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ASSESSMENT OF CATCH TRENDS OF INDUSTRIAL FISHERIES IN LIBERIA

BY

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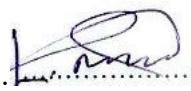
DECLARATION

I, Eugenia L. Nagbe, declare that this thesis, entitled "Assessment of Catch Trends of Industrial Fisheries in Liberia," is my original work and has not been submitted previously for any academic award or qualification at any other institution.

I confirm that all the work presented herein is my own, except where specifically acknowledged and referenced. Where other sources of information have been used, these have been appropriately cited, and any collaborations or external assistance have been duly acknowledged.

Signed: …  …… Date……..30th November, 2025……

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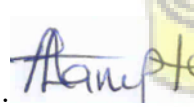
Signed: …  …… Date: …30th November, 2025……

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DEDICATION

I dedicate this work to my beloved parents, Mr and Mrs Nagbe whose prayers, love, and sacrifices have always been the foundation of my success. Your unwavering belief in me keeps pushing me forward.

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LIST OF ABBREVIATIONS

AIS ..... Automatic Identification System

ALC..... Automatic Location Communicator

BNF ..... Bureau of National Fisheries

BRD..... Bycatch Reduction Device

CAADP ..... Comprehensive Africa Agriculture Development Programme

CPUE..... Catch Per Unit Effort

EIA ..... Environmental Impact Assessment

EPA ..... Environmental Protection Agency

EU..... European Union

FAC ..... Fisheries Advisory Council

FAO..... Food and Agriculture Organization

FAPS ..... Fisheries and Aquaculture Policy and Strategy

FMC ..... Fisheries Monitoring Centre

FMS..... Fisheries Management System

GDP..... Gross Domestic Product

GEF ..... Global Environment Facility

GIS ..... Geographic Information System

GPS ..... Global Positioning System

GRT..... Gross Registered Tonnage

HF..... High Frequency

ICZM..... Integrated Coastal Zone Management

IEZ..... Inshore Exclusive Zone

IUU.....Illegal, Unreported, and Unregulated

LiMA.....Liberia Maritime Authority

LSMFP ..... Liberia Sustainable Management of Fisheries Project

ABSTRACT

Industrial trawlers in Liberia play a significant role in the country's fisheries sector, contributing to food security, employment, and government revenue. However, concerns about the sustainability of marine resources have emerged due to fluctuating catch volumes, declining fish stocks, and increasing bycatch. This study aims to assess the seasonal and annual variability in catch and fishing effort trends of industrial fisheries in Liberia over a six-year period and inform policies for effective fisheries management. This study also examines the impact of industrial trawlers in Liberia, on fish stock abundance, species composition, and the environment. The study employed a mixed-methods approach that integrates qualitative and quantitative methodologies to achieve its objectives. Historical catch and fishing effort data, as well as spatial and temporal patterns, were analyzed to coordinate and identify trends in species composition and abundance. The findings indicated that while industrial trawlers significantly contributed to fish production, poor enforcement of fisheries regulations, illegal, unreported, and unregulated (IUU) fishing, and weak data collection systems pose serious threats to effective fisheries management in Liberia, and consequently, to the long-term sustainability of fisheries resources. This study concludes that adopting a holistic approach to fisheries management will promote the sustainable utilization of Liberia's marine resources for present and future generations. To address these challenges, several recommendations are proposed, including strengthening fisheries monitoring systems, enforcing fishing regulations, promoting the use of selective fishing gear, and implementing science-based catch limits.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Liberia is located on the West African coast, bordered by Sierra Leone to the northwest, Guinea to the north, Côte d'Ivoire to the east, and the Atlantic Ocean to the south, with a coastline stretching 579 km (FAO, 2019). It remains one of the world's poorest countries (World Bank, 2024), yet boasts an Exclusive Economic Zone (EEZ) of 246,000 km²—slightly larger than those of neighboring Sierra Leone and Côte d'Ivoire (MRAG, 2014).

Fishing activities in Liberia occur both in coastal and offshore waters and include small-scale and industrial operations using various fishing vessels and techniques (MRAG, 2014). Most of these activities take place along the continental shelf, which averages 36 km in width. It is narrower in the north (between Monrovia and Robertsport) and broader in the south (between Monrovia and the Côte d'Ivoire border), with trawling grounds extending to depths of 800 m (Jueseah et al., 2020). Liberia's coastal waters fall within the Guinea Current Large Marine Ecosystem, characterized by warm temperatures (>24 °C), stratified layers, variable salinity (</>35‰), and low nutrient levels—contributing to relatively low marine productivity (Jueseah et al., 2020).

Currently, six fish species assemblages are targeted: small, medium, and large pelagics; shallow- and deep-water demersals; and crustaceans (MRAG, 2014). These resources are exploited by two coastal small-scale fishing fleets—the Kru and Fanti—as well as by a coastal industrial fleet and an offshore fleet. The industrial fleet consists primarily of trawlers using bottom and midwater

trawls to catch shallow- and deep-water demersal fish and shrimp. In recent years, these trawlers have increasingly targeted semi- and medium-pelagic species using midwater trawls (MRAG, 2014). The offshore fleet comprises large industrial tuna vessels, mostly from the European Union (EU), operating under the Sustainable Fisheries Partnership Agreement (SFPA). These vessels mainly use purse seines to target large pelagic species such as tuna (MRAG, 2014). The fishing industry is vital to Liberia's economy, contributing 3.2% of GDP (Yates, 2024), serving as a major source of livelihood, and providing approximately 65% of the animal protein consumed by the population—with average annual per capita fish consumption at 9.4 kg (FAO, 2020). Due to high unemployment and open-access policies in small-scale fisheries, the sector also serves as an economic safety net for many Liberian youth (Jueseah *et al.,* 2020).

To strengthen and develop the sector, the Government of Liberia—through the National Fisheries and Aquaculture Authority (NaFAA), supported by the World Bank—is working on a strategic business plan (World Bank, 2020). Established in 2017 as an autonomous entity, NaFAA is mandated to sustainably manage Liberia's fisheries resources and protect its marine ecosystems (NaFAA, 2017). For NaFAA to achieve its goals, it must operate with a commercial orientation to attract investment and generate revenue to support operations and development. Liberia's fisheries and aquaculture resources have benefited from improved management over the years. These resources must be used sustainably to support economic growth, employment, human capital development, and environmental protection (MRAG, 2021). Management practices will continue to be guided by scientific evidence, incorporating precautionary and ecosystem-based approaches to maintain fish stocks at sustainable levels and maximize socio-economic benefits (FAO, 2022).

With support from the Global Environment Facility (GEF) via the World Bank's West Africa Regional Fisheries Project (WARFP), NaFAA is also developing infrastructure such as the Robertsport Fish Landing Cluster to reduce post-harvest losses and enhance fish product value chains (World Bank, 2011; 2018).

1.1.1 Commercially Exploited Fish Species in Liberia

Liberia's waters host a range of commercially valuable fish species, including small, medium, and large pelagics; shallow- and deep-water demersals; and crustaceans (MRAG, 2014). Small pelagics (12–25 cm) are typically found in coastal waters at depths of 40–70 m. Common species include *Sardinella* spp., Atlantic bumper (*Chloroscombrus chrysurus*), and flying fish (*Cheilopogon melanurus*) (MRAG, 2014). Also, Medium pelagics (18–55 cm, modal length 41 cm) inhabit turbid coastal and offshore waters, typically at depths of 0–40 m near the thermocline. These include species like barracuda (*Sphyraena spp.*) (Belhabib *et al*., 2018).

Finally, Large pelagics occur at depths of 0–300 m in offshore waters. Targeted species include yellowfin tuna (*Thunnus albacares*), bigeye tuna (*Thunnus obesus*), skipjack (*Katsuwonus pelamis*), swordfish (*Xiphias gladius*), marlin (*Istiophorus spp.*), hammerhead shark (*Sphyrna* spp.), and various rays (MRAG, 2014). Shallow-water demersals include cassava fish *(Pseudotolithus spp.), threadfin (Galeoides decadactylus)*, solefish (*Cynoglossus spp.*), and marine catfish (*Arius spp.*), generally caught at depths ≤ 30 m. Deep-water demersals such as groupers (*Epinephelus spp.*), snappers (*Lutjanus spp.*), grunts (*Pomadasys spp.*), and sparids (*Pagrus caeruleostictus, Pagellus bellottii*, *Sparus*, *Dentex spp.*) are found primarily at depths ≥ 30 m (MRAG, 2014). Crustaceans, typically found at 30–60 m depth, include pink shrimp (*Penaeus notialis*), deep-water shrimp (*Parapenaeus*

longirostris) blue swimming crab (*Callinectes spp*.), and tropical spiny lobster (*Panulirus ornatus*) (MRAG, 2014).

1.2 Problem Statement

Research highlights significant underreporting in Liberia's industrial fisheries. In 2008, industrial catch figures were notably underestimated due to unmonitored transshipments and mislabeling of catches as originating from countries like Côte d'Ivoire, Senegal, Mauritania, and Morocco that comply with EU export standards (Togba, 2008). While fishery observers have since been placed onboard vessels, their effectiveness has been questioned, with observer reports often inconsistent with port inspections. Around 38% of vessels were found to underreport their catches (Togba, 2008). Observer coverage remains inadequate, and even when observers are present, transshipment activities are often overlooked or inaccurately reported. These lapses compromise the reliability of official data and hinder sustainable fisheries management (Pauly *et al*., 2016). The lack of oversight, coupled with limited sampling and monitoring, continues to challenge accurate reporting. While independent reconstructions like the Sea Around Us Project offer alternative estimates using expert knowledge and local data, official statistics remain unreliable.

1.3 Justification

Globally, fisheries are crucial to food security and economic well-being, particularly for coastal populations (FAO, 2022). In Liberia, fish remains a staple, providing 65% of animal protein intake in 2002 due to its affordability and availability (FAO, 2007). The sector is also vital for national revenue and economic stability, contributing significantly to GDP (Jueseah, 2021). Revenues are generated through licensing, vessel registration, inspections, observer fees, export/import duties,

and fines. Given its socio-economic importance, accurately assessing catch trends in Liberia's industrial fisheries is essential for informed decision-making and effective resource management.

1.4 Research Questions

a)What are the primary factors driving fluctuations in catch trends among Liberia's industrial trawlers?

b) How have fisheries management policies and enforcement mechanisms affected catch efficiency, species diversity, and bycatch levels?

c) How effective are current regulations and management strategies in controlling industrial trawling and promoting sustainable fishing practices?

1.5 Objective

This study aims to assess the seasonal and annual variability in catch and effort trends of industrial fisheries in Liberia over six years, to inform policies for effective fisheries management.

1.5.1 Specific objectives

The specific objectives of this thesis include to:

a) Analyse the total catch trends of industrial trawl fisheries of Liberia from 2018 to 2023.

b) Estimate the effort (number of trips) per vessel over the years

c) Estimate the catch per unit effort per dominant commercial fish species over the period.

CHAPTER TWO

LITERATURE REVIEW

2.1 The Industrial Fisheries Sector in Liberia

Industrial fishing in Liberia began in 1955, with vessels originally landing their catches at the fishing pier located within the Free Port of Monrovia (Belhabib *et al*., 2015). The marine industrial fisheries sector is primarily composed of two key segments: a shrimp trawl fishery and a demersal finfish fishery. Target species include shrimp and a variety of demersal finfish such as croakers, grunts, threadfins, seabreams, and sea perch, all of which are harvested using trawling methods (Belhabib *et al*., 2015).

This sector is dominated by vessels that are either foreign-owned or registered under the Liberian flag. By 2009, eight industrial fishing companies—mainly foreign—were operating 35 trawlers (both side and stern rigged) licensed for fishing and shrimping (Belhabib *et al*., 2015; FAO, 2017). The industrial fleet is diverse in terms of size and equipment, ranging from 60 GRT Chinese pair trawlers (used as ice carriers) to 251 GRT trawlers equipped with onboard freezing, processing, and storage facilities (FAO, 2017; FAO, 2019). A typical industrial fishing trip lasts approximately 21 days, including two days to reach the fishing grounds and two days to return to port. During operations, vessels generally conduct four hauls per day, with each haul lasting around two hours (Belhabib et al., 2015). In terms of output, the large pelagic fishery—primarily targeting tuna and similar species—produced 2,878.19 tons in 2016 and 10,640.15 tons in 2017 (FAO, 2019). Notably, there were no small industrial pelagic vessels operating during this period (Belhabib *et al.*, 2015).

Industrial fishing activities are officially limited to waters beyond six nautical miles from the coast. However, incidents of illegal, unreported, and unregulated (IUU) fishing persist—often occurring at night when industrial vessels encroach into the Inshore Exclusive Zone (IEZ) to fish unlawfully (Rouse, 2024). These actions have posed ongoing challenges to Liberia's fisheries governance, particularly under the new regulatory frameworks established by the National Fisheries and Aquaculture Authority (NaFAA) (Belhabib *et al.,* 2015). In response, a Memorandum of Understanding (MoU) on fisheries monitoring, control, and surveillance (MCS) was signed in 2011 by key maritime stakeholders, marking the formal launch of the Monitoring, Control, and Surveillance Coordination Committee (MCSCC) (Maritimeafrica, 2022). This initiative contributed to a temporary decline in the number of industrial fishing vessels, thereby enhancing access to marine resources for the artisanal fishing fleet (Belhabib *et al.,* 2015). Despite these early gains, recent studies have documented a resurgence in industrial fishing activity. The number of licensed industrial vessels has increased again in recent years (see examples in Appendix, Plate 1 and 2), and total catches have risen markedly between 2018 and 2023 (Jueseah *et al*., 2021).

Table 2.1 shows the annual industrial fishing catch from 2018 to 2023, highlighting a significant increase in total catch in 2019, and a subsequent fluctuating decreasing trend to date. Overall, 27.58 million kg was harvested during the period under review.

Table 2.1: Total Industrial Catch in Liberia Per Year from 2018 to 2023

Year	Total Catch (kg)
2018	1,880,553
2019	6,168,756
2020	5,112,714
2021	4,292,087
2022	5,133,931
2023	4,991,043
Total	27,579,084

Source: NaFAA Report (2024).

2.2 Trade Policy and GDP

Fisheries contribute approximately 10% to Liberia's Gross Domestic Product (GDP) (Jueseah *et al*., 2020), and the small-scale fisheries sector is a major source of employment, supporting an estimated 33,000 people nationwide (Chu *et al*., 2017). The fisheries sector in Liberia is broadly classified into two main categories: artisanal and semi-artisanal coastal fisheries—which collectively account for about 86% of national fisheries activity (Nyiawung *et al*., 2022)—and industrial fisheries. According to the National Fisheries and Aquaculture Authority (NaFAA), artisanal fisheries produced 18,086 tons of fish in 2020, while industrial trawlers landed 5,113 tons during the same period in Liberian waters (Wour and Mabon, 2022).

Trade policy reforms and international partnerships have become crucial to Liberia's goal of modernizing its fisheries sector. Through the Liberia Sustainable Management of Fisheries Project (LSMFP), supported by $40 million from the World Bank, the country aims to enhance fish landing infrastructure, promote sustainable aquaculture practices, and strengthen institutional capacity. (Glassco, 2021). The OPEC Fund for International Development has also contributed $20 million in loans and $240,000 in technical assistance to the exact cause. (OPEC Fund, 2022). Although a previous Sustainable Fisheries Partnership Agreement (SFPA) with the EU expired in 2020, it marked a notable step in integrating Liberia into the global fisheries economy (EU, 2015).

Despite these efforts, the sector continues to face significant challenges, including illegal, unreported, and unregulated (IUU) fishing, limited access to modern equipment, and inadequate infrastructure (FAO, 2022). Through the National Fisheries and Aquaculture Authority (NaFAA), the government is working to strengthen monitoring and enforcement mechanisms and implement a medium-term business strategy. (IMF, 2021). Continued investment and policy reforms are essential for transforming Liberia's fisheries into a sustainable and productive industry that significantly contributes to the national GDP, employment, and food security.

2.3 Fisheries Policies of Liberia

Since 2014, the development of Liberia's fisheries sector has been guided by several key national policy documents, including the National Fisheries and Aquaculture Policy and Strategy (FAPS) (MOA, 2014), the Pro-Poor Agenda for Prosperity and Development (PAPD) (MFDP, 2018), and the updated FAPS (NaFAA, 2020). These documents serve as frameworks for assessing the sector's performance and identifying areas for improvement in the Liberian fishing industry.

The Pro-Poor Agenda for Prosperity and Development (PAPD) outlines Liberia's broader development goals, focusing on building capable and trustworthy state institutions and enhancing the income security of its citizens (MFDP, 2018). The central aim of the PAPD is to consolidate national peace and reconciliation efforts. Within this framework, fisheries development is addressed under the pillar of governance and transparency, with a specific objective to increase the competitiveness of existing industries, including improvements in the fisheries sector (MFDP, 2018). The most recent Fisheries and Aquaculture Policy and Strategy (NaFAA, 2020) build on the foundational 2014 strategy, which first introduced a long-term vision of achieving sustainably managed and economically viable fisheries by 2030. Together, these policy instruments provide the strategic direction for promoting responsible fisheries management, institutional reform, and economic growth within the sector.

The government, under the "fisheries improvement" of the Pro-Poor Agenda for Prosperity and Development (PAPD), intends to "support artisanal communities to increase domestic fish supply from 8,000 tons to 16,000 tons annually by 2023" (MFDP, 2018). The government plans to facilitate private investment in constructing a modern fishing harbour complex with facilities for repairing and maintaining fishing vessels, as well as storing, preserving, and processing fish (MFDP, 2018).

2.4 Fisheries Management Strategy (FMS)

The fisheries management strategy (FMS) is used to regulate primary fisheries, along with the legal foundation and institutional framework that underpin the governance of the fishing industry (NaFAA, 2020). The primary goal of the Liberian Fisheries Management Strategy (FMS) is to

promote the long-term sustainable use of fisheries resources and their associated environments for the benefit of Liberia (NaFAA, 2019). Management of coastal industrial fisheries is implemented through individual vessel catch quotas, fishing licenses, and technical regulations, including minimum mesh size requirements, area restrictions, and gear limitations (NaFAA, 2020). Meanwhile, small-scale fisheries (SSF) management focuses on licensing and allocating fishing rights (NaFAA, 2020). This includes community fishing rights, territorial user rights for fisheries (TURFs), and additional technical measures such as minimum fish size regulations and gear restrictions (NaFAA, 2019).

The legal framework governing fisheries management in Liberia includes the Natural Resources Law of (1958), the National Fisheries and Aquaculture Authority (NaFAA) Act of 2017 (NaFAA, 2017), the Fisheries and Aquaculture Management and Development Law of 2019 (NaFAA, 2019), and the Fisheries and Aquaculture Policy and Strategy (FAPS) developed by the Ministry of Agriculture in 2014 (NaFAA, 2014). In collaboration with the Liberian Coast Guard, NaFAA enforces a Monitoring, Control, and Surveillance (MCS) system to oversee fishing activities within Liberia's Exclusive Economic Zone (EEZ) (NaFAA, 2019).

NaFAA operates a Fisheries Monitoring Centre (FMC) and implements the fisheries observer program to enhance its Monitoring, Control, and Surveillance (MCS) efforts, with a particular focus on coastal industrial and offshore tuna fisheries (NaFAA, 2023). According to NaFAA's official MCS page, the department "maintains a functioning Fisheries Monitoring Centre (FMC) and Vessel Monitoring System (VMS) to combat illegal, unreported, and unregulated fishing" (NaFAA, 2024).

However, the MCS system faces limitations in effectively covering small-scale fisheries (SSF). NaFAA acknowledges that inland and small-scale operations often escape adequate surveillance, further exacerbating enforcement gaps. (NaFAA, 2024). Violations of fisheries laws and regulations are addressed through the judicial system, which imposes appropriate sanctions on offenders. Notably, in 2013, Liberia generated approximately USD 6 million in administrative fines through negotiated settlements for breaches of the 2010 Fisheries Regulations, as reported by (Belhabib *et al*., 2018; NaFAA, 2022).

2.5 Institutional Structure and Framework

The National Fisheries and Aquaculture Authority (NaFAA) was established under the National Fisheries and Aquaculture Authority Act of 2017, effective October 9, (2017) and later reinforced by the Fisheries Management and Development Law of 2019, forming an autonomous government agency responsible for Liberia's fisheries sector (NaFAA, 2020). NaFAA operates under the oversight of a nine-member Board of Directors, appointed by the President of Liberia, with the Minister of Agriculture serving as Chairperson. The Board includes representatives from ministries such as Defense, Finance, Commerce and Industry, and the Liberia Maritime Authority (Jueseah *et al*., 2021; FAO, 2017). In addition to the Board, NaFAA is advised by a 15-member Fisheries Advisory Council (FAC), formed in 2020. FAC members are nominated by multiple government ministries and appointed by the Director General of NaFAA. Their primary role is to provide policy advice and guidance on conservation, sustainable use, and aquaculture development by international agreements (Jueseah *et al*., 2021).

NaFAA's funding sources include revenue from license fees, fish import and export permits, transshipment authorizations, certificates, fines for legal violations, grants, and donations, as stipulated in the NaFAA Act 2017 (FAO, 2017). Revenue is distributed between NaFAA and the Liberian government, with 60% retained by NaFAA and 40% remitted to the government's consolidated account (FAO, 2017). NaFAA is supported by the Liberia Sustainable Management of Fisheries Project (LSMFIP), financed by the World Bank. This project aims to enhance the management and sustainable use of selected fisheries (World Bank, 2021). Key support areas include improving governance frameworks, strengthening monitoring, control, and surveillance (MCS) systems, and engaging regional technical experts for project implementation at both national and community levels (World Bank, 2021).

2.5.1 Observer Program

The observer program in Liberia's industrial fisheries is a critical mechanism for ensuring sustainable fishing practices and compliance with national and international fisheries regulations. Coordinated by the National Fisheries and Aquaculture Authority (NaFAA), the program places trained fisheries observers on industrial fishing vessels to monitor catch composition, fishing effort, and bycatch handling (NaFAA, 2023). This initiative supports Liberia's commitments under global agreements such as the FAO Port State Measures Agreement. It aims to reduce illegal, unreported, and unregulated (IUU) fishing in Liberian waters. (FAO, 2022). Observers play a vital role in collecting reliable data to inform fisheries management and ensure compliance with marine conservation measures. (MRAG, 2021).

Despite its significance, the observer program faces several operational challenges. These include insufficient funding, limited numbers of trained observers, and safety concerns aboard some industrial vessels Environmental Justice Foundation [EJF, 2022). Moreover, some vessel operators have obstructed observer activities, creating gaps in data collection and reporting (EJF, 2022). Strengthening legal protections for observers, expanding training programs, and implementing electronic monitoring systems could significantly enhance the program's efficiency. Collaboration with regional fisheries bodies, such as the Fisheries Committee for the West Central Gulf of Guinea (FCWC, 2021), could further enhance regional data-sharing and compliance efforts.

Data collected by Liberia's observer program are essential for informing stock assessments, developing fisheries management plans, and enforcing regulations against IUU fishing. This information contributes to the sustainable management of key fish stocks that are critical for national food security and economic livelihoods (NaFAA, 2023). Looking ahead, expanding observer coverage and integrating technology such as electronic monitoring will be essential for Liberia to meet international fisheries management standards and safeguard its marine resources (FAO, 2022).

2.6 Fisheries Monitoring Centre (FMC)

The Fisheries Monitoring Center (FMC) of Liberia, operating under the National Fisheries and Aquaculture Authority (NaFAA), plays a critical role in safeguarding Liberia's marine resources (NaFAA, 2020). Its key functions include monitoring fishing vessel activities through a Vessel Monitoring System (VMS), coordinating surveillance patrols, and enforcing compliance with

fisheries laws to combat illegal, unreported, and unregulated (IUU) fishing. (NaFAA, 2024). The FMC also manages the Fisheries Integrated Management System (FIMS), which digitizes licensing, permits, and real-time fisheries data. (NaFAA, 2024). Through collaboration with international partners, such as the FAO and FiTI, as well as regional maritime bodies, the FMC works to strengthen fisheries governance and transparency. (FiTI, 2025). Additionally, it conducts training programs for fisheries inspectors and observers, enhancing the country's monitoring and enforcement capacity. (Analyst Liberia, 2024).

Despite these advancements, the FMC faces significant challenges. Limited offshore patrol vessels and weak infrastructure, including poor internet connectivity, restrict real-time monitoring and surveillance activities (1library, 2023). Operational gaps, such as inadequate training, a lack of Standard Operating Procedures (SOPs), and weak inter-agency coordination, further hamper effectiveness (1library, 2023). Nevertheless, the FMC has recorded notable achievements: Liberia launched the FIMS system in 2024, improving transparency and licensing processes (NaFAA, 2024); the country also joined the Fisheries Transparency Initiative (FiTI), demonstrating its commitment to open governance (FiTi,2025). With ongoing technical support and regional cooperation, the FMC is gradually strengthening its capacity to sustainably manage Liberia's fisheries resources (World Bank, 2021).

2.7 Vessel Monitoring System (VMS)

The Liberia Vessel Monitoring System (VMS) is a satellite-based surveillance tool that tracks and manages fishing vessel activities within Liberia's Exclusive Economic Zone (EEZ) (NaFAA, 2020). Implemented by the National Fisheries and Aquaculture Authority (NaFAA), the VMS enhances maritime oversight by requiring industrial fishing vessels to install automatic location communicators that transmit real-time position data. (NaFAA, 2020). This enables authorities to monitor vessel movements, prevent illegal, unreported, and unregulated (IUU) fishing, and enforce licensing regulations effectively (NaFAA, 2024).

In 2024, Liberia further strengthened its fisheries governance by integrating the VMS into a broader Fisheries Integrated Management System (FIMS) (FAO, 2021). FIMS serves as a digital platform for managing permits, licenses, and authorizations, improving transparency and efficiency in the fisheries sector (NaFAA, 2024). Now feeding directly into FIMS, the VMS enables NaFAA and the Liberian Coast Guard to detect unauthorized activities in real-time, such as fishing in protected zones or entering territorial waters without proper clearance. (NaFAA, 2024). This integration supports Liberia's compliance with international agreements, such as the Port State Measures Agreement (PSMA), which aims to combat illegal, unreported, and unregulated (IUU) fishing globally (FCWC, 2023).

Liberia's fisheries monitoring efforts are further supported through partnerships with international organizations, including the European Union and the Environmental Justice Foundation (EJF) (EFCA, 2018). These collaborations have helped expand technical capacity, provide training, and

assess the effectiveness of transparency and governance measures in the fisheries sector. (EJF, 2024). VMS also contributes to scientific data collection, supporting decisions on marine conservation, fishing quotas, and spatial planning. Altogether, the VMS and associated digital tools are pivotal in ensuring the long-term sustainability of Liberia's marine resources and the economic well-being of its coastal communities.

2.8 Licence Process

The process of acquiring a fishery license in Liberia is managed by the National Fisheries and Aquaculture Authority (NaFAA), which regulates fisheries to ensure sustainable management, compliance with local and international standards, and protection of marine resources (NaFAA, 2020). Applicants, including domestic, semi-industrial, and industrial fishing operators, can submit their applications to NaFAA's Licensing Unit in Monrovia or regional offices (NaFAA, 2020). Required documents include a completed application form, vessel details (such as registration, specifications, and safety equipment), proof of ownership or charter agreements, crew certifications, an Environmental Impact Assessment (EIA) report for industrial fishing operations, and proof of payment of the application fee (NaFAA, 2020).

Once the application is submitted, NaFAA conducts a vessel inspection to ensure compliance with safety, sanitation, and operational standards, often in collaboration with the Liberia Maritime Authority (NaFAA, 2020; LIMA, 2021). Certain vessels, particularly industrial ones, may also be required to accommodate fisheries observers during operations to monitor compliance (NaFAA, 2020). Applications are then reviewed by NaFAA, focusing on adherence to the Fisheries and Aquaculture Management and Development Law of 2019, the sustainability of proposed activities, and

compliance with regional and international agreements such as the Sub-Regional Fisheries Commission (SRFC) or the United Nations Fish Stocks Agreement (UNFSA) (NaFAA, 2019). If approved, licenses are issued for a specific duration, typically one year, and must be renewed annually (NaFAA, 2021). Licensing fees depend on the vessel type, tonnage, and fishery category, with foreign vessels generally paying higher fees (NaFAA, 2021). Licensed operators must submit regular catch data reports to NaFAA, comply with closed seasons, gear restrictions, and no-fishing zone regulations, and pay penalties for illegal, unreported, and unregulated (IUU) fishing violations (FAO, 2021).

NaFAA monitors compliance through a Vessel Monitoring System (VMS) to track vessel activities, onboard observers for industrial vessels, and regular patrols to prevent illegal fishing (NaFAA, 2021). While efforts are being made to simplify the process, foreign vessels often face additional scrutiny (NaFAA, 2022). The government is working to improve transparency, particularly for artisanal fishers. Licenses are issued by Total Allowable Catch (TAC) quotas to ensure sustainability (NaFAA, 2021). Applicants can obtain further information by contacting NaFAA or visiting their official website (NaFAA, 2023).

2.8.Catch Trends

Fishery landings have likely fluctuated due to various factors, including seasonality, fishing effort, and environmental changes. We can examine trends in total catch volume, target species, and seasonal shifts in catches. This includes identifying the dominant species in the catch, which may include pelagic species such as tuna and mackerel, or demersal species like snapper and grouper (Belhabib *et al.*, 2015).

2.8.1 Species Composition and Abundance:

The analysis involves understanding the abundance of different species in the catch (Nunoo et al., 2006). Species like Sardinella or Tuna are often dominant in tropical West African fisheries (Thiaw et al., 2017). Monitoring species composition helps assess fisheries and the health of fish populations (Trindade-Santos Isaac., 2020). A look at fisheries indices or other metrics (Shannon-Weaver Index) could indicate how diverse or stable the ecosystem is (Nunoo et al, 2006).

2.8.2. Seasonal and Annual Variability:

Fishery data often exhibit clear seasonal patterns due to breeding cycles, changes in water temperature, and other environmental factors. Additionally, annual variability may reflect longer-term trends, such as shifts in migratory patterns, concerns over overfishing, or the effects of climate change (Diouf, 2021).

2.8.3.Fishing Effort and Practices:

It is essential to examine the scope of fishing activities, encompassing the number of vessels, types of gear used, and the balance between industrial and artisanal fishing. Data on fishing practices helps understand the pressure on fish stocks and informs sustainable management strategies (Jueseah *et.al*, 2020).

CHAPTER THREE

MATERIALS AND METHODS

3.1.Study Area

The study area encompassed the nine coastal counties of Liberia along the entire 570-kilometre coastline, with an exclusive economic zone (EEZ) that extends 200 nautical miles offshore (Figure 3.1). This zone consists of relatively warm waters with low nutrient content (Jueseah *et al.,* 2022). The continental shelf extends from Côte d'Ivoire to Robertsport in Liberia, with an average width of 34 km and the widest part in the central region of Liberia (Jueseah *et.al*, 2020). An inshore exclusion zone (IEZ) reserves the six nautical miles closest to shore for subsistence, artisanal, and semi-industrial fishing activities - trawling is not allowed inside the IEZ (Jueseah *et al.*, 2022). The introduction of the six-mile Inshore Exclusion Zone (IEZ) in 2010 restricted and banned industrial fishing activities in the area, making it an offshore large pelagic fishery (Jueseah *et al.*, 2022).

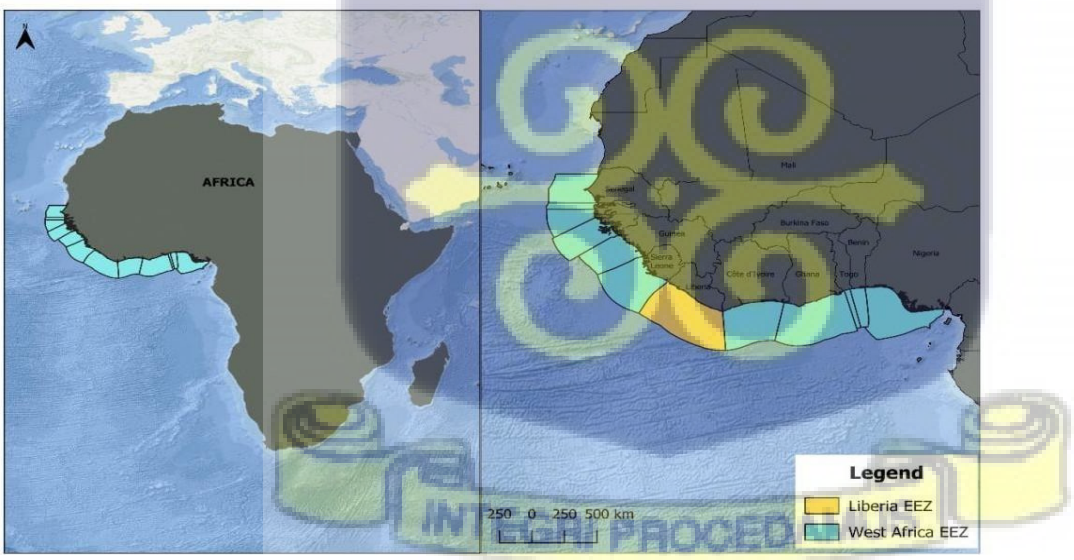

Figure 3.1: Map of West Africa showing the demarcations of Liberia's EEZ (Flanders Marine Institute, VLIZ, 2023)

3.2.Study Design

The study focused on industrial trawl vessels, employing a mixed-methods approach that integrates qualitative and quantitative methodologies to achieve its objectives. It analyzed historical catch and effort data, identified spatial and temporal patterns, and examined trends in species composition and abundance. The study also reviewed secondary data from online sources, peer- reviewed journals, and industry reports to provide context and comparisons. Additionally, interviews or consultations with National Fisheries and Aquaculture Authority (NaFAA) experts and other relevant stakeholders supplemented the quantitative data.

3.3.Sample Size

The study employed a full enumeration of catch and fishing effort data from 2018 to 2023, recorded in the logbooks of all the six operational trawlers with full Enumerations operating within Liberia's Exclusive Economic Zone (EEZ). This time frame was chosen to capture recent trends in fishery activities, identify any significant changes in species composition, and assess the sustainability of fishing practices.

3.4.Sampling Method

The study employed a purposive sampling approach to focus on key commercial species commonly caught by the six industrial trawlers. These species were selected based on their economic importance (the value of the species per the sale value obtained from fisheries enumerator data and prices observed from cold storage of the six industrial vessels), frequency of occurrence (landing data from the six trawlers), and contribution to total landings. The analysis encompassed both temporal (monthly and annual) and spatial (fishing zones within the Exclusive Economic Zone, or EEZ) dimensions to provide

a comprehensive understanding of catch patterns. Primary sources were historical logbook data, observer reports, and electronic monitoring systems.

3.5.Data Collection

Secondary data were collected from two Departments, namely Research and Statistics and Monitoring, Control, and Surveillance (MCS) of NaFAA. These departments provided access to vessel logbooks, catch certificates, observer reports, and electronic monitoring data. Specifically, the FAO Technical Code of Conduct for Responsible Fisheries were used to provide international standards and benchmarks for sustainable fishing practices, ensuring that the analysis aligned with global best practices. The State of World Fisheries and Aquaculture 2012 report was included to establish a historical baseline and trace changes in global fisheries that contextualize Liberia's situation. The Fishery and Aquaculture Country Profiles – Monrovia, Liberia, offered country- specific insights into the structure, performance, and challenges of Liberia's fisheries sector. The FAO Annual Report of 2021 provided recent institutional perspectives and statistical updates relevant to global and regional fisheries management. Finally, the State of World Fisheries and Aquaculture (2024) edition was consulted to incorporate the most up-to-date global trends, policy directions, and sustainability frameworks applicable to Liberia's fisheries context.

3.6.Data Analysis

The data collected was analyzed using a combination of Microsoft Excel and R. Descriptive statistics (mean, standard deviation) were used to summarize catch and fishing effort data. Species composition was analyzed through graphical representations such as bar charts and bar graphs. Trend analyses were used to examine temporal changes in fishing activities.

CHAPTER FOUR

RESULTS

4.1 Composition of Species Caught by the Six Trawlers

Figure 4.1and Table 4.1 illustrate fluctuations in the trend of species caught in Liberia's trawl fisheries per year from 2018-2023. It generally indicates a slight decline in the catch of commercially viable species, such as *Pseudotolithus spp., Scomberomorus tritor, Galeoides decadactylus,* and the Family Batrachoididae. However, some species, such as *Carcharhinus leucas, Portunus validus, Sarda sarda*, and *Dasyatis margarita*, have shown steady increases. These fluctuations and declines in major indicative species in catches may be due to overfishing. Moreover, some species, such as *Acanthocybium solandri, Sphyrna leonina, Stromateus fiatola*, and *Echeneis naucrates*, were consistently present in earlier years but were not as frequently recorded in the production data from 2021 onwards. Their absence became evident when comparing catch records between 2018–2020, where these species were recorded in varying quantities, and 2021–2023, where no entries for these species appeared. This disappearance may be attributed to factors such as overexploitation, changes in fishing effort, or environmental conditions that reduced their availability in trawl fisheries.

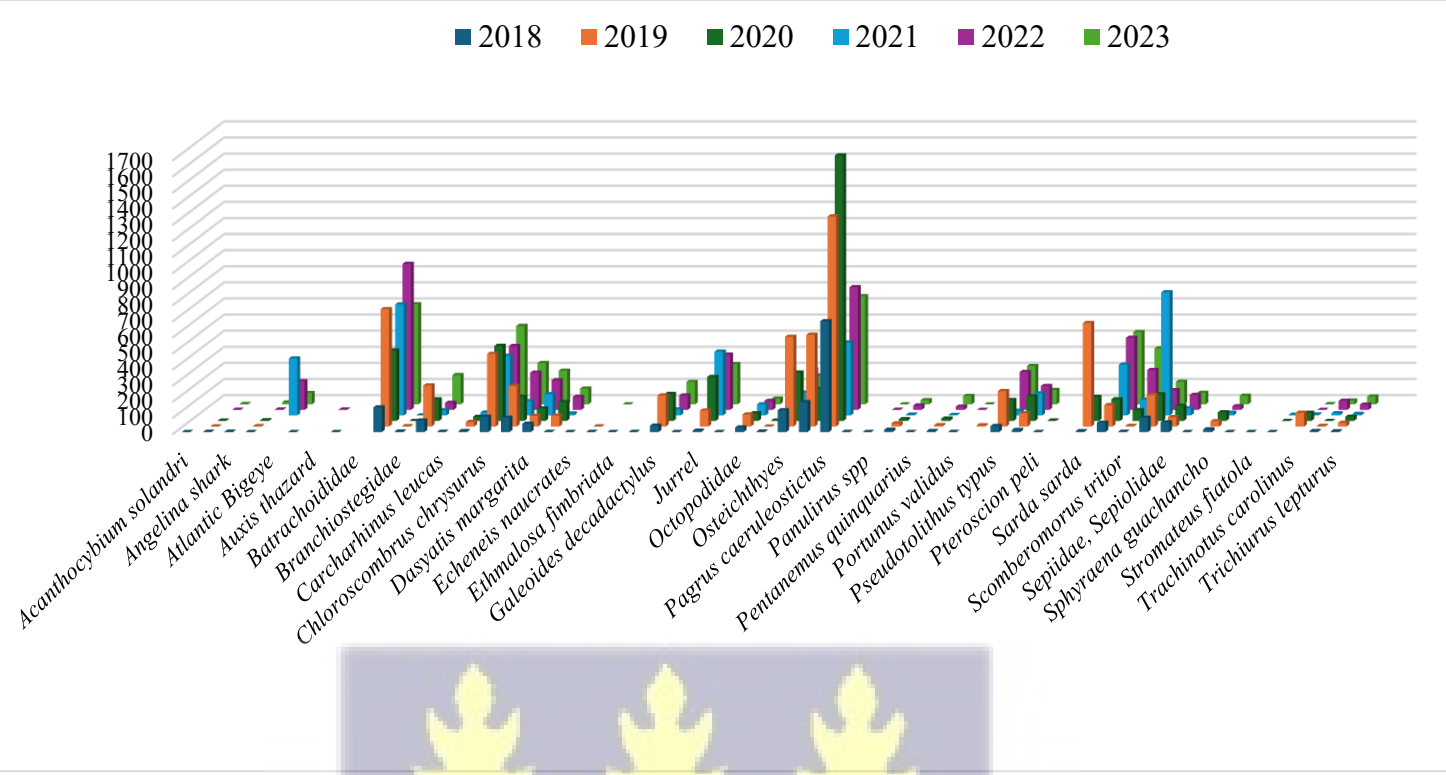

Figure 4.1: Fluctuation in trend of the species caught in the trawl fisheries of Liberia.

4.2 Fishing Effort data for the trawl sector from 2018 to 2023

Effort data in fisheries typically refers to the time, labour, or resources used to harvest fish. Proxies, such as the number of vessel trips, are often used to estimate fishing effort when direct data on fishing hours or gear deployment is unavailable. (FAO 2022). In this dataset, each unique combination of vessel name and date of arrival represents a single trip, and we assume that each trip represents a consistent unit of fishing effort. The formula used for effort in this context is Fishing Effort (f) per vessel per year = Number of fishing trips per vessel per Year

In 2019, *Brachydeuterus auritus* had 53 trips associated with its catch, while *Pagrus caeruleostictus* had 62 trips. These numbers proxy for the amount of fishing activity dedicated to catching each species. This method provides an accessible and reasonable measure of effort, especially when more granular data, such as fishing days, net soak time, or gear-specific effort, is unavailable. Effort data help us understand how targeted a fishery is toward a specific species. For instance, in 2018, *Cynoglossus senegalensis* had 557 trips, the highest among the species, which may indicate it was either widely available or highly targeted. However, high effort does not necessarily translate into high yield if the catch rate is low. From 2018 to 2023, the effort had varied significantly across species. For *Brachydeuterus auritus*, the number of trips rose from 366 visits in 2018 to 65 in 2023, while the effort for *Pagrus caeruleostictus* remained relatively stable between 55 and 67 visits annually.

Industrial Fisheries Catch Trends (Kg) (2018–2023)

Table 4.1: Dominant fish species caught per year between 2018-2023

Year	Species	Catch (Kg)
2018	*Brachydeuterus auritus*	366
2019	*Pagrus caeruleostictus*	62
2020	*Cynoglossus senegalensis*	65
2021	*Galeoides decadactylus*	45
2022	*Sardinella spp*	48
2023	*Brachydeuterus auritus*	65

4.3Analysis of the CPUE Trend (2018–2023)

Figure 4.2 below shows the Catch Per Unit Effort (CPUE) trend of Liberia's six trawlers operating within the Exclusive Economic Zone (EEZ) from 2018 to 2023. CPUE was low in 2018 and sharply increased in 2019. After peaking in 2019, CPUE steadily declined until 2021. Since 2021, CPUE has stabilized, with slight annual fluctuations.

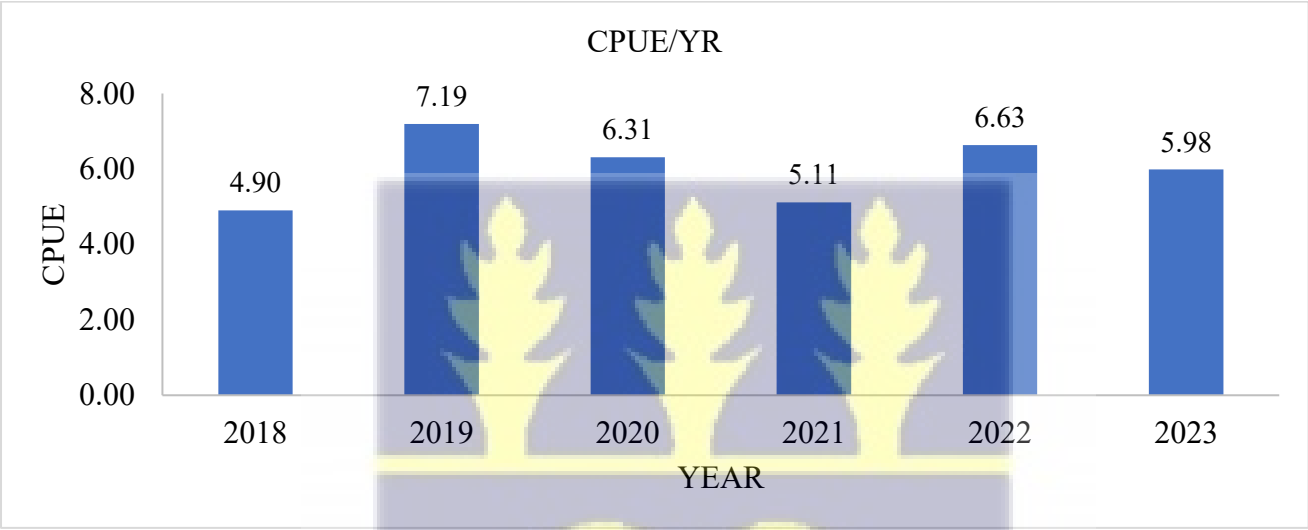

Figure 4.3: The catch per unit effort (CPUE) measured in tons per year, trends of the total production from the six trawlers operating in the Liberian waters from 2018 to 2023.

Table 4.2: Annual catch, fishing effort, and CPUE by species from 2018 to 2023 (See also Appendix 3)

YEARS	SPECIES	TOTAL CATCH (TONS)	EFFORT(TRIPS)	CPUE (TONS/TRIPS)
2018	*Brachydeuterus auritus*	152.93	366	0.42
	Cynoglossus senegalensis	89.02	557	0.16
	Galeoides decadactylus	39.98	175	0.23
	Pagrus caeruleostictus	688.39	615	1.12
	Sardinella spp	57.78	159	0.36
2019	*Brachydeuterus auritus*	549.36	47	3.62
	Cynoglossus senegalensis	252.02	42	6.00
	Galeoides decadactylus	169.96	47	3.62
	Pagrus caeruleostictus	1305.04	62	21.05
	Sardinella spp	1069.66	56	19.10
2020	*Brachydeuterus auritus*	438.26	65	6.74
	Cynoglossus senegalensis	150.86	65	2.32
	Galeoides decadactylus	168.32	54	3.12
	Pagrus caeruleostictus	1649.58	65	25.38
	Sardinella spp	134.58	58	2.32
2021	*Brachydeuterus auritus*	690.34	55	12.55

YEARS	SPECIES	TOTAL (TONS)	EFFORT(TRIPS)	CPUE (TONS/ TRIPS)
	Cynoglossus senegalensis	88.54	55	1.61
	Galeoides decadactylus	37.58	45	0.84
	Pagrus caeruleostictus	453.03	55	8.24
	Sardinella spp	315.74	55	5.74
2022	*Brachydeuterus auritus*	907.04	60	15.12
	Cynoglossus senegalensis	231.38	61	3.79
	Galeoides decadactylus	89.98	40	2.25
	Pagrus caeruleostictus	762.14	62	12.29
	Sardinella spp	447.92	48	9.33
2023	*Brachydeuterus auritus*	621.78	65	9.57
	Cynoglossus senegalensis	256.80	65	3.95
	Galeoides decadactylus	139.16	57	2.44
	Pagrus caeruleostictus	672.18	67	10.03
	Sardinella spp	448.96	56	8.02

Note: "*Sardinella* spp" includes both "*Sardinella maderensis*" and "*Sardinella aurita*."

4.4: CPUE of Key Indicative Species

Galeoides decadactylus

Figure 4.4 below shows the trend in CPUE from 2018 to 2023 of *Galeoides decadactylus*. The CPUE increased significantly from 2018 to 2019, remained relatively stable in 2020, and then sharply declined in 2021. It partially recovered in2022 and 2023.

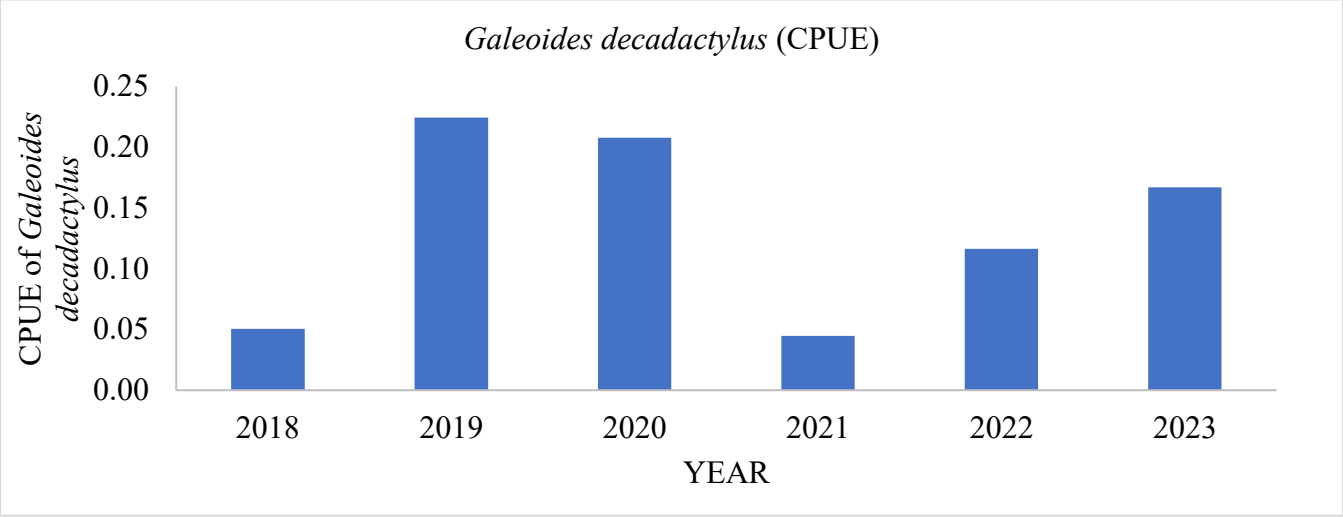

Figure 4.4: The catch per unit effort (CPUE) trends of *Galeoides decadactylus* from the six trawlers operating in the Liberian waters from 2018 to 2023.

4.4.1 *Pagrus caeruleostictus* (CPUE)

The CPUE increased sharply from 2018 to 2020 (Figure 4.5), peaking at 2.04, but dropped significantly in 2021, with a modest recovery in 2022 and 2023.

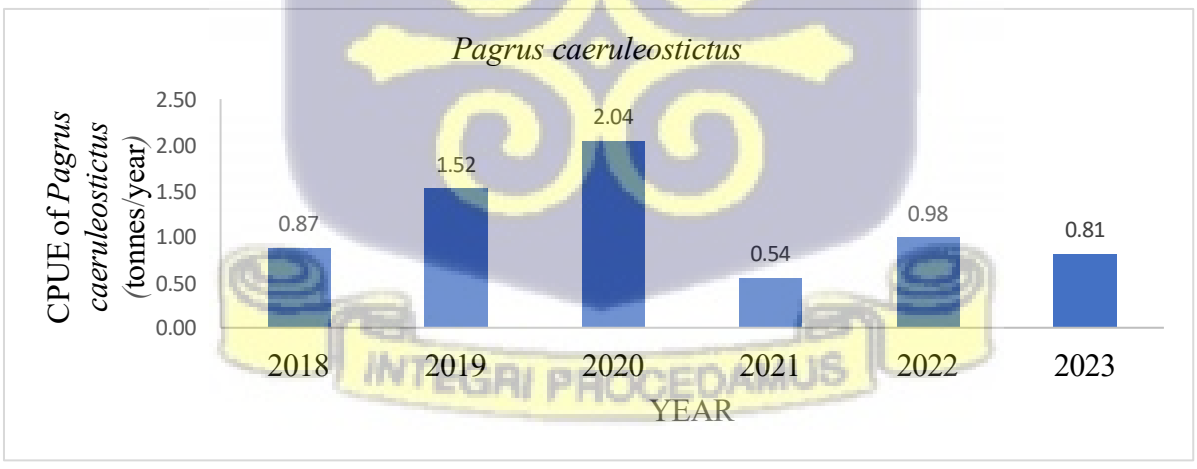

Figure 4.5: The catch per unit effort (CPUE) trend of *Pagrus caeruleostictus* from the six trawlers operating in the Liberian waters from 2018 to 2023.

4.4.2 *Brachydeuterus auritus* (CPUE)

The CPUE increased sharply from 2018 to 2019, fluctuated between 2020 and 2021, and peaked at 1.17 in 2022 and then declined to 0.75 in 2023 (Figure 4.6).

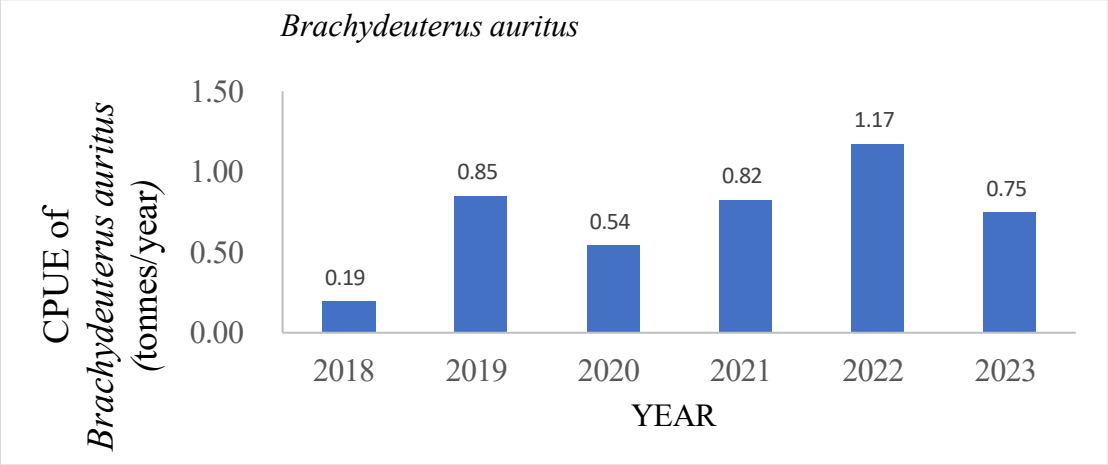

Figure 4.6: The catch per unit effort (CPUE) trend of *Brachydeuterus auritus* from the six trawlers operating in the Liberian waters from 2018 to 2023

4.4.3 *Cynoglossus senegalensis* (CPUE)

The CPUE increased from 2018 to 2019, declined in 2020 and 2021, and steadily progressed in 2022 and 2023 (Figure 4.7).

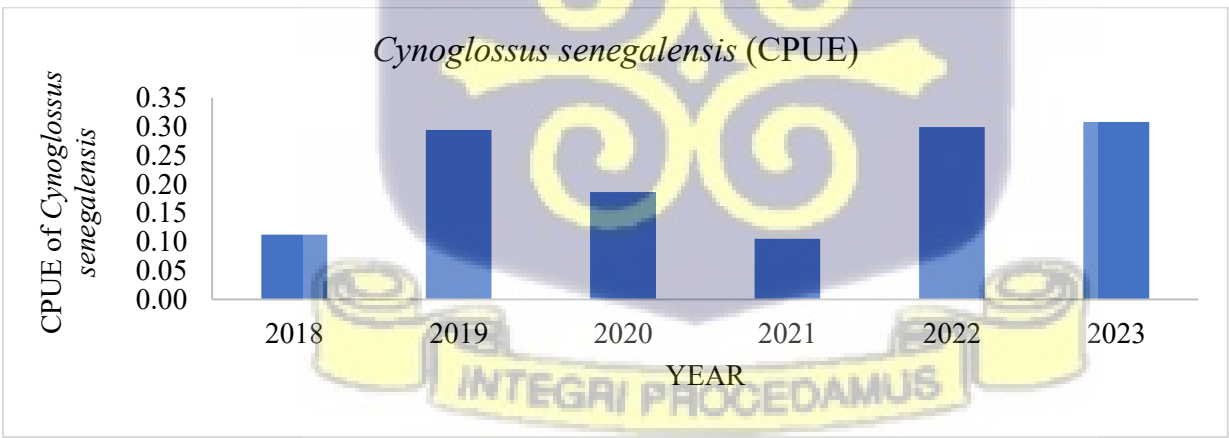

Figure 4.7: The catch per unit effort (CPUE) trend of *Cynoglossus senegelensis* from the six trawlers operating in the Liberian waters from 2018 to 2023.

4.4.4 *Sardinella spp*. (CPUE)

The CPUE consistently increased from 2018 to 2022, peaking at 0.58 before slightly declining to 0.54 in 2023 (Figure 4.8). The gradual rise suggests an improvement in *Sardinella spp*. Population abundance could be due to favourable environmental conditions, better recruitment, or reduced fishing pressure. The slight decline in 2023 might indicate the onset of resource exploitation or environmental fluctuations

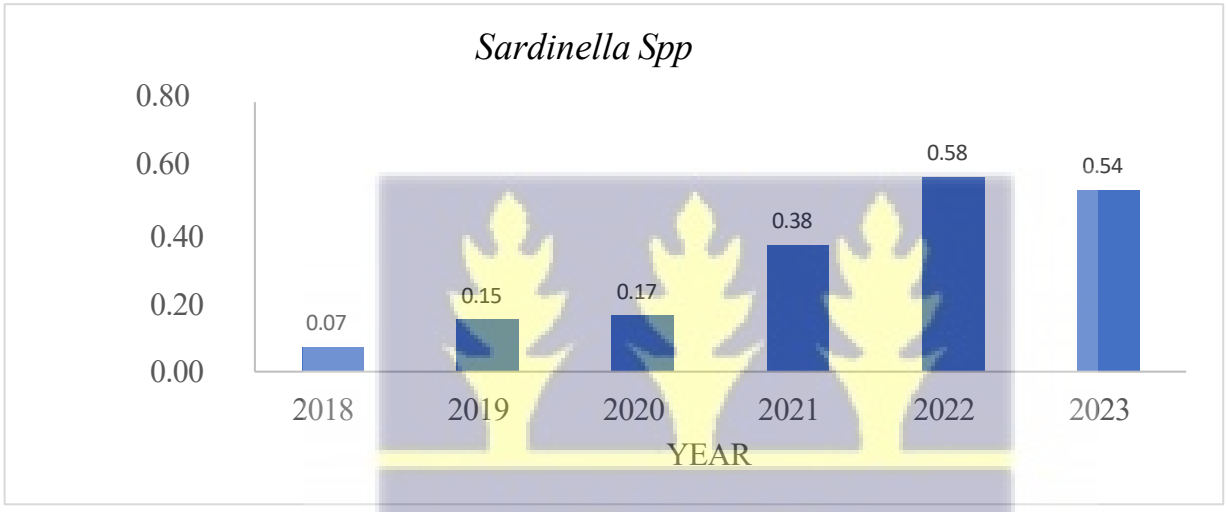

Figure 4.8: The catch per unit effort (CPUE) trend of Sardinella spp from the six trawlers operating in the Liberian waters from 2018 to 2023.

CHAPTER FIVE

DISCUSSION

5.1. Catch Trends Analysis

Over the past decade, the analysis of industrial fisheries in Liberia has revealed fluctuating trends in catch volumes, species composition, and seasonal variations. These variations influence factors such as fishing effort, regulatory measures, and environmental conditions. (Jueseah *et al.,* 2021). The total annual catch has demonstrated both increases and declines, corresponding with changes in fishing activity, regulatory enforcement, and natural ecosystem fluctuations. Notably, peak catch volumes in certain years align with periods of increased industrial fishing activities, whereas declines suggest either overexploitation, regulatory interventions, or unfavourable environmental conditions. (Jueseah *et al*., 2020). Studies on Liberia's fisheries have shown that significant changes in catch trends are linked to shifts in regulatory frameworks (Jueseah *et al*., 2020).

The trends observed in species composition further highlight the dynamic nature of Liberia's industrial fisheries as usually portrayed by most fish populations. Historically, small pelagic species such as Sardinella spp. have constituted a substantial proportion of the catch, fluctuating in abundance due to seasonal and environmental factors. Similarly, demersal species, including *Galeoides decadactylus*, have been key targets, though their populations have shown signs of depletion due to persistent fishing pressure (Jueseah *et al.,* 2020). The competition between artisanal and industrial fleets has exacerbated stock depletion, with artisanal fishers experiencing reduced access to critical fishery resources due to the activities of industrial vessels. (Belhabib *et al*., 2017). A review of seasonal catch trends indicates that peak fishing periods generally occur between June and September, coinciding with

oceanographic upwelling that enhances fish aggregation and catchability. Conversely, lower catch volumes are recorded between December and February, reflecting seasonal migration patterns and environmental conditions influencing fish availability (MRAG, 2014). Understanding these seasonal trends is crucial for developing adaptive fisheries management policies that align with biological cycles and promote sustainability. Policies restricting fishing during key breeding periods could help prevent overexploitation and support stock replenishment (FAO, 2021).

The impact of international fishing fleets operating within Liberia's Exclusive Economic Zone (EEZ) is another critical factor influencing catch trends. Many foreign-flagged vessels exploit Liberia's waters under the Sustainable Fisheries Partnership Agreement (SFPA) (European Union, 2020). However, they are often associated with unregulated practices that challenge national enforcement capabilities (European Union, 2020). The Vessel Monitoring System (VMS), implemented in 2021, has contributed to improved tracking of industrial fishing operations (Jueseah *et al*., 2021). However, 30 limitations in enforcement capacity and compliance monitoring still undermine its effectiveness in deterring illegal activities (MRAG, 2019). A comparative assessment of Liberia's catch trends with neighbouring West African nations underscores the regional dimension of fisheries management. Countries such as Ghana and Sierra Leone have reported similar fluctuations in industrial fisheries, often linked to regional stock migration, climate variability, and shared resource exploitation (Belhabib *et al.,* 2015). This highlights the need for strengthened regional cooperation under frameworks such as the West Africa Regional Fisheries Program (WARFP) to ensure sustainable management of transboundary fish stocks (World Bank, 2021).

Liberia's industrial fisheries sector continues to experience dynamic catch trends influenced by regulatory, environmental, and international factors. While national policies such as the 2019 Fisheries and Aquaculture Management Law and NaFAA oversight have enhanced governance, persistent challenges remain. (FCWC, 2025). Illegal, unreported, and unregulated (IUU) fishing, especially by foreign fleets operating under flags of convenience, along with data inconsistencies and weak enforcement capabilities, continues to threaten sustainability. (FCWC, 2025) (NaFAA, 2022). The sector also faces external pressure, including the risk of an EU "red card" warning due to enforcement gaps. (NaFAA, 2024). Future fisheries management strategies must prioritize stricter regulatory compliance, enhanced monitoring technologies, and regional collaboration through MoUs and transparency initiatives to ensure the long-term viability of Liberia's marine resources (NaFAA, 2023).

5.2 Species Composition and Fisheries

Liberia's industrial trawling sector is primarily dominated by foreign-owned or joint venture fleets, mainly targeting demersal species such as croakers (*Pseudotolithus spp.*), groupers (*Epinephelus spp.*), and snappers (*Lutjanus spp.*) (EJF, 2021). A 2021 Environmental Justice Foundation (EJF) assessment showed that the most frequently landed species in Liberian industrial trawl fisheries were *Pseudotolithus elongatus, Galeoides decadactylus*, and *Arius* spp. (EJF, 2021). However, non-target species, including juveniles of pelagic fish and vulnerable species such as rays and sea turtles, are often caught and discarded, raising concerns about fisheries (EJF, 2021).

5.3 Trends in Fish Abundance and Fishing Pressure

From 2018 to 2023, the Catch Per Unit Effort (CPUE) of key indicative fish species in Ghanaian marine waters displayed distinct trends. *Galeoides decadactylus* showed a sharp

increase in CPUE from 0.05 t/y in 2018 to 0.22 t/y in 2019, followed by a stable level in 2020 and a steep decline to 0.04 t/y in 2021. This dip likely resulted from heightened fishing effort and potentially stricter administrative controls during that year. A partial recovery in 2022 and 2023 may indicate ecological rebound or variability in fishing activity. Similarly, *Pagrus caeruleostictus* reached its highest CPUE in 2020 at 2.04 t/y, before dropping significantly to 0.54 t/y in 2021 and then experiencing a modest recovery. Literature supports this pattern; Nunoo and Asiedu (2013) observed signs of overexploitation in *Pagrus* populations, highlighting the need for regulated effort and seasonal closures to prevent stock depletion. *Brachydeuterus auritus* exhibited a different pattern, increasing from 0.19 t/y in 2018 to 0.85 t/y in 2019, fluctuating slightly in 2020 and 2021, and peaking at 1.17 t/y in 2022 before dropping to 0.75 t/y in 2023. The apparent resilience of this species aligns with FAO/CECAF (2008) findings, which warn against interpreting consistent CPUE increases as indicators of healthy stocks due to possible hyperstability-where catch remains high despite declining population sizes.

In the case of *Cynoglossus senegalensis*, CPUE increased from 0.11 t/y in 2018 to 0.29 t/y in 2019, dropped in 2020 and 2021, and then steadily improved to 0.31 t/y by 2023. This recovery could be attributed to lower fishing pressure or favourable environmental conditions, as suggested by Neufville (2022), who noted that demersal flatfish benefit from reduced trawling and protected areas. *Sardinella* spp. demonstrated a consistent upward trend from 0.07 t/y in 2018 to a peak of 0.58 t/y in 2022, before a slight decrease in 2023. This trend reflects the sensitivity of small pelagic species to oceanographic conditions such as temperature and productivity.

The overarching patterns observed in the CPUE data resonate with broader regional assessments. Lazar (2017) emphasized that CPUE trends in Ghana's demersal fisheries are

often driven by management strategies, particularly effort restrictions and monitoring. Moreover, Lemrabott (2023) highlighted the issue of serial depletion, particularly along the West African coast, where heavily targeted stocks experience temporary recovery only to decline again without consistent regulation. Across all species examined, the peaks and troughs in CPUE suggest dynamic interactions between fishing effort, environmental changes, and stock resilience.

5.4 Seasonal and Annual Variability

The seasonal variability in catch volumes aligns with broader ecological patterns within West African fisheries (Belhabib *et al*., 2015). The highest catches typically occur between June and September, which is associated with increased fish aggregation due to oceanographic conditions such as upwelling and nutrient availability (Belhabib *et al*., 2015). The upwelling phenomenon enhances primary production, thereby increasing the availability of food for fish and resulting in higher catch rates. (MRAG, 2014). This period often coincides with the breeding season of many commercially important species, necessitating well-structured regulatory frameworks to prevent overexploitation (Jueseah *et al.*, 2021) (FAO, 2022). Conversely, the lowest catch volumes are recorded between December and February, characterized by declining water productivity and unfavourable environmental conditions resulting in lower fish availability (FAO, 2021).

Seasonal fluctuations have profound implications for fisheries management, particularly for stock assessments and catch regulations. The migratory nature of many pelagic species, such as Sardinella spp. and Trachurus spp., means they move between different regions in response to oceanographic and climatic conditions. (Jueseah *et al*., 2020). These species respond to temperature gradients, changes in salinity, and variations in prey availability, which

significantly influence their spatial distribution and abundance (Rutterford *et al*., 2023). Understanding these migration patterns is crucial for implementing effective temporal closures and fishing restrictions to protect fish stocks during sensitive breeding and recruitment periods (Belhabib, 2018).

Multiple factors influence the interannual variations in fish catch volumes, including changes in ocean conditions, fishing pressure, regulatory interventions, and illegal, unreported, and unregulated (IUU) fishing activities. Some years experienced exceptionally high fishery yields due to favourable environmental conditions (Pauly *et al*., 2013; Lehodey *et al.*, 2003). In contrast, other years witnessed declines, often attributed to overfishing and ecological degradation. (FAO,2022).

The effects of climate change are increasingly evident, with rising sea surface temperatures, ocean acidification, and shifting ocean currents significantly affecting fish population dynamics and catch rates (EPA, 2025). These climate-driven shifts may lead to the displacement of certain fish stocks, reducing their availability to local fishers and disrupting traditional fishing patterns (FAO, 2022). Moreover, industrial fisheries exert significant pressure on fish stocks, particularly when seasonal catch surges coincide with intensified fishing activities (Pauly *et al*., 2021). Overfishing during peak abundance seasons depletes reproductive-age fish, reducing spawning success and compromising long-term stock sustainability (Cheung *et al*., 2016). Regulatory bodies such as the National Fisheries and Aquaculture Authority (NaFAA) have implemented measures to curb excessive fishing, including closed seasons and restricted fishing zones (NaFAA, 2024).

However, enforcement remains challenging due to limited monitoring capacity and inadequate surveillance mechanisms (MRAG, 2019). Strengthening monitoring, control, and surveillance (MCS) systems is crucial for mitigating the effects of excessive fishing effort and ensuring sustainable catch levels (FAO, 2023). Adaptive fisheries management strategies are critical in addressing seasonal and interannual fluctuations in fishery yields (Hilborn *et al*., 2020). Integrating climate variability data, stock assessments, and real-time monitoring can provide valuable insights for decision-making and policy formulation (Perry *et al*., 2009).

Collaborative regional efforts, particularly under frameworks such as the West Africa Regional Fisheries Program (WARFP), have shown promise in fostering shared management strategies and enhancing resource sustainability across national boundaries. Food and Agriculture Organization. (FAO, 2021).

Future research should investigate the long-term effects of climate change on seasonal fisheries productivity and evaluate the efficacy of regulatory interventions in mitigating fish stock depletion. Seasonal and annual variability in fisheries production presents opportunities and challenges for sustainable fisheries management in Liberia (Belhabib *et al*., 2015; Mueller, 2020). Understanding the ecological and climatic drivers of these fluctuations is crucial for developing effective regulatory frameworks that balance economic needs with conservation goals (Cheung *et al*., 2016). Enhancing data collection, enforcing stringent fishing regulations, and promoting regional cooperation will ensure the long-term viability of Liberia's fisheries sector. By adopting evidence-based management strategies, Liberia can safeguard its marine resources against environmental uncertainties and ensure food security and economic stability for its fishing communities.

5.3 CPUE (Catch Per Unit Effort)

CPUE is a widely used indicator of fish stock abundance and fishery productivity. It expresses the catch obtained per standard unit of fishing effort and provides a standardized method for comparing fishing success across time or areas. The CPUE values for all five species were relatively very low in 2018. *Brachydeuterus auritus* had a CPUE of only 0.42 kg/trip, while *Cynoglossus senegalensis* and *Galeoides decadactylus* recorded 0.16 and 0.23 kg/trip, respectively. The highest CPUE in that year was for *Pagrus caeruleostictus*, at 1.12 kg per trip. These low values may indicate either poor stock abundance or inefficient fishing efforts. This baseline year represents a period when fishers may have exerted high effort but received minimal returns, indicating that stock levels were low or not effectively targeted (FAO, 2020).

In 2019, there was a drastic increase in CPUE across all species. For example, *Pagrus caeruleostictus* increased from 1.12 to 21.05 kg/trip, and *Sardinella spp* jumped from 0.36 to 19.10 kg/trip. *Brachydeuterus auritus* also increased significantly to 11.69 kg/trip. This sharp improvement suggests either a recovery in fish stocks, changes in fishing strategy, or the use of more efficient gear (FAO, 2020). It could also indicate seasonal aggregations or improved knowledge of fishing grounds (Pauly *et al*., 2016). Regardless, 2019 marks a significant shift in catch efficiency, raising both economic benefits and concerns about sustainability.

CPUE remained high for several species in 2019, particularly *Pagrus caeruleostictus*, which peaked at 25.38 kg per trip, its highest value across all years. *Brachydeuterus auritus* had a CPUE of 6.74, and *Cynoglossus senegalensis* recorded 2.32. However, *Sardinella spp* saw a

steep decline to 2.32 kg/trip after its 2019 peak. This decline could be due to environmental variability, overfishing, or migratory shifts in the stock (Cury *et al*., 2000). Despite some fluctuations, CPUE values in 2020 generally remained higher than in 2018, suggesting continued improvements in fishing efficiency or a temporary increase in fish availability (MRAG, 2021). In 2021, CPUE values declined for most species compared to the previous two years. *Pagrus caeruleostictus* dropped to 8.24 kg/trip, and *Sardinella spp* to 5.74 kg/trip. *Galeoides decadactylus* fell further to 0.84 kg/trip. While *Brachydeuterus auritus* showed an increase to 12.55 kg per trip, most species recorded lower catch efficiency, possibly reflecting signs of stock stress or reduced fish availability. This decline underscores the importance of careful management following high-yield years, as sustained pressure can lead to stock depletion (FAO, 2018), particularly in the absence of quotas or catch limits (NaFAA, 2022).

In 2022 and 2023, CPUE trends were mixed. In 2022, *Brachydeuterus auritus* and *Sardinella spp* both rebounded to 15.12 and 9.33 kg/trip, respectively, while *Pagrus caeruleostictus* had 12.29 kg/trip. By 2023, *Pagrus caeruleostictus* declined again to 10.03, and *Brachydeuterus auritus* to 9.57. These variations suggest that while some stocks remained productive, others might be under pressure from fishing. Overall, the period from 2019 to 2023 was characterized by higher catch per unit effort (CPUE) compared to 2018, but with significant year-to-year variability, underscoring the need for ongoing monitoring and adaptive management to prevent overfishing and support sustainable yields (FAO, 2022).

Licensing industrial fishing vessels in Liberia is a fundamental regulatory measure to control fishing efforts and ensure adherence to sustainable fishing practices. However, inconsistencies in licensing procedures and enforcement mechanisms have resulted in challenges in effectively managing fisheries resources. Many foreign vessels operate under licensing agreements but

often engage in practices that undermine sustainability goals, including underreporting catches and engaging in illegal, unreported, and unregulated (IUU) fishing activities. NaFAA has strengthened regulatory frameworks by introducing stricter licensing requirements and improving compliance monitoring through digital tracking mechanisms to address these concerns. For example, the Fisheries Integrated Management System (FIMS), launched in May 2024, enables digital applications, real-time tracking of licenses, and automated compliance checks. (NaFAA, 2024).

Observer programs ensure that industrial fishing activities comply with established regulations. Observers are tasked with monitoring onboard fishing operations, collecting data on catch volumes and species composition, and reporting violations of fisheries regulations. However, the effectiveness of these programs has been hindered by logistical challenges, inadequate funding, and resistance from industrial fishing operators. Studies indicate that limited observer coverage and the lack of enforcement mechanisms have contributed to persistent non-compliance among industrial fleets operating within Liberia's Exclusive Economic Zone (EEZ) (Pew Charitable Trusts, 2023).

Strengthening observer programs by increasing coverage, ensuring the independence of observers, and leveraging technology such as electronic monitoring systems can enhance transparency and accountability within the sector. The World Wildlife Fund (WWF) and the Food and Agriculture Organization (FAO) provide toolkits and technical guidance for implementing EMS, emphasizing their role in improving data accuracy and reducing IUU fishing (WWF, 2023)

In addition to direct monitoring measures, Monitoring, Control, and Surveillance (MCS) programs have been implemented to combat IUU fishing and improve enforcement capabilities. According to NaFAA's MCS department, priorities include fisheries patrols, operationalizing Liberia's obligations under the PSMA, and maintaining both the Fisheries Monitoring Centre and the Vessel Monitoring System (VMS) (NaFAA, 2020). NaFAA, in collaboration with international organizations such as the Environmental Justice Foundation (EJF) and the European Union, launched the DASE mobile app in 2021, enabling artisanal fishers to report illegal fishing incidents with geotagged photos and videos, thereby enhancing surveillance (NaFAA, 2021). However, resource constraints, including inadequate funding, insufficient personnel, and limited logistics, continue to hinder the effectiveness of MCS. (NaFAA, 2020).

Enhancing interagency collaboration, securing additional financial resources, and investing in technological solutions such as satellite-based vessel tracking can help strengthen MCS operations and improve overall fisheries governance. For instance, the Fisheries Committee for the West Central Gulf of Guinea (FCWC) and the West Africa Task Force (WATF) held an interagency MCS capacity-building workshop in Monrovia in May 2023, bringing together NaFAA, the Coast Guard, Liberia Maritime Authority, and international partners to improve port state measures and vessel tracking. (FCWC, 2023).

Another critical aspect of fisheries management policies is establishing marine protected areas (MPAs) to conserve fisheries and ensure the sustainability of key fish stocks. MPAs provide refuge for overexploited species and serve as essential breeding and nursery grounds for commercially valuable fish populations (EJF, 2015). Despite their ecological significance,

implementing and enforcing MPAs in Liberia has faced challenges, including limited patrol capacity, funding shortages, and weak community engagement (EJF, 2015). Similar governance and enforcement hurdles have been identified globally, where effective MPA management depends on adequate surveillance, interagency cooperation, and local stakeholder involvement (Farina, 2024).

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study set out to assess the seasonal and annual variability in catch and effort trends of industrial fisheries in Liberia from 2018 to 2023, and the findings clearly that while some commercially valuable stocks such as *Pseudotolithus spp*., *Scomberomorus tritor, Galeoides decadactylus*, and the Family Batrachoididae experienced declines, other species, including *Carcharhinus leucas, Portunus validus*, and *Sarda sarda* increased steadily, and still others such as *Acanthocybium solandri* and *Sphyrna leonina* were rarely caught in later years. This variability in species presence and absence, as well as in relative abundance, reflects the seasonal and annual population dynamics, fishing pressure and environmental factors are also altering the ecological balance within Liberia's trawl fisheries.

The effort data further demonstrated these fluctuations, with vessel trips used as a proxy indicating that targeting intensity differed not only by species but also across years. These findings illustrate that effort is not evenly distributed across seasons or years and also reinforce that high effort does not guarantee proportionally high yields, thereby highlighting the importance of examining efficiency alongside activity. The implication of these findings is that Liberia's industrial fisheries are experiencing both biological and operational variability that influence their sustainability. The declining trends in some key commercial species point to potential stress on stocks, while the disappearance of certain species from catch records signals deeper ecological shifts.

At the same time, the increase in CPUE observed for certain species in specific years demonstrates that stock abundance and catch efficiency are not uniformly declining but are instead highly variable, shaped by ecological cycles and fishing behaviour. The introduction of the National Fisheries and Aquaculture (NaFAA) in 2017, along with subsequent policies, has sought to impose stricter controls on Industrial trawlers; however, despite these interventions, underreported catches, unmonitored transshipment, and illegal incursions into restricted fishing zones persist. Moreover, disparities between reported and actual catches have raised concerns about the effectiveness of fisheries governance in ensuring sustainable exploitation.

6.2 Recommendations

Strategic recommendations are essential to ensure the sustainable management of Liberia's industrial trawling sector. Strengthening fisheries monitoring and data collection systems is crucial for providing accurate and up-to-date information on catch volumes, species composition, and fishing effort. Through the National Fisheries and Aquaculture Authority (NaFAA), the government should adopt digital technologies, such as electronic reporting systems and vessel monitoring systems (VMS), to enhance data accuracy and transparency.

Enforcing fisheries regulations and combating illegal, unreported, and unregulated (IUU) fishing should be prioritized to protect marine resources. The Liberian Government should provide NaFAA with enough logistics to enable them increase patrol vessel deployment, enhance surveillance capacity, and impose stiffer penalties on vessels violating fishing laws.

Collaborating with neighboring and international partners in joint patrols, joint closures, joint capacity building can further strengthen enforcement and monitoring efforts.

Promoting the use of selective and eco-friendly fishing gears, such as bycatch reduction devices (BRDs) and turtle excluder devices (TEDs), will help minimize bycatch and protect endangered species, thereby contributing to more sustainable fishing practices.

Implementing science-based catch limits and seasonal closures is crucial in preventing overfishing, protect gravid and juvenile fish species and enabling fish stocks to recover. These measures should be based on comprehensive stock assessments and collaborative research between NaFAA, research institutions, and regional bodies.

Furthermore, fostering stakeholder participation, establishing co-management committees and engaging fishing communities in decision-making can strengthen compliance and promote inclusive governance.

Encouraging sustainable certification programs, such as the Marine Stewardship Council (MSC), will improve the reputation of Liberia's fisheries sector and enhance market access for sustainably sourced fish. Fishing companies willing to pursue eco-friendly certification standards should receive financial and technical support. Additionally, public awareness and education campaigns on marine conservation should be intensified to promote responsible fishing practices among fishers, coastal communities, and the general public.

Finally, the nationwide data collection systems be improved. This can be achieved through the use of standardized logbooks, electronic monitoring devices, and trained fisheries officers at landing sites. Such improvements will ensure accurate and reliable records that can support informed management decisions.

APPENDICES

Appendix 1: Industrial fishing vessel GUO JI 828 docked at the Freeport of Monrovia during fisheries inspection and offloading operations. (Source: NaFAA, 2024; Photograph by Subah)

Appendix 2: Industrial fishing vessel GUO JI 829 undergoing port inspection at the Freeport of Monrovia, with fisheries observers and port inspectors present. (Source: NaFAA, 2024; Photograph by Subah, Y. Z)

Appendix 3: Annual catch effort (kg) by species from 2018 to 2023

Year	Brachydeuterus auritus	Cynoglossus senegalensis	Galeoides decadactylus	Pagrus caeruleostictus	Pseudotolithus typus????	Sardinella spp
2018	152.93	89.02	39.98	688.39	37.53	57.78
2019	549.36	252.02	169.96	1305.04	183.20	1069.66
2020	438.26	150.86	168.32	1649.58	130.02	134.58
2021	690.34	88.54	37.58	453.03	28.70	315.74
2022	907.04	231.38	89.98	762.14	235.72	447.92
2023	621.78	256.80	139.16	672.18	238.42	448.96

Observer code					Vessel code						Trip ID									
					Date/ Time						Position									
Hual	Totalnets	Sample?	Target	Sustrate		Day	Month	Year	Time (24-hr)	Lat-Deg	Lat-Min	Lat- N/S	Long-Deg	Long-Min	Long-E/W	Depth,bottom(	Speed (Knots)	Retained catch (mt)	Totalcatch Est.(mt)	Method
					Start						.			.						
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Gear performance codes:	Target:	Total catch method:
1. No problem	S-shrimp	1. Weigh the entire catch
2 Door and warp-related problem	Substrate:	2. Weigh subsample & extrapolate to total count (basket, carton)
Net not fishing(bogged, obstructed, bag untied,torn,etc)	M-Mud	3. Volumetric estimate: Bin or codend
Net lost	R-Rocky	4. Catch/effort ratio 6. Unable to obtain total catch estimate
Other	CM-corals & mud	5. Captain/Vessel estimate 7. Other

Appendix 4: National fisheries and Aquaculture Authority Industrial Data Sheet.

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