results section). Having checked the quality attributes of the model measurement indicators (i.e., outer model), the next step is therefore to examine the inner model involving the latent constructs (Hair et al., 2011).

Inner Model Evaluation

Coefficient of Determination (R^2)

As PLS-SEM has been adopted in this case, and because this approach makes no assumptions about the normality of distribution of the data, the inner model was evaluated using variance-based, non-parametric criteria (Chin, 2010; Henseler et al., 2009). Primary to this inner model evaluation was the coefficient of determination (R^2), which measured the amount of variance in the latent dependent construct that is explained by the latent independent constructs.

Model Fit

Some researchers (e.g., Henseler et al., 2016; L. Hu & Bentler, 1999; L.-T. Hu & Bentler, 1998) have recommended the use of Standardised Root Mean-square Residual (SRMR) as a robust measure of the quality of fitted model results. According to the authors, SRMR values of 0.08 and less are ideal and reasonable confirmation that the data used followed the composite-based (formative) PLS-SEM model and not reflective CB-SEM model. This means measurement indicators influenced constituted latent constructs. Furthermore, an SRMR value of 0.08 or less would mean that if the current study's fisheries data contained some inaccuracies, then the SEM model would address these inadequacies if the numerical differences between the accurate and these inaccurate data were 0.08 or less. This suggests, even in the worst-case scenario of inaccurate data, that the SEM model would still be well-fitted to give accurate results.

Tests for Heterogeneity (Observed & Unobserved)

Subpopulation/groups within the sample may differ in terms of how latent variables impact on intention to adopt the proposed traceability solution. For example, Facilitating Conditions (FC) may have a more significant effect on intention in the case of marine than freshwater fishers. This would mean that there is heterogeneity within the fishers' sample in terms of the effect of the FC independent latent construct/variable. Heterogeneity can either be observable or unobservable (Hair et al., 2011). Observable heterogeneity simply means that data has been collected on a socio-demographic dimension causing the heterogeneity, while unobserved heterogeneity means that data have not been captured for the socio-demographic dimension causing the effect. As heterogeneity cannot always be captured fully by the researcher's preconceived theoretical model (Jedidi et al., 1997), it is necessary to define these two forms of heterogeneity so that unobserved heterogeneity can be tested for. According to Lubke & Muthén (2005), observed heterogeneity occurs when subpopulations are defined, *a priori*, based on known variables, while unobserved heterogeneity occurs when the subpopulations in the data are unknown. Observable heterogeneity is an assessment of the existence of statistically significant segment differences (Cheah et al., 2020). This occurs when segment parameter differences are expected, *a priori*, for a given variable, based on well-established theory incorporating moderators (Becker et al., 2013). These moderators or contextual factors may include cultural differences (e.g., individualism versus collectivism; Srite & Karahanna, 2006). Other moderators include demographic differences (e.g., gender, income, and education; Venkatesh et al., 2003), and organisational demographic differences such as large versus small business firms (Rai et al., 2006). In the current study, however, all heterogeneity would be observable because the tests are to be undertaken on five potential moderators that had been identified *a priori* with socio-demographic variables that already existed in the data.

Based on the preceding definition of observed heterogeneity, it was necessary in the context of the current study to establish whether there were significant statistical differences between two fisheries segments: freshwater fishers/boat owners (N=177) and marine fishers/boat owners (N=357). These differences were tested on such dimensions as the latent independent constructs, and demographic variables like age, experience, education, and profitability. If found significant, these subpopulation differences would need to be accounted for in terms of moderating effects on relationships between the latent independent constructs and the latent dependent construct. This is because heterogeneity is believed to be a common characteristic of various consumer populations, leading to observable market segmentation strategies for diverse offerings of products and services (Cheah et al., 2020). Therefore, to enhance the reliability and validity of this work, it was necessary to test for heterogeneity between various subpopulations in the current study (Sarstedt & Ringle, 2010) including freshwater and marine fishers. Therefore, the observable subpopulation heterogeneity was tested through the multi-group analysis (MGA) function available in the

SmartPLS package (Ringle et al., 2015). This MGA procedure tested whether significant statistical moderating effects existed in the identified five subpopulation variables. As presented earlier, these moderating subpopulations were fishery type, age, experience, education, and profitability.

Appendix B4: Results of Fishers' Large-Scale Survey

Multicollinearity

Table 53: Deleted and Retained Singular Matrix Elements for the Independent Latent Construct of Complementary Technology (CT).

Complementary Technology (CT) elements	Statistical analysis Label	Repetitive elements (1s/534)*	1s as percentage of responses	Decision
Mobile text messages	CT11	29	5%	Retained
Mobile money	CT15	34	6%	Retained
Non-smart mobile phone	CT10	37	7%	Retained
Fish ice storage	CT17	131	25%	Retained
Bank account	CT16	177	33%	Retained
Smart mobile phone	CT9	215	40%	Retained
Radio frequency identification (RFID) sensors	CT14	294	55%	Retained
Email on mobile device/phone	CT7	332	62%	Retained
Internet on mobile device/phone	CT4	350	66%	Retained
Google Maps Platform Services	CT20	413	77%	Deleted
Internet of things (IoT)	CT6	425	80%	Deleted
iPads	CT2	434	81%	Deleted
Internet on computer	CT5	447	84%	Deleted
Email on computer	CT8	447	84%	Deleted
Google Cloud Services	CT21	448	84%	Deleted
General use of computers	CT1	451	84%	Deleted
Digital cameras	CT3	456	85%	Deleted
Quick response (QR) codes	CT13	475	89%	Deleted
Fish deep cold storage facilities	CT18	505	95%	Deleted
Barcodes	CT12	516	97%	Deleted
Blockchain	CT19	533	100%	Deleted

Source: Researcher's own calculations.

Note: * These 1s relate to responses from fishers (boat owners) suggesting they had not experienced using listed technology items.

Table 54: Multicollinearity Between Measurement Indicators Contributing to Latent Constructs (Outer Model).

Measurement indicator description	Indicator label	VIF (initial)	VIF (final)
I intend to pay for and use traceability solution in future fishing.	BI1	2.5	2.5
I will definitely pay for and use traceability solution in daily fishing.	BI2	1.7	1.7
I am planning to pay for and use traceability solution in future fishing.	BI3	2.4	2.4
Usage of internet on mobile device/phone	CT4	3.7	3.7
Usage of email on mobile device/phone	CT7	3.5	3.5
Usage of smart mobile phone	CT9	1.9	1.9
Usage of non-smart mobile phone	CT10	1.7	1.7
Usage of mobile text messages	CT11	2.6	2.6
Usage of radio frequency identification (RFID) sensors	CT14	1.6	1.6
Usage of mobile money services	CT15	2.1	2.1
Usage of bank account	CT16	1.5	1.5
Usage of fish ice storage	CT17	1.8	1.8
Effort to use this traceability solution in fishing is acceptable.	EE1	7.1	-
Traceability solution easy to use in fishing activities.	EE2	4.4	3.4
It is easy to learn skills needed to use this traceability solution in fishing.	EE3	5.9	3.4
Interaction with this traceability solution is clear and understandable to me.	EE4	1.1	1.1
I have resources necessary to use traceability solution in fishing.	FC1	6.8	3.8
I have knowledge necessary to adopt and use traceability solution in fishing.	FC2	7.5	-
This traceability solution is compatible with other technologies I use.	FC3	7.1	-
Others can help me when I have difficulties using this traceability solution in fishing.	FC4	5.9	3.8
I'm motivated to use traceability solution in future fishing.	HM1	3.7	3.7
I'm motivated to use traceability solution in present fishing.	HM2	2.5	2.5
Experience of using traceability solution in fishing would be rewarding to me.	HM3	2.9	2.9
Using this traceability solution in fishing would become a habit for me.	HT1	2.3	2.3
I will be addicted to using this traceability solution in fishing.	HT2	1.7	1.7
I will definitely have to use this traceability solution in fishing.	HT3	2.0	2.0
Using this traceability solution in fishing will become natural.	HT4	1.4	1.4
This traceability solution will enhance my fishing catch volumes.	PE1	3.0	3.0

This traceability solution will enhance my fishing growth and scaling-up.	PE2	2.3	2.3
This traceability solution will enhance my fishing cost reduction.	PE3	2.9	2.9
This traceability solution will enhance my fishing productivity.	PE4	2.1	2.1
This traceability solution will enhance my profitability in fishing.	PE5	2.0	2.0
This traceability solution will enhance higher local fish prices.	PE6	1.9	1.9
This traceability solution will enhance higher fish export prices in UK & EU.	PE7	1.7	1.7
This traceability solution will enhance avoidance of breaching illegal & unsustainable fishing regulations.	PE8	1.5	1.5
This traceability solution is reasonably priced for benefits it would provide.	PV1	2.6	2.6
This traceability solution is good value for money in fishing.	PV2	1.5	1.5
This traceability solution has value and would address problems I experience in fishing.	PV3	2.2	2.2
Important people would encourage me to use this traceability solution in fishing.	SI1	1.6	1.6
My behavioural influential people would approve of my using this traceability solution in fishing.	SI2	1.4	1.4
People with valuable opinions would prefer I use traceability solution in fishing.	SI3	1.7	1.7

Source: Researcher's own calculations.

Table 55: Multicollinearity Between Independent Latent Constructs (Inner Model).

Construct	VIF Value
Behavioural Intention (BI)	-
Complementary Technology (CT)	2.5
Effort Expectancy (EE)	2.0
Facilitating Conditions (FC)	2.3
Habit (HT)	1.7
Hedonic Motivation (HM)	1.6
Performance Expectancy (PE)	1.5
Price Value (PV)	1.7
Social Influence (SI)	1.1

Source: Researcher's own calculations.

Table 56: Outer Model Bootstrapping Results – Significance of Model Measurement Indicator Weights (Coefficients).

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
BI1 → Behavioural Intention	0.129	0.123	0.101	1.272	0.203
BI2 → Behavioural Intention	0.185*	0.190	0.080	2.309	0.021
BI3 → Behavioural Intention	0.776**	0.773	0.091	8.486	0.000
CT10 → Complementary Technology	0.028	0.021	0.098	0.289	0.773
CT11 → Complementary Technology	0.100	0.068	0.139	0.724	0.469
CT14 → Complementary Technology	-0.293	-0.159	0.259	1.128	0.260
CT15 → Complementary Technology	0.135	0.081	0.143	0.942	0.346
CT16 → Complementary Technology	-0.124	-0.058	0.137	0.906	0.365
CT17 → Complementary Technology	0.685	0.388	0.553	1.237	0.216
CT4 → Complementary Technology	0.009	0.009	0.123	0.074	0.941
CT7 → Complementary Technology	-0.078	-0.032	0.136	0.569	0.569
CT9 → Complementary Technology	-0.096	-0.048	0.125	0.770	0.441
EE2 → Effort Expectancy	0.082	0.082	0.168	0.488	0.625
EE3 → Effort Expectancy	0.835**	0.828	0.154	5.431	0.000
EE4 → Effort Expectancy	0.258**	0.255	0.093	2.766	0.006
FC1 → Facilitating Conditions	0.821**	0.820	0.158	5.205	0.000
FC4 → Facilitating Conditions	0.202	0.199	0.173	1.167	0.243
HM1 → Hedonic Motivation	0.243	0.238	0.162	1.504	0.133
HM2 → Hedonic Motivation	0.272	0.273	0.161	1.697	0.090
HM3 → Hedonic Motivation	0.570**	0.566	0.148	3.860	0.000
HT1 → Habit	0.274	0.275	0.143	1.912	0.056
HT2 → Habit	0.369**	0.356	0.126	2.934	0.003
HT3 → Habit	0.366**	0.363	0.136	2.683	0.007
HT4 → Habit	0.257*	0.254	0.114	2.253	0.024
PE1 → Performance Expectancy	-0.275	-0.269	0.156	1.761	0.078
PE2 → Performance Expectancy	0.168	0.162	0.141	1.193	0.233
PE3 → Performance Expectancy	0.485**	0.470	0.155	3.128	0.002
PE4 → Performance Expectancy	0.021	0.025	0.133	0.155	0.877

PE5 → Performance Expectancy	0.058	0.062	0.142	0.410	0.682
PE6 → Performance Expectancy	0.408**	0.393	0.129	3.156	0.002
PE7 → Performance Expectancy	0.218	0.206	0.132	1.645	0.100
PE8 → Performance Expectancy	0.165	0.164	0.119	1.386	0.166
PV1 → Price Value	0.072	0.071	0.173	0.416	0.678
PV2 → Price Value	0.580**	0.574	0.123	4.700	0.000
PV3 → Price Value	0.518**	0.513	0.136	3.797	0.000
SI1 → Social Influence	0.563*	0.532	0.267	2.106	0.035
SI2 → Social Influence	0.894**	0.848	0.197	4.547	0.000
SI3 → Social Influence	-0.740**	-0.691	0.251	2.944	0.003

Source: Researcher's own calculations. Notes: The SmartPLS data analysis settings were: 5,000 resamples, Parallel Processing, Two-tailed test, Complete Bootstrapping and Bias-Corrected and Accelerated (BCa) Bootstrap, Weighting Scheme: Path; Maximum Iterations: 300; Stop Criterion: $1x10^{-7}$.*=significant at 5% level; **=significant at 1% level.

Table 57: Improved Outer Model Bootstrapping Results – Significance of Model Measurement Indicator Weights (Coefficients).

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (O/STDEV)	P values
BI1 → Behavioural Intention	0.130	0.127	0.098	1.326	0.185
BI2 → Behavioural Intention	0.167*	0.172	0.076	2.193	0.028
BI3 → Behavioural Intention	0.788**	0.784	0.086	9.151	0.000
CT14 → Complementary Technology	-0.387**	-0.384	0.081	4.766	0.000
CT15 → Complementary Technology	0.144	0.142	0.087	1.645	0.100
CT17 → Complementary Technology	0.730**	0.728	0.076	9.643	0.000
EE3 → Effort Expectancy	0.904**	0.901	0.047	19.085	0.000
EE4 → Effort Expectancy	0.262**	0.260	0.094	2.787	0.005
FC1 → Facilitating Conditions	0.819**	0.818	0.158	5.179	0.000
FC4 → Facilitating Conditions	0.204	0.201	0.173	1.177	0.239
HM1 → Hedonic Motivation	0.243	0.238	0.161	1.503	0.133
HM2 → Hedonic Motivation	0.269	0.269	0.161	1.670	0.095
HM3 → Hedonic Motivation	0.574**	0.570	0.147	3.906	0.000
HT1 → Habit	0.272	0.273	0.144	1.895	0.058
HT2 → Habit	0.369**	0.355	0.126	2.925	0.003
HT3 → Habit	0.368**	0.365	0.136	2.704	0.007
HT4 → Habit	0.258*	0.255	0.115	2.253	0.024
PE1 → Performance Expectancy	-0.260	-0.255	0.154	1.689	0.091
PE2 → Performance Expectancy	0.176	0.174	0.140	1.255	0.210
PE3 → Performance Expectancy	0.512**	0.504	0.142	3.604	0.000
PE6 → Performance Expectancy	0.412**	0.401	0.130	3.168	0.002
PE7 → Performance Expectancy	0.226	0.218	0.131	1.733	0.083
PE8 → Performance Expectancy	0.166	0.166	0.119	1.395	0.163
PV2 → Price Value	0.602**	0.599	0.103	5.866	0.000
PV3 → Price Value	0.561**	0.558	0.105	5.358	0.000
SI1 → Social Influence	0.553*	0.522	0.268	2.066	0.039
SI2 → Social Influence	0.900**	0.854	0.196	4.599	0.000
SI3 → Social Influence	-0.740**	-0.690	0.253	2.926	0.003

Source: Researcher's own calculations. Notes: The SmartPLS data analysis settings were: 5,000 resamples, Parallel Processing, Two-tailed test, Complete Bootstrapping and Bias-Corrected and Accelerated (BCa) Bootstrap, Weighting Scheme: Path; Maximum Iterations: 300; Stop Criterion: 1x10^{-7}.*=significant at 5% level; **=significant at 1% level.

Table 58: Model Fit Measures.

Measure	Saturated Model	Estimated Model
SRMR	0.037	0.038

Source: Researcher's own calculations.

Table 59: Multigroup Analysis (MGA) Fishery Differences Test (Heterogeneity)– Freshwater & Marine Fishers.

Construct relationships	Path Coefficients-diff (freshw - marine)	1-tailed (freshw vs marine) p-value	2-tailed (freshw vs marine) p-value
Complementary Technology → Behavioural Intention	0.019	0.405	0.809
Effort Expectancy → Behavioural Intention	-0.116	0.840	0.320
Facilitating Conditions → Behavioural Intention	0.154	0.089	0.179
Habit → Behavioural Intention	-0.152	0.909	0.182
Hedonic Motivation → Behavioural Intention	-0.012	0.534	0.933
Performance Expectancy → Behavioural Intention	-0.178	0.950	0.099
Price Value → Behavioural Intention	0.200*	0.021	0.043
Social Influence → Behavioural Intention	0.163	0.080	0.160

Source: Researcher's own calculations. Notes: Basic settings made on SmartPLS software: Groups are "freshwater fishers", (N=177); and "marine fishers", (N=357); Subsamples = 5000; Do Parallel processing; Amount of results = Complete bootstrapping; Confidence interval method: Bias-Corrected and Accelerated (BCa) Bootstrap; Test type: Two-tailed; Significance level =0.05; weighting scheme = Path; Maximum iterations = 300; stop criterion = 10^{-7}. *= significant at 5% level

Table 60: Multigroup Analysis (MGA) Test of Age differences (Heterogeneity) – Young & Mid-Old Fishers.

	Path Coefficients-diff (young - mid-old)	1-tailed (young vs mid-old) p-value	2-tailed (young vs mid-old) p-value
Complementary Technology → Behavioural Intention	-0.076	0.752	0.496
Effort Expectancy → Behavioural Intention	0.137	0.120	0.240
Facilitating Conditions → Behavioural Intention	0.133	0.128	0.257
Habit → Behavioural Intention	0.060	0.294	0.588
Hedonic Motivation → Behavioural Intention	-0.120	0.873	0.253
Performance Expectancy → Behavioural Intention	-0.034	0.620	0.759
Price Value → Behavioural Intention	-0.064	0.729	0.543
Social Influence → Behavioural Intention	-0.061	0.734	0.532

Source: Researcher’s own calculations. Notes: Basic settings made on SmartPLS software: Groups are “young fishers”, (N=311); and “mid to old fishers”, (N=223); Subsamples = 5000; Do Parallel processing; Amount of results = Complete bootstrapping; Confidence interval method: Bias-Corrected and Accelerated (BCa) Bootstrap; Test type: Two-tailed; Significance level =0.05; weighting scheme = Path; Maximum iterations = 300; stop criterion = $10^{-7.}$

Table 61: Multigroup Analysis (MGA) Test of Differences (Heterogeneity) Between Lowly Experienced and Highly Experienced Fishers.

	Path Coefficients-diff (<=10 years - >10 years)	1-tailed (<=10 years vs >10 years) p-value	2-tailed (<=10 years vs >10 years) p-value
Complementary Technology → Behavioural Intention	-0.047	0.674	0.652
Effort Expectancy → Behavioural Intention	0.188	0.049	0.099
Facilitating Conditions → Behavioural Intention	-0.081	0.756	0.489
Habit → Behavioural Intention	-0.063	0.714	0.573
Hedonic Motivation → Behavioural Intention	-0.001	0.499	0.999
Performance Expectancy → Behavioural Intention	-0.175	0.951	0.098
Price Vale → Behavioural Intention	0.142	0.076	0.151
Social Influence → Behavioural Intention	0.015	0.413	0.826

Source: Researcher’s own calculations. Notes: Basic settings made on SmartPLS software: Groups are “experienced fishers <=10 years”, (N=273); and “experienced fishers > 10 years”, (N=261); Subsamples = 5000; Do Parallel processing; Amount of results = Complete bootstrapping; Confidence interval method: Bias-Corrected and Accelerated (BCa) Bootstrap; Test type: Two-tailed; Significance level =0.05; weighting scheme = Path; Maximum iterations = 300; stop criterion = $10^{-7.}$

Table 62: Multigroup Analysis (MGA) Test of Differences (Heterogeneity) Between Fishers Without Formal Education and Formally Educated Fishers.

	Path Coefficients-diff (not formal - formal)	1-tailed (not formal vs formal) p-value	2-tailed (not formal vs formal) p-value
Complementary Technology → Behavioural Intention	-0.034	0.603	0.794
Effort Expectancy → Behavioural Intention	0.010	0.469	0.938
Facilitating Conditions → Behavioural Intention	-0.325**	0.998	0.005
Habit → Behavioural Intention	0.160	0.078	0.156
Hedonic Motivation → Behavioural Intention	0.092	0.199	0.399
Performance Expectancy → Behavioural Intention	0.178	0.059	0.118
Price Vale → Behavioural Intention	0.002	0.491	0.981
Social Influence → Behavioural Intention	-0.010	0.516	0.967

Source: Researcher’s own calculations. Notes: Basic settings made on SmartPLS software: Groups are “formally educated fishers”, (N=348); and “fishers without formal education”, (N=186); Subsamples = 5000; Do Parallel processing; Amount of results = Complete bootstrapping; Confidence interval method: Bias-Corrected and Accelerated (BCa) Bootstrap; Test type: Two-tailed; Significance level =0.05; weighting scheme = Path; Maximum iterations = 300; stop criterion = $10^{-7.}$ **= significant at 1% level.

Table 63: Multigroup Analysis (MGA) Test of Differences (Heterogeneity) Between Fishers With up to TZS50.0 Million and With Over TZS50.0 Million in Annual Pretax Profits.

	Path Coefficients-diff (<=TZS50.0mil - >TZS50.0mil)	1-tailed (<=TZS50.0mil vs >TZS50.0mil) p-value	2-tailed (<=TZS50.0mil vs >TZS50.0mil) p-value
Complementary Technology → Behavioural Intention	-0.074	0.716	0.568
Effort Expectancy → Behavioural Intention	-0.078	0.758	0.484
Facilitating Conditions → Behavioural Intention	0.191	0.058	0.117
Habit → Behavioural Intention	-0.061	0.695	0.610
Hedonic Motivation → Behavioural Intention	0.141	0.097	0.193
Performance Expectancy → Behavioural Intention	0.058	0.313	0.627
Price Vale → Behavioural Intention	-0.003	0.509	0.983
Social Influence → Behavioural Intention	-0.103	0.838	0.324

Source: Researcher's own calculations. Notes: Basic settings made on SmartPLS software:
Groups are "fishers with profit up to TZS50.0 million", (N=279); and "fishers with profit over TZS50.0 million", (N=255); Subsamples = 5000; Do Parallel processing; Amount of results = Complete bootstrapping; Confidence interval method: Bias-Corrected and Accelerated (BCa) Bootstrap; Test type: Two-tailed; Significance level =0.05; weighting scheme = Path; Maximum iterations = 300; stop criterion = 10^{-7}.

Table 64: Complete Final SEM-Model Results – Modelling of Direct and Indirect (Moderating and Mediating) Effects.

Hypothesised direct and indirect effects	Original sample	Sample mean	Standard deviation	T statistics	P values
Direct (main) effects					
Complementary Technology → Behavioural Intention	0.200	0.194	0.156	1.281	0.200
Complementary Technology → Effort Expectancy	0.462**	0.462	0.055	8.335	0.000
Education moderator → Behavioural Intention	0.016	0.017	0.078	0.201	0.841
Effort Expectancy → Behavioural Intention	0.014	0.016	0.157	0.092	0.927
Effort Expectancy → Hedonic Motivation	0.159**	0.160	0.054	2.946	0.003
Facilitating Conditions → Behavioural Intention	-0.020	-0.010	0.136	0.151	0.880
Facilitating Conditions → Effort Expectancy	0.288**	0.289	0.048	6.067	0.000
Facilitating Conditions → Hedonic Motivation	0.344**	0.343	0.053	6.514	0.000
Fishery moderator → Behavioural Intention	0.033	0.036	0.079	0.417	0.677
Habit → Behavioural Intention	0.093	0.110	0.139	0.669	0.504
Hedonic Motivation → Behavioural Intention	0.132	0.100	0.157	0.843	0.399
Performance Expectancy → Behavioural Intention	0.056	0.059	0.146	0.388	0.698
Performance Expectancy → Hedonic Motivation	0.118**	0.119	0.045	2.610	0.009
Price Value → Behavioural Intention	0.344*	0.353	0.134	2.574	0.010
Social Influence → Behavioural Intention	0.079	0.110	0.118	0.674	0.500
Indirect (moderating) effects					
Fishery moderator x Habit → Behavioural Intention	0.164	0.154	0.116	1.412	0.158
Fishery moderator x Price Value → Behavioural Intention	-0.263*	-0.267	0.121	2.162	0.031
Education moderator x Facilitating Conditions → Behavioural Intention	0.324**	0.311	0.121	2.665	0.008
Fishery moderator x Hedonic Motivation → Behavioural Intention	-0.035	-0.012	0.137	0.252	0.801
Fishery moderator x Facilitating Conditions → Behavioural Intention	-0.071	-0.080	0.122	0.576	0.565
Fishery moderator x Social Influence → Behavioural Intention	-0.091	-0.098	0.101	0.902	0.367

Fishery moderator x Effort Expectancy → Behavioural Intention	0.147	0.142	0.127	1.156	0.248
Fishery moderator x Performance Expectancy → Behavioural Intention	0.210	0.200	0.120	1.757	0.079
Fishery moderator x Complementary Technology → Behavioural Intention	-0.072	-0.062	0.127	0.571	0.568
Education moderator x Complementary Technology → Behavioural Intention	-0.023	-0.019	0.133	0.175	0.861
Education moderator x Habit → Behavioural Intention	-0.129	-0.133	0.123	1.050	0.294
Education moderator x Performance Expectancy → Behavioural Intention	-0.071	-0.065	0.120	0.591	0.555
Education moderator x Effort Expectancy → Behavioural Intention	0.075	0.068	0.136	0.553	0.580
Education moderator x Social Influence → Behavioural Intention	-0.027	-0.035	0.104	0.260	0.795
Education moderator x Hedonic Motivation → Behavioural Intention	-0.089	-0.069	0.121	0.733	0.464
Education moderator x Price Value → Behavioural Intention	-0.137	-0.140	0.114	1.197	0.231

Indirect (mediating) effects:

Hypothesised mediation effects	Coefficient (p_1 x p_2)	T-statistics	P values	Is (p_1 x p_2) significant? Y/N	Is p_3 significant? Y/N	Mediation Outcome (results)
EE→HM→BI	0.021	0.764	0.445	N	N	No effects (no mediation)
FC→HM→BI	0.046	0.836	0.403	N	N	No effects (no mediation)
PE→HM→BI	0.016	0.769	0.442	N	N	No effects (no mediation)
CT→EE→BI	0.007	0.091	0.928	N	N	No effects (no mediation)
FC→EE→BI	0.004	0.091	0.928	N	N	No effects (no mediation)

Note:
p_1 = a coefficient of the relationship between an independent construct to a mediator construct.
p_2 = a coefficient of the relationship between a mediator construct and a dependent construct.
p_3 = a coefficient of the (direct) relationship between an independent construct and a dependent construct.
The SmartPLS data analysis settings to capture direct and indirect (moderation and mediation) effects were: 5,000 resamples, Parallel Processing, Two-tailed test, Complete Bootstrapping and Bias-Corrected and Accelerated (BCa) Bootstrap, Weighting Scheme: Path; Maximum Iterations: 300; Stop Criterion: $1x10^{-7}$, * and ** = respectively significant at 5% and 1% levels.
Source: Researcher’s own calculations.

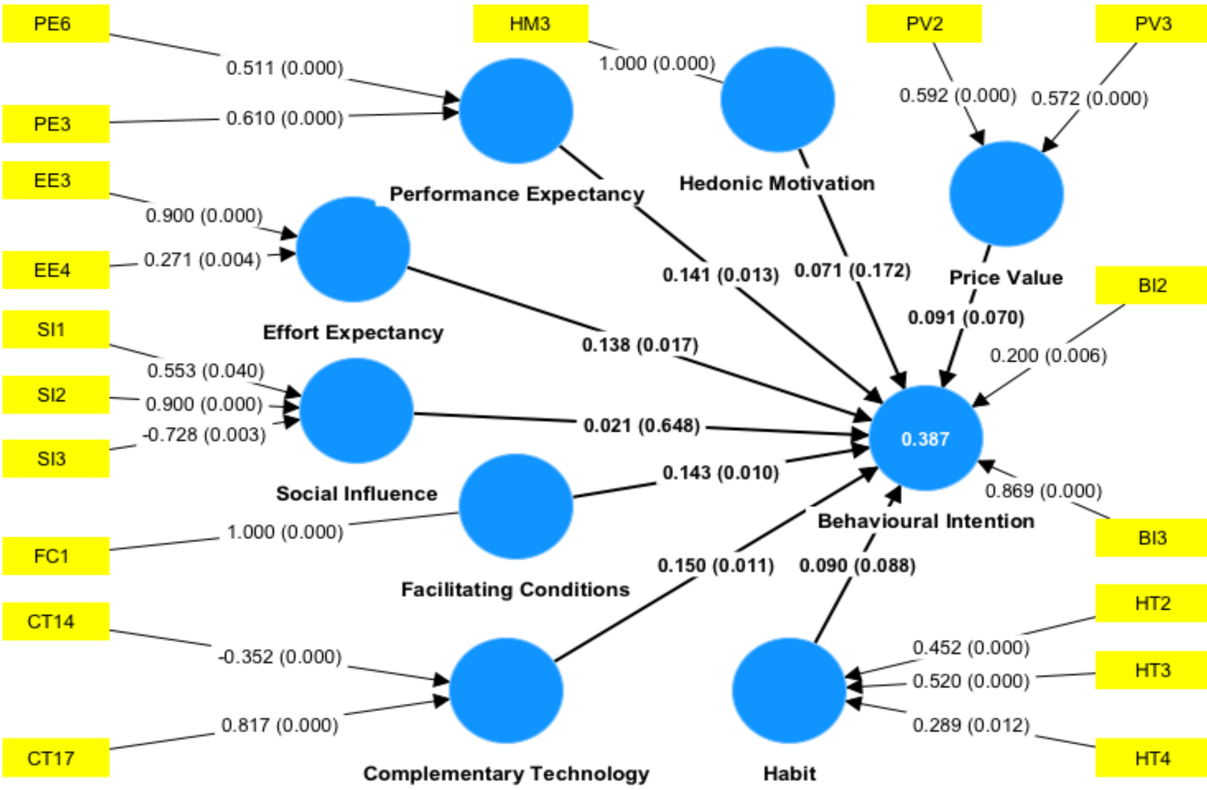

Figure 23: Estimated Parsimonious SEM-Model with Unadjusted R^2=38.7% (Behavioural Intention, BI).

Other values in the figure are regression path coefficient weights and corresponding p-values in brackets.

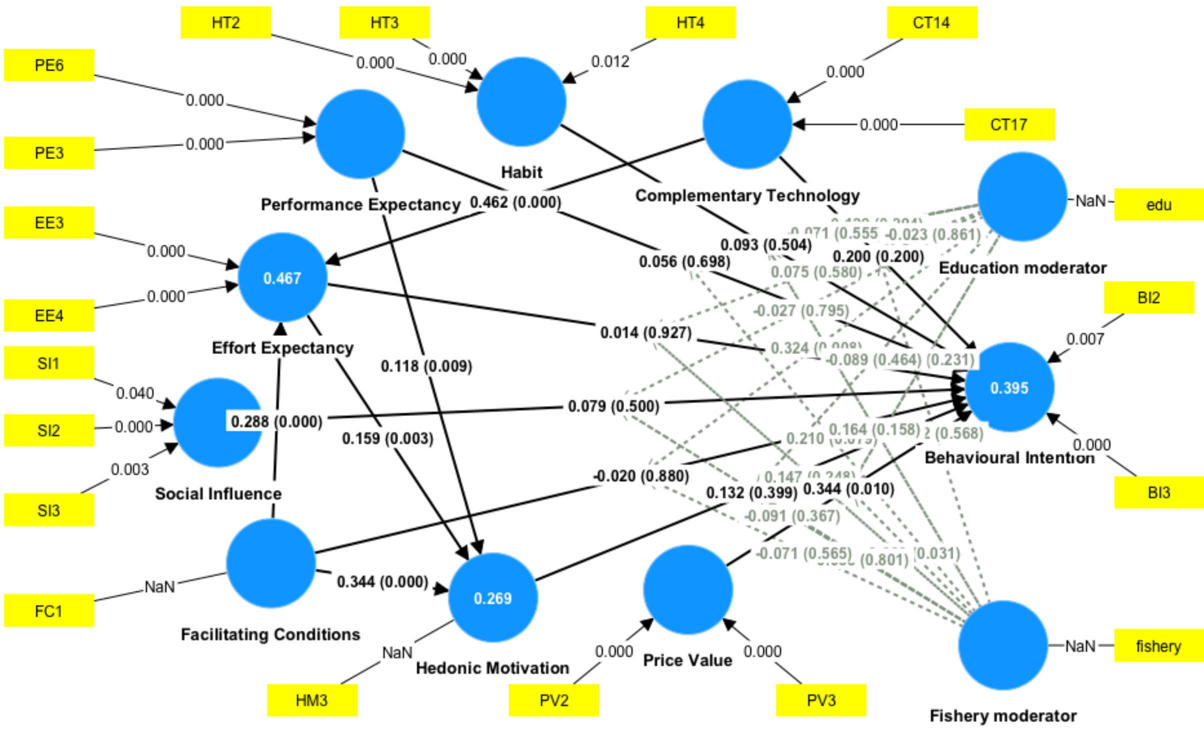

Figure 24: Final SEM-Model with Direct and Indirect (Moderating and Mediating) Effects. Adjusted R^2 = 39.5% (Behavioural Intention, BI).

Other values in the figure are regression path coefficient weights and corresponding p-values in brackets.
NaN = Not a Number.
Source: Researcher's own Figure.

Table 65: Comparing Hypothesised Direct and Moderated Relationships to Empirical Results.

Hypothesis description (i.e., latent independent constructs and moderators' influence on adoption of proposed traceability solution).	Hypothesised relationship (+ve) or (-ve)	Final results
Latent Independent Constructs Results		
H1: Performance Expectancy (PE) positively influences fishers' Behavioural Intention (BI).	PE→BI (+ve)	(+ve)*
H2: Effort Expectancy (EE) positively influences the fishers' Behavioural Intention (BI).	EE→BI (+ve)	(+ve)*
H3: Social Influence (SI) positively influences fishers' Behavioural Intention (BI).	SI→BI (+ve)	INS
H4: Facilitating Conditions (FC) positively influence the fishers' Behavioural Intention (BI).	FC→BI (+ve)	INS
H5: Hedonic Motivation (HM) positively influences fishers' Behavioural Intention (BI).	HM→BI (+ve)	INS
H6: Price Value (PV) positively influences the fishers' Behavioural Intention (BI).	PV→BI (+ve)	(+ve)**
H7: Usage of similar or Complementary Technology (CT) positively influences the fishers' Behavioural Intention (BI).	CT→BI (+ve)	(+ve)*
H8: Habit (HT) positively influences the fishers' Behavioural Intention (BI).	HT→BI (+ve)	INS
Results of Moderating Effects/Differences [(Moderator) →Independent Construct→Behavioural Intention (BI)]		
H9: Some or all of fishery type, gender, age, experience, education level, and profitability will moderate the effect of Facilitating Conditions (FC) on fishers' Behavioural Intention (BI).	(education)→FC→BI (+ve)	(+ve)*
	(MOD_1)→FC→BI (+ve)	INS
H10: Some or all of Fishery type, gender, age, experience, education level, and profitability will moderate the effect of Facilitating Conditions (FC) on fishers' Behavioural Intention (BI) such that the effect will be stronger among highly experienced and educated young men in freshwater fisheries.	(MOD_2)→FC→BI (+ve)	INS
H11: Fishery type, gender, age, experience, education level, and profitability will moderate the effect of Hedonic Motivation (HM) on fishers' Behavioural Intention (BI).	(MOD_3)→HM→BI (+ve)	INS
H12: Fishery type, gender, age, experience, education level, and profitability will moderate the effect of Hedonic Motivation (HM) on fishers' Behavioural Intention (BI) such that the effect will be stronger among more educated young freshwater male fishers with less experience.	(MOD_4)→HM→BI (+ve)	INS
H13: Fishery type, gender, age, education level, and profitability will moderate the effect of Price Value (PV) on fishers' Behavioural Intention (BI) to adopt the proposed traceability solution.	(fishery)→PV→BI (+ve)	(-ve)*
	(MOD_5)→PV→BI (+ve)	INS
H14: Fishery type, gender, age, education level, and profitability will moderate the effect of Price Value (PV) on	(MOD_6)→PV→BI (+ve)	INS

fishers' Behavioural Intention (BI) such that the effect will be stronger among less educated young male marine fishers.		
H15: Fishery type, gender, age, education level, and profitability will moderate the effect of Habit (HT) on fishers' Behavioural Intention (BI).	(fishery)→HT→BI (+ve)	(+ve)*
	(MOD_7)→HT→BI (+ve)	INS
H16: Fishery type, gender, age, education level, and profitability will moderate the effect of Habit (HT) on fishers' Behavioural Intention (BI) such that the effect will be stronger among more educated young freshwater male fishers with less experience.	(MOD_8)→HT→BI (+ve)	INS

Notes: *=significant at 5% level; **=significant at 1% level; INS= insignificant; (+ve)=positive influence; (-ve)=negative influence; MOD=Moderator(s); MOD_1, MOD_2,….MOD_8 = sets of moderator variables under each hypothesis.
Source: Researcher's own calculations.

Table 66: Bootstrapping FIMIX-PLS Results for Fishery Type Moderator Segments

Freshwater Fishers (N=177)

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (O/STDEV)	P values
Complementary Technology → Behavioural Intention	0.140	0.101	0.129	1.086	0.277
Effort Expectancy → Behavioural Intention	0.090	0.090	0.092	0.973	0.330
Facilitating Conditions → Behavioural Intention	0.236**	0.227	0.088	2.672	0.008
Habit → Behavioural Intention	0.001	0.027	0.090	0.014	0.989
Hedonic Motivation → Behavioural Intention	0.051	0.042	0.097	0.527	0.598
Performance Expectancy → Behavioural Intention	0.074	0.09	0.087	0.847	0.397
Price Value → Behavioural Intention	0.210**	0.216	0.076	2.778	0.005
Social Influence → Behavioural Intention	0.137	0.149	0.104	1.323	0.186

Marine Fishers (N=357)

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (O/STDEV)	P values
Complementary Technology → Behavioural Intention	0.122	0.127	0.071	1.703	0.089
Effort Expectancy → Behavioural Intention	0.206**	0.203	0.072	2.847	0.004
Facilitating Conditions → Behavioural Intention	0.082	0.071	0.073	1.129	0.259
Habit → Behavioural Intention	0.154*	0.161	0.069	2.217	0.027
Hedonic Motivation → Behavioural Intention	0.063	0.059	0.065	0.969	0.332
Performance Expectancy → Behavioural Intention	0.251**	0.248	0.064	3.908	0.000
Price Value → Behavioural Intention	0.010	0.017	0.063	0.166	0.869
Social Influence → Behavioural Intention	-0.026	-0.003	0.060	0.428	0.669

Notes:
Basic settings made on SmartPLS software: Set-up Parameter Settings: Subsamples = 5000; Ticked = Parallel Processing; Amount of Results = Complete Bootstrapping; Confidence Interval Method = Bias-Corrected and Accelerated (BCa) Bootstrap; Test Type = Two Tailed; Significance Level = 0.05. Partial Least Square Settings: Weighting Scheme = Path; Maximum Iterations = 300; Stop Criterion (10^-X) = 7, that is 10^{-7}. Bootstrapped Groups: Whole sample with 2 fishery type (freshwater & marine) moderating segment samples. *=Significant at 5% Level; **= Significant at 1% Level.

Table 67: Bootstrapping FIMIX-PLS Results for Education Moderator Segments

Fishers Without Formal Education (N=186)

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (O/STDEV)	P values
Complementary Technology → Behavioural Intention	0.124	0.129	0.110	1.130	0.259
Effort Expectancy → Behavioural Intention	0.146	0.150	0.097	1.505	0.132
Facilitating Conditions → Behavioural Intention	-0.070	-0.081	0.092	0.760	0.447
Habit → Behavioural Intention	0.193*	0.202	0.094	2.053	0.040
Hedonic Motivation → Behavioural Intention	0.133	0.113	0.087	1.529	0.126
Performance Expectancy → Behavioural Intention	0.285**	0.281	0.091	3.128	0.002
Price Value → Behavioural Intention	0.083	0.096	0.085	0.983	0.326
Social Influence → Behavioural Intention	0.027	0.051	0.102	0.262	0.793

Fishers With Formal Education (N=348)

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (O/STDEV)	P values
Complementary Technology → Behavioural Intention	0.158*	0.155	0.071	2.221	0.026
Effort Expectancy → Behavioural Intention	0.136*	0.134	0.065	2.083	0.037
Facilitating Conditions → Behavioural Intention	0.254**	0.246	0.067	3.775	0.000
Habit → Behavioural Intention	0.033	0.047	0.062	0.522	0.602
Hedonic Motivation → Behavioural Intention	0.041	0.037	0.068	0.603	0.546
Performance Expectancy→Behavioural Intention	0.106	0.111	0.065	1.633	0.102
Price Value →Behavioural Intention	0.081	0.084	0.061	1.333	0.182
Social Influence → Behavioural Intention	0.036	0.053	0.054	0.669	0.504

Notes:
Basic settings made on SmartPLS software: Set-up Parameter Settings: Subsamples = 5000; Ticked = Parallel Processing; Amount of Results = Complete Bootstrapping; Confidence Interval Method = Bias-Corrected and Accelerated (BCa) Bootstrap; Test Type = Two Tailed; Significance Level = 0.05. Partial Least Square Settings: Weighting Scheme = Path; Maximum Iterations = 300; Stop Criterion (10^-X) = 7, that is 10^{-7}. Bootstrapped Groups: Whole sample with 2 education moderating segment samples (fishers without formal education & with formal education). *=Significant at 5% Level; **= Significant at 1% Level.

Freshwater fisheries

Table 68: Test Results of Direct and Indirect Effects for Freshwater Fisheries

Hypothesised Direct and Indirect Effects (Relationships)	Coefficient *(p_3)*	Sample mean (M)	Standard deviation	T statistics	P values
Direct (main) effects					
Complementary Technology → Behavioural Intention	0.137*	0.140	0.058	2.348	0.019
Complementary Technology → Effort Expectancy	0.462**	0.462	0.055	8.335	0.000
Effort Expectancy → Behavioural Intention	0.146*	0.143	0.059	2.499	0.012
Effort Expectancy → Hedonic Motivation	0.159**	0.160	0.054	2.946	0.003
Facilitating Conditions → Behavioural Intention	-0.038	-0.038	0.077	0.489	0.625
Facilitating Conditions → Effort Expectancy	0.288**	0.289	0.048	6.067	0.000
Facilitating Conditions → Hedonic Motivation	0.344**	0.343	0.053	6.514	0.000
Habit → Behavioural Intention	0.258**	0.261	0.086	2.986	0.003
Hedonic Motivation → Behavioural Intention	0.066	0.061	0.052	1.255	0.209
Performance Expectancy → Behavioural Intention	0.146*	0.144	0.058	2.517	0.012
Performance Expectancy → Hedonic Motivation	0.118**	0.119	0.045	2.610	0.009
Price Value → Behavioural Intention	0.090	0.094	0.049	1.843	0.065
Social Influence → Behavioural Intention	0.013	0.030	0.044	0.288	0.773
education moderator → Behavioural Intention	0.011	0.009	0.072	0.145	0.884
Indirect (moderating) effects					
education moderator x Habit → Behavioural Intention	-0.244*	-0.238	0.097	2.526	0.012
education moderator x Facilitating Conditions → Behavioural Intention	0.280**	0.274	0.084	3.337	0.001
Indirect (mediating) effects					
Hypothesised effects (relationships)	Coefficient *(p_1xp_2)*	Sample mean (M)	Standard deviation	T statistics	P values
Facilitating Conditions → Effort Expectancy → Hedonic Motivation → Behavioural Intention	0.003	0.003	0.003	1.035	0.301
Complementary Technology → Effort Expectancy → Hedonic Motivation → Behavioural Intention	0.005	0.005	0.005	1.036	0.300
Effort Expectancy → Hedonic Motivation → Behavioural Intention	0.010	0.010	0.010	1.057	0.291

Performance Expectancy → Hedonic Motivation → Behavioural Intention	0.008	0.007	0.007	1.081	0.280
Facilitating Conditions → Effort Expectancy → Behavioural Intention	0.042*	0.041	0.018	2.328	0.020
Facilitating Conditions → Hedonic Motivation → Behavioural Intention	0.023	0.021	0.018	1.247	0.213
Complementary Technology → Effort Expectancy → Hedonic Motivation	0.073**	0.074	0.027	2.712	0.007
Complementary Technology → Effort Expectancy → Behavioural Intention	0.068*	0.066	0.029	2.370	0.018
Facilitating Conditions → Effort Expectancy → Hedonic Motivation	0.046**	0.046	0.017	2.659	0.008

Note:
p_1 = a coefficient of the relationship between an independent construct to a mediator construct.
p_2 = a coefficient of the relationship between a mediator construct and a dependent construct.
p_3 = a coefficient of the (direct) relationship between an independent and a dependent construct.
The SmartPLS data analysis settings to capture mediation effects were: 5,000 resamples, Parallel Processing, Two-tailed test, Complete Bootstrapping and Bias-Corrected and Accelerated (BCa) Bootstrap, Weighting Scheme: Path; * and **= significant at 5% and 1% levels, respectively.
Source: Researcher's own calculations.

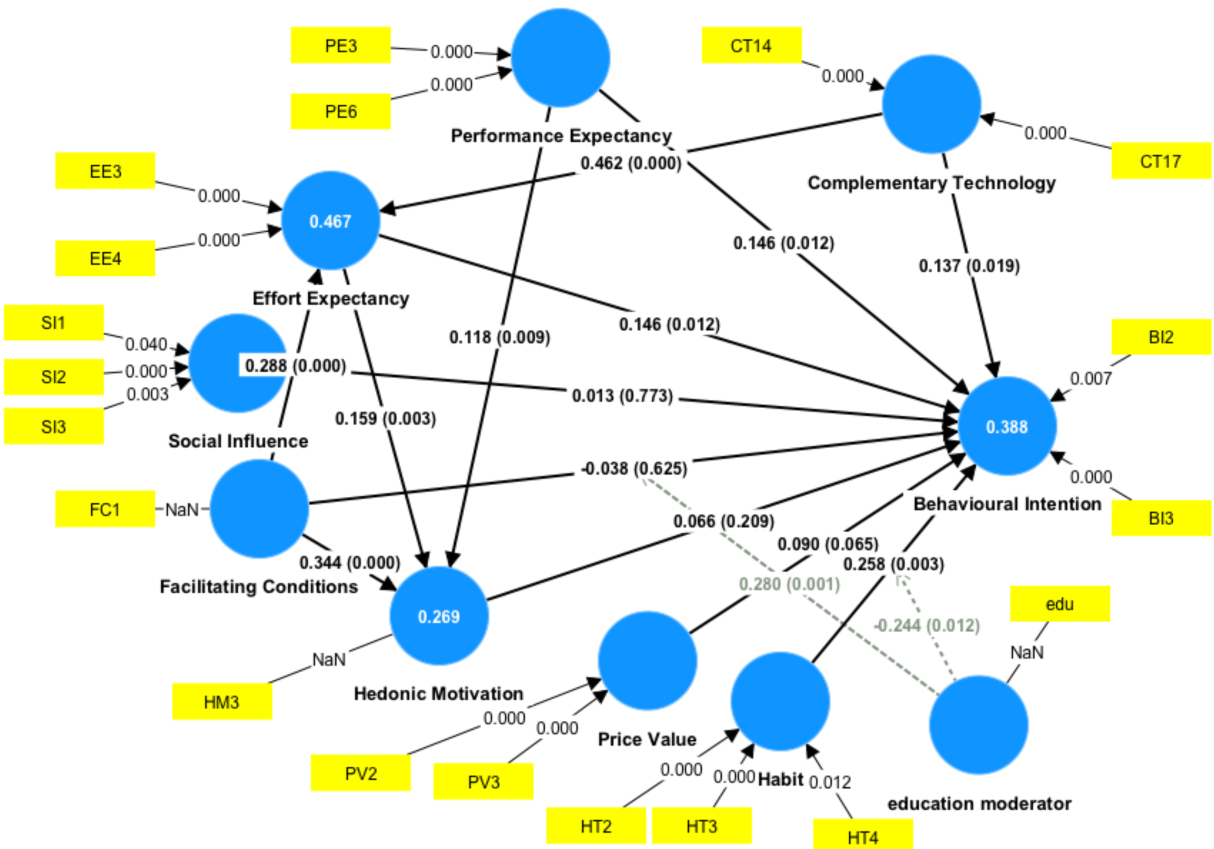

Figure 25: Final Parsimonious SEM-Model (Freshwater Fisheries) with Direct and Indirect (Moderating and Mediating) Effects.

Note: Adjusted R^2 = 38.8% (Behavioural Intention). Other values in the figure are regression path coefficient weights and corresponding p-values in brackets. The SmartPLS data analysis settings were: 5,000 resamples, Parallel Processing, Two-tailed test, Complete Bootstrapping and Bias-Corrected and Accelerated (BCa) Bootstrap, Weighting Scheme: Path; Maximum Iterations: 300; Stop Criterion: $1x10^{-7}$. NaN = Not a Number.

Source: Researcher's own Figure.

Marine fisheries

Table 69: Test Results of Direct and Indirect Effects for Marine Fisheries

Hypothesised Direct and Indirect Effects (Relationships)	Coefficient (p_3)	Sample mean (M)	Standard deviation	T statistics	P values
Direct (main) effects					
Complementary Technology → Behavioural Intention	0.092	0.097	0.073	1.256	0.209
Complementary Technology → Effort Expectancy	0.445**	0.444	0.080	5.554	0.000
Effort Expectancy → Behavioural Intention	0.215**	0.210	0.076	2.825	0.005
Effort Expectancy → Hedonic Motivation	0.198**	0.201	0.068	2.925	0.003
Facilitating Conditions → Behavioural Intention	-0.022	-0.027	0.093	0.242	0.809
Facilitating Conditions → Effort Expectancy	0.295**	0.293	0.062	4.742	0.000
Facilitating Conditions → Hedonic Motivation	0.334**	0.332	0.062	5.356	0.000
Habit → Behavioural Intention	0.277**	0.283	0.095	2.918	0.004
Hedonic Motivation → Behavioural Intention	0.064	0.059	0.066	0.970	0.332
Performance Expectancy → Behavioural Intention	0.261**	0.256	0.064	4.050	0.000
Performance Expectancy → Hedonic Motivation	0.105	0.105	0.058	1.819	0.069
Price Value → Behavioural Intention	0.014	0.020	0.062	0.231	0.817
Social Influence → Behavioural Intention	-0.028	-0.005	0.059	0.467	0.640
education moderator → Behavioural Intention	0.032	0.034	0.082	0.386	0.699
Indirect (moderating) effects					
education moderator x Habit → Behavioural Intention	-0.231*	-0.228	0.116	2.000	0.046
education moderator x Facilitating Conditions → Behavioural Intention	0.209*	0.199	0.103	2.026	0.043
Indirect (mediating) effects					
Hypothesised effects (relationships)	Coefficient (p_1xp_2)	Sample mean (M)	Standard deviation	T statistics	P values

Facilitating Conditions → Effort Expectancy → Hedonic Motivation → Behavioural Intention	0.004	0.004	0.004	0.828	0.408
Complementary Technology → Effort Expectancy → Hedonic Motivation → Behavioural Intention	0.006	0.005	0.007	0.829	0.407
Effort Expectancy → Hedonic Motivation → Behavioural Intention	0.013	0.012	0.015	0.855	0.392
Performance Expectancy → Hedonic Motivation → Behavioural Intention	0.007	0.006	0.008	0.789	0.430
Facilitating Conditions → Effort Expectancy → Behavioural Intention	0.063*	0.062	0.027	2.392	0.017
Facilitating Conditions → Hedonic Motivation → Behavioural Intention	0.021	0.019	0.022	0.954	0.340
Complementary Technology → Effort Expectancy → Hedonic Motivation	0.088*	0.090	0.036	2.465	0.014
Complementary Technology → Effort Expectancy → Behavioural Intention	0.096*	0.093	0.038	2.509	0.012
Facilitating Conditions → Effort Expectancy → Hedonic Motivation	0.058*	0.059	0.023	2.513	0.012

Note:
p_1 = a coefficient of the relationship between an independent construct to a mediator construct.
p_2 = a coefficient of the relationship between a mediator construct and a dependent construct.
p_3 = a coefficient of the (direct) relationship between an independent and a dependent construct.
The SmartPLS data analysis settings to capture mediation effects were: 5,000 resamples, Parallel Processing, Two-tailed test, Complete Bootstrapping and Bias-Corrected and Accelerated (BCa) Bootstrap, Weighting Scheme: Path; * and **= significant at 5% and 1% levels, respectively.
Source: Researcher's own calculations.

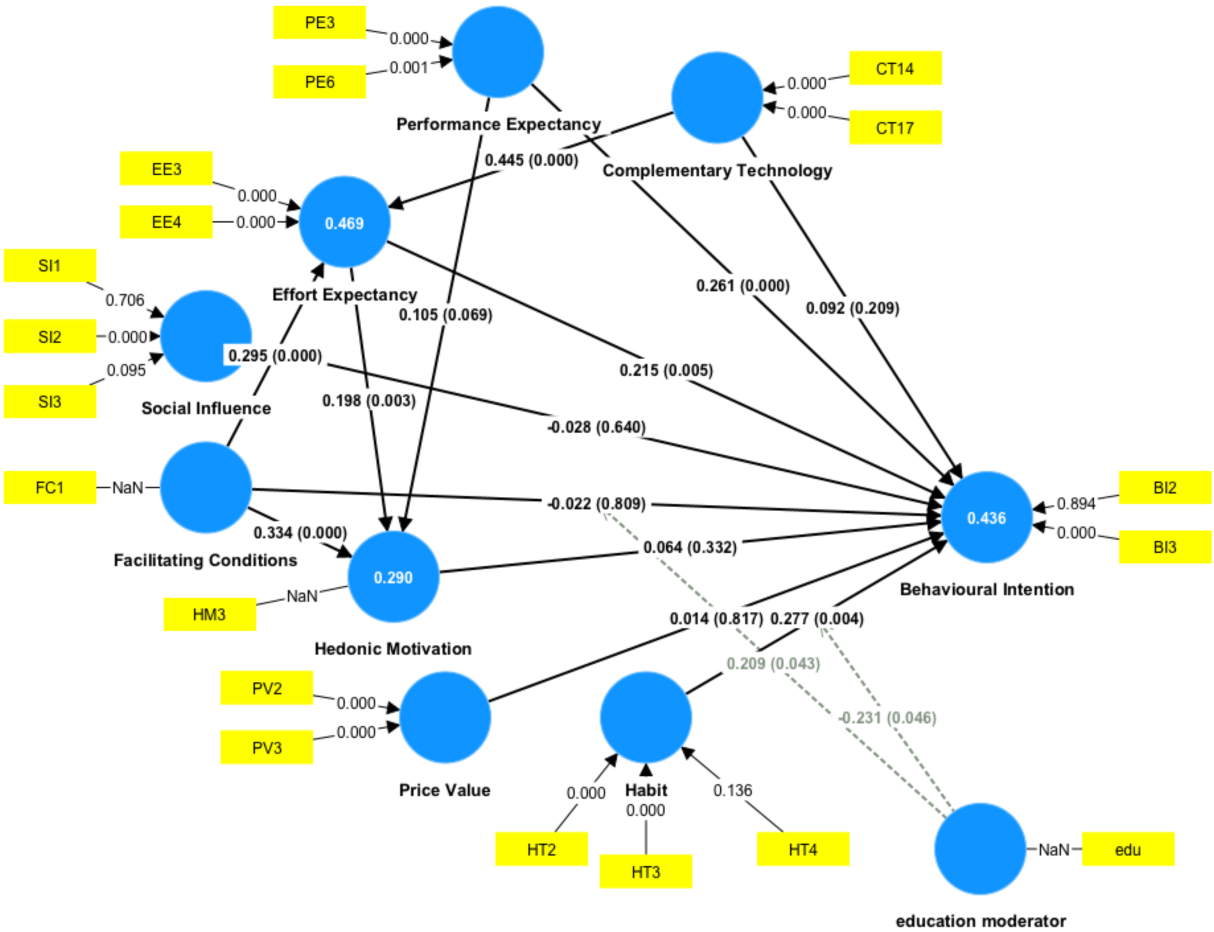

Figure 26: Final Parsimonious SEM-Model (Marine Fisheries) with Direct and Indirect (Moderating and Mediating) Effects.

Note: Adjusted R^2 = 43.6% (Behavioural Intention). Other values in the figure are regression path coefficient weights and corresponding p-values in brackets. The SmartPLS data analysis settings were: 5,000 resamples, Parallel Processing, Two-tailed test, Complete Bootstrapping and Bias-Corrected and Accelerated (BCa) Bootstrap, Weighting Scheme: Path; Maximum Iterations: 300; Stop Criterion: $1x10^{-7}$. NaN = Not a Number.

Source: Researcher's own Figure.

Appendix C4: Fishers' Large Scale Survey Questionnaire

IMPROVING CREDIBILITY AND TRACEABILITY IN FISHERIES SUPPLY AND VALUE CHAINS: THE CASE STUDY OF TANZANIA

Data entry code/ID:……………..

Participant Information Sheet

This project is being undertaken by a PhD student at the University of Reading in the United Kingdom. The purpose of the survey is to explore the willingness of Tanzanian fishers (boat owners) to adopt, pay for and use technology solutions to some key problems in the fisheries supply and value chains. I would be grateful if you could assist with this study by answering the questions in this survey, which should take no more than 15-20 minutes to complete. Your responses will be kept in strict confidence and will only be released as summaries. Your identification will remain anonymous as your name and other personal details will not be collected as part of your survey responses and thus can never be associated with the data. Your participation is entirely voluntary and there are no right or wrong answers to questions. To participate in this survey, you must be 18 or older and owner of fishing boat(s) operating in Tanzania's marine or freshwaters.

If you have any comments or questions about this research, please feel free to contact the student, or his supervisor, Mr. Philip Jones, using the contact details provided below. If you feel unable to continue with the interview once it has begun, please feel free to opt out at any time. You are also free to withdraw any information that you have supplied, without having to provide an explanation, by contacting me, citing the reference number printed on this letter, using the contact details below, before 31st December 2021, after which I will start processing the data. The data you provide will be used for purposes of the student's PhD research, and may also be reported at conferences, and published in research papers, and technical reports. In the future, the statistical data may be used for other academic purposes, for example in teaching. There are no anticipated risks to participating in this study. Benefits include providing a broader understanding of the barriers to adoption of new technologies in the fisheries sector to inform industry and public policy. You will have free access to this information if you so wish.

The data will be destroyed within two years of completion of the PhD programme. By answering questions/completing the attached questionnaire, you are acknowledging that you understand the terms of participation and that you consent to these terms. Please keep a copy of this letter for your records. As the survey work will be conducted in person, the field data collection activities will adhere to the generally approved protocol for Covid-19 (e.g., wearing face masks especially during indoor meetings, doing interviews outdoors where possible, always applying hand sanitiser after contacts, etc.). This survey has passed the review procedure specified by the University's Research Ethics Committee and has been given a favourable ethical opinion for conduct.

Regards,
Charles Domician, PhD student, School of Agriculture, Policy and Development, University of Reading, UK. email: c.domician@pgr.reading.ac.uk, Mobile: +447597274270.
Supervisor email and phone: p.j.jones@reading.ac.uk, +441183788186.

Icebreaker Question

Q1. In which of the following countries do you undertake fishing activities? (Only those operating in Tanzania will continue with the survey).

- Tanzania (1)
- Other East African country than Tanzania (2)
- Other African Country than East African (3)
- UK or EU (4)
- Other(s) (5)

Q2. In which of the following Tanzanian regions do you live?

- Dar es Salaam (1)
- Geita (2)
- Kagera (3)
- Lindi (4)
- Mara (5)
- Mtwara (6)
- Mwanza (7)
- Pwani/Coast (8)
- Simiyu (9)
- Shinyanga (10)
- Tanga (11)
- Zanzibar (12)
- Other (please fill in box below). (13)

____

Q3. In which region's waters do you undertake fishing activities in Tanzania? (You can select multiple regions if applicable).

- Dar es Salaam (1)
- Geita (2)
- Kagera (3)
- Lindi (4)
- Mara (5)
- Mwanza (6)
- Mtwara (7)
- Pwani/Coast (8)
- Simiyu (9)
- Tanga (10)
- Zanzibar (11)
- Other (please fill in box below). (12)

____

Q4. What type of fishing do you undertake?

- o Freshwater fishing (1)
- o Marine fishing (2)

Q5. What is your gender?

- o Male (1)
- o Female (2)
- o Prefer not to say (3)

Q6. What is your age? (Only those aged 18 to 80 years will continue with the survey).

____

Description of a Packaged Blockchain and Google Satellite GPS Technological Solution (The Proposed Traceability Solution)

The purpose of this survey is to explore fishers' willingness to adopt, pay for and use new technologies. The proposed new technologies are considered as capable to overcome some longstanding problems in the Tanzanian fisheries sector, e.g., the lack of trust between trading parties and government regulation. These technologies include Blockchain and Google Maps and Cloud platforms. Blockchain technology uses Google-supported satellite GPS locators to store fisheries data in multiple locations so that it cannot be tempered with. Different people (e.g., fishers or other actors) can have simultaneous access to the same stored data and can update the records to capture transactions from various fisheries activities. Many different digital devices can be used to enter and receive data on a Blockchain platform including the handy mobile phone applications and satellite GPS devices.

The Google-supported GPS satellite technology helps to keep communications flowing reliably in situations (e.g., fishing at sea) where conventional telecoms and internet signals are weak or non-existent. To illustrate, fitting Google-supported GPS communications devices to fishing boats and linking these to a Blockchain database/platform via satellite means that a record is made of where each boat has obtained their catch. This data can then be monitored and managed by regulators and fishers to ensure sustainable fishing practices. For instance, fishers can see their locations while fishing at sea using their mobile phones linked to GPS network devices. This helps to prevent inadvertent illegal fishing in protected areas, provides buyers with assurance that fish were not caught in protected areas and provides fishers a defence against false claims against them of illegal fishing. Presented below are potential benefits and downsides of a package of Blockchain Technology and Google's Satellite GPS Communications System devices.

Benefits/advantages of adopting a package of Blockchain and Google-enabled Satellite GPS systems in fisheries

1. Provides reliable proof that fishers have not been operating illegally (e.g., in protected areas).

2. Fisheries data stored on Blockchain is difficult or impossible to falsify, thus enhancing traceability, performance and transparency in fisheries supply and value chains.

3. Enables rescue and help notifications on possible incidences of accidents or theft of fish and fishing gear at sea (piracy & illegal fish transshipment).

4. Guides fishers away from marine protected areas, thus avoiding breaches of regulation and protecting fish stocks for long term fisheries sustainability.

5. Maps are presented with information about fishing locations such as sea temperature and chlorophyll concentrations which are indicative of rich fishing grounds.

Limitations of adopting a package of Blockchain and Google-enabled Satellite GPS systems in fisheries.

1. Would require one-off investment in equipment/devices mountable on boats.

2. Fishers/boat owners would be required to pay periodic service subscription charges.

3. Training may be costly to operate the equipment and new technology system (e.g., cryptography and information technology (ICT) skills).

4. Guidance at sea may be lost if devices on boats are turned off due to low battery or otherwise (e.g., obscured from open sky for strong satellite signals).

5. Technology enabled easy identification and access to richer fishing grounds may result in overfishing practices.

Monthly Pricing of the Whole Package (Package of all modules: maps, places and routes).
(i.e., Blockchain enhanced Google Cloud & Maps Satellite GPS Services and Subscription for tracking and transmission of asset location data).

Basic features of the package

1. Google Maps helps the determination of fishers' locations at sea (i.e., geocoding). This helps the tracking of potential incidences of piracy and illegal trans-shipments (e.g., fish theft), hence triggering a recovery effort and/or avoiding the location in future.

2. Google’s geofencing application transmits near real time information when a fishing vessel enters or exits an area of interest (a geofence) like a marine protected area or an international marine border. This helps the tracking of illegal/unsustainable practices as well as fish smuggling activities. Geofencing is also applicable to traceability of fishery products as they move from one actor to another along the value chain (from producer/fisher, to distributor, to retailer until final consumer).

3. Access to atmospheric and environmental information (e.g., humidity, temperature, and chlorophyll concentrations) at fishing locations for potential quality and quantity/volumes of fish catch.

4. Estimating optimal compass-based navigation directions; plus, distance covered on fishing activity or expedition routes for enabling resources planning and management.

The package price

The full package taken together as presented above from Numbers 1 to 4 costs US$100.00 when used up to 1000 times a month.

Testing Fishers' adoption of the Packaged Blockchain and Google Satellite GPS Technological Solution

Q7. Performance Expectancy

Please rate each of the following statements at a level you agree or disagree with them.

	Strongly disagree (1)	Somewhat disagree (2)	Neither agree nor disagree (3)	Somewhat agree (4)	Strongly agree (5)
This traceability technology solution will be useful to enhance my fishing catch volumes through the mapping of fish-rich locations. (Q7_1)	○	○	○	○	○
This traceability technology solution will increase my chances of growing or scaling-up my fishing business. (Q7_2)	○	○	○	○	○
This traceability technology solution will help me accomplish cost reduction in my fishing business more quickly. (Q7_3)	○	○	○	○	○
This traceability technology solution will increase productivity in my fishing business activities. (Q7_4)	○	○	○	○	○
This traceability technology solution will better enhance my fishing business profitability. (Q7_5)	○	○	○	○	○
This traceability technology solution will enhance my access to new domestic markets offering higher prices than at present. (Q7_6)	○	○	○	○	○
This traceability technology solution will enhance my access to foreign (export) markets offering higher prices (e.g., UK and/or EU). (Q7_7)	○	○	○	○	○
This traceability technology solution will help me avoid prosecutions for breaching fisheries protected area regulations. (Q7_8)	○	○	○	○	○

Q8. Effort Expectancy

Please rate each of the following statements at a level you agree or disagree with them.

	Strongly disagree (1)	Some what disagr ee (2)	Neither agree nor disagree (3)	Some what agree (4)	Strongly agree (5)
The effort required to use this traceability technology solution in my fishing business is acceptable. (Q8_1)	○	○	○	○	○
This traceability technology solution will be easy for me to use in my fishing activities. (Q8_2)	○	○	○	○	○
It will be easy for me to learn the skills needed to use this traceability technology solution in my fishing activities. (Q8_3)	○	○	○	○	○
The interaction with this traceability technology solution is clear and understandable to me. (Q8_4)	○	○	○	○	○

Q9. Social Influence

Please rate each of the following statements at a level you agree or disagree with them.

	Strongly disagree (1)	Some what disagr ee (2)	Neither agree nor disagree (3)	Some what agree (4)	Strongly agree (5)
Other fishers that I respect will be using this traceability technology solution in their fishing operations. (Q9_1)	○	○	○	○	○
People who are important to me would encourage me to use this traceability technology solution in my fishing activities. (Q9_2)	○	○	○	○	○
People who influence my behaviour would approve of my using this traceability technology solution in my fishing business. (Q9_3)	○	○	○	○	○

Q10. Facilitating Conditions

Please rate each of the following statements at a level you agree or disagree with them.

	Strongly disagree (1)	Some what disagree (2)	Neither agree nor disagree (3)	Some what agree (4)	Strongly agree (5)
I have the resources necessary to use this traceability technology solution in my fishing activities. (Q10_1)	○	○	○	○	○
I have the knowledge necessary to adopt and use this traceability technology solution in my fishing activities. (Q10_2)	○	○	○	○	○
This traceability technology solution is compatible with other technologies I use. (Q10_3)	○	○	○	○	○
I can get help from others when I have difficulties using this traceability technology solution in my fishing activities. (Q10_4)	○	○	○	○	○

Q11. Hedonic Motivation

Please rate each of the following statements at a level you agree or disagree with them.

	Strongly disagree (1)	Some what disagree (2)	Neither agree nor disagree (3)	Some what agree (4)	Strongly agree (5)
I am motivated to use this traceability technology solution in my future fishing activities. (Q11_1)	○	○	○	○	○
I feel motivated to use this traceability technology solution in my present fishing activities. (Q11_2)	○	○	○	○	○
I believe the experience of using this traceability technology solution in my fishing activities would be rewarding. (Q11_3)	○	○	○	○	○

Q12. Price Value

Please rate each of the following statements at a level you agree or disagree with them.

	Strongly disagree (1)	Some what disagree (2)	Neither agree nor disagree (3)	Some what agree (4)	Strongly agree (5)
This traceability technology solution is reasonably priced for the benefits that it would provide me. (Q12_1)	○	○	○	○	○
This traceability technology solution is a good value for money in my fishing activities. (Q12_2)	○	○	○	○	○
At the current prices, this traceability technology solution provides a good value for addressing problems I experience in my fishing activities. (Q12_3)	○	○	○	○	○

Q13. Habit

Please rate each of the following statements at a level you agree or disagree with them.

	Strongly disagree (1)	Somewhat disagree (2)	Neither agree nor disagree (3)	Somewhat agree (4)	Strongly agree (5)
Using this traceability technology solution in fishing activities would become a habit for me. (Q13_1)	○	○	○	○	○
I will be addicted to using this traceability technology solution in my fishing activities. (Q13_2)	○	○	○	○	○
I will definitely have to use this traceability technology solution in my fishing activities. (Q13_3)	○	○	○	○	○
Using this traceability technology solution in my fishing activities will become natural. (Q13_4)	○	○	○	○	○

Q14. Behavioural Intention to Adopt and Use the Traceability technology solution

Please rate each of the following statements at your considered level of likelihood.

	Extremely unlikely (1)	Somewhat unlikely (2)	Neither likely nor unlikely (3)	Somewhat likely (4)	Extremely likely (5)
I intend to pay for and adopt/use this traceability technology solution in my future fishing activities. (Q14_1)	○	○	○	○	○
I will definitely pay for and adopt/use this traceability technology solution in my daily fishing activities. (Q14_2)	○	○	○	○	○
I plan to pay for and adopt/use this traceability technology solution in my future fishing activities. (Q14_3)	○	○	○	○	○

Q15. Usage Frequency of Complementary Technology (How often do you use the following technologies?)

	Never (1)	Sometimes (2)	About half the time (3)	Most of the time (4)	Always (5)
Computers (Q15_1)					
iPads (Q15_2)					
Digital cameras (Q15_3)					
Internet browsing on a mobile phone/device (Q15_4)					
Internet browsing on a computer (Q15_5)					
Internet of Things (IoT) (Q15_6)					
E-mail on mobile phone/device (Q15_7)					
E-mail on computer (Q15_8)					
Smart mobile phones (Q15_9)					
Non smart mobile phones (Q15_10)					
Mobile Text Messages (Q15_11)					
Barcodes (Q15_12)					
Quick Response (QR) codes (Q15_13)					
Radio frequency identification (RFID) sensors (Q15_14)					
Mobile money (Q15_15)					
Bank account (Q15_16)					
Fish ice storage (Q15_17)					
Fish deep cold storage facilities (Q15_18)					
Blockchain (Q15_19)					
Google Maps Platform Services (Q15_20)					

Google Cloud Platform Services (Q15_21)	○	○	○	○	○

Q16. How long is your experience in fishing activities?

- o Under 1 year (1)
- o 1 to 5 years (2)
- o 6 to 10 years (3)
- o Over 10 years (4)

Q17. What is the nature of your fishing business organisation and ownership?

- o Sole proprietor (1)
- o Group partnership or cooperative (2)
- o Limited company (3)
- o Family business (4)
- o Other (please fill in box below). (5) ____

Q18. Please indicate where you presently have membership to among the following forms of organisation (You can make multiple selections).

- o None (I have no membership to any organisation) (1)
- o Local beach management unit (BMU) (2)
- o Informal (unregistered) fisher group(s) (3)
- o Formal (registered) fisher group(s)/cooperative(s) (4)
- o Regional or national fisher umbrella organisation (5)
- o Other (please fill in the box below) (6)

____

Q19. Please indicate the length (i.e., the time range) of your membership until now in the following organisation(s).

	None (I have no membership) (1)	Below 1 year (2)	1 to 5 years (3)	6 to 10 years (4)	Over 10 years (5)
Local beach management unit (BMU) (Q19_1)	○	○	○	○	○
Informal (unregistered) fisher group (Q19_2)	○	○	○	○	○
Formal (registered) fisher group (Q19_3)	○	○	○	○	○
Regional fishers' organisation (Q19_4)	○	○	○	○	○
National fishers' umbrella (Q19_5)	○	○	○	○	○
Other form of fishers' organisation (Q19_6)	○	○	○	○	○

Q20. How are your periodic membership financial contributions/subscriptions fees spent? You can make multiple selections.

- I don't pay membership fees (1)
- I don't know how my subscription fees are used (2)
- Members' immediate needs (e.g. rescue at sea, death or family support, office/admin expenses) (3)
- Training programmes (e.g. sustainable fishing practices) (4)
- Acquisition of modern fishing technology and equipment (5)
- Searching local and foreign fish markets for members (6)

Q21. How many boats do you own and/or operate based on motorisation type below?

	Don't have these boats (1)	1 to 5 (2)	6 to 10 (3)	11 to 15 (4)	16 to 20 (5)	21 and above (6)
Inboard engine boats (Q21_1)	o	o	o	o	o	o
Outboard engine boats (Q21_2)	o	o	o	o	o	o
Boats without engine (Q21_3)	o	o	o	o	o	o

Q22. What size are your inboard engine motorised boats? (You may choose multiple options that apply to you).

- o Don't have inboard engine boats (1)
- o Under 18 feet (Under 6 metres) (2)
- o 18 to 24 feet (6 to 8 metres) (3)
- o 25 to 30 feet (9 to 10 metres) (4)
- o 31 to 36 feet (11 to 12 metres) (5)
- o 37 feet and above (12.5 metres and above) (6)

Q23. What size are your outboard engine motorised boats? (You may choose multiple options that apply to you).

- o Don't have outboard engine boats (1)
- o Under 18 feet (Under 6 metres) (2)
- o 18 to 24 feet (6 to 8 metres) (3)
- o 25 to 30 feet (9 to 10 metres) (4)
- o 31 to 36 feet (11 to 12 metres) (5)
- o 37 feet and above (12.5 metres and above) (6)

Q24. What size are your boats without engine/motorisation? (You may choose multiple options that apply to you).

- o Don't have boats without engine (1)
- o Under 18 feet (Under 6 metres) (2)
- o 18 to 24 feet (6 to 8 metres) (3)
- o 25 to 30 feet (9 to 10 metres) (4)
- o 31 to 36 feet (11 to 12 metres) (5)
- o 37 feet and above (12.5 metres and above) (6)

Q25. What is your average total fish catch weight in tonnes per week per boat under each boat motorisation type below?

	No catch (1)	0.1 to 2.5 (2)	2.6 to 5.0 (3)	5.1 to 7.5 (4)	7.6 and above (5)
Inboard engine boats (Q25_1)	○	○	○	○	○
Outboard engine boats (Q25_2)	○	○	○	○	○
Boats without engines (Q25_3)	○	○	○	○	○

Q26. According to your most recent experience, during which months of a given year are you actively fishing? (Select all months that apply to you).

- o January (1)
- o February (2)
- o March (3)
- o April (4)
- o May (5)
- o June (6)
- o July (7)
- o August (8)
- o September (9)
- o October (10)
- o November (11)
- o December (12)

Q27. For each of the species listed below, please fill in the space provided a percentage proportion of your annual fish catch by weight. (Note: write figures without a % sign).

- Sardines or anchovies (dagaa) : _______ (1)
- Nile Perch (sangara) : _______ (2)
- Tilapia (sato) : _______ (3)
- Tuna species (jodari) : _______ (4)
- Snapper species (changu) : _______ (5)
- Mackerel (vibua) : _______ (7)
- Rabbit fish (tasi) : _______ (8)
- Jacks (kolekole) : _______ (9)
- Other fish species (please fill in box below) : _______ (6)
- Total : ________

Q28. What is your average total catch weight in tonnes per week under each of the fish species categories below?

	No catch (0 tonnes) (1)	1 to 5 tonnes (2)	6 to 10 tonnes (3)	11 to 15 tonnes (4)	16 to 20 tonnes (5)	21 tonnes and above (6)
Sardines or anchovies (dagaa) (Q28_1)	○	○	○	○	○	○
Nile Perch (sangara) (Q28_2)	○	○	○	○	○	○
Tilapia (sato) (Q28_3)	○	○	○	○	○	○
Tuna species (jodari) (Q28_4)	○	○	○	○	○	○
Snapper species (changu) (Q28_5)	○	○	○	○	○	○
Mackerel (vibua) (Q28_7)	○	○	○	○	○	○
Rabbit fish (tasi) (Q28_8)	○	○	○	○	○	○
Jacks (kolekole) (Q28_9)	○	○	○	○	○	○
Other fish species (Q28_6)	○	○	○	○	○	○

Q29. Based on your recent experience, what price did you receive for the following fish species in Tanzanian shillings (TZS) per kilogramme?

	Didn't sell these species (1)	1 to 2,500 (2)	2,501 to 5,000 (3)	5,001 to 7,500 (4)	7,501 to 10,000 (5)	10,001 and above (6)
Sardines and anchovies (dagaa) (Q29_1)	o	o	o	o	o	o
Nile Perch (sangara) (Q29_2)	o	o	o	o	o	o
Tuna species (jodari) (Q29_3)	o	o	o	o	o	o
Tilapia (sato) (Q29_4)	o	o	o	o	o	o
Snapper species (changu) (Q29_5)	o	o	o	o	o	o
Rabbit fish (tasi) (Q29_6)	o	o	o	o	o	o
Mackerel (vibua) (Q29_7)	o	o	o	o	o	o
Jacks (kolekole) (Q29_8)	o	o	o	o	o	o
Other species (please specify in box) (Q29_9)	o	o	o	o	o	o

Q30. What onboard fish storage systems or technologies do you have on your fishing vessel(s) for maintaining and extending fish quality at sea before landing catch? (You may select multiple choices that suit you).

- o None (1)
- o Industrial level cold storage facilities (2)
- o Deep freezers (3)
- o Fridges (4)
- o Ice buckets/chambers (5)
- o Gutting (6)
- o Salting (7)
- o Other means (please fill in box below) (8)

____

Q31. What is the average number of fishers employed on each of your owned and/or operated boats for each motorisation category below?

	Don't have this boat type (1)	1 to 20 fishers (2)	21 to 40 fishers (3)	41 to 60 fishers (4)	61 to 80 fishers (5)	81 fishers and above (6)
Inboard engine boats (Q31_1)	o	o	o	o	o	o
Outboard engine boats (Q31_2)	o	o	o	o	o	o
Boats without engine (Q31_3)	o	o	o	o	o	o

Q32. When you sell your fish catch, what percentage proportion of your total sales value has to show proof of having met local and/or foreign sustainable fishing certification requirements? (e.g., observance and certification of practices that ensure sustainable fish stocks, minimal marine environmental impact and effective fisheries management systems). Note: Do not include the % sign.

Proportion (%) meeting local certification requirements : ________ (1)

Proportion (%) meeting foreign/export certification requirements : ________ (2)

Proportion (%) NOT showing proof of meeting local certification requirements : ________ (3)

Proportion (%) NOT showing proof of meeting foreign/export certification requirements : ________ (4)

Total : ________

Q33. What are the sustainable fishing certification requirements that you must prove to have met just before you can sell your fish catch at landing sites or local Tanzanian market?

- o None or not applicable (1)
- o Fishing outside the marine protected areas (2)
- o Laboratory fish quality tests on chemical substances contamination (3)
- o Maintaining fishing quota per unit period (e.g. year) (4)
- o Reliable storage of fisheries data (5)
- o Having GPS locator devices on fishing boats/vessels (6)
- o Others (please fill in box below) (7) ____

Q34. What are the sustainable fishing certification requirements that you must prove to have met just before you can sell your fish catch in East Africa and other neighbouring foreign countries.

- None or not applicable (1)
- Fishing outside marine protected areas (2)
- Laboratory fish quality tests on chemical substances contamination (3)
- Maintaining fishing quota per unit period (e.g. year) (4)
- Reliable fisheries data (5)
- Having GPS locator devices on fishing boats/vessels (6)
- Others (please fill in box below) (7) ____

Q35. What are the sustainable fishing certification requirements that you must prove to have met just before you can sell your fish catch in foreign European markets (e.g. UK & EU)?

- None or not applicable (1)
- Fishing outside marine protected areas (2)
- Laboratory fish quality tests on chemical substances contamination (3)
- Maintaining fishing quota per unit period (e.g. year) (4)
- Reliable fisheries data (5)
- Having GPS locator devices on fishing boats/vessels (6)
- Others (please fill in box below) (7) ____

Q36. What is your total weekly average running cost estimate in TZS per inboard engine boat? (Costs being fuel, repairs/maintenance, food, labour, fish sales levy, marketing, communications, etc.).

- Don't have inboard engine boat (1)
- 0 to TZS 2.5 million (2)
- TZS 2.6 to 5.0 million (3)
- TZS 5.1 to 7.5 million (4)
- TZS 7.6 to 10.0 million (5)
- TZS 11.0 million and above (6)

Q37. What is your total weekly average running cost estimate in TZS per outboard engine boat? (Costs being fuel, repairs/maintenance, food, labour, fish sales levy, marketing, communications, etc.).

- Don't have outboard engine boat (1)
- 0 to TZS 2.5 million (2)
- TZS 2.6 to 5.0 million (3)
- TZS 5.1 to 7.5 million (4)
- TZS 7.6 to 10.0 million (5)
- TZS 11.0 million and above (6)

Q38. What is your total weekly average running cost estimate in TZS per boat without engine? (Costs being repairs/maintenance, food, labour, fish sales levy, marketing, communications, etc.).

- o Don't have boat without engine (1)
- o 0 to TZS 2.5 million (2)
- o TZS 2.6 to 5.0 million (3)
- o TZS 5.1 to 7.5 million (4)
- o TZS 7.6 to 10.0 million (5)
- o TZS 11.0 million and above (6)

Q39. Your fishing business is funded by your own resources and what other funding sources? (Tick multiples if applicable)

- o None (my fishing business is funded by myself 100%) (1)
- o Bank loan(s) (2)
- o Government support/funding (3)
- o Member-based credit schemes (SACCOS, VICOBA, etc) (4)
- o Fish buyers' credit (e.g., fish factories, hotels/restaurants, etc) (5)
- o Others (please fill in box below). (6) ____

Q40. What other fisheries related income-generating activities do you undertake along the fisheries supply and value chain aside from selling your fish catch at landing sites? (You may tick more than one)

- o None (I have no other fisheries income generating activity) (1)
- o Fish storage and transport (2)
- o Fish processing, packaging and other value adding activities (3)
- o Local fish trading (4)
- o Export fish trading (5)

Q41. Please estimate the percentage proportions of your fish sales by value based on the following served market segments in a year (Note: Do not include the % sign).

Local markets (direct consumers) : _______ (1)

Local markets (dealers/suppliers) : _______ (2)

Supplying major fish processors or factories : _______ (3)

Foreign or export markets : _______ (4)

Own consumption : _______ (5)

Total : ________

Q42. Please indicate in percentage proportions your most important fish export markets in terms of fish sales value. (Note: Please write figures without % sign).

East African countries : _______ (1)

Neighbouring but non East African countries : _______ (2)

Other African countries : _______ (3)

Asian countries : _______ (4)

European markets (UK & EU) : _______ (5)

North America (USA & Canada) : _______ (6)

The Rest of the World (RoW) : _______ (7)

Selling locally (no exports) : _______ (8)

Total : ________

Q43. What ways, devices or technologies do you use to communicate or market your fish catch to potential buyers while still on the boat at sea and at landing site? (You may tick multiple options).

- o Landing catch at usual fish market site (1)
- o Mobile phones (SMS texts and calls) (2)
- o Satellite or GPS devices (satellite-based custom or tailored email/text message notifications) (3)
- o Email and internet on mobile phones or other devices (4)
- o Other means (please fill in box below). (5)

____

Q44. What is an estimate of net profit before tax for your fishing business each year in Tanzanian shillings (TZS)?

- o 0 to TZS25.0 million (1)
- o TZS25.0 million to 50.0 million (2)
- o TZS51.0 million to 75.0 million (3)
- o TZS76.0 million to 100.0 million (4)
- o TZS101.0 million and above (5)

Q45. What is your highest level of education or training?

- o No formal education (1)
- o Primary education (2)
- o Secondary education (3)
- o University or college education (4)