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ASSESSING THE COMPLIANCE OF THE 2021 CLOSED SEASON IN GHANA USING AIS DATA

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TABLE OF CONTENTS

FIGURES AND TABLES

ABSTRACT

SECTION I: INTRODUCTION

OBJECTIVES:

SECTION II: LITERATURE REVIEW

2.1 OVERFISHING

2.1.2 WHY OVERFISHING OCCURS

2.1.3 HOW OVERFISHING AFFECTS BIODIVERSITY

2.1.4 EFFORTS TO PREVENT OVERFISHING

2.1.5 CAN WE STOP OVERFISHING?

2.1.6 OVERFISHING IN GHANA

2.1.7 OVERFISHING FACTS AND STATISTICS GLOBALLY

2.2 FISHING INDUSTRIES IN GHANA

2.2.1 THE ARTISANAL CANOE SECTOR

2.2.2 SEMI-INDUSTRIAL SECTOR

2.2.3 INDUSTRIAL SECTOR

2.4 REVIEW OF THE CURRENT STATE OF FISHERIES GLOBALLY.

2.5 THE FISHERIES SECTOR IN GHANA

2.6 THE CLOSED SEASON

2.6.1 What is it and Why?

2.6.2 Closed Season – “A Biological Rest Period": Is this the Best Way to Preserve Resources?

2.6.3 Better Prices for Fish

2.6.4 Closed Season: Only One of the Tools of Sustainable Exploitation of Resources.

2.6.5 To Be Effective, the "Closed Season" Must Be Part of a Larger Plan

2.6.6 Monitoring of Ghana’s Closed season for Artisanal Fishermen

2.7 WHAT IS AIS?
2.7.1 The Pros And Cons Of AIS
2.7.2 Identifying Vessel Behaviour Using AIS
2.7.3 Improving Fishing Activities Using AIS Data
2.7.4 AIS Combined with Operational Tools
2.7.5 AIS Combined with Diplomatic and Multilateral Engagement
2.7.6 AIS Combined with VMS
2.7.7 Recommendations for the Application of AIS

SECTION III: METHODOLOGY
3.0 Area of Study
3.1 Materials Used
3.2 AIS Data Processing
3.3 Data Cleaning and Sampling
3.4 Fishing Behaviour Identification
3.5 Mapping Fishing Grounds

SECTION IV: RESULTS
4.1 Fishing Vessel Activity in a Non-Closed Season Month.
Figure 7
4.2 Fishing Vessel Activity of Closed Season Months
4.3.1 Ghana
4.3.2 France
4.3.3 Belize
4.3.4 China

SECTION V: DISCUSSION
5.1.1 Quota Management System
5.1.2 The Closed Season
5.1.3 Protected Areas
5.1.4 The Introduction of CITES.

CONCLUSION

ACRONYMS AND ABBREVIATIONS

REFERENCES

FIGURES AND TABLES

FIGURES

Figure 1 - Artisanal Canoes

Figure 2 - Semi-industrial fishing vessels

Figure 3 - Industrial fishing fleets

Figure 4 - Coastal Zones of Ghana

Figure 5 - Chart flow of Processing Data

Figure 6 - Distribution of fishing vessel speeds of industrial fishing fleets operating within the EEZ of Ghana from June-2021 to September 2021. Red line are speeds associated with fishing periods and green line represent steaming speeds to fishing grounds.

Figure 7 - Spatial Distribution of Vessels during Open Season

Figure 8 - Spatial Distribution of Vessels during Closed Season

Figure 9 - Distribution of Fishing Vessels in September 2021

Figure 10 - Spatial Distribution of Fishing Vessels at Sea during Closed Season

Figure 11 - Bar Chart Distribution of Number of Fishing Vessels against Flag Countries

Figure 12 - Spatial Distribution of vessels (Ghana) during the Closed Season

Figure 13 - Chart of Days against Months (June to Sept.) of Vessels (Ghana) at sea

Figure 14 - Spatial Distribution of vessels (France) during the Closed Season

Figure 15 - Chart of Days against Months (June to Sept.) of Vessels (France) at sea

Figure 16 - Spatial Distribution of vessels (Belize) during the Closed Season

Figure 17 - Chart of Days against Months (June to Sept.) of Vessels (Belize) at sea

Figure 18 - Spatial Distribution of vessels (China) during the Closed Season

Figure 19 - Chart of Days against Months (June to Sept.) of Vessels (China) at sea

TABLE

Table 1 - The Pros and Cons of AIS

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ABSTRACT

Crisis pertaining to irregular, unregulated, unreported fishing activities are being faced by the entire globe, affecting the economic growth of various states. Observations reveal that there are numerous records of Asian and European vessels engaging in extensive and frequently illegal fishing activities in West African waters, with a relatively small number of natives being culprits. This paper aims to identify and describe fishing behaviours, detect pair-trawling and also assess the effectiveness of the 2021 closed season period in Ghana using AIS. Automatic Identification System (AIS) is collected by satellites and terrestrial receivers that can be used to identify distinct fishing behaviour based on the movement of vessels over time. Using the Automatic tracking System (ATS) or AIS, each vessel periodically reports information including the Vessel's identity, type, positions, speed, navigational status and other safety-related information.

CHAPTER ONE (1)

1.0 INTRODUCTION

Human activities in the oceans are causing undeniable issues and overfishing is a serious threat that marine ecosystems worldwide are facing today. It has been widely recognized that activities pertaining to fishing are largely dependent on the marine environment and have considerable socio-economic importance to the society and the world at large as well as contributing to food and security. However, in recent years, marine and freshwater resources are being overexploited. And now, we are harvesting fish from already depleted zones and regions of water bodies.

Illegal, Unreported, and Unregulated fishing activities, often referred to as IUU, has become a global issue, threatening ocean ecosystems and sustainable fisheries (Agnew et al., 2009). IUU is most common in West Africa, followed by the Western Central Pacific Ocean which is recorded to have the highest rate of IUU fishing globally. In Western Central Pacific Ocean, IUU fishing reports about 34 percent of the total catch. This contributes to the overutilization of fisheries resources, preventing recovery and leading to collapses in the ecosystem.

Ghana has valuable fisheries that generate in the order of US$ 1 billion in revenue each year. The fisheries support 135,000 fishers in the marine sub-sector alone. Ghana's fisheries contribute 4.5 percent to annual GDP and indirectly support the livelihoods of 2.2 million people or 10% of all

people in Ghana. Ghana's small pelagic fish populations, such as sardinella, have dropped 80% in the past two decades. One species, sardinella aurita, has fully collapsed. Chinese industrial fishing trawlers are responsible for catching most of Ghana's fish. China is the world's worst IUU offender, according to the IUU Fishing Index. In view of this emergency, the Ministry of Fisheries and Aquaculture Development (MoFAD) in collaboration with the Fisheries Commission launched the 2021 Closed Season for artisanal and industrial fishing fleets in Ghana which commenced July 1st to August 31st, 2021. According to the Ministry, artisanal fishers were to observe July 1st to July 31st, 2021 as the closed season period while industrial fishers were to go off from July 1st to August 31, 2021.

Globally, closed seasons are considered as one of the key fisheries management procedures to help protect fish stocks and also increase their population. There are two breeding seasons in Ghana with the main breeding season occurring in August every year. This makes absolute sense that the closed season is observed during that time. The need to observe the closed season is to reduce fishing pressure on stocks when they are most productive in terms of allowing fishes to lay their eggs to replace the lost population due to fishing and other natural causes. This can enhance the supply available for fishing in a few years to come by safeguarding the pregnant fish.

With the emergence of technology such as the Vessel Monitoring System (VMS) and the Automatic Identification Systems (AIS) which provide high-resolution fishing vessel position data, tracking, positioning and mapping of vessels are done with much less tediousness. AIS-SARTs have been available on the market since at least 2009. Recent regulations have mandated the installation of AIS systems on all Safety Of Life At Sea (SOLAS) vessels and vessels over 300 tons. The United States of America requires fishing vessels over 65 feet long to have an AIS device. More than 70,000 fishing vessels use AIS devices that collect data such as the directions, speed, location and identification of the vessel which is automatically sent to land-based receivers and satellites almost every 2-30 seconds. These AIS signals are made public on websites like Global Fish Watch, and they provide details about fishing vessels and other users all across the world. This contributes to fishing vessel accountability and transparency while also ensuring a safe and secure environment. However, not all vessels are mandated to use AIS devices and some switch them off or tamper with them in order to offer misleading information to the public, defeating the purpose of all.

AIS has a number of benefits over other currently available detection methods. AIS provides a series of benefits over VMS as a vessel tracking system, both in terms of data accessibility and cost

effectiveness. VMS data is notoriously difficult to obtain for purposes other than control and enforcement.

This project centres on how AIS is used to track and monitor fishing vessels during the closed season in Ghana. Much light is thrown on the movements of the vessels and also the effectiveness of the close season will be outlined.
In many fisheries, seasonal closures are the first management strategy employed and subsequently supplemented or replaced with more effective measures. This paper is focused on how effective the closed season in 2021 was by using AIS data.

OBJECTIVES:

The primary objective of this study is to develop processing tools for analysing AIS data to understand fishing behaviour as well as detect fishing infractions. The specific objectives of the study are:

- build tools that will allow you to detect pair-trawling.
- quantify pair-trawling infractions and identify the culprits.
- access whether industrial fishing boats complied with the closed season directive by the Ministry of Fisheries and Aquaculture .

CHAPTER TWO (2)

2.0 LITERATURE REVIEW

2.1 OVERFISHING

Overfishing occurs when a large number of fish are caught at once, causing the population to become too low to recover. As a result, fish populations in the overfished area decline, causing the ecosystem to become unbalanced. Overfishing is frequently associated with commercial fishing and firms bringing in enormous amounts of fish hauls that are sometimes accompanied by other sea inhabitants they didn't want to catch, known as bycatch.

The big question here is when did widespread overfishing of the seas begin, according to marine scientists? Here's a look at the most pressing issues surrounding overfishing, from its consequences on biodiversity to mitigation attempts' limited efficacy.

2.1.2 WHY OVERFISHING OCCURS

The first overfishing began in the early 1800s when people were in search of blubber for lamp oil. This destroyed the whale population off the coast of Cape Cod near Stellwegen Bank. By the mid-nineteenth century, some species used in the United States such as Atlantic cod, herring and California sardines had been depleted to the point of extinction. The food chain was severely disrupted by these discrete regional depletions and became more unstable in the late twentieth century.

Countries all around the world worked to improve their fishing capacities in the mid-twentieth century to assure the availability and affordability of protein-rich diets. Favourable regulations, loans, and subsidies hastened the emergence of large industrial fishing enterprises, which have fast displaced indigenous fishermen as the world's primary supply of seafood.

These enormous, profit-driven commercial fleets were ruthless, searching the world's oceans and inventing ever-more sophisticated ways and technology for discovering, harvesting and processing their prey. Consumers quickly became accustomed to having a large assortment of fish at reasonable rates.

However, by 1989, when roughly about 90 million tonnes (metric tonnes) of fish were removed from the sea and the business had reached its peak, yields have since decreased or remained stagnant. Because of a paucity of fish, fisheries for the most sought-after species, such as orange roughy , Chilean sea bass and bluefin tuna have collapsed. Scientific research published in 2003 projected that industrial fishing has reduced the population of huge ocean fish to barely 10% of its pre-industrial level.

2.1.3 HOW OVERFISHING AFFECTS BIODIVERSITY

With large-fish stocks collapsing, commercial fleets began looking for feasible catches deeper in the ocean and further down the food chain. This so-called "fishing down" has set off a chain reaction that is disturbing the sea's biological system's ancient and fragile equilibrium.

Overfishing, for example, is highly harmful to coral reefs. Plant-eating fish keep these ecosystems in check by eating algae, which keeps the coral clean and healthy so it may thrive. Too many

herbivores caught in the net, whether intentionally or as bycatch, can weaken reefs and make them more vulnerable to extreme weather and climate change. The fragile corals that make up the reef foundations can also be physically destroyed by fishing equipment and detritus.

Other marine species may be harmed as a result of overfishing. Trawling, which involves boats towing large nets behind them in the water, catches more than simply shrimp and bluefin tuna—it catches anything in its path. As a result of bycatch, sea turtles, dolphins, sea birds, sharks, and other creatures are being threatened.

2.1.4 EFFORTS TO PREVENT OVERFISHING

As fisheries have caught less and fewer fish, humans have begun to realise that the seas, formerly thought to be infinitely vast and bountiful, are extremely vulnerable. According to a study of catch statistics published in the journal Science in 2006, all the world's fisheries would collapse by 2048 if unsustainable fishing rates persist. Many scientists believe that most fish populations might be restored with more aggressive fisheries management and stricter enforcement of catch rules, such as the imposition of harvest quotas. Increased usage of aquaculture (seafood production) might also be beneficial. And there is reason for optimism in many areas. In its 2020 report, the United Nations Food and Agriculture Organisation (FAO), which sets worldwide standards for fisheries management, noted that the percentage of stocks that are sustainably generating the most food possible has increased slightly, which is the goal of fisheries management.

There are still numerous obstacles to overcome. Around a third of worldwide fish stocks are overfished, and the overall proportion of fish stocks that are sustainable is decreasing. This deterioration of fish supplies, according to the FAO research, can be evident "in places where fisheries management is not in place, or is inadequate." The Mediterranean and Black Seas had the largest percentage of stocks fished at unsustainable levels (62.5%) among the places the organisation monitors.

2.1.5 CAN WE STOP OVERFISHING?

Subsidies to the fishing industry from the government remain a substantial barrier to altering this alarming trend. According to a global assessment, countries paid $22 billion in 2018 on so-called detrimental subsidies that drive overfishing up 6% from 2009. Harmful subsidies, as National Geographic observed at the time, are those that subsidise operations that would not otherwise be lucrative, such as the fuel expenditures of industrial trawlers. Over the last decade, China, for example, has boosted its detrimental subsidies by 105 percent.

Since 2001, members of the World Trade Organisation have been debating ways to reduce these subsidies, with little progress. Despite members of the United Nations promising to reach an agreement by 2020, the deadline has gone without resolution. WTO Director-General Ngozi Okonjo -Iweala urged countries to reach an agreement in 2021, claiming that failure to do so would threaten "the ocean's biodiversity and the sustainability of the fish stocks on which so many people rely for food and income." It's questionable if countries will be able to gather the political will to carry it out. However, scientists agree that it is one of many measures that must be taken to save the world's seas.

2.1.6 OVERFISHING IN GHANA

The fisheries sector in Ghana, beset with overfishing and a dramatic depletion of stocks, is facing imminent crisis. Illegal, unreported, and unregulated (IUU) fishing is common. The Ghanaian fishing industry is strongly endowed with significant and valuable stocks of fish. Ghana produces 430,000 tons of fish annually. Thus, the fishing industry in Ghana remains an attractive industry for both local and foreign fisher-folk, making it a major source of employment and livelihood. Marine fisheries in Ghana are overexploited, thus requiring a number of laws and regulations to sanitise the industry. The predominant laws regulating the activities of the fisheries sector include:

- The Fisheries Act 2002 (Act 625)
- Fisheries (Amendment) Act 2014 (Act 880)
- Fisheries Regulations 2010 (L.I 1968)
- Fisheries (Amendment) Regulations 2015 (L.I 2217)

As a result of IUU fishing, coastal communities have lost a large amount of potential revenue. Industrial and artisanal fishing vessels compete for small pelagic stocks in the country's fishery sector, which employs 20% of the active labour force (2.7 million people). There are significant political barriers to resolving the issue in both sectors.

Currently, there are 82 registered industrial trawlers operating in the Ghanaian waters, down from the peak number of 103 in 2014. However, because trawlers' average fishing capacity has been growing, it is unclear if the decrease in the number of trawlers has resulted in a decrease in total trawling operations. Trawlers must obtain licences before they may operate. The main source of government revenue from the trawling industry is licensing fees.

According to official data, catches from the trawlers constitute about 6% of total marine catches. However, this figure is likely to be an underestimation by a significant margin.

First, the Fisheries Commission (FC) lacks the capacity to determine actual catches: The catch figures are based on trawlers' self-reporting, which might be manipulated. The trawlers then engage in illegal fishing activities on a regular basis. Many trawlers fished inshore exclusive zones (IEZ) until recently, battling with artisanal fishers for declining small pelagic species. By-catch species (locally known as saiko) are disguised frozen in pallets and transshipped at sea to artisanal boats. These catches go unnoticed.

There are also flaws in the criminal justice system for offenders. When trawlers are detected breaking fishing rules, the case may be taken to court or the offenders may choose to settle through an arbitration process known as Alternative Dispute Resolution (ADR), which often results in less harsh penalties. Offenders are not deterred by these agreements. Many government officials are said to have vested interests in these firms. By implication, any attempt to enact stronger regulation of the industrial fisheries will be met with political opposition.

Canoe fishing has severe overcapacity. There are no fishing quotas or licence requirements. The lack of other work alternatives creates a classic "tragedy of the commons" situation. Furthermore, the government's power to enforce existing rules and regulations is limited, and it has been unable to prevent illicit fishing methods from being used.

The government subsidises artisanal fishermen's premix fuel. The premix fuel administration wields considerable political clout, and members of the ruling political party profit directly from diverted fuel sold to the manufacturing sector. As a result, the premix fuel subsidy has been maintained for political reasons (to earn the votes of artisanal fishermen) as well as financial advantage for political elites involved in fuel diverts to industries.

In the lack of alternative livelihoods, persuading canoe fishermen to reduce their efforts is a huge difficulty. Any meaningful reduction in canoe fishing would need to be complemented by a well-thought-out plan for generating new sources of income and employment. Fishers are unlikely to voluntarily agree with a policy that restricts fishing chances if there are no alternatives. Another issue is that the nature of electoral politics makes rules restricting canoe fishing extremely difficult to execute. Political parties and leaders are hesitant to implement such limitations for fear of losing support in fishing villages, which might be crucial in elections. Cuts or reductions in fuel subsidies are likewise politically problematic for the same reason.

There is a possibility that efforts to ban canoe fishing will have a negative impact on fishing communities. Canoe-fishing tribes are among Ghana's poorest, relying solely on fishing for their livelihood. Any restriction on fishing operations must be supplemented by direct assistance to the

affected communities, such as alternative employment, training and education, or direct economic transfers. Because of these obstacles—elite interests in maintaining the current system, insufficient administrative ability, a lack of trust in authorities, a lack of alternative livelihoods, and electoral risks—limiting fishing activity is extremely difficult. In the end, the issues are political. The implementation of more sustainable fisheries management strategies is hampered by strong political interests, such as the danger of electoral losses and opposition from political elites who profit from overfishing. To address them, strong political will and the ability to oppose the interests of those who profit from the current scenario are required.

2.1.7 OVERFISHING FACTS AND STATISTICS GLOBALLY

A whopping 80% of all life on Earth resides in the oceans. Only 3% of Pacific Bluefin Tuna are still alive today. The $42 billion global tuna business is in danger of failing due to overfishing. As bycatch, about 50 million sharks every year are killed. Shark extinction is being caused for the first time by humans. Due to fishing, six of the seven species of sea turtles are either endangered or threatened. According to research, the fishing industry in the United States captures, kills, or injures about 4,600 sea turtles annually. 10,000 dolphins may be killed each year as bycatch in the Atlantic Ocean off the French coast by irresponsible trawlers. . 86 percent of the huge plastic debris in the Pacific garbage patch is made up of fishing nets. From the Caribbean to the Middle East, fishing is now a serious danger to coral reefs. By 2050, 90% of the coral reefs in the globe are expected to have died. Every minute, up to 5 million fish are taken, totaling 2.7 trillion annually. Up to 13 jumbo jets can fit inside the biggest trawl nets.

2.2 FISHING INDUSTRIES IN GHANA

Fisheries play a vital role in supporting livelihoods and food security in Ghana. While there's a large industrial fishing fleet, over two-thirds of Ghana’s total marine fish catch is dilii>4.3 enforcement offor by artisanal fishers. These fishers now share Ghana’s marine domain with the country’s emerging oil sector, an industry that has raised hopes of a major economic boost for the country while at the same time eliciting concerns around potential environmental and social impacts.

The fisheries sector plays a major role within the socioeconomic development of Ghana. Bordered on the se0f43outh by the Gulf of Guinea, Ghana, spanning a region of 238 500 km2, incorporates a

narrow ocean bottom with a complete area of about 24 300 km2. Ghana includes a territorial sea of 12 nautical miles (nm) , a contiguous zone of 24 nm and an Exclusive Economic Zone (EEZ) of 200 nm, covering a district of 225 000 km2. With this mixture of val, and a 550-kilometre coastline which stretches from Aflao within the East to Half Assini within the West, Ghana's fisheries sector contributes significantly towards sustainable livelihoods, food security and poverty reduction. Ghana's fishing industry started within the 1700s as an artisanal fishery with very simple and inefficient gear, craft and methods, operating near coastal waters, lagoons, estuaries and rivers. Currently, the arena is predicated on fishery resources from the ocean and, to a lesser extent, inland fisheries and aquaculture. While marine species are fished within the abundant territorial marine waters, seafood are sourced from Lake Volta, rivers, reservoirs and inland aquacy for ultra and traffic **tracking** technologies and AIS data is essential and systems.

Ghana's fisheries sector consists of a varied and vigorous spectrum of fishing activities, ranging in scope from subsistence to semi-industrial, to uable attributes fisheries. Within this broad range, fish stocks are harvested from rivers, lakes, coastal lagoons and shallow seas and offshore waters within the Atlantic Ocean. Six different sources of domestic fish supply, including marine fishery, lagoon fishery, Lake Volta, other inland fisheries, aquaculture and imports, are often obtained in Ghana. The fishing operations in Ghana accommodates three subsectors: industrial, semi-industrial and artisanal (canoe) subsectors. The craft-type employed in Ghana's marine capture fishery includes dugout canoes, canoes with outboard motors, trawlers, and huge steel-hulled foreign-built vessels used for industrial fishing. The dugout canoes and canoes fitted with outboard motors are mostly employed by the artisanal fishers while trawlers and steel-hulled vessels are used mainly within the semi-industrial and industrial marine fisheries. there's currently a total of 12 000 marine artisanal canoes operating along the coast, 150 semi-industrial vessels and 84 licensed industrial trawlers in Ghana's marine waters. About 6 405 of the artisanal canoes are motorised. Many larger fishing vessels also are motorised with 40 horsepower outboard engines whereas smaller canoes still use sail power. Larger canoes, mainly motorised, concentrate on hook and line, and use ice to preserve high-value fish in insulated containers, with some using electronic fish finding devices like echo-sounders.

2.2.1 THE ARTISANAL CANOE SECTOR

Individual fishing households engage in various small-scale, low-technology, low-capital fishing activities known as artisanal fishing or subsistence fishing. Many of the households belong to ethnic groups from the coast or islands. These families go fishing near the shore on short (rarely overnight) expeditions. Their produce is primarily for local consumption and is sometimes not processed.

Traditional fishing techniques such as beach seines, hook and line, cast nets, and small traditional fishing boats are used in artisanal fishing. Commercial and subsistence fishing could both be done through artisanal fishing.

It differs from large-scale modern commercial fishing in that it is frequently less wasteful and less demanding on fish populations than industrial fishing. Because of its dispersed character, the total volume and economic benefit of artisanal fishing is poorly reported, but it is comparable to that of commercial fishing. Though the exact definition of "artisanal" fishing varies, the Food and Agriculture Organisation (FAO) defines it as "traditional fisheries involving fishing households (as opposed to commercial companies), using relatively little capital and energy, using relatively small fishing vessels (if any), making short fishing trips, near shore, primarily for local consumption." It contrasts with large-scale modern commercial fishing practices in that it's often less wasteful and less stressful on fish populations than modern industrial fishing. Thanks to its diffused nature, the whole volume and economic good thing about artisanal fishing is poorly documented but is also approximately capable of business fishing. Though the definition on exactly what qualifies as “artisanal” fishing is kind of variable, the Food and Agriculture Organisation (FAO) defines it as: traditional fisheries involving fishing households (as against commercial companies), using relatively bit of capital and energy, relatively small fishing vessels (if any), making short fishing trips, near shore, mainly for local consumption. In practice, definition varies between countries, e.g., from gleaning or a one-man canoe in low income developing countries, to over 20 m trawlers, seiners, or long-liners in developed ones.

Artisanal fisheries are often subsistence or commercial fisheries, providing for local consumption or export. they're sometimes cited as small-scale fisheries. The road between what's artisanal and what's industrial is often quite blurry occasionally so it's best to see it as a wage schedule and not just black and white. By comparing the dimensions of the boats used with the quantity of capital invested per man on board it's easier to determine these divisions. Meaning that even an outsized wooden canoe, that's man-powered and using headlines would qualify as artisanal thanks to the tiny technological investment. While a little ultra-light boat equipped with the most recent global positioning systems, downriggers, and sonar could still qualify as industrial. The key feature that differentiates industrial and artisanal fishing is their purpose in fishing. The main goal of an industrial fishery is to catch as many fish as possible for economic gain. This type of fishing entails several dangers, including overfishing, which can lead to the collapse of a fishery. Artisanal fishermen sell a small portion of their catch at marketplaces, but they mostly fish for survival. That is, they will go fishing to capture enough food to feed their families while also making a profit. This smaller scale, more environmentally friendly goal carries a lower chance of putting fish populations

in jeopardy, yet that isn't to suggest that all artisanal fisheries are "better." Artisanal fisheries don't pose an excellent risk to many ecosystems and marine species. Often, it's what technology is employed, how it's employed, and the way the fishery is managed that defines how eco-friendly an artisanal fishery is.

Fishing gear commonly employed in the artisanal fishery includes purse seines (“poli/watsa”), beach seines, drift gill nets, and surface set nets. Artisanal fishers also employ various kinds of bottom set-nets, and hook and line (“lagas”). Fishing vessels equipped with either drift gill nets or hook and line usually operate beyond 50-metre depth water zones. Specifically, those fishing with hook and line (“lagas”) wear board ice, food and fishing aids like fish finders and Global Positioning System (GPS). Artisanal marine fishing accounts for about 80 percent of total annual marine fish catch by volume.

Figure 1. Artisanal fishing vessels of Ghana. (Retrieved from https://hakaimagazine.comwest-africas-artisanal-fisherset/)

2.2.2 SEMI-INDUSTRIAL SECTOR

Semi-industrial (inshore) fishing employs locally built wooden boats measuring 9-12 metres in length and powered by 30-90 horsepower motors to exploit fisheries resources. Most vessels are multi-purpose, with the ability to utilise trawls and purse seines. These vessels fish with purse seines primarily inshore waters at depths of 30-50 metres during the upwelling seasons, competing with the artisanal fishing fleet. During the process, the land contributes around 2% of the total marine output.

Figure 2. Semi-industrial fishing vessels of Ghana. (Retrieved from: www.pulse.com.gh)

2.2.3 INDUSTRIAL SECTOR

The industrial fishing fleet operates offshore at depths of 50-75 metres, with engines rated at 30-200 horsepower and purse seines or pole and line live-baited with anchovy, to catch tunas (skipjack, yellowfin, and bigeye) and high-value cephalopods that are frozen at sea for export. Large steel-hulled foreign-built trawlers, tuna pole-and-line vessels, purse seiners, and shrimpers are among them. Industrial fishing accounts for around 6% of overall marine productivity.

Figure 3. Industrial fishing vessels. (Retrieved from https://stopillegalfishing.com/case.studies/)

2.4 REVIEW OF THE CURRENT STATE OF FISHERIES GLOBALLY.

- Ten years ago, we reached the maximum levels of catch that populations of bottom fish and small pelagic fish could sustainably handle. [FAO - "State of the World's Fisheries 2012."] The 2020 edition of *The State of World Fisheries and Aquaculture* continues to demonstrate the significant and growing role of fisheries and aquaculture in providing food, nutrition and employment. It also shows the major challenges ahead despite the progress made on a number of fronts. For example, there is growing evidence that when fisheries are properly managed, stocks are consistently above target levels or rebuilding, giving credibility to the fishery managers and governments around the world that are willing to take strong action. However, the report also demonstrates that the successes achieved in some countries and regions have not been sufficient to reverse the global trend of overfished stocks, indicating that in places where fisheries management is not in place, or is ineffective, the status of fish stocks is poor and deteriorating. This unequal progress highlights the urgent need to replicate and re-adapt successful policies and measures in the light of the realities and needs of specific fisheries. It calls for new mechanisms to support the effective implementation of policy and management regulations for sustainable fisheries and ecosystems, as the only solution to ensure fisheries around the world are sustainable.

FAO is a technical agency created to fight hunger and poverty. Yet, as we approach a world of 10 billion people, we face the fact that since 2015 the numbers of undernourished and malnourished people have been growing. While there is no silver bullet to fix this problem, there is little doubt that we will need to use innovative solutions to produce more food, ensure access to it, and improve nutrition. While capture fisheries will remain relevant, aquaculture has already demonstrated its crucial role in global food security, with its production growing at 7.5 percent per year since 1970. Recognizing the capacity of aquaculture for further growth, but also the enormity of the environmental challenges the sector 70,000 o9[9]must face as it intensifies production, demands new sustainable aquaculture development strategies. Such strategies need to harness technical developments in, for example, feeds, genetic selection, biosecurity and disease control, and digital innovation, with business developments in investment and trade. The priority should be to further develop aquaculture in Africa and in other regions where population growth will challenge food systems most.

Substantial global population expansion and fast-growing economics drive an increasing demand for fish products. In addition, global climate change that tends to have an impact on agricultural production pushes people to depend more on fish for nutrient needs. Modern fishing technologies and advanced fishing equipment bring about an excessive and continuous increase in fishing effort. More and more fish are caught than can be reproduced naturally in the oceans. The oceans now are under great pressure from global overfishing which causes a dramatic decline in the fish population. Several major commercial fish species are endangered which disturbs the balance of the food chain and threatens the ocean ecosystem. This also affects millions of people who depend on fish products as their main source of protein and income. According to a report in 2014, the State of World Fisheries and Aquaculture (SOFIA) by The United Nations Food and Agriculture Organization (FAO), fish accounts for 20 percent of animal protein intake for more than 2.9 billion people, a9nd 15 percent of animal pro- tein intake for 4.3 billion people. FAO estimated that fisheries and aquaculture support the livelihoods of 10 to 12 percent of the world's population. According to the 2014 report, more than 90 percent of global fisheries are overexploited. A study published in 2006 in the journal Science extrapolated fisheries catch data into the future and predicted that if the current volume of fishing activities remain unchanged or even increasing, all the world's fish stocks would collapse by the year 2048

Unfortunately, in many cases these fishing activities are Illegal, Unreported and Unregulated which are referred to as IUU fishing. IUU fishing takes place when fishing takes place in a restricted area without permission, violating conservation and management measures such as ignoring quotas or by-catch limits, catching protected species, fishing certain species without a licence, and failing to report or misreporting catches. It is estimated that over 11-26 million tons of fish are caught by IUU fishing each year resulting in a $10-23 billion economic cost. Governments and fishery

The aspiration of the legislators behind the obligatory use of vessel identification systems was the need to control fishing and combat Illegal, Unreported and Unregulated fishing (IUU). IUU depletes fish stocks, destroys marine habitats, distorts competition, puts honest fishers at an unfair disadvantage, and weakens coastal communities, particularly in developing countries like Ghana.

2.5 THE FISHERIES SECTOR IN GHANA

Ghana's fisheries sector consists of marine capture fisheries, inland fisheries and aquaculture. In addition to providing much-needed animal protein, the fisheries sector creates jobs for 20% of the active labour force (2.7 million people), including women who engage solely in processing and distribution. The marine fisheries sector has four subsectors: artisanal or small-scale, semi-industrial

or inshore, industrial, and tuna fisheries. The industrial sector is made up of trawl vessels and shrimpers. Small pelagic fish species dominate the catches of all the sectors, except that of the tuna fleets. Available statistics indicate that total fish landings generally increased from 1970, peaked in 1996 and started to decline through 2016. In addition to overfishing the targeted demersal stocks, trawlers in Ghana actively engage in IUU fishing activities. Until recently, many trawlers fished within the inshore exclusive zones, compelling artisanal fishers over dwindlinand 8g stocks of small pelagic species. Such species are disguised as by-catches (locally termed saiko), frozen in blocks and transshipped at sea to artisanal boats.

- The legal and regulatory framework of fisheries management in Ghana is informed by the Fisheries Act (Act 625), Fisheries Regulations (L. I. 1968), National Premix Fuel Committee Regulations (L. I. Lf the Fisheries Commission, which is the implementation jagency of MOFAD. The Ministry of Fisheries and Aquaculture Development (MOFAD) is responsible for the management of fisheries resources in Ghana and for the development of the fishing industry. The Fisheries Commission, one of two agencies under MOFAD, implements the policies and regulations of MOFAD.

Recognizing the existence of general overcapacity in the fishery sector, it is the stated aim of the government to reduce the number of industrial trawlers. Industrial and artisanal fishing vessels compete for space in Ghana’s waters. Currently, there are 76 registered industrial trawlers in Ghana, down from the peak number of 103 in 2014. However, average fishing efforts of trawlers have increased, so it is not clear that the reduction in the number of trawlers has led to a reduction in total trawling activities. Trawlers are obliged to purchase licences in order to operate. These fees, which have been assessed as being too low, are the main source of government revenue from the trawling sector. Industrial trawlers are required to have majority Ghanaian ownership you closed season in 2021.

The Ghanaian Ministry of Fisheries and Aquaculture Development (MoFAD), in partnership with the Fisheries Commission, declared the 2021 Closed Season for artisanal and industrial fishing fleets, which would run from July 1 to August 31, 2021.

According to the Ministry, artisanal fishers were to observe July 1st to July 31st, 2021 as the cl9 I'll ii m okoosed season period while industrial fishers were to go off from July 1st to August 31, 2021. In 2019, the observation of the closed season generated some controversy among key stakeholders in the industry under the former Minister, Mrs. Elizabeth Naa Afoley Quaye.

- Speaking at the Launch of the 2021 closed season, the Sector Minister, Mavis Hawa Koomson noted that this year's closed season would become the most successful one as all stakeholders are involved. The closed season, explained by the sector minister, was a way of reducing fishing pressure thereby allowing the fish to lay their eggs to replace the lost population due to fishing and other natural causes. The Minister who is also the Member of Parliament for Awutu Senya East said the marine and inland sub-sectors were confronted with challenges that had the tendency to overturn the benefits from the fisheries sector if no action was taken. She said with the exception of Tuna resources, the marine fishery resources were over-exploited and that there were signs that some fish species had depleted. Mrs Hawa Koomson said it was important that necessary measures were put in place to reduce the excessive fishing pressure and allow for recovery of overexploited fish stocks and rebuild the depleted fish stocks.

She said to address the situation, the Ministry and the Fisheries Commission (FC) in accordance with Section 84 (1) of the Fisheries Act, 2002 (Act 625) which states that,

1. The Commission may by notice in the Gazette declare closed season loop pons, including their duration, for fishing in specified areas of the coastal waters or the reverie system.
2. A declaration made under subsection (1) shall be given reasonable publicity and, where possible, shall be given in advance of the closed season.
3. A closed season declared by an international body of which Ghana is a member shall be regarded as a closed season declared under this Act
4. A person who engages in fishing during a closed season declared in accordance with this section commits an offence and is liable on summary conviction to a fine of not less than
    a) $500,000 and not more than $2 million in respect of a local industrial or semi-industrial fishing vessel or a foreign fishing vessel, or
    b) one hundred penalty units and not more than five hundred penalty units in any other case, and in addition, the catch, fishing gear or vessel or any other apparatus or any combination of them used in the commission of the offence may be forfeited to the Republic.

And the Marine Fisheries Management Plan (20152019) has been implementing a Closed Season since 2016, which was not observed in 2020 due to COVID-19 management measures.

Mrs Hawa Koomson said the Ministry recognized the fact that the desired result of implementing Closed Seasons will be attained when other types of illegal fishing activities, such as transshipment

(popularly known as Saiko), the use of poisonous and toxic chemicals, dynamites, and other explosives were controlled. “In the light of this, the Ministry in collaboration with the law enforcement agencies like the Ghana Navy and the Ghana Marine Police would intensify the fight against all forms of illegal fishing activities”.

She said efforts were underway to procure four patrol boats for the fisheries to enhance monitoring, control and surveillance activities on marine waters, sector and research vessels to provide adequate data on marine fish stocks even as we embark on this recovery process.

While steps are being taken towards the recovery of the depleted marine fish stocks, efforts are also being made to promote the development of aquaculture which is expected to improve domestic fish production, create additional jobs along the value chain and help reduce the over dependence on the marine fisheries resources. Major ongoing aquaculture initiative being implemented by the Ministry is the Flagship Programme “Aquaculture for Food and Jobs”, which I wish to promote in coastal areas ".

Mavis Hawa Koomson also called on the fish folks to adhere to the directive for the betterment of their work. There were representatives from the National Fisheries Association of Ghana, Ghana National Canoe Fishermen Council, Ghana Tuna Association, Ghana Industrial Trawlers Association and National Fish Processors and Traders Association.

2.6 CLOSED SEASON – A TOOL FOR FISHERIES MANAGEMENT

2.6.1 What is it and Why?

The vast majority of fish breed by the female fish releasing their eggs into the water and then having the male fish fertilise them. A female fish can lay up to several hundred thousand eggs or even sometimes a million eggs depending on the species and the size of fish. For example, our *sardinella* in Ghana, often referred to as ‘the people’s fish’, can release tens of thousands of eggs at one time during the breeding season. There are two breeding seasons in Ghana with the major breeding season occurring around August every year. Eggs from older female fish are bigger and much more likely to be fertilised and produce baby fish than those of small and younger fish. Eggs and tiny baby fish are subject to the natural conditions of the sea around them. These conditions include how many get eaten by other organisms, the temperature of the ocean, unusual currents that take them in the wrong direction, lack of food, and so on. Scientists estimate

that out of an average of one million eggs produced, only a few make it to become juvenile fish and fewer still make it to be adults and breed themselves. This low survival rate to adulthood is one of the reasons female fish release so many eggs.

Reproduction, or spawning, for most species occurs in the open ocean and then, once hatched, the baby fish drift into the coastal zones and estuaries. This is one of the reasons that Ghana's estuaries and many coastal zones are known as 'nurseries' where baby fish can find shelter and food until they grow to a point where their chance of survival to adult size is greater. Once they grow older and bigger, they return to the open ocean to the fishing grounds where they can spawn themselves or be caught by fishermen. A problem arises when the pressure of fishing is so high that few fish grow to adulthood and never live to reproduce and replenish the stock. This is called overfishing. Overfishing is similar to constantly withdrawing more money than you deposit into your account. Eventually, the account runs dry. When we talk about the people's fish in Ghana, mainly *sardinella* (known in Fante as eban) the seas are now running dry of them. It is estimated that without urgent action, Ghana's sardinella stocks could become so low that by 2020 fishermen will no longer have them to catch and sustain themselves unless the government fully supports them. Overfishing can occur in the open seas and inside nursery areas where small juvenile fish are caught before they get a chance to grow and spawn at least once in their lifetime. In Ghana, the use of nets with mesh sizes that are smaller than allowed by the fisheries regulation is common and results in catching juveniles before they are old enough to breed.

Essentially, it is already not financially viable for most fishermen to stay in business. Today, many Ghanaian canoe fishers would find it financially difficult to continue to fish without subsidised fuel, called Premix. Receiving government subsidised Premix fuel means that they never have to really absorb the full cost of going fishing. In essence, they already can't catch enough fish to meet the real costs of fishing. And the stock has gotten so thin in traditional nearshore fishing grounds that they must travel farther and farther to sea in search of fish. Still, they often return with their boats nearly empty. Latest studies suggest that fish is collapsing putting in danger the livelihoods, food and nutritional security and future economic development of 2.7 million Ghanaians who are directly or indirectly depending on the canoe fishing industry, not to mention the many millions more who depend on these fish for their daily protein (Apetorgbor, n.d.). If this fishery is lost, the most vulnerable will be the poor, pregnant mothers as well as young children who need sufficient protein for their brain and bodily development.

2.6.2 Closed Season – “A Biological Rest Period": Is this the Best Way to Preserve Resources?

Fishes move to areas where the water conditions are good for them to lay their eggs, find prey and have optimal conditions for growth. They aggregate and move in large schools close to shore or in estuaries at this time of spawning. They become easy to catch by canoe nets and even “trawlers”. Over the years, canoe and trawler fishers know where these areas are and they take large quantities of spawning fish over a short amount of time. Fish processors acknowledge this. But they complain that they have to squeeze out the eggs from fish before processing to prevent them from being so only after smoking and then having to sell them for a lower price. In Ghana, the peak spawning period for fish such as sardinella, anchovies and mackerel is in August.

This period is known as the period of the “bumper” harvest where more than 40% of the annual catch is released throughout the coastal areas of Ghana. In fact, the highest catches were recorded in the late 1990s and since then the ‘bumper’ season has been decreasing. In 2017, Ghana recorded the lowest annual catch in the history of its fishery due to falling stocks.

The term "closed season”, or “biological rest period", refers to the stopping of fishing during the spawning period of the fish. It is a way of reducing fishing pressure on stocks when they are most productive in terms of allowing the fish a chance to lay their eggs to replace the lost population due to fishing and other natural causes. Provided that a sufficient number of fish remain to breed, the "closed season" can, by "protecting the pregnant fish", increase the stock available for fishing in just a few years. A closed season will be most successful when other types of fishing pressure are also controlled such as use of illegal small mesh size nets, light fishing, use of poisons and toxic chemicals, and dynamite or other explosives.

2.6.3 Better Prices for Fishing

Proper application of closed seasons also prevents the kind of high supply – low price situation that happens every August in Ghana. There are so many fish landed that the value of fish is reduced. Fishermen get lower prices and so do fish processors. There are so many fish that some fish remain unsold. Also, during this time, the caught pregnant fish are very oily because they have so many eggs. With so many eggs, fish break open during processing and produce low quality fish for food.

2.6.4 Closed Season: Only One of the Tools of Sustainable Exploitation of Resources.

The management of fishery resources is based on a simple basic principle: fishing must not exceed the natural ability of fish to renew themselves. This calls for such things as closed seasons to help fish resources regenerate and renew themselves. It also means that fishing pressure must be controlled. In Ghana, this means that the number of trawlers and eventually the number of canoes must be limited. In Ghana, all these strategies are contained in the National Fisheries Management Plan 2015-2019. This was adopted by the previous government.

2.6.5 To Be Effective, the "Closed Season" Must Be Part of a Larger Plan

The National Fisheries Management Plan outlines a number of actions that must be taken to sustain the people's fish in Ghana that includes the reduction of fishing pressure through a number of combined actions. Also, the Fisheries Act 2002 (Act 625), states that "The Commission may by notice in the Gazette declare closed seasons, including their duration, for fishing in specified areas of the coastal waters or the reverie system.

1) A declaration made under subsection (1) shall be given reasonable publicity and, where possible, shall be given in advance of the closed season.
2) A closed season declared by an international body of which Ghana is a member shall be regarded as a closed season declared under this Act
3) A person who engages in fishing during a closed season declared in accordance with this section commits an offence and is liable on summary conviction to a fine of not less than

a) $500,000 and not more than $2 million in respect of a local industrial or semi-industrial fishing vessel or a foreign fishing vessel, or
b) one hundred penalty units and not more than five hundred penalty units in any other case, and in addition, the catch, fishing gear or vessel or any other apparatus or any combination of them used in the commission of the offence may be forfeited to the Republic. ”

The currently planned closed season is only one measure in the National Fisheries Management Plan and all the other measures must be implemented to ensure fish remain a part of Ghana’s future economy, and importantly the livelihoods, health, nutrition and food security of those estimated 2.7 million people who directly and indirectly depend on this industry around the people’s fish. Once the closed season becomes a regular annual rest period to allow pregnant fish to spawn, and illegal means of fishing are controlled or eliminated, the landing of the people’s fish can be expected to increase from the current 20,000 metric tons to over 90,000 metric tons within 10 years. Every year that we delay the closed season is another year that Ghana’s economic development, and food and nutritional security, is delayed. Surely, this kind of effort is worth supporting.

2.6.6 Monitoring of Ghana’s Closed season for Artisanal Fishermen

In a bid to avert Ghana’s depleting fish stock, the government announced a closed season for artisanal fishers from May 15 to June 15, 2019. The measure was considered to be one of the tools for effective conservation and management of fisheries. CEMLAWS Africa’s field experts monitored and assessed the closed season for the artisanal fisher-folk throughout the designated period. The objective was to engage fisher-folk and other relevant stakeholders on the closed season and to gather essential information pertaining to the closure. Twenty-two fishing communities were engaged. CEMLAWS Africa launched a report on the findings of the observed closed season and presented relevant recommendations to serve as a guide for future bans. In attendance were relevant stakeholders including Members of Parliament, representatives from USAID, Fisheries Commission, Ministry of Fisheries and Aquaculture Development and many other development partners and NGOs.

2.7 WHAT IS AIS?

Automatic Identification System is an automatic nautical tracking system onboard ships that gathers and provides ship information to other ships and shore organisations such as the Vessel Traffic Services (VTS). AIS is a self-reporting system, which has been widely applied in maritime traffic surveillance (Tetreault, 2005). The data may be shown on the AIS display or Radar/Electronic Chart Display and Information System (ECDIS) equipment and used for many other purposes in maritime logistics systems besides traffic safety. AIS allows the exchange of both the navigational information (like position, velocity, course, etc.) and vessel information such as (Maritime Mobile Service Identity (MMSI), length, breadth, and draught etc.,) in-between ships and between ships and shore-based AIS stations using very high-frequency (VHF) radio transmission. Land-based AIS, i.e., terrestrial AIS, relies on shore-based monitoring stations to receive signals; airborne AIS, i.e., satellite AIS (S-AIS) employs satellites to collect signals (BigOceanData, 2016; Carson-Jackson, 2012; Holsten, Tobehn, & Borowy, 2009; Høye, Eriksen, Meland, & Narheim, 2008) thus is capable of tracking vessels in the open oceans. AIS data transmit interval depends on the vessel's navigational state, specifically, every 2–10 s for sailing vessels and around 3–6 min for vessels at anchoring vessels. From July 1, 2002, AIS is compulsory for all passenger vessels and vessels larger than 300 gross tonnage (GT) (International Maritime Organisation (IMO). As of now, most commercial vessels are equipped with an AIS transmitter, serving as an important technique as part of collision avoidance and maritime traffic safety enhancement.

It assists ships and maritime authorities to identify and monitor ships' movements. AIS data typically includes the transmit time and position, a unique Maritime Mobile Service Identity (MMSI) and IMO vessel number, length, draft, beam, type, cargo, navigational status, course, and speed. According to the International Telecommunication Union, each transmission can include over a dozen variables. (Meyers et al., 2021). Not all ships have the necessary technical equipment for k6 tracking.

However, in 2004 it was decided that all vessels over 300 gross tonnes (GT) on international voyages must have AIS equipment on board—part of requirements set out by the International Maritime Organisation Convention for the Safety Of Life At Sea (SOLAS) Regulation V/19.2.4.(Kraetzig, n.d.)

AIS data are mainly used to prevent ship collisions (Silveira et al., 2013) and monitor maritime navigation (Pelich et al., 2015; Zhang L. et al., 2019). Accumulated AIS data are also used to mine maritime traffic conflict trajectories (Lei, 2019), analysis ship behaviour (Zhen et al., 2017) and curb illegal, unreported and unregulated (IUU) fishing (Akinbulire et al., 2017; Park et al., 2020).

The coverage and validity of ship AIS data are important conditions for the analysis and mining of regional information and knowledge. Land-based AIS mainly receives ship information within 60 km offshore. Satellite-based AIS use satellite platforms to carry AIS receivers, allowing ship monitoring to occur anywhere in the world, particularly in areas devoid of land-based stations, such as open oceans and polar regions (Zhao et al., 2013b). To ensure the safety of fishing vessels at sea, China mandates that all fishing vessels be equipped with AIS equipment, thus ensuring the coverage of the data utilised herein. The AIS data used in this work were purchased from Bomao Xin (Beijing) Technology Co.

AIS data is accessible through several online portals such as MarineTraffic, FleetMon, AISlive or Vessel Finder, providing free-of-charge access to vessel identification and positioning in real-time the world over. These portals now also enable maritime traffic density maps to be generated (for a specific year and for either all types of vessel, or by type or size), or vessel trajectory history to be viewed, among other things. You can also submit a request for pre-processed data history for a specific zone or period. In some cases, it may be worthwhile to exploit non-anonymous raw AIS data (NMEA format) as this provides the following advantages: (1) terrestrial and satellite AIS data is acquired (optimum coverage) (2) data is received up to every two seconds (high temporal resolution) whereas the rate is lower with pre-processed data (minimum of every three minutes). However, this data then has to be extracted and pre-processed to obtain data that can be used in a GIS.

2.7.1 The Pros And Cons Of AIS

AIS, as any other tool used in fisheries enforcement has both benefits and shortcomings in its performance. These pros and cons of AIS use are summarised in the table below.

PROS	**CONS**
Cost – AIS is the least expensive vessel monitoring system capable of both near shore and high seas monitoring.	Analysis required – AIS data requires evaluation to be useful, which adds time and cost to the MCS system.

Transparency – Data is transmitted via unencrypted radio frequencies anyone with the appropriate equipment can receive.	Susceptible to tampering – Data transmitted, including vessel identification and location information, can be changed.
Prevalence – Hundreds of thousands of vessels already carry AIS transponders.	Prosecutorial limitations – Generally cannot be used as the sole piece of evidence to prosecute illegal fishing acts.
Complementary – Provides data that complements existing fisheries enforcement tools.	Industry resistance – 'Proprietary' and 'sensitive' vessel fishing information can be easily acquired
Existing legal mandates – Many flag and coastal States have mandated its use on fishing vessels.	
Quantity of data – Although transmissions from VMS are received in near real time, the frequency of reporting is in practice usually not more often than every 1-4 hours. AIS reporting from both Class A and B units is much more frequent, and provides better data for analysing vessel movements.	
Coverage – AIS provides the opportunity to identify vessels other than those that are already licensed and most likely transmitting VMS. This includes not only fishing vessels, but other vessels that are engaged in fisheries operations, such as reefers and tankers – which are also of relevance to fisheries authorities.	

Table 1. Pros and Cons of AIS

While AIS is by no means a single all-encompassing solution to illegal fishing, its cons should be analysed with some additional perspective. All vessel tracking systems require some degree of analysis for the data to be made useful for fisheries enforcement purposes. Vessel tracking systems provide the very important information of where a vessel is and when the vessel is in that location;

this information must be analysed against vessel licence databases and national and international regulations to turn this positional information into indicators of compliant or non-compliant activity.

AIS' susceptibility to tampering, also known as 'spoofing' is a real challenge. Manipulation of vessels' reported positions is becoming increasingly common and 1-2 % of all ships report fake vessel names and identification numbers on their AIS.29 30 Several cases investigated by FISH-i Africa, such as that of the CHI HSIANG NO. 7, show deliberate falsification of AIS and vessel identity. Vessels also attempt to hide their true position by either simply entering false positions into their AIS transponder, or by disconnecting their GPS; however, vessels can also accidentally report incorrect or no positions.Threats such as pirate attacks and other parties interfering with operations can legitimately cause the AIS to be deactivated (MIS Marine, 2020, p. 32). Fisheries authorities must be cognisant of the security measures put in place by the data provider that they might choose to use, as incidents have proven that free AIS web viewers are susceptible to hacking.

2.7.2 Identifying Vessel Behaviour Using AIS

The behaviour of vessels can reveal whether or not they follow the restrictions of the closed season. Vessel behaviour is not the specific behaviour of a ship but it refers to the mode and law of similar actions of ship groups, which not only depend on human consciousness,thinking, decision making and manipulation but are also affected by the characteristics of the ship and the surrounding environment.(Shi et al., 2022) The majority of methods for distinguishing between fishing and non-fishing activities rely on the examination of speed profiles, either through statistical and data mining approaches or through the use of expert knowledge-based thresholds. The assumption of a fishing behaviour of a fishing vessel is highly reliant and characterised by speed. The frequency distributions of speed profiles of fishing vessels with towing gear often have a bimodal form, with the first mode corresponding to fishing activity at lower speeds and the second mode corresponding to steaming at higher speeds (Natale et al., 2015). Different kinds of vessels are used in commercial, artisanal and recreational fishing. The type of a vessel determines the fishing gear it has available and the characteristics of the observable pattern it produces when fishing.

2.7.3 Improving Fishing Activities Using AIS Data

Management organisations are taking actions to instil long-term sustainable fisheries. Nations work collaboratively on placing restrictions on their territorial waters together with fishery management organisations which take a series of measures to better manage and conserve endangered international fish species. However, IUU fishing could be any size or type of fishery and could happen anywhere, which makes tracing it a challenge. Tracking and monitoring vessels aim to

obtain reliable information about activities of vessels from vessel movement data. Thus, in order to make fishing activities more transparent, better fishing activity detection is urgently needed.

2.7.4 AIS Combined with Operational Tools

To detect non-compliance with fisheries rules, operational tools such as surface patrol vessels and patrol aircraft, both manned and unmanned, are commonly utilised. Indeed, several rules that compel fishers to take positive action while fishing (such as the release or retention of bycatch or the use of specific types of fishing equipment) also necessitate an on-scene presence to detect infractions. Finding the 'right' fishing vessels to investigate is a common issue in successfully executing these types of patrols. This is when the information provided by AIS can be quite useful in detecting illicit conduct.

For intelligence to be useful for targeting patrol vessels and aircraft, it needs to be recent, reliable and substantive. AIS received by shore-based AIS stations is near-instantaneous, and by satellite is delayed by minutes or at most an hour. Assuming the information can be transmitted to the patrol assets in a timely manner, intelligence derived from AIS data can be easily provided to patrol assets quickly enough to be useful. AIS is, compared to most actionable intelligence, highly reliable. The previous section discussed the emerging problem of AIS tampering, which is a growing concern. However, AIS has proven that it provides substantive information in cases that FISH-i has successfully executed, such as for the F/V PREMIER. If patrol assets are equipped with AIS, this assists in identifying the ‘right’ fishing vessel as they often operate in close proximity to each other and they can move from their last reported position quite quickly. Shipboard AIS units have the capability of receiving AIS signals 20nm or more from the vessel, and aircraft can receive signals from even greater distances, greatly decreasing the time it takes to find the target fishing vessel

2.7.5 AIS Combined with Diplomatic and Multilateral Engagement

Diplomatic and multilateral engagement is an important tool in deterring and prosecuting illegal activity that includes diplomatic approaches to vessel flag States notifying them of illegal activity conducted by a vessel carrying their flag and requesting action, or requesting the listing of a vessel on an RFMO IUU fishing list. For both, having adequate proof of illegal activity is very important. Nearly all fisheries law is in some way location-based; even if a law applies throughout a country’s EEZ, it must be proven that a vessel was operating in the EEZ. In one recent example, AIS data proved the location of the transhipment vessel DAMANZAIHAO in the South Pacific RFMO area, which when combined with additional evidence of illegal operations in that area ultimately resulted in the vessel being listed on the IUU fishing vessel list.

2.7.6 AIS Combined with VMS

VMS are fisheries management and monitoring tools used in commercial fishing. They were designed specifically for allowing fisheries management organisations to monitor the position, course and speed of fishing vessels and, in some units, to receive frequent catch reporting data. VMS are satellite-based systems, for which transmission occurs either at predefined intervals, or at both pre-defined intervals and random times allowing fisheries monitoring centres to request information on-demand. 33 VMS are mandated at both the national and international level. At the national level, the United States and all European Union countries, amongst many others, require the use of VMS by vessels that fish in their coastal waters. To control their vessels, some major flag States, such as the Republic of Korea, also require use of VMS at all times by all fishing vessels that carry their flag. At the international level, nine RFMOs mandate the use of VMS by vessels authorised to fish the waters they manage. The Indian Ocean Tuna Commission (IOTC) is one such RFMO.

The inherent weaknesses and strengths of VMS and AIS for fisheries monitoring are generally complementary. For example, AIS signals are totally transparent and unencrypted, while VMS signals are only visible to a narrowly-defined group of members of a national or international organisation. Alternatively, AIS signals can be manipulated to transmit inaccurate information more easily than VMS, for which the most viable tampering approach is faking a unit malfunction by cutting its power supply or blocking its signal. This complementarity provides an opportunity if both AIS and VMS carriage by fishing vessels is mandatory as this increases the transparency of fishing vessel movements with the AIS transponders, and increases the reliability of the vessel position data with the VMS transponders. The chance of both a VMS and AIS unit malfunctioning at the same time are very small and manipulation of both systems to show an identical false vessel position would be extremely difficult.

2.7.7 Recommendations for the Application of AIS

The following are recommendations for the application of AIS going forward that will help to maximise its impact on illicit fishing activity.

Although many fishing vessels presently carry and broadcast AIS on a voluntary basis, there are valid worries and evidence that as awareness of its usage as a vessel monitoring tool grows, this number may drastically decline. Increasing the number of vessels mandated to carry AIS under coastal, flag, and port State legislation, as well as international conservation and management

measures, would assist to reverse this trend. The following are some of the options for mandating AIS:

- Flag States mandate that all fishing vessels carrying their flag over a reasonable size carry and operate AIS units. As an example, EU-flagged vessels over 15 metres are required to carry and operate AIS.39
- Coastal States mandate that all fishing vessels permitted to fish in their waters carry and operate AIS units. As an example, all FFA member nations have already taken this step effective January 2015.
- Port States mandate that all fishing vessels permitted to enter their ports carry and operate AIS units. As an example, the port of Phuket, Thailand has required that all foreign vessels, regardless of size or type, have an operational AIS onboard if they pull into port.
- Coastal States mandate that all vessels operating in their waters carry and operate AIS units. This has been executed in various ways by many countries; the United States requires all commercial vessels 20 metres and greater operating in their navigable waters to operate AIS.
- Coastal States act in regional cooperation and mandate AIS carriage requirements as a unified region. Again, there is precedence for this action in the FFA's recent resolution.
- Coastal States propose the adoption of AIS carriage requirements for RFMOs. Combining AIS and VMS into a single vessel tracking monitoring system greatly decreases the opportunity for tampering and increases fisheries authority awareness of on-the-water activity.

While there is currently no RFMO that mandates AIS carriage beyond existing IMO requirements, there is documentation of national authorities supporting RFMOs, including the North Pacific Anadromous Fish Commission (NPAFC), using AIS as an enforcement and surveillance tool.

AIS information can be accessed both by shore-based and satellite-based monitoring systems, and to be made useful it must be evaluated for indications of illicit or suspect activity. General recommendations include:

- Consider a system that combines both shore-based and satellite-based systems. To monitor vessels operating more than 40nm from shore S-AIS data is required. For closer proximities shorebased systems provide real-time information and do not suffer the same limitations in receiving Class B AIS signals or dropping vessel signals in high density areas.
- Analysis of AIS data is essential and should be included in cost considerations. In its rawest form, an AIS data feed will provide the user with hundreds of thousands of data points in a

single day. Without human expertise and software tools that can translate this data into usable intelligence, AIS will have minimal utility to MCS operations.

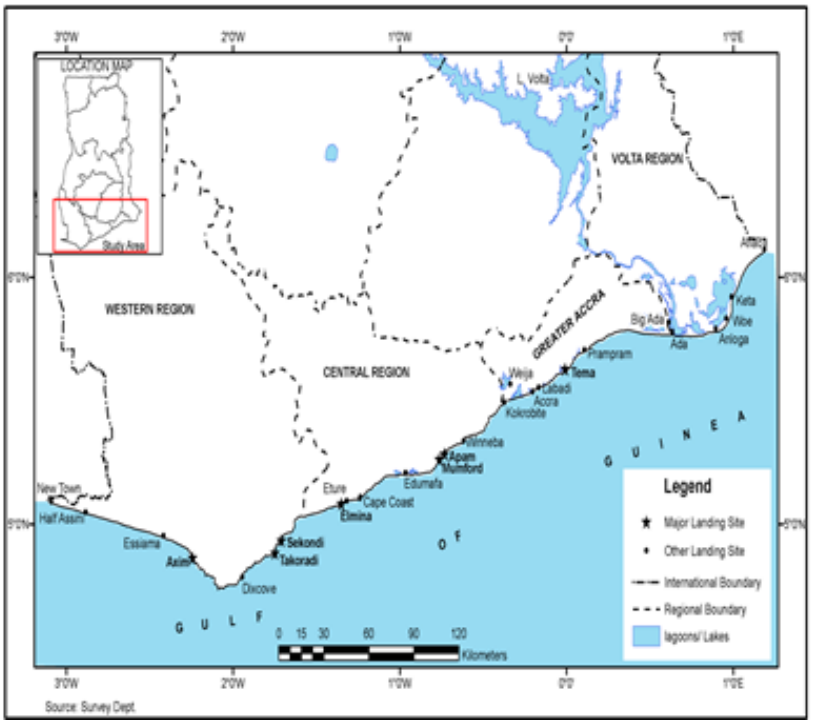
The use of AIS intelligence data increases the efficiency of operational assets and increases the likelihood that violations will be found by fisheries officers. It also can provide a key piece of evidence when engaging in bilateral or multilateral diplomatic correspondence. The use of AIS intelligence data in these contexts is strongly recommended.

CHAPTER THREE (3)

3.0 METHODOLOGY

3.1 Area of Study

Ghana has a coastline of about 550km and maritime domain, including the territorial sea and the Exclusive Economic Zone (EEZ) of 228,000km^2. A coastal upwelling system, which causes cold water rich in nutrients to be transported to the surface and stimulate the ecosystem that propels the productivity of Ghana's marine fisheries. Ghana experiences two distinct upwelling seasons: a large one from July through September and a lesser one from late December to early February. About fifty-eight thousand AIS records of one-hundred



and thirteen vessels were collected from June, 2021 to September, 2021.

Figure 4. A coastal map of Ghana, showing major and other landing sites.

3.2 Materials Used

Materials for the study included, AIS data in CSV format, Python, Jupyter Notebook software. Packages including Pandas, matplotlib, numpy and datetime were installed for the purpose of this project.

3.3 AIS Data Processing

Compressed AIS data from June 2021 to September 2021 were procured from Global Monitoring Environment Security and Africa (GMES and Africa) of Regional Marine Centre.
The AIS data contains information about the vessel's name, MMSI and IMO numbers, vessel type, vessel size, draught, flag, longitude and latitude in *WGS84* coordinates, position, speed, course, coordinated universal time, and other details.

Based on AIS data, by means of Geographic Information System (GIS) spatial analysis and coding learning methods, this report mapped the distribution of various vessels found on the oceans of Ghana and their supposed activities, and assessed the effectiveness of the closed season. The technical workflow is shown in Figure 5. It was mainly separated into five steps: data cleaning and sampling, fishing behaviour identification, optimization and comparison of mapping results (pair-trawling), and analysis of fishing grounds, and assessing the effectiveness of the closed season for 2021.

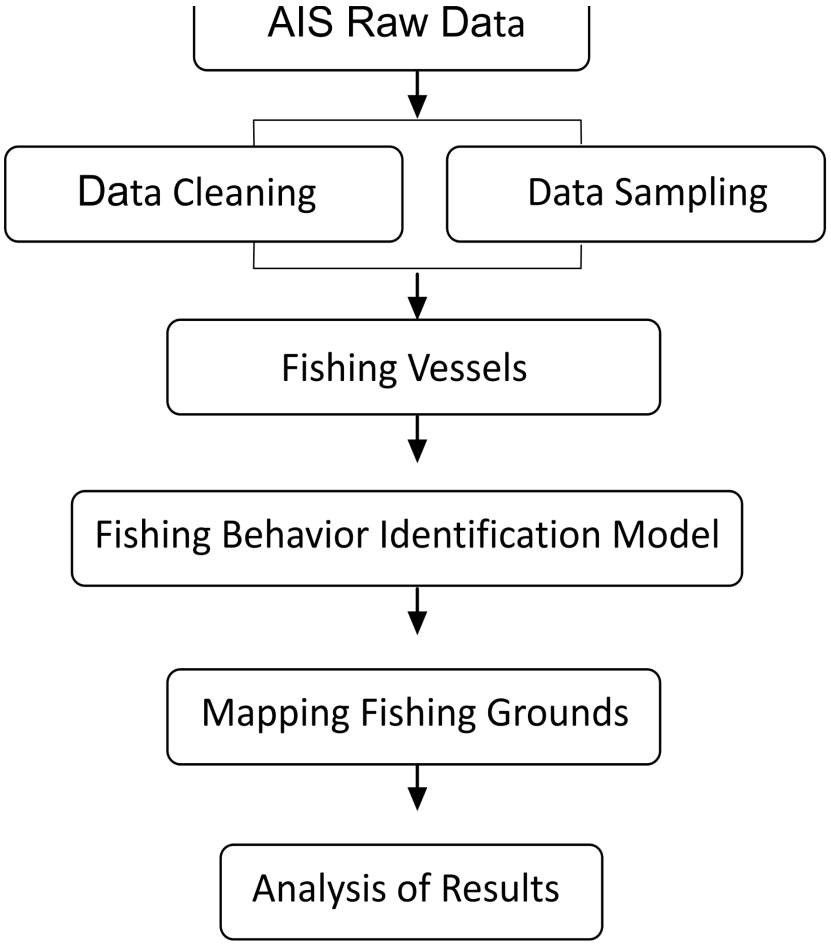


Figure 5. Flowchart of steps involved in the processing of data.

3.4 Data Cleaning and Sampling

Considering the hefty amount of AIS data, firstly, the AIS data was cleaned. Data with an abnormal, irregular format, and those who were close to the shoreline—specifically, those from 10 kilometres close to the shoreline—were eliminated. Secondly, AIS data of fishing vessels were extracted conferring to the "type of vessel" field, approximately *298* vessels were obtained, and then data recess sampling was performed. The vessel location messages were extracted every 60 seconds with the goal of guaranteeing the integrity of the vessel trajectory and minimum data samples. Additionally, vessels with "null" or no more than 300 received messages per month were deleted and vessel position data was removed to prevent meddling from unrepresentative data.

3.5 Fishing Behaviour Identification

It was feasible to describe fishing behaviour by tracking vessels during their voyage and dynamically splitting into homogeneous paths (depicting certain activities like cruising) and non-homogeneous ones. This was made possible by the high temporal precision of AIS data.

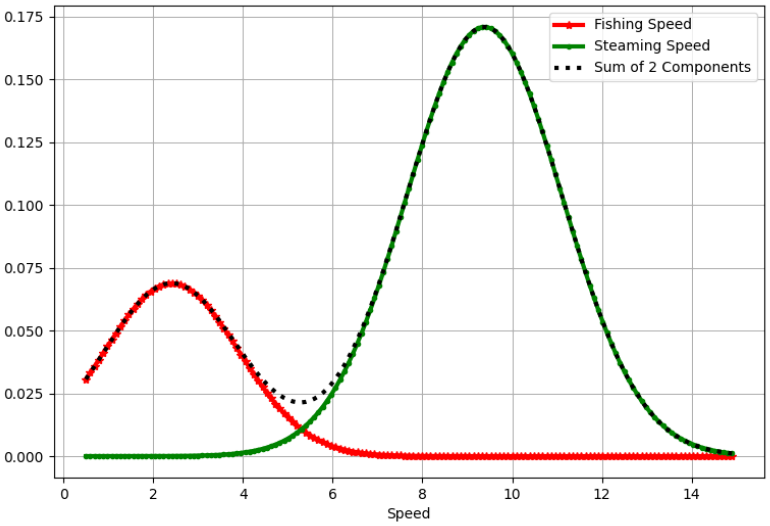


Figure 6. Distribution of fishing vessel speeds of industrial fishing fleets operating within the EEZ of Ghana from June-2021 to September 2021. Red lines are speeds associated with fishing periods and green lines represent steaming speeds to fishing grounds.

Figure 6 shows the range of speeds for a vessel that is steaming and one that is fishing. The average speed of a moving vessel may be determined by where the two cross. It is safe to presume that any vessel moving at a speed less than 0.5 is engaged in fishing.

3.6 Mapping Fishing Grounds

While fishing activities can occur anywhere in the ocean, previous studies have shown that fishers

tend to cluster at specific locations. We defined these areas as core fishing areas (CFAs) or locations which are repeatedly visited and where there is dense fishing activity. The spatiotemporal distribution patterns of fishing grounds around the area under study were significantly different for the months June, July, August and September.

CHAPTER FOUR (4)

4.0 RESULTS

As a data basis for the entire paper, records from a large region, particularly the Exclusive Economic Zones of Ghana were used in order to obtain a dataset that is as representative as possible.

Over 10,000 points of AIS data collected from satellites were collected within the EEZ of Ghana. The data analysed included positional information of various vessels, their models, IMEU's, flag states. At least a minimum travelled distance of 1km, and a maximal temporary gap of less than two minutes anchoring AIS records from each vessel, reporting by satellite transmissions was considered.

4.1 Fishing Vessel Activity in a Non-Closed Season Month.

In this study, data for the open season was June 2021. The distribution of fishing vessels during the period is shown in Figure 7 below. Fishing vessels activities were observed mainly on the continental shelf and some deep water regions within EEZ. There were numerous fishing areas identified during this period. There was almost no fishing observed off the Volta estuary and the

areas where the FPSOs were operating. There were a few fishing spots identified in the deeper waters especially between longitude 1^{0}W to 1^{0}E. Figure 7 suggests there was intense fishing activity during the month June.

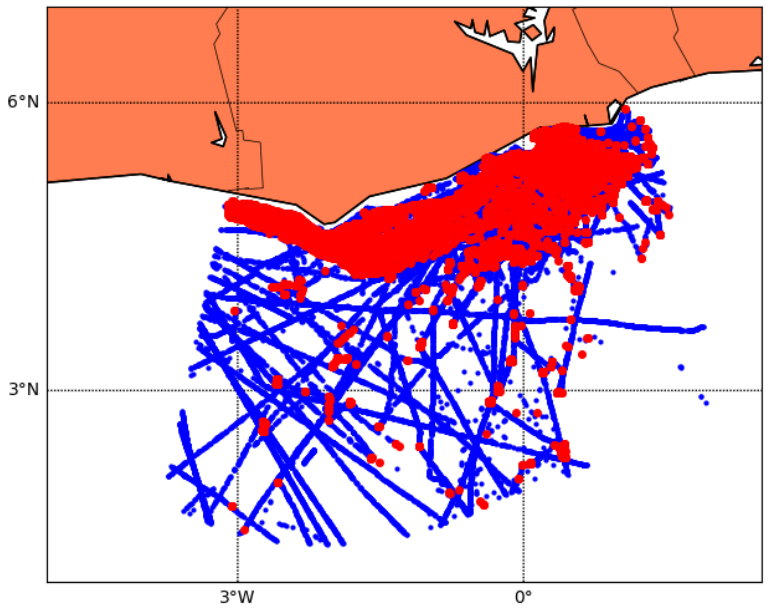


Figure. 7. Map illustrating the spatial distribution of industrial fishing vessels' activities in the EEZ of Ghana before the closed season, June-2021. Blue streaks indicate steaming speeds and red streaks indicate fishing periods.

4.2 Fishing Vessel Activity of Closed Season Months

Data for the closed season were obtained in this study during the months of July, August, and September 2021. Figure 8 depicts the dispersion of fishing vessels throughout the month of July. Fishing vessel activity was mostly seen on the continental shelf between 0^{0} and 3^{0}E, as well as in some deep ocean zones within the EEZ. Between 3^{0}W and 2^{0}W, very little fishing was observed close to the continental shelf. There was a slight rise in the number of fishing locations discovered in deeper seas, particularly between longitudes 1^{0}W and 1^{0}E. The result indicates that there was less fishing activity in July than in June.

The activity of the fishing vessels that was seen throughout the month of August can be observed in figure 8. Mainly on the continental shelf and in a few deep ocean areas inside the EEZ, fishing vessel activity was seen to be distributed. The identification of several fishing spots during this time was noted. Off the Volta estuary and the locations where the FPSOs were operational, hardly any fishing activity was shown. Effective fishing spots have been found, particularly between longitudes 2^0 W and 2^0 E, in the deep oceans. The data indicates that fishing activity was relatively less in August as compared to June.

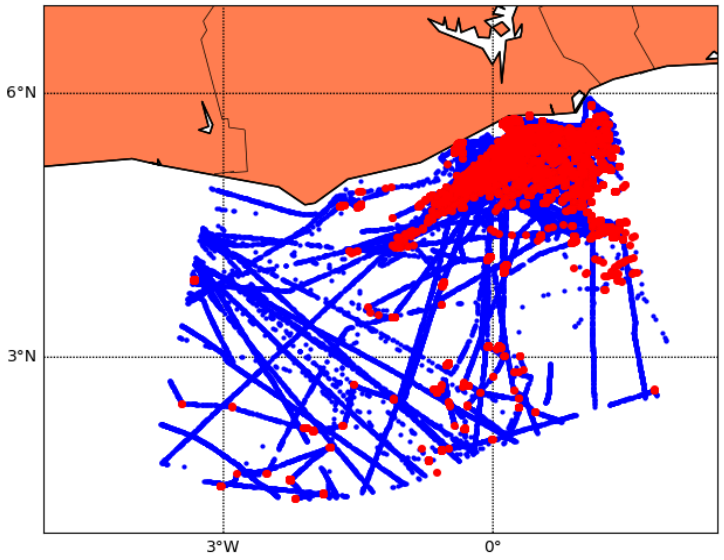


Figure 8. Map illustrating the spatial distribution of industrial fishing vessels' activities in the EEZ of Ghana during the closed season, July-2021. Blue streaks indicate steaming speeds and red streaks indicate fishing periods.

Fig. 9 indicates the activity of the fishing vessels that was seen throughout the month of September. Mainly on the continental shelf and in a few deep ocean areas inside the EEZ, fishing vessel activity was seen to be distributed. The identification of several fishing locations during this time was noted. Off the Volta estuary and the locations where the FPSOs were working, hardly any fishing activity was seen. Effective fishing locations have been found in the deeper water between 3^0W and 2^0E. On the deep water between longitudes 3^0W and 3^0E, there was some fishing activity seen. According to the data statistics, fishing was practised in September.

Figure 9. Map illustrating the spatial distribution of industrial fishing vessels' activities in the EEZ of Ghana during the closed season, August-2021. Blue streaks indicate steaming speeds and red streaks indicate fishing speeds.

4.3 Fishing Activities of Selected Countries During The Closed Season.

Data was collected from June to September for vessels that showed fishing activities during the closed season. The data showed activities of vessels for various countries including Ghana, Belize, France, China, Netherlands Antilles, Liberia, Panama, Mauritania, El Savaldor, Guatemala, Senegal, Eritrea and Spain, cumulatively, vessels registered to 14 different countries. Some vessels did not show their flag states so in this study they were eliminated.

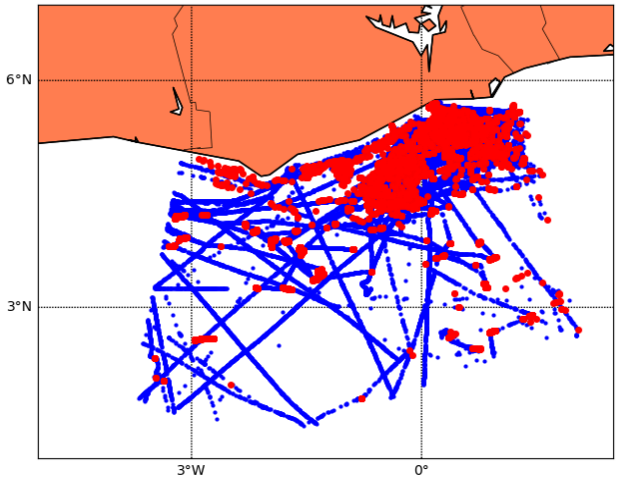


Figure 10. Map illustrating the spatial distribution of industrial fishing vessels' activities in the EEZ of Ghana during the closed season, September-2021. Blue streaks indicate steaming speeds and red streaks indicate fishing speeds.

From the distribution as seen in Figure 11, it shows clearly that about 58 vessels registered to Ghana were assumed to have engaged in fishing activities during the closed season. Followed by Ghana, it was observed that France, Belize and China had high records of vessels registered to them from the data collected. About 58 vessels were registered to Ghana, 10, 9 and 8 vessels were registered to France, Belize and China respectively. Although the highest recorded Flag vessels were ascribed to Ghana, about 70-90% of fishing vessels operating on Ghana waters are owned by Chinese (The Environmental Justice Foundation).

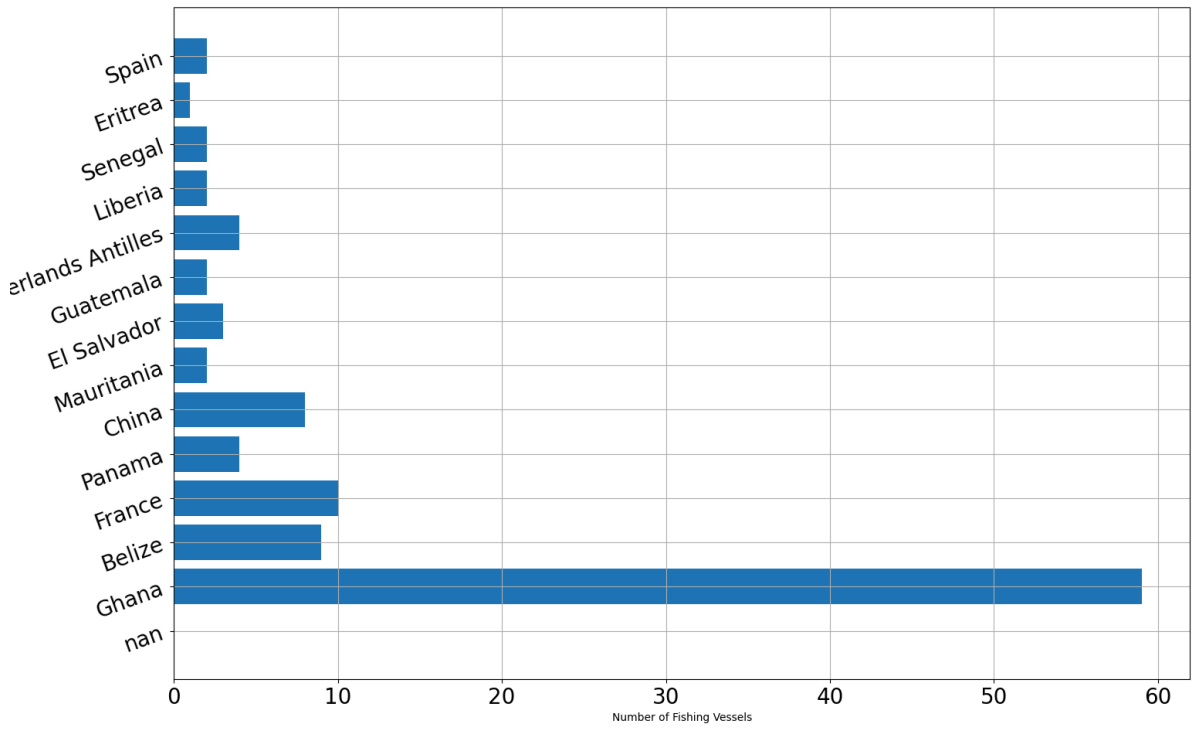


Figure 11. Bar chart of flag registration of fishing vessels identified in the coastal region of Ghana from June 2021 to September 2021.

We focused on four vessels from countries with the highest number of vessels which include Ghana, France, Belize and China.

4.3.1 Ghana

Figures 12 and 13 show the fishing activities and days of fishing of Ghanaian vessels throughout the closed season that is from July 2021 to September 2021. According to fig. 13, Ghanaian fishing vessels engaged in fishing operations both during the non-closed season and during the closed season with no days off. Figure 12 shows a multitude of fishing spots, especially along the continental shelf. Some fishing spots can also be identified in the deeper waters.

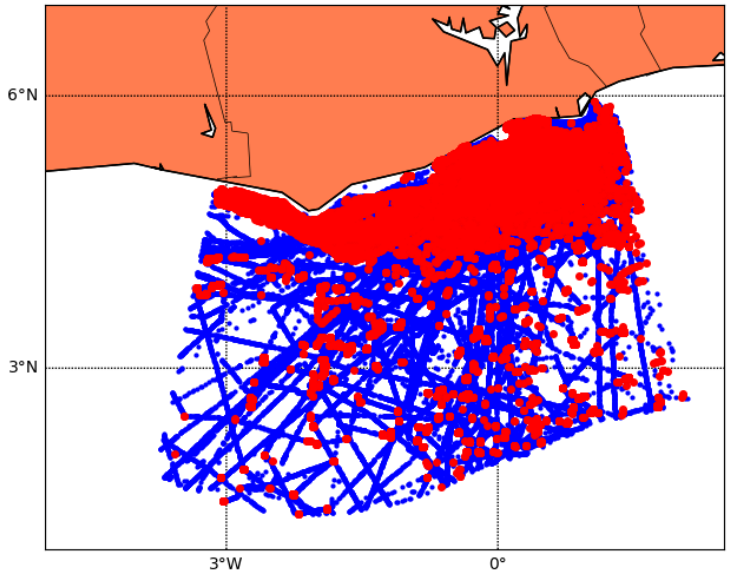


Figure 12. Map illustrating the spatial distribution of the activities of industrial fishing vessels registered in Ghana in the EEZ of Ghana from July-2021 to September-2021. Blue streaks indicate steaming speeds and red streaks indicate fishing periods.

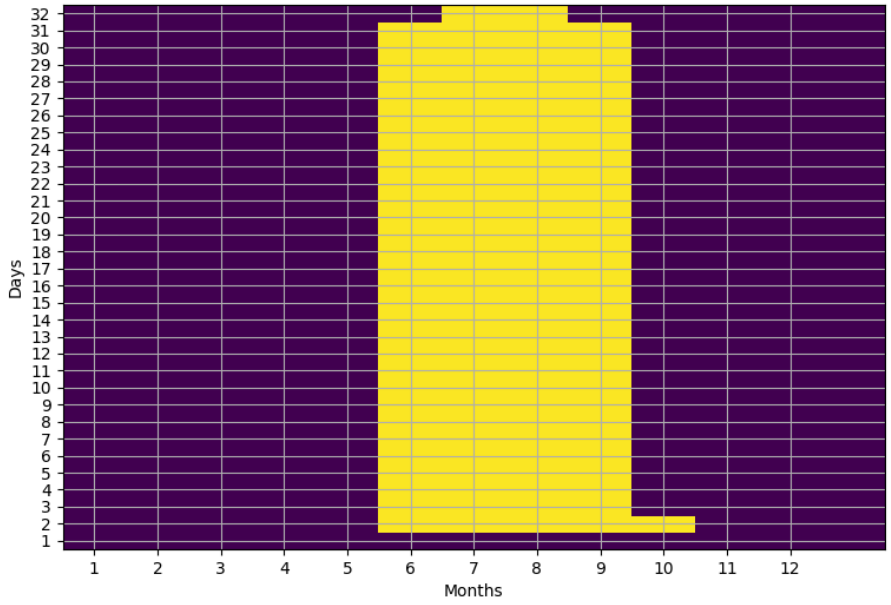
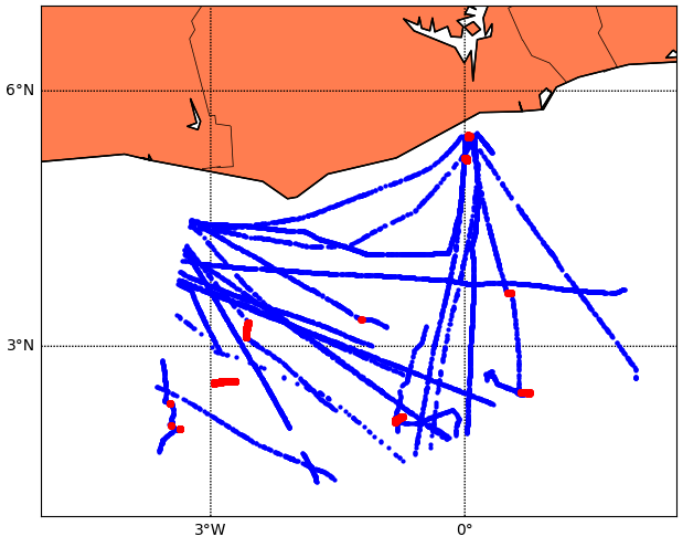


Figure 13. Graph demonstrating days on which industrial fishing vessels registered in Ghana engaged in fishing activities in the EEZ of Ghana from June-2021 to October-2021.

4.3.2 France

Figures 14 and 15 show the fishing activities of vessels from France. Less than 20 fishing spots can be identified throughout the EEZ. Majority of the fishing spots can be found after the continental shelf, closer to the deeper waters.Fishing was done for about 4 weeks total, from July to September.

Figure 14. Map illustrating the spatial distribution of the activities of industrial fishing



vessels registered in France in the EEZ of Ghana from July-2021 to September-2021. Blue streaks indicate steaming speeds and red streaks indicate fishing periods.

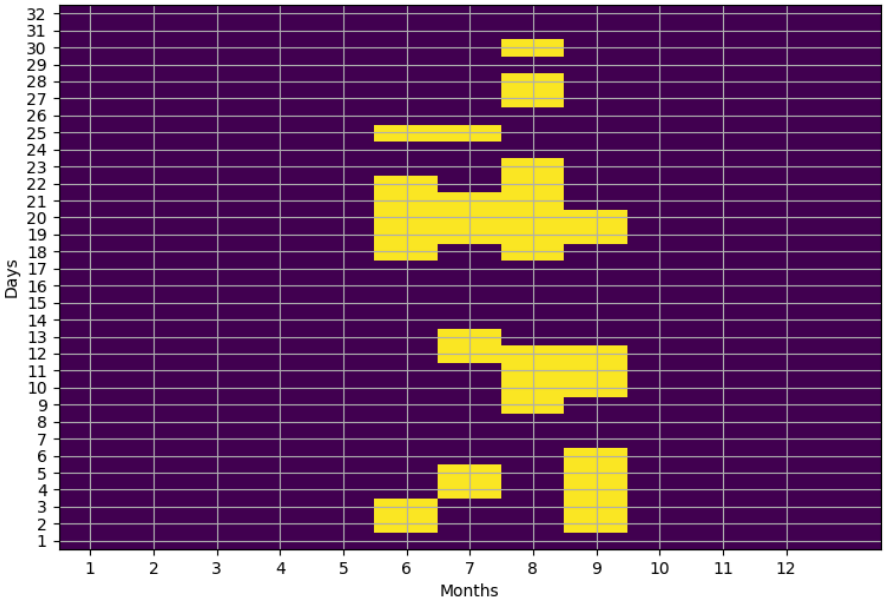


Figure 15. Graph demonstrating days on which industrial fishing vessels registered in France engaged in fishing activities in the EEZ of Ghana from June-2021 to September-2021.

4.3.3 Belize

Figure 9 shows the activity of fishing boats registered in Belize's name. There are only a few fishing spots that can be identified. The majority of the fishing spots are located between 2^0W and 1^0E on the continental shelf. Figure 10 also shows the dates on which these vessels were fishing. From July to September, there were fishing activities for about 5 weeks.

Figure 16. Map illustrating the spatial distribution of the activities of industrial fishing vessels registered in Ghana in the EEZ of Ghana from July-2021 to September-2021. Blue streaks indicate steaming speeds and red streaks indicate fishing periods.

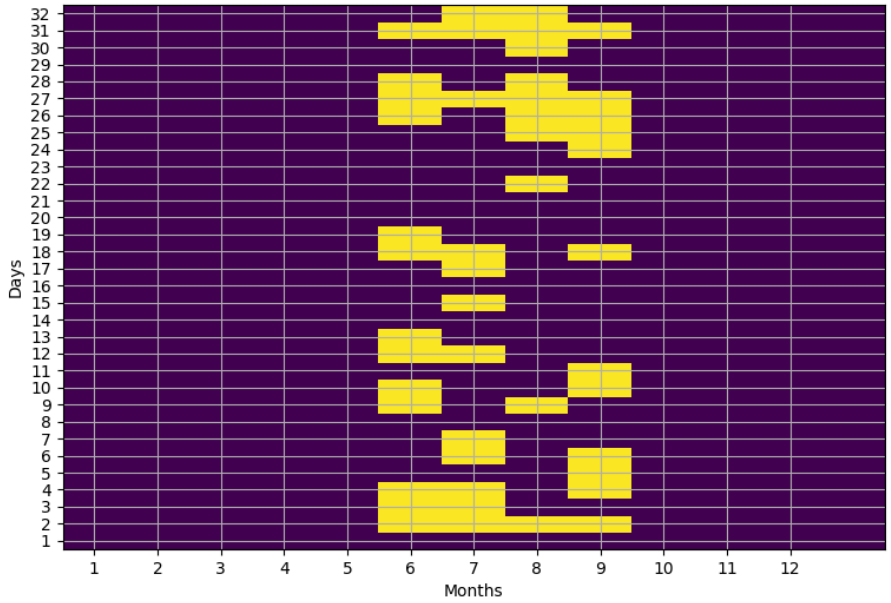


Figure 17. Graph demonstrating days on which industrial fishing vessels registered in Belize engaged in fishing activities in the EEZ of Ghana from June-2021 to September-2021.

4.3.4 China

Figure 11 displays the activities of fishing vessels registered under China's name. There are just two fishing sites visible. The fishing sites are located between 2^0W and 0^0 on the continental shelf. Figure 12 also illustrates the dates on which these vessels were fishing. From July through September, the fishing vessels fished for around three weeks.

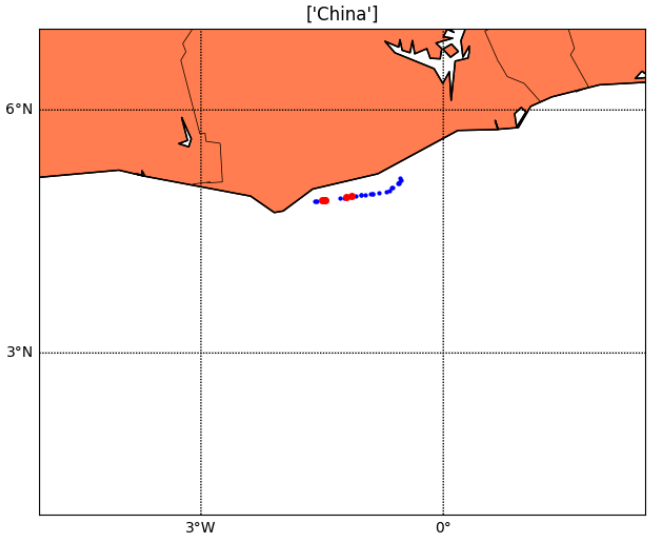


Figure 18. Map illustrating the spatial distribution of the activities of industrial fishing vessels registered in China in the EEZ of Ghana from July-2021 to September-2021. Blue streaks indicate steaming speeds and red streaks indicate fishing periods.

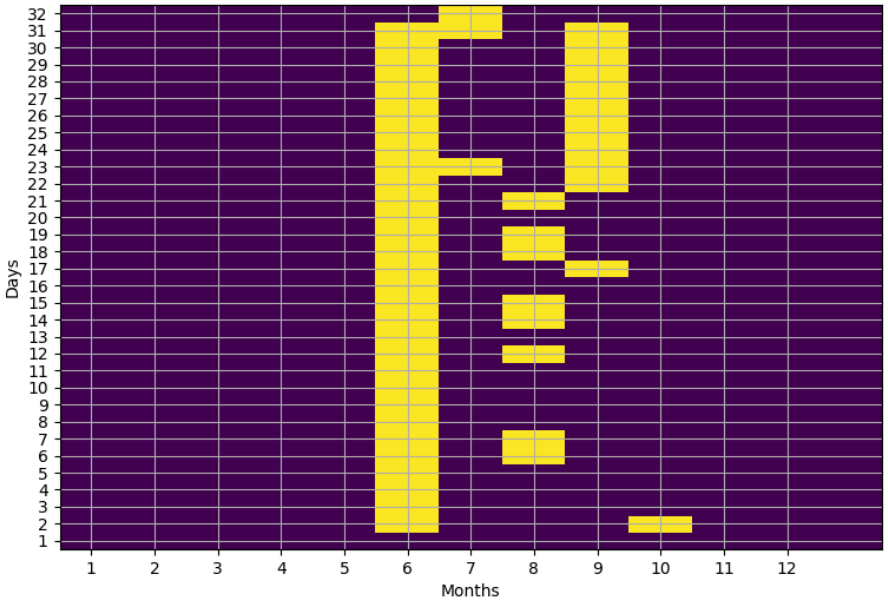


Figure 19. Graph demonstrating days on which industrial fishing vessels registered in China engaged in fishing activities in the EEZ of Ghana from June-2021 to October-2021.

CHAPTER FIVE (5)

5.0 DISCUSSION

The limitations of AIS data and the way they were processed may have caused mild variation in the study's findings. Signal coverage and data volume may have varied between periods due to the advancement of AIS technology and its installation rates. AIS transmitter installation is now only necessary for ships of a certain size. The technical regulations for the statutory inspection of domestic marine fishing vessels in China for example, mandate that fishing vessels with a length of 12 m or greater be equipped with AIS transmitters. Given that the number of fishing vessels may be undercounted because some small-scale fishing vessels may not have AIS transmitters. However, it is of no doubt that the introduction and use of advanced technological devices and equipment such as AIS and VMS tools has impacted our maritime significantly.

Fisheries are essential for the social systems of coastal communities, global economy, and food security. More and more individuals involved in the fishing industry are strengthening their commitments to sustainable fisheries management as they become more aware of how heavily dependent individual livelihoods are on the health of fisheries resources.

Large fishing fleets or vessels contribute a higher rate of overfishing and exerts pressure on the fishery resource. Large-scale commercial fishing often involves the use of large high-capacity boats, equipped with on-board facilities for freezing and processing seafood at sea. These boats can reach over 130m long with a hold capacity of more than 2,000 tonnes. They remain at sea for long periods of time and carry large crews for catching and processing fish on board. Large fishing boats can fish more oceanic areas since they can stay at sea for longer. A vast freezer-trawler ship could operate in a region that was thousands of miles wide for extended periods of time at sea. This may make it more difficult for management authorities to keep a close watch on their fishing operations, but it may also result in a decrease in total fishing intensity and the ability to fish far from continental shelves and delicate marine environments. Making the most of the benefits requires that these boats operate properly, which may be ensured by onboard observers and satellite tracking.

The world's marine fisheries play a significant role in the global food chain, and many around the globe depend heavily on them. There is widespread worry that fish stocks are declining throughout the majority of the world, and the majority of the available analyses indicate that overfishing is on

the rise. Regional and sub-regional bodies play a critical part in ensuring food and economic security around the world. In order to achieve the goal of sustainably utilising and managing the fish stock, they have carried out some strategies to help them reach this goal. Such strategies include implementation of

5.1.1 Quota Management System

The Quota Management System is mostly employed in New Zealand, where several governments manage fishing using individual fishing quotas (IFQs), often known as "individual transferable quotas" (ITQs). A species-specific total allowable capture (TAC) is established by the regulator, usually by weight and for a certain time frame. The TAC is then divided into quota shares, which are distributed to specific people. Transferability is the ability to purchase, sell, and lease quotas.

5.1.2 The Closed Season

As elaborated in the first chapter of this study, the implementation of the Closed Season period is to avoid and or minimize the activities of fishing during the months of June to September, to help the fish stock replenish.

5.1.3 Protected Areas

Some areas or regions are identified as closed or protected areas as there may be identified species within the zones which are endangered and therefore need to be protected.

5.1.4 The Introduction of CITES.

CITES is a multilateral treaty to protect endangered plants and animals from the threats of international trade. It was drafted as a result of a resolution adopted in 1963 at a meeting of members of the International Union for Conservation of Nature.

Per the 2021 Status of Stock report by NOAA, U.S. fisheries held steady with more than 90% of stocks not subject to overfishing, and 80% with population sizes sufficient to be considered not overfished. The number of stocks on the overfishing list held steady at 26, and the number of overfished stocks slightly increased to 51, up from 49.

CONCLUSION

A distinct way to describe marine human activities is made possible by AIS. The spatiotemporal distribution characteristics of fishing operations can be revealed through analysis based on AIS data, and the efficiency of fisheries regulatory measures like the closed season and marine protected areas can be evaluated. The location of the primary fishing site and shifts in fisheries resources can be indirectly predicted and studied by mapping the variety of fishing vessels operations. Understanding the features of how fishing activity is distributed is crucial for promoting the sustainable growth of fisheries.

The study explored the methods of mapping fishing grounds, revealed the spatiotemporal distribution characteristics of fishing vessel activities around the EEZ of Ghana, and evaluated the effectiveness of the Closed Season directive for 2021.

ACRONYMS AND ABBREVIATIONS

AIS Automatic identification system

CEMLAWS Centre for Maritime Law and Security

CITES Convention on International Trade in Endangered Species of Wild Fauna

ECDIS Electronic Chart Display and Information System

EEZ Exclusive economic zone

EU European Union

FFA Forum Fisheries Agency

IMO International Maritime Organisation

IOTC Indian Ocean Tuna Commission

IUU Illegal, unreported and unregulated (fishing)

MoFAD Ministry of Fisheries and Aquaculture Development

NPAFC North Pacific Anadromous Fish Commission

RFMO Regional fisheries management organisation

S-AIS Satellite Automatic Identification System

SOLAS Safety Of Life At Sea

VMS Vessel monitoring system

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