ENHANCING VESSEL MONITORING SYSTEMS (VMS) IN SIERRA LEONE TO COMBAT IUU FISHING

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ABSTRACT

Illegal, Unreported, and Unregulated (IUU) fishing poses a significant threat to marine ecosystems, fisheries sustainability, and food security in Sierra Leone. In response, the Government of Sierra Leone established the Joint Maritime Committee (JMC) in 2006 and introduced a Vessel Monitoring System (VMS) as a mandatory licencing requirement for industrial fishing vessels. This study assesses the effectiveness of VMS in combating IUU fishing and examines opportunities to improve the utilisation and accessibility of VMS data for enforcement, policymaking, and research. A mixed-methods approach was employed, combining structured questionnaires administered to Joint Operations Centre (JOC) operators and fisheries inspectors with key informant interviews involving the heads of key JMC institutions (n = 15). Quantitative data were analysed using descriptive statistics, and qualitative data were examined through thematic content analysis. The results indicate that respondents perceive VMS as having a high impact on reducing IUU fishing incidents, particularly by enabling vessel tracking, identifying incursions into restricted zones, and supporting targeted enforcement. VMS data were rated as highly useful for enforcement and policymaking, with moderate scope for improvement in research applications. Compliance among industrial fishing vessels was perceived as high, influenced by continuous monitoring, substantial financial penalties, and coordinated interagency enforcement. However, institutional challenges, particularly high staff attrition within the JMC, were identified as key constraints on sustained VMS effectiveness. Therefore, strengthening institutional capacity, improving staff retention, and enhancing data accessibility are essential to maximise the long-term contribution of VMS to fisheries governance in Sierra Leone.

Keywords: Vessel Monitoring System (VMS), Illegal, Unreported and Unregulated (IUU) fishing, Monitoring, Control and Surveillance (MCS), fisheries governance, Sierra Leone.

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ABBREVIATIONS AND ACRONYMS

AIS	Automatic Identification System
EEZ	Exclusive Economic Zone
FAO	Food and Agricultural Organization
FMC	Fisheries Monitoring Centre
IEZ	Inshore Exclusive Zone
IMO	International Maritime Organization
IUU	Illegal Unregulated and Unreported
JMC	Joint Maritime Committee
JOC	Joint Operation Centre
KII	Key Informant Interview
MCS	Monitoring Control and Surveillance
MDA	Ministries Department and Agencies
MFMR	Ministry of Fisheries and Marine Resources
MOU	Memorandum of Understanding
VMS	Vessel Monitoring System

1. INTRODUCTION

1.1 Background

A West African country, bordered by Guinea to the northwest, Liberia to the south, and the northern Atlantic Ocean to the southwest, encircles a country called Sierra Leone. Lying between latitude 8° 30' north and longitude 11° 30' west, it has a hot humid tropical climate and a rainy season with a population of about 7.5 million, and the country lies on a surface area of 71, 740 km². Additionally, mainland Sierra Leone has offshore islands, such as Yealiboya, Banana, Turtle, and Sherbro Islands, as well as other islets. The coastal area features vast mangrove marshes and several estuaries and rivers that are suitable for short-distance navigation (Seto, 2015).

Figure 1 below shows that Sierra Leone has a combined coastline stretching over 510 km and a continental shelf 100 km wide to the north, which shrinks down to 13 km southwards on the Liberian border and extends over a surface area of 30 000 km^2. The 200-nautical-miles EEZ covers an area of 157 000 km^2 (Seto, 2015). In the waters of Sierra Leone, the oceanographic conditions are marked by a consistent shallow thermocline positioned midway along the shelf, influencing fish distribution. Seasonal variations are attributed to the monsoonal wet season, which is characterised by increased river flow, decreased surface water salinity, reduced surface radiation, and a decline in mixed layer temperatures (Coker, 2019).

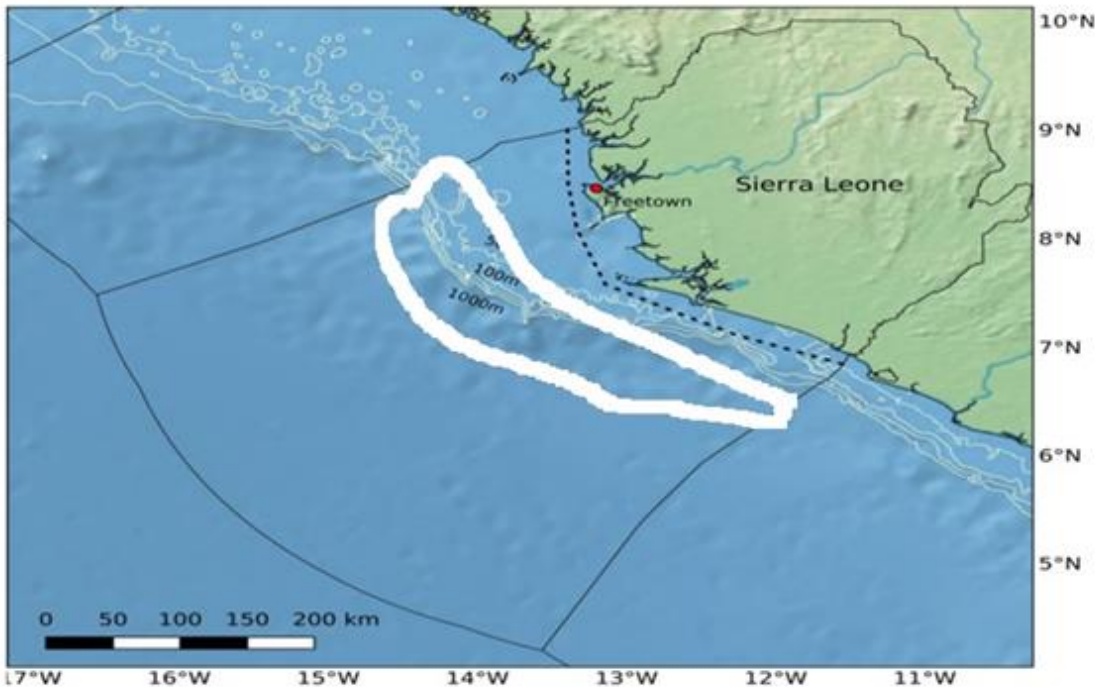

Figure 1. Map of Sierra Leone showing the Exclusive Economic Zone (EEZ). The dotted lines show the Inshore Exclusive Zone (IEZ), the prohibited area for industrial fishing vessels, and the bold white line indicating the Guinea Current (Marine Regions, 2018).

Sierra Leone's fisheries are situated in the Guinea Current, which is one of the world's most productive marine ecosystems. According to the MFMR (2018), between 400,000 and 500,000

people work in the fisheries sector. Fisheries account for 10% of the country's GDP and provide 80% of the population with dietary animal protein (Setoa, 2017).

The fisheries of Sierra Leone are broadly classified into three sub-sectors:

1.1.1 The industrial fishery.

The industrial fishing sector operates within the Exclusive Economic Zone (EEZ), extending 200 nautical miles from the coastline, and utilises a multinational fleet consisting of shrimp trawlers, purse seiners, canoe support vessels, mother ships, and transports. The primary targets of this industrial fishery include Sciaenidae *(Pseudotolithus senegalensis*), Haemulidae (*Pomadasys jubelini*), Sparidae (*Sparus caeruleostictus, Pagellus belloti, and Dentex canariensis*), Polynemidae (*Galeiodes decadactylus*), and Lutjanidae (*Lutjanus goreensis*) (Ssentongo & Ansa-Emmin, 1986). Pelagic stocks primarily comprise clupeids (*Sardinella maderensis, Ethmalosa fimbriata, Illisha africana, and Sardinella aurita*) and Caranx hippos, among others. The fishery also targets shellfish resources, which are dominated by crustaceans (*shrimps, crabs, and lobsters*), cephalopods (*cuttlefish*), and molluscs (*gastropods and bivalves*). This industry segment is primarily oriented towards exports, with a significant portion of the fleet owned by foreign entities, mainly comprising trawlers focusing on shrimp and bottom-dwelling finfish. Sierra Leone's industrial fishing sector originated in 1955 when Italian companies introduced trawlers to local waters, subsequently leading to increased fishing activity and agreements with the USSR, granting access to a large Soviet fleet of trawlers, purse seiners, and industrial vessels to national waters (Thorpe et al., 2009). Since 1981, the Ministry of Fisheries and Marine Resources (MFMR) has continuously recorded changes in the industrial fishing operations. In 1981, there were 183 licenced industrial fishing vessels in operation; by 1987, this number had increased to 327, and by 1993, it had decreased to 192 (Sheku Sei, 2016). The industrial fishing fleet consists mainly of demersal trawlers, shrimp trawlers, canoe support vessels, and purse seiners, owned by individuals of diverse nationalities, such as Chinese, Korean, Russian, Greek, Italian, and Spanish. Table 1 offers a summary of Sierra Leone's Industrial Fleet composition.

Table 1. Sierra Leone Industrial Fleet composition, October 2023 (mfmr.gov.sl, 2023)

Type of vessel	Number of vessels	Country of origin
Demersal trawler	33	China, Turkey, Sierra Leone
Shrimper trawler	08	Sierra Leone
Mid – water trawler	04	China
Tuna Purse Seiner	27	Spain, El Salvador, France, Panama, Guatemala, Belize, Senegal, Guinea
Carrier vessel	03	China, Sierra Leone
Supply vessel	08	Cape Verde, Curacao, Spain, Panama, Belize

1.1.2 The artisanal fishery.

The artisanal fishery, characterised by its small-scale nature, stands out because of its diverse range of fishing equipment and vessels. It represents a significant economic activity across 530 fishing landing sites located in coastal districts such as Western Area, Port Loko, Kambia, Moyamba, Bonthe, and Pujehun. In this fishery, a variety of dugout and planked canoes are utilised along with a range of fishing equipment. Over time, there has been a notable growth in the total number of fishing vessels in artisanal fisheries, increasing from approximately 6,000 in 1974 to approximately 12,000 (MFMR, 2012). It provides employment for approximately 30,000 fishermen directly, with an additional 250,000 jobs supported through related activities such as fish processing, marketing, boat construction, and engineering. Women play a significant role in the distribution of fish. As outlined in the Fisheries and Aquaculture Act of 2017 (section IV, 18(1)), the Inshore Exclusion Zone, which stretches six nautical miles from the coast, is reserved for artisanal and recreational fishing. The artisanal fishery operates in estuaries and coastal waters, from the shoreline to depths of 15 to 45 meters. The primary species caught in this sector are small pelagic species such as herring (*Sardinella spp*.) and bonga (*Ethmalosa fimbriata*), accounting for approximately 60% of the artisanal catch. Historically, most fishermen (44% full-time, 50% part-time) operated in the more productive fishing grounds to the north, where larger vessels were more common. This area hosts 71% of the national inventory of 3–5 man canoes and 44% of Ghana's boats (canoes with more than 10 men and equipped with ice boxes) (Thorpe et al., 2009).

1.1.3 Inland fisheries and aquaculture.

The Inland Fishery and Aquaculture sector operates within rivers, select lakes, floodplains, and swamps, and holds significant promise for advancement (MFMR, 2008). The primary cultivated species include the Nile tilapia *(Oreochromis niloticus)* and the African catfish *(Clarias spp.)* (FAO, 2008).

1.2 Overview of the industrial fisheries sector in Sierra Leone

Sierra Leone's industrial fishing industry operates within the range of 6 to 200 nautical miles (Nm), covering the continental shelf and the exclusive economic zone (EEZ). The industrial sector is predominantly focused on exports, driven by the growing demand for fish products in both developed and developing countries, such as China and South Korea. These markets have increased their supply by importing fish from developing nations and exploiting their waters, including those of Sierra Leone. The industrial fisheries sector in Sierra Leone dates back to 1955, when Italian trawlers were first introduced to local waters, leading to a gradual increase in fishing activities (MFMR, 2003). Initially targeting pelagic species, particularly those within the Sardinella genus, this sector has evolved significantly. Currently, Sierra Leone's industrial fisheries sector includes a diverse fleet from various nations, consisting of shrimp trawlers, purse seiners, canoe support vessels, demersal and pelagic trawlers, and carrier vessels (Coker, 2019). The focus has shifted towards targeting highly migratory tuna stocks and deep-water rose shrimps, primarily located offshore, which has led to the attraction of high-seas fishing vessels. In 2019, Sierra Leone had 129 licenced industrial fishing vessels (Seisay, 2019). Since the inception of trawlers in Sierra Leone, the industrial sub-sector has engaged in joint venture agreements with the owners of foreign-registered and foreign-based vessels (Thorpe, 2009). Significantly, the countries whose flags are flown by industrial fishing vessels operating in Sierra Leone include China, South Korea, Guinea, Spain, Panama, Italy, France, Cape Verde, Senegal, Russia, Comoros, San Marino, and Belize (MFMR, 2019). Fishing licences are issued based on vessel type and fishing gear characteristics, such as gross registered tonnage and

ownership. To facilitate regulation and management, vessels are classified into different types, including demersal fish trawlers, shrimp and cephalopod trawlers, pelagic and mid-water trawlers, carrier vessels, purse seiners, and tuna longliners (Sandi, 2020).

The fisheries policy and legislative framework have been reviewed to address the issues of illegal fishing activities to meet the European Union requirement. However, like many countries in the sub-region, Sierra Leone is not immune to Illegal Unregulated and Unreported (IUU) fishing. There are incidents of IUU fishing activities conducted by licenced foreign-flagged vessels fishing in the country's fishery waters. There have been reports of unlicensed (poaching) vessels illegally operating in Sierra Leone´s waters. Illegal fishing activities conducted by artisanal fishing operators include the use of illegal netting materials such as monofilaments or under-meshed nets, illegal fishing methods such as beach seining, the use of explosives, and the use of channel nets. Therefore, it is necessary for Sierra Leone to develop a comprehensive and integrated Fisheries Inspection plan to address the threats to the sustainability of its fisheries resources and to ensure the long-term exploitation and utilisation of fisheries resources and the associated economic benefits flowing from fisheries resources. To achieve optimal compliance with the fisheries legal and regulatory frameworks, it is essential to develop a robust and resilient compliance strategy. The National Fisheries Inspection Plan is a strategic tool that will be utilised to ensure compliance with fisheries regulations.

1.3 Institutional framework

In close collaboration with other fishery resource management institutions, the Ministry of Fisheries and Marine Resources is responsible for overseeing fisheries across the country's territorial waters, guided by the legal and regulatory framework outlined in the Fishery Development and Management Act (1994) and Fishing Regulations (1995). Additionally, the National Fishery Policy (2010) serves as a significant management tool for fisheries. The Fisheries Policy and Fisheries Strategy were reviewed and validated in 2015 and subsequently approved by the cabinet for implementation alongside the Fisheries Bill, all aimed at fostering sustainable fisheries management practices. Therefore, there is a critical need to implement robust measures to address Illegal, Unreported, and Unregulated (IUU) fishing in Sierra Leone's territorial waters.

To help combat the issue of IUU fishing, the Joint Maritime Committee (JMC), comprising major stakeholders in the maritime domain, was established and charged with the responsibilities of Monitoring Control and Surveillance to forestall illegal maritime activities, including piracy, IUU, counter narcotics, and people smuggling. The coming together of these stakeholders is a means to reduce costs and improve transparency. This framework brings together ministries, departments, and agencies (MDAs) to collaborate under a Memorandum of Understanding (MOU) and work collectively to combat IUU fishing. To help address the issue of IUU fishing, a Vessel Monitoring System (VMS) was introduced as a pre-licence condition for any industrial fishing fleet intending to fish in the waters of Sierra Leone.

Research Questions

- What impact does the implementation of VMS have, and to what extent can improvements be made in utilising and accessing its data for research, enforcement, and policy-making?

1.4 Rationale

Illegal, Unreported, and Unregulated (IUU) fishing within the Exclusive Economic Zone (EEZ) of Sierra Leone has posed significant obstacles, leading to the country's inability to export fish and fishery products to the European Union. This has resulted in substantial socio-economic losses for the country. In response to this pressing issue, a Joint Maritime Committee (JMC) was established. Although the JMC has made commendable efforts, there remains considerable room for improvement.

One of the primary tools employed by the JMC to combat IUU fishing is the Vessel Monitoring System (VMS). However, prior to the introduction of the VMS, data on IUU incidences were not readily available, hindering effective enforcement and policymaking efforts.

This study aims to enhance the effectiveness of the Vessel Monitoring System (VMS) in combating IUU fishing within the EEZ of Sierra Leone. Additionally, it seeks to facilitate the accessibility of VMS data for research, policy-making, and enforcement purposes. The goal is to assist Sierra Leone in effectively addressing the issue of IUU fishing and mitigating its adverse impacts on marine ecosystems.

1.5 Research objectives

The main purpose of this research is to enhance the effectiveness of the Vessel Monitoring System (VMS) in combating illegal, unreported, and unregulated (IUU) fishing activities within Sierra Leone's Exclusive Economic Zone (EEZ). The successful implementation of this research will help address the following principal objectives:

- Assess the impact of VMS implementation on the reduction of IUU fishing incidents in Sierra Leonean waters.
- Assess the usefulness of the VMS for research, policymaking, and enforcement in relation to IUU fishing prevention.
- Identify opportunities to improve the utilisation and accessibility of VMS data.

2. LITERATURE REVIEW

2.1 The Issue of IUU Fishing and Its Implications for Fisheries Management in Africa

Illegal, Unreported, and Unregulated (IUU) fishing is a comprehensive term that encompasses various forms of illicit fishing activities. IUU fishing spans different types and scales of fisheries, occurring in international waters and within national jurisdictions. It involves all aspects and phases of fish capture and utilisation and may be occasionally linked to organised criminal activities. (FAO, 2023).

IUU fishing undermines the conservation and management efforts of nations and regions, hindering progress towards achieving long-term sustainability and responsible fishing practices. Additionally, it unfairly disadvantages and discriminates against fishers who abide by the regulations and operate honestly under their fishing authorisations. When IUU fishers target vulnerable stocks subject to strict management controls or moratoria, it obstructs efforts to restore these stocks to healthy levels, jeopardising marine biodiversity, food security for communities dependent on fisheries for protein, and the livelihoods of those engaged in the sector (FAO, 2023).

Illegal, unreported, and unregulated (IUU) fishing poses a significant threat to marine ecosystems and the socio-economic stability of countries across the globe, particularly in the West African region. IUU fishing not only undermines efforts to conserve and manage fisheries resources sustainably but also deprives coastal communities of vital livelihoods and food security. In recent years, the prevalence of IUU fishing activities in West Africa has garnered increased attention from policymakers, researchers, and stakeholders, prompting concerted efforts to address this pressing issue (Seto, 2015).

As IUU fishing continues to pose complex challenges to sustainable fisheries management and marine conservation efforts in West Africa, there is a need for discussions and evidence-based policy interventions to curb IUU fishing activities, promote responsible fisheries governance, and foster the long-term sustainability of marine resources in the region (Seto, 2015).

2.2 Assessing the Effectiveness of Monitoring, Control and Surveillance of Illegal Fishing in West Africa

This study assessed illegal fishing in West Africa, a region heavily impacted by Illegal, Unreported, and Unregulated (IUU) fishing globally. Using a reconstruction method, it assesses the catch, economic losses, and amount recuperated through Monitoring, Control, and Surveillance (MCS) efforts, utilising data from national MCS units between 2010 and 2016 to gauge the effectiveness of surveillance measures in the area. The findings reveal significant revenue losses for Mauritania, Senegal, The Gambia, Guinea Bissau, Guinea, and Sierra Leone, estimated at approximately 2.3 billion USD annually, with only a minimal amount of 13 million USD recovered through MCS (Doumbuya, 2017).

There is increasing concern regarding the condition of worldwide fish populations and the consequences of their decline on food security and the economies of the most susceptible nations (FAO, 2016). In West African nations, fish serves as a primary protein source and a crucial income and employment generator for nearly 7 million individuals (Belhabib et al., 2015). In this area, fish stocks have diminished owing to overexploitation, excessive capacity, and illicit fishing practices (Daniels et al., 2016).

Previous research conducted by Belhabib et al. (2012, 2016) and Belhabib and Pauly (2015) indicates that illegal fishing in the region accounts for nearly 40 percent of all fish caught, marking the highest level globally (Agnew et al., 2009). This not only threatens the economies of vulnerable countries but also results in an estimated reduction of 300,000 jobs in the artisanal sector (Daniels et al., 2016). Assessing illegal fishing by industrial vessels is challenging, with existing estimates subject to considerable uncertainty due to the high mobility of illegal fishing vessels and their adoption of evasive techniques to elude surveillance, especially in regions with limited monitoring. Various factors drive illegal fishing, with economic gain being identified as a significant incentive, particularly in the national waters or exclusive economic zones (EEZs) of six West African countries (The Gambia, Guinea, Guinea-Bissau, Mauritania, Senegal, and Sierra Leone), where Monitoring Control and Surveillance (MCS) systems are relatively weak (Le Gallic and Cox, 2006; Sumaila et al., 2006; Andrews-Chouicha and Gray, 2005) (Doumbuya, 2017).

2.3 Formation of Joint Maritime Committee (JMC) in Sierra Leone

Combatting IUU fishing, along with other illicit factors associated with fishing operations, requires inter-agency coordination, particularly through the implementation of relevant international agreements (MFMR, 2006).

In this context, the JMC ad hoc Joint Working Group on IUU fishing and related matters was established in a Cabinet Conclusion dated 6th September 2006, which authorised the establishment of a Joint Maritime Committee (JMC) to ensure the effective security of the Territorial Waters (TTW) of Sierra Leone, safety at sea, and provide rapid response to disasters at sea. As a result of the call made by the United Nations Commission on Sustainable Development, which met in April 1999, the issue of flag and port State responsibilities and the need for FAO and IMO to cooperate on solving problems relating to IUU fishing was highlighted (MFMR, 2006).

2.4 Monitoring Control and Surveillance (MCS) Measures

Efficient monitoring, control, and surveillance (MCS) systems are vital elements of fisheries management strategies focused on fostering sustainability and addressing illegal, unregulated, and unreported (IUU) fishing practices. MCS involves the organized gathering, examination, and understanding of data to verify adherence to fisheries regulations and to oversee the well-being of fish stocks and marine environments (Fujii, Okochi, & Kawamura, 2021).

There has been a growing effort in MCS, especially in the past decade. Various types of MCS measures have been improved. Major MCS measures include vessel tracking and visual surveillance (especially patrol at sea for both domestic and foreign vessels), onboard observers, logbooks, and Port State Measures (PSM) (Fujii, Okochi, & Kawamura, 2021).

2.5 Vessel Monitoring System (VMS)

Vessel Monitoring Systems (VMS) have significantly enhanced the capacity for Monitoring, Control, and Surveillance (MCS) of fishing vessels. In recent years, numerous countries have implemented VMS, allowing the monitoring of fishing vessel activities and enabling vessels to actively report their catches to fisheries management authorities (FAO, Fishing Operations Vessel Monitoring System, 1998).

The vessel monitoring system (VMS) functions similarly to AIS in tracking vessels, albeit historically, access to VMS data has been limited to government regulators or fisheries

authorities. However, several countries have made their VMS data publicly available on the Global Fishing Watch map. VMS systems transmit vessel positions at predetermined intervals, with some systems permitting operators to adjust the transmission frequency as required. Certain vessels broadcast both AIS and VMS signals, allowing the integration of data from both systems to produce a more detailed vessel track (Long, 2023).

The VMS bolsters law enforcement efforts and deters infractions of laws and regulations. It also aids enforcement personnel in prioritising patrol efforts in regions with a heightened likelihood of substantial violations (Fisheries, 2020).

VMS are satellite-based monitoring systems in which vessels are equipped with a transmitter that transmits information on vessel identification, position, speed, and bearing at regular intervals. The information is received by a station on land and stored in a database, which can also consolidate other information about vessels and operators (e.g. vessel characteristics, contact information, licences, and registries), making this information available to managers (FAO, 2018). VMS are increasingly required for fishing fleets worldwide and represent a source of data complementary to that obtained from other sources, such as logbooks. The reliability of VMS transmissions (also known as pings) is high, although the interval between transmissions is relatively large (usually 30-120 minutes) owing to the cost of satellite communication, which limits the spatial resolution of the resulting data (Gerritsen & Lordan, 2011). The timing of transmission is unknown to the fishers to prevent any potential illicit activities between recordings (Vakily, 1995). VMS are mostly used to track the positions of vessels for safety purposes and to monitor compliance with fishery closures and other regulations.

The current VMS program oversees the activities of over 4,000 vessels, making it the largest national VMS fleet in the world. Operating round the clock, seven days a week, the system boasts near-flawless accuracy, rendering it a valuable resource for various users, such as the U.S. Coast Guard, academic institutions and coastal states. Due to legal mandates, VMS data are subject to stringent confidentiality standards (Fisheries, 2020).

Sierra Leone, like many coastal countries, has also instituted the installation of VMS on all industrial fishing vessels. The Vessel Monitoring System (VMS) was introduced as a management tool to monitor the position and activities of licenced fishing vessels. The current system was donated by the Government of the Isle of Man in 2013. An inspection team inspects all fishing vessels that intend to obtain authorisation for fishing in Sierra Leone. The installation of VMS transponders on-board fishing vessels is a pre-condition to obtain a licence, and presently, there is VMS coverage on licenced industrial fishing vessels in Sierra Leone. Monitoring the activity of vessels through the VMS is done in real time, on a 24-hour 7-day basis, at the MFMR radio and the Joint Maritime Committee (JMC) operations room called the Joint Operation Centre (JOC) at Murray Town in Freetown. The data collected by the VMS system are retained off-site by the VMS provider and can be obtained upon request.

2.6 How the VMS Works

The VMS is a satellite-based surveillance system predominantly utilised for tracking the positions and movements of commercial fishing vessels within the U.S. Exclusive Economic Zone and treaty regions. This system relies on satellite-based communication facilitated by transceiver units installed onboard specific vessels as a regulatory requirement. These transceiver units transmit position reports containing details such as vessel identification, time, date, and location, which are then mapped and visualised on the end-user's computer screen (Fisheries, 2020).

Usually, each vessel transmits position reports every hour, although it adjusts the intervals as needed when nearing environmentally sensitive areas. Notifications can be dispatched to VMS technicians and other staff if a vessel's location warrants further investigation or communication with the operator (Fisheries, 2020). Some examples of how VMS can be used are as follows:

- Managing sensitive and protected areas, such as marine sanctuaries.
- Monitoring activity and arrivals at the port to plan for sampling.
- Supporting catch-share programs.
- Tracking, monitoring, and predicting fishing efforts, activities, and locations.
- Managing observer programs.
- Verifying/validating data from other sources.
- Identifying fishing vessels.

2.7 How VMS is used in Battling IUU fishing.

The VMS provides detailed information on fishing distribution and vessel characteristics across all fishing zones, thereby offering high-resolution data. Additionally, it aids law enforcement efforts by visualising fishing activities through position density distributions and vessel records (Harrington et al., 2007). Furthermore, VMS data can be leveraged to assess the compliance of fishing vessels with regulations regarding fishing areas, equipment, methods, catch landings, and other legal requirements (Soemarmi, 2020).

2.8 What does the VMS do today?

Integrating VMS into operational practices for Monitoring, Control, and Surveillance (MCS) has empowered Fisheries Monitoring Centres (FMCs) of Flag States to remotely oversee fishing vessel operations. This includes tracking vessel identification, geographical position, date and time of position, course, and speed within specified geographic boundaries, notably within the Exclusive Economic Zone (EEZ) of the respective Member State, at least hourly. Additionally, these data enable Coastal States and relevant regional fishery organisations to monitor all vessels equipped with transponders within their jurisdiction. Through automated surveillance, the VMS delivers cost-effective and efficient support to control authorities, facilitating the swift identification of potential infringements for targeted investigations. Initially perceived as a supplementary tool, the VMS offers a relatively inexpensive means of continuous fishing activity monitoring, complementing traditional surveillance methods. Leveraging FMCs as integral components of the VMS system, a relatively small team of controllers can monitor individual data from numerous fishing vessels operating across vast geographical areas. Centralised monitoring of VMS data collated by FMCs enhances targeted surveillance efforts and optimises the deployment of inspection resources (O'Shea, 2006).

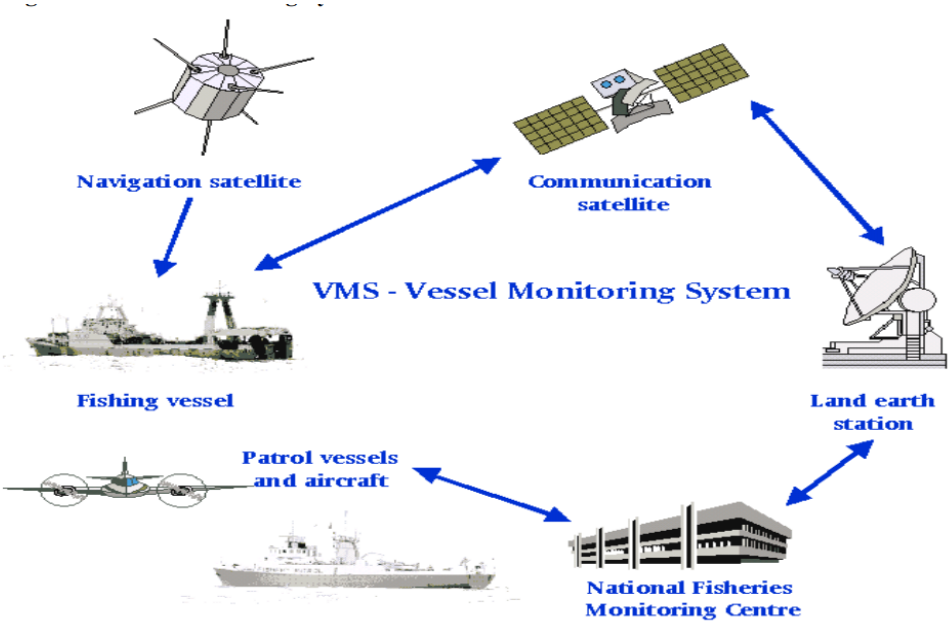

Figure 2: Vessel Monitoring System

Although VMS holds promise for collecting and storing data on fishing vessel operations, it has been observed that national authorities have been hesitant to fully utilise the Monitoring, Control, and Surveillance (MCS) potential inherent in the system, particularly in analysing the VMS data compiled at Fisheries Monitoring Centres (FMCs). The existing challenges partly stem from the necessity for the concurrent development of the three components comprising the system to fully realise its functionality and interconnectedness (O'Shea, 2006).

2.9 Edge Computing Approach for Vessel Monitoring System

The main problem stems from the significant profits gained through illegal, unreported, and unregulated (IUU) fishing. To combat this, the focus should be on reducing the profitability of IUU fishing, increasing the costs of operating and maintaining IUU vessels, and heightening the risks and expenses associated with participating in IUU activities. Moreover, weaknesses in governance structures and oversight mechanisms within the fisheries sector are highlighted as key factors enabling IUU activities. To address this issue, governments should establish stronger policy frameworks and improve control mechanisms. One crucial area for improvement is vessel tracking and the use of data analysis to identify fraudulent activities promptly. Accurate and comprehensive information about vessel operations in deep-sea areas is crucial, and the use of Vessel Monitoring Systems (VMS) is vital for this purpose, as it relies on detailed observations made on-site (Ferreira, 2019).

3. RESEARCH DESIGN AND METHODOLOGY

This study employed a mixed-method approach, utilising both qualitative and quantitative methods to collect primary and secondary data. Secondary data were gathered through a comprehensive review of relevant published and unpublished literature, including journal articles, reports, and official documents. Primary data collection involved two methods: administering structured questionnaires to Joint Operation Centre (JOC) operators and fisheries inspectors and conducting key informant interviews with representatives from five stakeholder institutions involved in the Joint Monitoring Center (JMC).

3.1 Study area.

The research was conducted in the Western Area, encompassing both urban and rural areas of Freetown, the port city and capital of Sierra Leone. Freetown has a population of approximately 1.1 million, constituting approximately 14.9% of the country's total population. Its surface area spans 82 km², accounting for less than 1% of Sierra Leone's total land area (Sankoh, 2021). These specific areas were chosen for the study because of their accessibility to the research participants.

Figure 3: Map of Freetown showing prominent areas.

3.2 Sample size

The study engaged five (5) out of the twelve (12) heads of stakeholder institutions within the JMC because they are the most paramount when it comes to matters related to VMS, five (5) JOC operators out of the eight (8,) and five (5) Fisheries Inspectors out of eight (8) were contacted. The expected participation involves approximately 15 individuals from these groups. The numbers are presented below.

Table 2. Showing number of respondents.

S/N	Questionnaires	Number	Key Informant Interview	Number
1.	JOC operators	5	Heads of JMC institutions	5
2.	Fisheries Officers/Inspectors	5		
	Sub Total	10		5
	Grand Total			**15**

3.3 Data Processing and analysis

The answered questionnaires were documented, entered into Microsoft Excel, and assigned codes for subsequent analyses. Quantitative data analysis was conducted using Excel, generating results in the form of frequencies, means, and percentages, which were displayed in tables and charts.

For the qualitative data obtained through Key Informant Interviews (KIIs), a content analysis approach was utilised to analyse the information based on themes. Content analysis is suitable for qualitative data, which may include direct quotes from respondents regarding their experiences, opinions, feelings, and knowledge.

4. RESULTS

This section presents analyses and discussions of enhancing VMS to combat IUU fishing based on the research conducted with the aim of answering the research question. The analyses and discussions mainly focused on the impact of VMS on IUU reduction (*objective 1*), the usefulness of VMS for research, policymaking, surveillance, and enforcement (*objective 2*), and identifying opportunities for improving the utilisation and accessibility of VMS data (*objective 3*).

4.1 The Impact of VMS on IUU reduction

The first objective is to assess the impact of VMS implementation on the reduction of IUU fishing incidents within Sierra Leonean waters. The results, as indicated in Table 3, show that the mean (M) value was 4.1. The analysis of the Likert scale data suggests that respondents generally view VMS as having a significant impact on reducing IUU fishing incidents.

Overall, the results indicate that VMS has a high impact on reducing IUU fishing, with 30% of responses falling into the "Very High" impact category and 50% falling into the "High" impact category. This suggests that VMS technology plays a significant role in addressing IUU fishing.

While Fisheries Inspectors also have a high impact, it is slightly lower than that of VMS Operators. This implies that while human oversight and enforcement are crucial, technology-driven solutions such as VMS are particularly effective in combating IUU fishing.

The responses for VMS Operators showed a Very High impact, with 60% falling into the "High" category and 40% falling into the "Very High" category. This underscores the importance of skilled operators in effectively utilising VMS technology to monitor and address IUU fishing activities.

Table 3 : Impact of VMS on IUU reduction

Category	N	Very low	Low	Moderate	High	Very High	M	Interpretation
Overall	10	0%	0%	20%	50%	30%	4.1	High Impact
Fisheries Inspectors	5	0%	0%	40%	40%	20%	3.8	High impact
VMS Operators	5	0%	0%	0%	60%	40%	4.4	Very High impact

4.1.1. Implementation of VMS in IUU fishing reduction

Based on the responses provided by the KII in Figure 4, the implementation of Vessel Monitoring Systems (VMS) in Sierra Leonean waters has contributed to the reduction of Illegal, Unreported, and Unregulated (IUU) fishing incidents. For instance, the majority of the respondents (80%; N= 5) indicated that VMS is used for instances of vessels being arrested for violating fishing regulations, particularly from 2018 onwards.

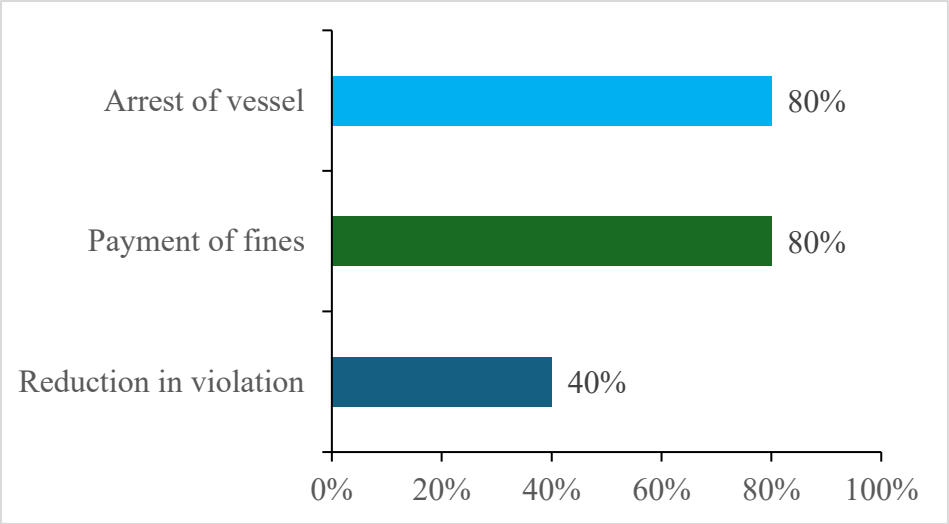

Figure 4. Implementation of VMS in IUU fishing reduction.

The response indicates that vessels guilty of IUU fishing are subjected to fines, detention, or other punitive measures. This demonstrates the effectiveness of VMS data in identifying violators and facilitating enforcement action against them.

> *''There were instances of vessels being arrested for violating fishing regulations, particularly from 2018 onwards Respondent 01'*

However, only a few (40%; N =5) of the respondents reported that:

> *''Before the introduction of VMS in 2011, industrial fishing vessels were frequently found fishing in the Inshore Exclusion Zone. However, after the implementation of VMS and the prosecution of violators, there was a significant reduction in fishing activities within the IEZ, eventually leading to its complete eradication. Respondent 001"*

This suggests that the VMS plays a crucial role in enforcing regulations and deterring vessels from encroaching on restricted zones.

4.2 The Usefulness of VMS for Research, Policymaking, Surveillance, and Enforcement

The second objective is the usefulness of VMS data for research, policymaking, surveillance, and enforcement. The results, as shown in Table 4, indicate that respondents generally perceive the utilisation of VMS data for policymaking, surveillance, and enforcement purposes to be very good to good, based on the Likert scale responses. VMS data appear to be well-utilised for policymaking, with 50% of responses falling into the "Good" category and 40% into the "Very Good" category. This suggests that VMS data play a significant role in informing and shaping fisheries policies.

VMS data are predominantly utilised for surveillance purposes, with 80% of responses falling into the "Good" category. However, there is still room for improvement, with only 10% falling into the "Very Good" category.

VMS data are highly utilised for enforcement, with 50% of responses falling into the "Very Good" category and 40% into the "Good" category. This indicates that VMS data significantly contribute to enforcing regulations and combating illegal fishing activities.

Fisheries Inspectors

Fisheries Inspectors utilise VMS data for policymaking, albeit to a slightly lesser extent than the overall utilisation, with 60% of responses falling into the "Good" category.

VMS data are predominantly utilised for surveillance by Fisheries Inspectors, with 80% of responses falling into the "Good" category.

VMS data are well-utilised for enforcement purposes by Fisheries Inspectors, with 40% of responses falling into the "Good" category and 40% into the "Very Good" category.

VMS Operators

VMS Operators demonstrated a very high level of utilisation of VMS data for policymaking, with 60% of responses falling into the "Very Good" category.

VMS data are primarily utilised for surveillance by VMS Operators, with 80% of responses falling into the "Good" category.

VMS data are highly utilised for enforcement purposes by VMS Operators, with 60% of responses falling into the "Very Good" category.

Table 4. VMS data for policymaking, surveillance, and enforcement

Overall	N	Very poor	Poor	Neither poor nor Good	Good	Very Good	M	Interpretation
VMS data utilisation for policymaking.	10	0%	0%	10%	50%	40%	4.3	Very Good
VMS data utilisation for surveillance.	10	0%	0%	10%	80%	10%	4	Good
VMS data utilisation for enforcement.	10	0%	0%	10%	40%	50%	4.4	Very Good
Fisheries Inspectors								
VMS data utilisation for policymaking.	5	0%	0%	20%	60%	20%	4	Good
VMS data utilisation for surveillance.	5	0%	0%	20%	80%	0%	3.8	Good
VMS data utilisation for enforcement.	5	0%	0%	20%	40%	40%	4.2	Good

Table 4 (continued)

Overall	N	Very poor	Poor	Neither poor nor Good	Good	Very Good	M	Interpretation
VMS Operators								
VMS data utilisation for policymaking.	5	0%	0%	0%	40%	60%	4.6	Very Good
VMS data utilisation for surveillance.	5	0%	0%	0%	80%	20%	4.2	Good
VMS data utilisation for enforcement.	5	0%	0%	0%	40%	60%	4.6	Very Good

4.2.1. Usefulness of VMS for research purpose

From Figure 5, the response from the KII (80%; N=5) indicates that the generation of fishing zones from VMS data presents an opportunity to manage fishing vessels more effectively. This could involve optimising fishing activities to prevent overfishing in certain areas or directing vessels to areas with higher productivity, thereby promoting sustainable practices.

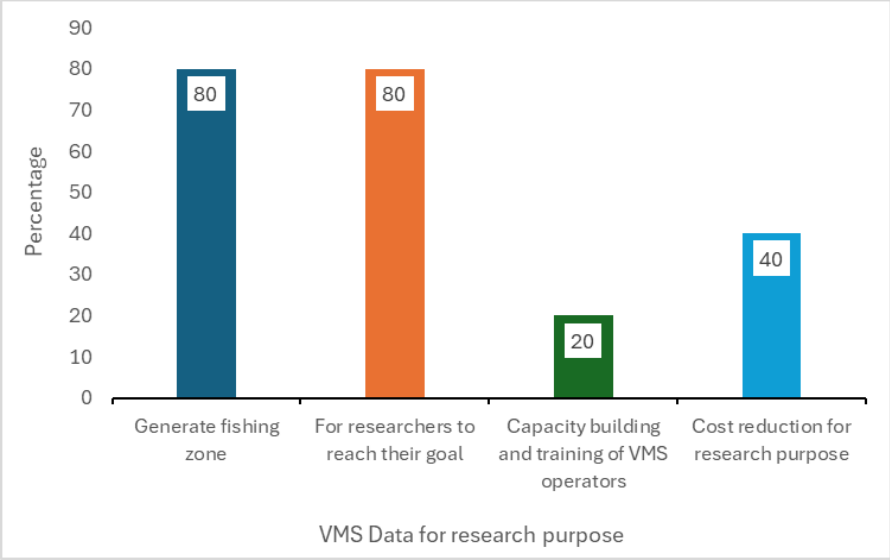

Figure 5. VMS data for research purposes.

It was also observed that 80% (N=5) of the respondents believed that VMS data facilitate the achievement of research goals by providing valuable information for analysis and interpretation. Researchers can use VMS data to address specific research questions or objectives related to fisheries management, conservation and marine spatial planning. The availability of comprehensive and reliable data enhances the credibility and rigor of the research findings.

However, 40% (N=5) of the respondents believed that utilising VMS data for research purposes can reduce costs and save time compared to traditional data collection methods. This is particularly relevant in resource-constrained settings, where conducting field surveys or collecting data through other means may be prohibitively expensive or time-consuming. The accessibility of the VMS data streamlines the research process, enabling researchers to focus on the analysis and interpretation.

Only 20% (N=5) of the respondents believe that capacity building of VMS operators is crucial for maximising the utility of VMS data for research purposes. The quality and reliability of VMS data can be improved by enhancing the skills and expertise of operators in data collection, processing, and analysis. This strengthens the foundation for scientific research and promotes collaboration between researchers and fisheries management authorities.

4.2.2. Usefulness of VMS data to battle IUU fishing.

From Figure 6, it was observed from the KII that the majority of the respondents (100 %; N= 5) reported that VMS data is a valuable tool for tracking vessels that engage in IUU. This suggests that VMS data enables security operatives to focus their surveillance efforts more effectively, thereby enhancing the detection and enforcement of fisheries regulations.

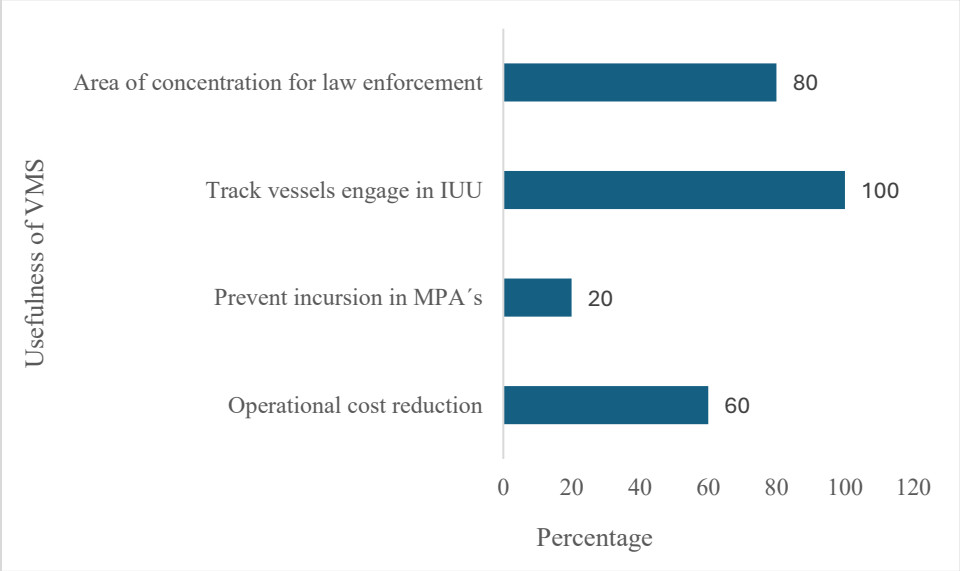

Figure 6: Usefulness of VMS data to battle IUU.

Most respondents (80%: N=5) noted that VMS data aids security operatives in detecting areas of concentration during law enforcement operations. This suggests that VMS data provide valuable intelligence that enhances the effectiveness of on-the-ground enforcement activities.

Furthermore, respondents mentioned that VMS data help reduce the operational costs associated with searching for illegal vessels. This indicates that leveraging VMS data can lead to resource savings by optimising patrol routes and targeting specific areas of concern in the fishery.

However, only 20% of the respondents (one out of five) reported that VMS was used to prevent incursions in MPAs.

4.2.3 The use of VMS for policymaking

In Figure 7, it was observed that 100% (N=5) of the respondents agreed that VMS data could inform policy development by providing insights into fishing zones and catch areas. KII further said by combining VMS data with length frequency data, policymakers can identify areas with high concentrations of juvenile fish and develop policies to protect them. For example, fishing zones with potentially high catches can be identified, and policies can be implemented to regulate fishing activities in these areas. By restricting access to certain zones or implementing seasonal closures, policymakers can promote sustainable fishing practices and prevent the overexploitation of marine resources.

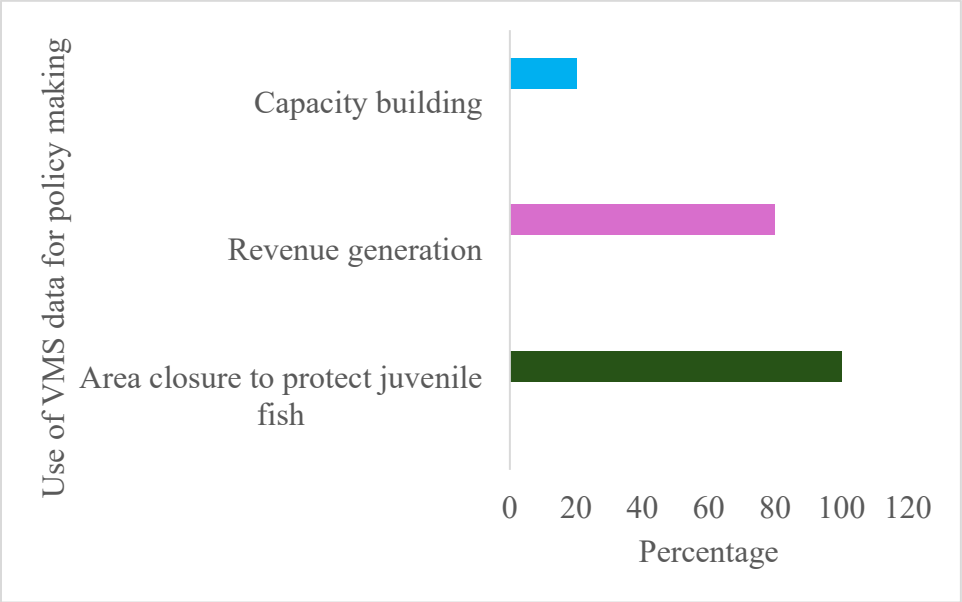

Figure 7: Use of VMS data for policymaking.

Notwithstanding, (80%; N=5) of respondents believed that effective utilisation of VMS data can lead to revenue generation opportunities for governments. By implementing policies based on VMS data insights, such as selling licences for entry into high-catch areas at higher costs, governments can generate additional revenue. This revenue can be reinvested in fisheries management and conservation efforts, further enhancing the sustainability of marine ecosystems.

Meanwhile, 20% (N=5) of the respondents said that the capacity building of VMS operators is crucial for maximising the utility of VMS data for policy-making purposes. By enhancing the skills and expertise of operators in data collection, analysis, and interpretation, governments can ensure the reliability and accuracy of the VMS data. This strengthens the foundation for evidence-based policymaking and enhances the effectiveness of fisheries management efforts.

4.2.4. How JMC uses VMS to battle IUU fishing?

In Figure 8, it was observed that (80%; N=5) of the respondents believed in the positive assessments of the JMC's effectiveness in using VMS to combat IUU fishing. However, despite the effectiveness of JMC using VMS in battling IUU fishing activities, there are challenges, according to the KII.

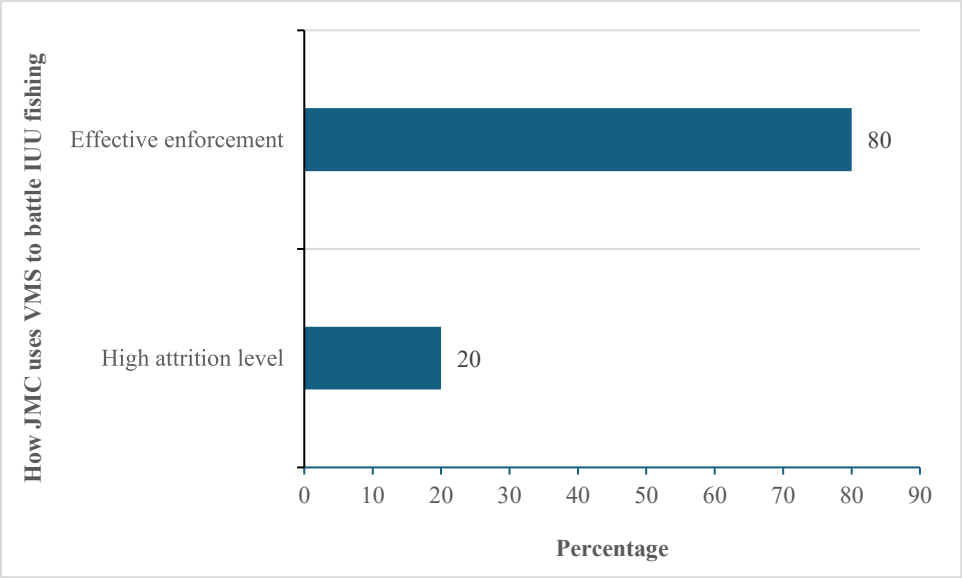

Figure 8. How JMC uses VMS to battle IUU

Moreover, 20% (N= 5) of the respondents talked about high levels of attrition; some personnel have been trained, but they are often transferred to other postings or promoted, resulting in a loss of expertise within the JMC.

> *´´Few personnel working at the JMC have received training on the use of VMS to combat IUU fishing. However, the challenge is that personnel at JMC belong to different institutions and most of them after the training are transferred to other postings or promoted, thereby giving up their services at the JMC. It is but necessary to have a core team within MFMR with the requisite training to manage VMS data, as MFMR personnel are always at the centre in the fight against illegal fishing´´ Respondent 01*

4.3. Opportunities for Improving the Utilisation and Accessibility of VMS.

The third objective is to examine opportunities to improve the utilisation and accessibility of VMS data in battling IUU fishing regarding compliance.

From Figure 9, it can be observed that fines were imposed on defaulters, and this emerged as a significant factor influencing compliance. This suggests that penalties for non-compliance encourage adherence to regulations. One contributing factor to compliance appears to be the regular monitoring conducted by personnel at the Joint Operations Centre (JOC) at the Joint Maritime Committee (JMC) Headquarters. This suggests that active oversight is crucial for ensuring compliance.

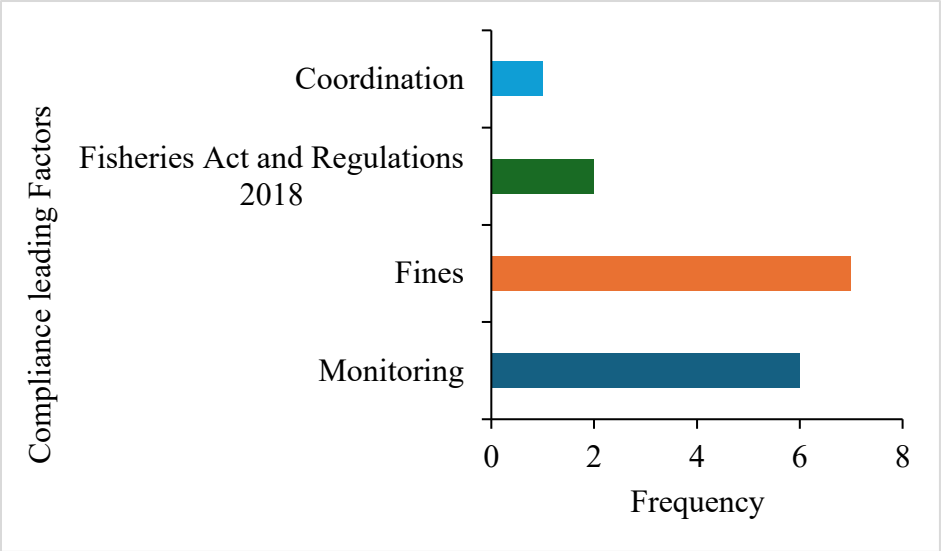

Figure 9. Compliance leading factors.

4.3.1 Compliance leading factors

The KII mentioned the 24-hour monitoring of fishing vessel activities at the JMC headquarters. Continuous surveillance is likely to act as a deterrent to non-compliance. The effectiveness of the VMS monitoring system was highlighted as a contributing factor. A reliable and efficient monitoring system is likely to enhance compliance by providing real-time oversight of vessel activities. Good coordination among stakeholders at the JMC is noted as a contributing factor. This underscores the importance of collaboration and communication among regulatory bodies and other relevant entities involved in enforcing compliance.

4.3.2 Penalties for non-compliant fishing vessels operating without VMS.

It was observed that all KII (100%; N=5) respondents referred to The Fisheries and Aquaculture Act of 2018. This is highlighted as a key legal instrument governing the installation and management of VMS on-board fishing vessels.

The KII specifically mentioned Section 37 of the Act, which is dedicated to this aspect, indicating a clear legal requirement for VMS installation. Moreover, significant penalties are associated with non-compliance, emphasising the seriousness with which the issue is addressed within the legal framework.

4.3.3. Compliance of Industrial fishing vessels with VMS

The results in Table 5 imply that the Likert scale data can be interpreted as respondents perceiving the compliance of industrial fishing vessels with VMS requirements as high. This indicates a widespread belief among respondents that industrial fishing vessels adhere well to VMS regulations, which is a positive indicator of effective fisheries management and enforcement efforts.

This indicates a high level of compliance among industrial fishing vessels with the VMS operating in Sierra Leonean waters. Specifically, 100% of the responses fell into the "High" compliance category. This suggests that the implementation of VMS technology has been effective in ensuring that industrial fishing vessels adhere to the regulations and guidelines.

Both Fisheries Inspectors and VMS Operators also demonstrated a high level of compliance, with 100% of responses falling into the "High" compliance category for each group. This

indicates that not only are the fishing vessels compliant, but also that the stakeholders responsible for monitoring and enforcing compliance are effectively carrying out their duties.

Table 5. Compliance of Industrial fishing vessels with VMS

Overall	N	Very Low	Low	Moderate	High	Very High	M	Interpretation
Compliance of industrial fishing vessels with VMS	10	0%	0%	0%	100%	0%	4	High Compliance
Fisheries Inspectors	5	0%	0%	0%	100%	0%	4	High Compliance
VMS Operators	5	0%	0%	0%	100%	0%	4	High Compliance

4.3.4. Limitation(s) perceived with the current operational measures utilised by the VMS to ensure compliance.

From Table 6, it was observed from both VMS operators and fisheries inspectors that resource constraints are perceived as the most significant factor affecting the utilisation of vessel monitoring systems (VMS) for enforcement purposes, followed by technological constraints.

Technological Constraints: The responses indicated that technological constraints were perceived as a moderate obstacle, with 40% of the responses falling into the "Moderate" category. This suggests that there are challenges related to the technology itself that may hinder its effectiveness in ensuring compliance.

Resource Constraints: Resource constraints were perceived as a high obstacle, with 50% of responses falling into the "High" category. This indicates that limitations in terms of financial resources, manpower, or other resources may affect the ability to effectively utilise VMS for compliance.

Evasive Tactics of Offenders: Evasive tactics of offenders were perceived as a low obstacle, with 40% of responses falling into the "Low" category. While this suggests that some offenders may attempt to evade compliance measures, it is not considered a significant barrier overall.

Limited Coverage: Limited coverage was perceived as a Very Low obstacle, with 40% of responses falling into the "Very Low" category. This indicates that there may be areas where VMS coverage is lacking, potentially compromising its effectiveness in ensuring compliance.

External Pressure: External pressure was also perceived as a Very Low obstacle, with 20% of responses falling into the "Very Low" category. This suggests that external factors, such as political pressure or influence, may not significantly impact compliance measures.

Fisheries inspectors perceive technological constraints as a high obstacle, highlighting the potential challenges they face in effectively utilising VMS technology.

Resource constraints are perceived as very high, indicating a strong awareness of limitations in resources that may impact compliance efforts.

Evasive tactics of offenders, limited coverage, and external pressure are perceived as relatively minor obstacles among fisheries inspectors.

VMS operators perceive resource constraints as a significant obstacle, suggesting that they are aware of the limitations in resources that may impact their ability to ensure compliance.

Technological constraints, offenders' evasive tactics, limited coverage, and external pressure are perceived as relatively minor obstacles by VMS operators.

Table 6. Obstacle(s)/limitation(s) perceived with the current operation measures utilised by the VMS to ensure compliance.

Overall	N	Very low	Low	Moderate	High	Very high	M	Interpretation
Technological Constrains.	10	0%	40%	40%	10%	10%	2.9	Moderate
Resource Constrans.	10	0%	10%	20%	50%	20%	3.8	High
Evasive tactics of offenders.	10	10%	40%	50%	0%	0%	2.4	Low
Limited Coverage.	10	40%	40%	20%	0%	0%	1.8	Very Low
External pressure.	10	20%	80%	0%	0%	0%	1.8	Very Low
Fisheries Inspector								
Technological Constrains.	5	0%	0%	60%	20%	20%	3.6	High
Resource Constrans.	5	0%	0%	20%	60%	20%	4	Very High
Evasive tactics of offenders.	5	20%	40%	40%	0%	0%	2.2	Low
Limited coverage.	5	20%	40%	40%	0%	0%	2.2	Low
External pressure.	5	100%	0%	0%	0%	0%	1	Very Low
VMS Operators								
Technological Constrains.	5	0%	80%	20%	0%	0%	2.2	Low
Resource Constrans.	5	20%	0%	20%	40%	20%	3.4	High
Evasive tactics of offenders.	5	0%	40%	60%	0%	0%	2.6	Low
Limited coverage.	5	60%	40%	0%	0%	0%	1.4	Very Low
External pressure.	5	40%	60%	0%	0%	0%	1.6	Very Low

4.3.5. Are there Industrial fishing vessels operating without VMS?

Figure 10 shows that while there is some awareness of non-compliance among a minority of respondents, the majority are unaware of such instances. Thirty% of respondents were aware of instances of non-compliance among industrial fishing vessels operating in Sierra Leonean waters without VMS. Seventy% of respondents were not aware of any instances of non-compliance among industrial fishing vessels operating in Sierra Leonean waters without VMS.

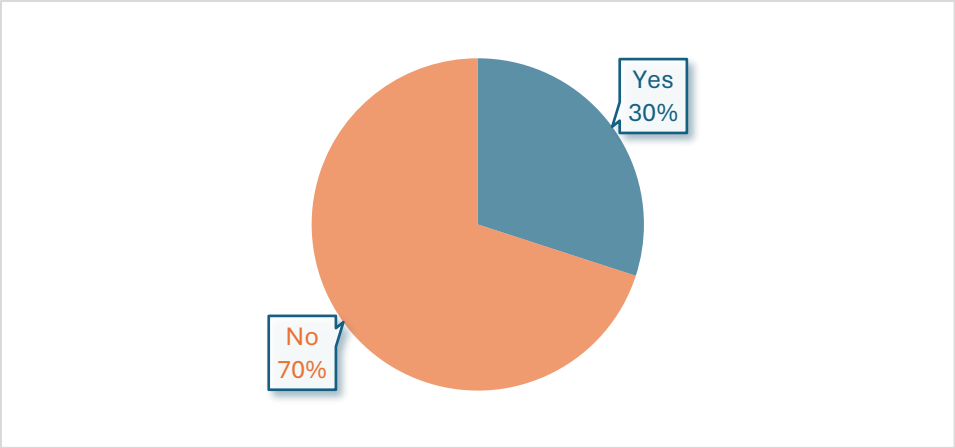

Figure 10. Are there Industrial fishing vessels operating without VMS?

4.3.6. Effectiveness of JOC in using VMS for monitoring

Table 7 shows that the respondents perceive both the effectiveness of the JOC in utilising VMS for monitoring and the effectiveness of monitoring employed by VMS operators as effective.

Overall, the effectiveness of the JOC in utilising VMS for monitoring was rated as effective, with 80% of responses falling into the "Effective" category and 20% into the "Very Effective" category. This indicates that JOCs play a significant role in utilising VMS technology to monitor activities.

Similarly, the effectiveness of monitoring employed by VMS operators was rated as effective, with 90% of responses falling into the "Effective" category and 10% into the "Very Effective" category. This suggests that VMS operators are proficient in performing monitoring tasks effectively.

Fisheries inspectors perceive both the effectiveness of the JOC in utilising VMS for monitoring and the effectiveness of monitoring employed by VMS operators. This indicates a high level of satisfaction with the performance of both the JOCs and VMS operators in monitoring activities.

VMS operators perceive the effectiveness of the JOC in utilising VMS for monitoring as Very Effective, with 60% of responses falling into the "Very Effective" category and 40% into the "Effective" category. They also perceive the monitoring employed by VMS operators as effective, with 100% of responses falling into the "Effective" category.

Table 7. Effectiveness of JOC in using VMS for monitoring; effectiveness of VMS operators in monitoring.

Overall	N	Very Ineffective	Ineffective	Moderately effective	Effective	Very effective	M	Interpretation
Effectiveness of JOC in utilising VMS for monitoring.	10	0%	0%	0%	80%	20%	4.2	Effective
Effectiveness of monitoring employed by VMS operators.	10	0%	0%	0%	90%	10%	4.1	Effective
Fisheries Inspectors								
Effectiveness of JOC in utilising VMS for monitoring.	5	0%	0%	0%	100%	0%	4	Effective
Effectiveness of monitoring employed by VMS operators.	5	0%	0%	0%	80%	20%	4.2	Effective
VMS Operators								
Effectiveness of JOC in utilising VMS for monitoring.	5	0%	0%	0%	60%	40%	4.4	Very Effective
Effectiveness of monitoring employed by VMS operators.	5	0%	0%	0%	100%	0%	4	Effective

4.3.7. Functions of JOC in utilising VMS for MCS activities

As shown in Figure 11, these JOC functions collectively contribute to the effective enforcement of maritime regulations and the protection of marine resources in Sierra Leone's waters, according to the KII.

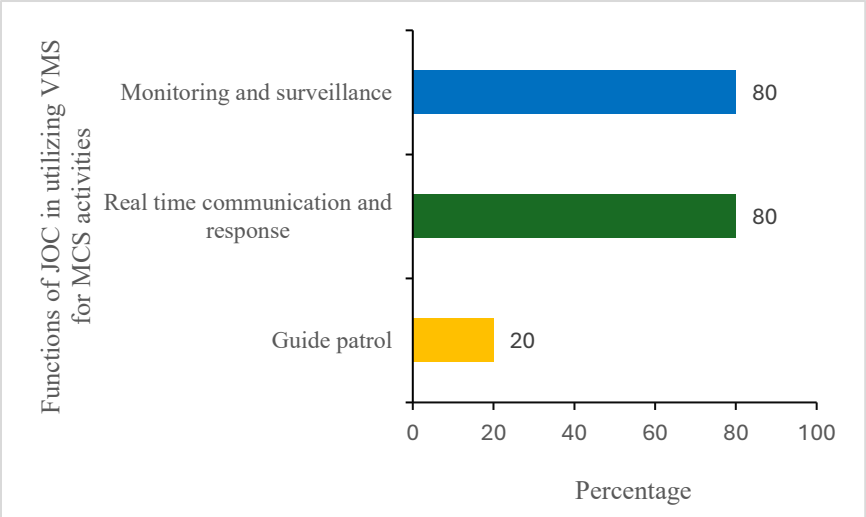

Figure 11. Functions of JOC in utilising VMS for MCS activities.

Moreover, (80%; N=5) of the respondents reported that the JOC monitors all types of vessels in Sierra Leone's Exclusive Economic Zone (EEZ) using not only VMS but also the Automatic Identification System (AIS) and other open sources. This broader scope extends beyond fisheries monitoring and includes activities relevant to other maritime institutions, such as the Navy, Marine Police, and Ports Authority.

However, (80%; N=5) of respondents reported that the JOC has the capability to instantly communicate with fishing vessels moving towards or attempting to enter prohibited fishing grounds. This real-time communication enables the JOC to issue warnings or directives to vessels, preventing unauthorised fishing activities and enhancing enforcement.

From the survey, it was observed that (20%; N=5) of the respondents believed that the JOC generated general fishing vessel maps to guide patrols on vessel concentration areas during at-sea fisheries patrols. This function helps optimise patrol routes and the deployment of resources to areas where fishing activity is concentrated, enhancing the efficiency of surveillance efforts.

5. DISCUSSION

The VMS is an important MCS tool that facilitates international cooperation and collaboration in combating IUU fishing through information sharing and joint enforcement efforts. The Sub-Regional Fisheries Commission (SRFC), for example, relies on VMS data from member states to monitor fishing activities in the region and enforce conservation and management. By sharing VMS data and coordinating surveillance efforts, SFRC member states can effectively combat IUU fishing and promote sustainable fisheries management in the region (Doumbuya, 2017). In Sierra Leone, it is strongly believed that VMS data can be used to track fishing vessels engaged in illegal activities. The results show that 100 % (N=5) of respondents believed that VMS data is a valuable tool for tracking vessels that engage in IUU fishing. The VMS enables authorities to monitor vessel movements in real time, allowing them to detect suspicious activities indicative of illegal fishing. By analysing vessel trajectories, deviations from established fishing zones or patterns inconsistent with legitimate fishing operations can be identified, triggering further investigation.

Vessel monitoring systems are predominantly employed for fisheries enforcement objectives; however, they also offer insights into the spatial and temporal patterns of fishing activity, aiding in fisheries management and environmental assessment (Gardner, 2022). Juvenile fish are a critical component of marine ecosystems, serving as future breeding stocks for fish populations and playing a vital role in maintaining ecosystem balance. However, juvenile fish are particularly vulnerable to exploitation because of their smaller size, limited mobility, and reliance on specific habitats for survival. Consequently, protecting juvenile fish populations is essential for ensuring the long-term sustainability of fisheries and the health of marine ecosystems. It was strongly observed from the results of this research that (100%; N=5) of the respondents agreed that VMS data can inform policy development by providing insights into fishing zones and catch areas. By combining VMS data with length frequency data, policymakers can identify areas with high concentrations of juvenile fish and develop policies to protect them. Area closures play a crucial role in protecting juvenile fish populations and supporting sustainable fisheries management. By safeguarding nursery habitats, reducing fishing pressure, protecting spawning grounds, and promoting ecosystem resilience, closures help ensure the long-term viability of fish stocks and the health of marine ecosystems.

VMS also assists enforcement personnel in directing their patrol efforts towards areas where there is a greater likelihood of encountering significant violations. VMS are critical tools used to guide fisheries patrols, enhance their effectiveness, and optimise resource allocation.

The assessment of Monitoring, Control, and Surveillance (MCS) factors in regional realities such as governance, available human and financial resources, and the presence of corruption is important. The objective is to draw insights from regional trends that can feasibly be implemented within a framework of limited resources. Sierra Leone achieved a score of 33.5 out of a maximum of 44, leading the region, followed by The Gambia with 24, Guinea with 23.3, Senegal with 22.7, and Guinea Bissau with 13.4. This ranking suggests that Sierra Leone's MCS system is the most effective in the region, despite experiencing increased illegal fishing activity during the Ebola crisis (Doumbuya, 2017). The VMS plays a crucial role in monitoring compliance with fisheries regulations and enforcing maritime laws. By providing verifiable documentation of vessel movements and activities, VMS data serve as evidence for prosecuting offenders engaged in illegal fishing, transshipment, or other illicit activities. The transparency afforded by the VMS promotes accountability among vessel operators, deters non-compliance, and fosters a culture of legality and responsibility within the maritime industry. VMS-guided surveillance efforts contribute to deterring illegal activities, protecting marine resources, and promoting sustainable fisheries management practices. This is clearly shown from the result, as

80% (N=5) of the respondents reported that the JOC monitors all types of vessels in Sierra Leone's Exclusive Economic Zone (EEZ) using not only VMS but also the Automatic Identification System (AIS) and other open sources. VMS are indispensable tools for monitoring and surveillance in fisheries management and maritime security. Through real-time tracking and monitoring, geofencing capabilities, data analysis, interoperability, and compliance enforcement.

Upon closer examination, it becomes evident that the extent of illegal fishing, encompassing various forms investigated, diminishes as penalties for the most egregious instances of Illegal, Unreported, and Unregulated (IUU) fishing increase. Additionally, Sierra Leone and The Gambia possess the most effective Monitoring, Control, and Surveillance (MCS) systems, resulting in the apprehension and prosecution of a greater number of offenders with substantial fines. Conversely, despite Senegal's enactment of new legislation aimed at enhancing MCS in 2015, this improvement does not appear to be reflected in scoring outcomes (Doumbuya, 2017). The findings indicate that imposing heavy fines on violators significantly influences compliance, emphasising the role of penalties in promoting adherence to regulations. Another factor contributing to compliance appears to be the consistent monitoring conducted by personnel at the JOC located at the JMC headquarters. This underscores the importance of active oversight to ensure compliance. The KII highlighted the continuous 24-hour monitoring of fishing vessel activities at the JMC headquarters, suggesting that ongoing surveillance serves as a deterrent against non-compliance. Additionally, the effectiveness of the VMS monitoring system itself emerged as a contributing factor, with a reliable and efficient monitoring system likely enhancing compliance by providing real-time oversight of the vessel activities. The importance of good coordination among stakeholders at the JMC was also noted, underscoring the significance of collaboration and communication among regulatory bodies and other relevant entities involved in enforcing compliance.

Efficient deployment of a Monitoring, Control, and Surveillance (MCS) framework entails gathering and organising data, establishing communication and coordination channels, and implementing operational protocols. Typically, these responsibilities are assumed by the Fisheries Monitoring Centre (FMC). Therefore, when establishing, executing, or enhancing MCS systems, it is essential to ensure that the FMC is appropriately structured to effectively fulfil its multifaceted roles (Camilleri, 2024). A limited number of staff members at the JMC have undergone training in using VMS to address IUU fishing. However, a significant challenge arises because JMC personnel come from different institutions. Consequently, after receiving training, many of these personnel are either reassigned or promoted, resulting in a loss of expertise within the JMC itself. Therefore, it is imperative to establish a dedicated core staff within the Ministry of Fisheries and Marine Resources (MFMR) equipped with the necessary training to manage VMS data effectively. Given that MFMR personnel are consistently at the forefront of combating illegal fishing, having core staff proficient in VMS operations would ensure sustained effectiveness in this critical endeavour.

6. CONCLUSION

The VMS, as shown in this study, is a pivotal step in the ongoing battle against illegal fishing. By leveraging real-time tracking, geofencing capabilities, data analytics, and interoperability, enhanced VMS systems empower authorities to detect, deter, and prosecute offenders engaged in illegal fishing activities more effectively than ever before in Sierra Leone.

The study reveals that the payment of heavy fines by defaulting fishing vessels is a significant factor influencing compliance, coupled with a 24/7 monitoring and surveillance system in place. It was also observed that VMS data can help inform policy development by providing insight into fishing zones and catch areas. Areas with high catch can be identified, and juvenile fish can be protected for sustainable fisheries management. Tracking vessels engaged in IUU fishing activities and enabling patrol teams to focus on their surveillance efforts, thereby enhancing the detection and enforcement of fisheries regulations, also makes it very useful.

Furthermore, a critical area for enhancement is vessel tracking and the use of data analytics for the timely detection of fraudulent activities, as it is imperative to ensure the availability of accurate and comprehensive information on vessel operations in deep-sea areas. The availability of VMS data in the shortest possible time is crucial. The study revealed that high attrition affects the JMC, as JMC staff will undergo training in utilising VMS to address IUU fishing. However, a significant obstacle arises as these personnel represent various institutions, and many of them are either reassigned or promoted after completing their training, resulting in their departure from the JMC.

7. RECOMMENDATIONS

- Sierra Leone should expand the utilisation of VMS beyond combating IUU fishing for a multifaceted opportunity to enhance fisheries management and maritime governance. By fully harnessing the capabilities of VMS, Sierra Leone can significantly bolster policymaking, research endeavours, monitoring, surveillance, and enforcement in the maritime domain.

- Sierra Leone should ensure that personnel utilising VMS are adequately trained and knowledgeable about the system which is paramount for maximising its effectiveness. Prioritising the training, retention, and knowledge management of personnel utilising VMS to maximise the benefits of this technology for fisheries management and maritime governance. By investing in comprehensive training programs, on-the-job mentoring, knowledge management systems, retention strategies, and succession planning initiatives, Sierra Leone should ensure that its VMS users are knowledgeable, skilled, and equipped to leverage VMS for sustainable fisheries management effectively.

- Sierra Leone should take steps to ensure the timely availability of VMS data which is crucial for maximising its utility in combating IUU fishing activities. It is important to ensure that VMS data are available in time so that they can be utilised effectively in battling IUU. By taking proactive steps to enhance data-sharing protocols, improve data transmission systems, implement real-time monitoring technologies, strengthen data management infrastructure, promote data transparency and access, enhance institutional capacity, and engage with regional and international partners, Sierra Leone can maximise the impact of VMS data in not only combating IUU fishing but also promoting sustainable fisheries management.

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REFERENCES

Amiek S. E. I. (2020). The use of vessel monitoring system as fishery ship obligation in Indonesia. *AACL Bioflux*.

Agnew, D. J., Pearce, J., Pramod, G., Peatman, T., Watson, R., Beddington, J. R., & Pitcher, T. J. (2009). *Estimating the worldwide extent of illegal fishing.* PLOS ONE, 4(2), e4570. https://doi.org/10.1371/journal.pone.0004570

Andrews-Chouicha, E., & Gray, K. (Eds.). (2005). *Why fish piracy persists: The economics of illegal, unreported and unregulated fishing.* OECD Publishing.

Belhabib, D., Sumaila, U. R., & Pauly, D. (2015). *Feeding the poor: Contribution of West African fisheries to employment and food security.* Ocean & Coastal Management, 111, 72–81. https://doi.org/10.1016/j.ocecoaman.2015.04.010

Belhabib, D., Zeller, D., Harper, S., & Pauly, D. (Eds.) (2012). *Marine fisheries catches in West Africa, 1950–2010, Part I*. Fisheries Centre Research Reports, 20(3). University of British Columbia.

Belhabib, D., & Pauly, D. (2015). *Euros vs. yuan: Comparing European and Chinese fishing access in West Africa*. PLOS ONE, 10(3), e0118351. https://doi.org/10.1371/journal.pone.0118351

Belhabib, D., Mendy, A., Subah, Y., Broh, N. T., Jueseah, A. S., Nipey, N., Willemse, N., Zeller, D., & Pauly, D. (2015). *Fisheries catch under-reporting in The Gambia, Liberia and Namibia and the three large marine ecosystems which they represent*. Environmental Development, 16, 104–118

Camilleri, M. B. K. (2024). *Checklists and technical guidelines to combat illegal, unreported and unregulated (IUU) fishing. Volume III: Checklist of monitoring, control and surveillance (MCS) systems, operations, procedures and tools.* Rome: FAO.

Coker, I. C. (2019). *Feasibility of using the vessel monitoring system in Sierra Leone to monitor and assess the industrial fishery.* Rekjavik: United Nations University Fisheries Training Programme.

Daniels, A., Gutiérrez, M., Fanjul, G., Guereña, A., Matheson, I., & Watkins, K. (2016). *Western Africa's missing fish: The impacts of illegal, unreported and unregulated fishing and under-reporting of catches by foreign fleets.* Overseas Development Institute (ODI). https://odi.org/en/publications/western-africas-missing-fish-the-impacts-of-illegal-unreported-and-unregulated-fishing-and-under-reporting-catches-by-foreign-fleets/

Doumbouya, A., Camara, O. T., Mamie, J., Intchama, J. F., Jarra, A., Ceesay, S., … Belhabib, D. (2017). Assessing the effectiveness of monitoring, control and surveillance of illegal fishing: The case of West Africa. *Frontiers in Marine Science, 4*, 50. https://doi.org/10.3389/fmars.2017.00050

FAO. (1998). *Fishing Operations Vessel Monitoring System.* Rome: FAO.

FAO. (2023). *Report of the fourth meeting of the Part 6 Working Group established by the Parties to the Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing, .* Rome: FAO.

Ferreira, J. C., & Martins, A. L. (2019). Edge computing approach for vessel monitoring system. Energies, 12(16), 3087. https://doi.org/10.3390/en12163087

Fisheries, N. (2020). *Enforcement: Vessel Monitoring.* Alaska: NOAAR .

Fujii, I., Okochi, Y., & Kawamura, H. (2021). Promoting Cooperation of Monitoring, Control, and Surveillance of IUU Fishing in the Asia-Pacific. *Sustainability MDPI*.

Gardner, C. D. R. (2022). Linking Vessel Monitoring System and Habitat Data to Assess Commercial Exploitation on Artificial Structures in the Gulf of Mexico. *Frontiers in Marine Science*.

Harrington, J., Semmens, E., & Payne, J. (2007). Analysis of vessel monitoring system (VMS) data for fisheries compliance and enforcement. FAO Fisheries Circular No. 1038. Food and Agriculture Organization of the United Nations.

Long, T. (2023). *Global fishing Watch.* Global Fishing Watch.

Le Gallic, B., & Cox, A. (2006). An economic analysis of illegal, unreported and unregulated (IUU) fishing: Key drivers and possible solutions. Marine Policy, 30(6), 689–695. https://doi.org/10.1016/j.marpol.2005.09.008[1](https://isiarticles.com/bundles/Article/pre/pdf/28315.pdf)

MFMR. (2006). *Memorandum of understanding between all stakeholder institutions of the joint maritime committee establishing arrangements for the administrative and operational functioning of the joint maritime committee (JMC).* Freetown: GoSL.

MFMR. (2018). *Fisheries Management Plan 2020 - 2025.* Freetown: Ministry of Fisheries and Marine Resources.

O'Shea, B. (2006). *The Innovative Application of Vessel Monitoring Systems for the Effective Fisheries Monitoring Control and Surveillance.* Brussels: Directorate General for Fisheries and Maritime Affairs, Regulation and Monitoring Fisheries Inspection .

Sandi, S. P. (2020). *Estimation of the total catch and effort of the industrial fishery in Sierra Leone, 2008-2019.* Reyjavik: UNESCO GRÓ-Fisheries Training Programme.

Sankoh, P. O. (2021). *2021 Mid-Term Population and Housing Census.* Freetown: Statistics Sierra Leone.

Sei, S. (2011). *Fisheries Governance Reform in Sierra Leone: Law, Policy and Institutional Arrangements.* New York: Division for ocean affairs and the law of the sea office of legal affairs, the United Nations New York, 2011.

Seisay, A. (2019). *Industrial fisheries licensing statistics for Sierra Leone (2019)*. Ministry of Fisheries and Marine Resources, Government of Sierra Leone.

Sheku Sei, a. A. (2016). *Fisheries management in data deficient industrial fisheries of Sierra Leone.* Freetown: Natural Resource Management Consortium (NaReMaC), Fourah Bay College Campus, Freetown, Sierra Leone.

Seto, K. C. D. (2015). *Colonialism, conflict, and fish: A reconstruction of marine fisheries catches for Sierra Leone, 1950–2010*. Fisheries Centre, University of British Columbia.

Seto, K. C. D. (2017). *War, fish, and foreign fleets: The marine fisheries catches of Sierra Leone*. *Marine Policy*, 153–163.

Soemarmi, A., Indarti, E., Pujiyono, Wardhani, L. T. A. L., Diamantina, A., & Ristyawati, A. (2020).The use of the vessel monitoring system as fishery ship obligations in Indonesia. Biodiversitas Journal of Biological Diversity, 21(4), 1483–1494.https://bioflux.com.ro/docs/2020.1483-1494.pdf

Ssentongo, G. W., & Ansa-Emmim, M. (1986). Marine fishery resources of Sierra Leone: A review of exploited fish stocks (CECAF/ECAF Series No. 86/34). Food and Agriculture Organization of the United Nations.

Sumaila, U. R., Alder, J., & Keith, H. (2006). Global scope and economics of illegal fishing. *Marine Policy*, 30(6), 696–703. https://doi.org/10.1016/j.marpol.2005.11.001

Thorpe, A., Whitmarsh, D., Ndohamina, E. T., Baio, A., Kemokai, M., & Lebbie, T. (2009). Fisheries and failing states: The case of Sierra Leone. Marine Policy, 33(2), 393–400. https://doi.org/10.1016/j.marpol.2008.09.002

Vakily, J. M. (1995). Monitoring, control and surveillance in fisheries management. In Report of the Expert Consultation on Monitoring, Control and Surveillance (MCS) for Fisheries Management. Food and Agriculture Organization of the United Nations (FAO), Rome.

APPENDICES

APENDIX 1

Questionnaire for both JOC and Inspectors

STRUCTURED QUESTIONNAIRE

INTRODUCTION:

The researcher is conducting research on enhancing the vessel monitoring system (VMS) to combat IUU fishing. Your response is critical to enhancing the performance of the VMS in addressing the issue of IUU fishing. Your participation is very important to obtain valuable data for this research, which may contribute to policy making in Sierra Leone's industrial fisheries.

Designation of respondent…….
Date ……

1. On a scale of 1 to 5, how would you rate the effectiveness of the Joint Operation Centre (JOC) in utilizing Vessel Monitoring Systems (VMS) for monitoring and surveillance activities?
   1) Very ineffective
   2) Ineffective
   3) Neither ineffective or effective
   4) Effective
   5) Very effective

2. On a scale of 1 to 5, how would you rate the impact of VMS implementation on the reduction of Illegal Unreported and Unregulated (IUU) fishing incidents within Sierra Leonean waters?
   1) Very low impact
   2) Low impact
   3) Moderate impact
   4) High impact
   5) Very high impact

3. On a scale of 1 to 5, how would you rate the current utilization and accessibility of VMS data for surveillance purposes?
   1) Very poor
   2) Poor
   3) Neither poor nor good
   4) Good
   5) Very good

4. On a scale of 1 to 5, how would you rate the current utilization and accessibility of VMS data for policymaking purposes?
   1) Very poor
   2) Poor
   3) Neither poor nor good
   4) Good

5) Very good

5. On a scale of 1 to 5, how would you rate the current utilization and accessibility of VMS data for enforcement purposes?
1) Very poor
2) Poor
3) Neither poor nor good
4) Good
5) Very good

6. On a scale of 1 to 5, how would you rate the overall compliance of industrial fishing vessels with VMS operating in Sierra Leonean waters?
1) Very low compliance
2) Low compliance
3) Moderate compliance
4) High compliance
5) Very high compliance

7. What factors do you believe contributed to the level of compliance among industrial fishing vessels with VMS operating in Sierra Leonean waters?
……
……..

8.To your knowledge, are there any instances of non-compliance among industrial fishing vessels operating in Sierra Leonean waters without VMS?
a) Yes
b) No

9. How effective do you perceive the monitoring systems employed by the VMS operators at the monitoring centre?
a) Very Ineffective
b) Ineffective
c) Moderately effective
d) Effective
e) Very Effective

10. What obstacle(s) or limitation(s) do you perceive with the current operational measures utilized by the VMS to ensure compliance with fisheries regulations? ***Tick as applicable***

No.	**Obstacle(s)/Limitation(s)**	**Very Low**	**Low**	**Moderate**	**High**	**Very High**
1.	Technological Constrains					
2.	Resource Constrains					
3.	Evasive Tactics of Offenders					
4.	Limited Coverage					
5.	External Pressure					

THANK YOU

APENDIX 2

KEY INFORMANT INTERVIEW

INTRODUCTION:

The researcher is conducting research on enhancing the vessel monitoring system (VMS) to combat IUU fishing. Your response is critical to enhancing the performance of the VMS in addressing the issue of IUU fishing. Your participation is very important to obtain valuable data for this research, which may contribute to policy making in Sierra Leone's industrial fisheries.

Name of Organization…… ……. Date ……..……
Designation of respondent…….…….

1. How useful is VMS data in battling IUU?
   ……..
   ……..……
   ……
   ……

2. Can you provide specific examples or instances where VMS implementation has contributed to the reduction of IUU fishing incidents in Sierra Leonean waters?
   ……
   .....
   .....
   .....

3. What specific opportunities do you see for enhancing the utilization and accessibility of VMS data for research purposes?
   …….

   ……..

4. What penalties or enforcement mechanisms are in place to address instances of non-compliance by industrial fishing vessels operating in Sierra Leonean waters without VMS? ……
   ……
   ……
   ……

5. What specific opportunities do you see for enhancing the utilization and accessibility of VMS data for policymaking purposes?
   ……

   ……
……

6. How good is JMC in using VMS to battle IUU?
   …….

…….

7. Can you describe the functions of the Joint Operation Centre (JOC) in utilizing Vessel Monitoring Systems (VMS) for monitoring and surveillance activities?

……..
……

8. What specific opportunities do you see for enhancing the utilization and accessibility of VMS data for enforcement purposes?
   …….

…….
…….

THANK YOU