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Governance of illegal, unreported, and unregulated (IUU) fishing in Bangladesh: status, challenges, and potentials

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Illegal, unreported, and unregulated (IUU) fishing can result in loss of revenue, environmental damage, and economic loss for coastal communities, as well as a reduction in fish stocks. This study aims to generate comprehensive knowledge of the historical patterns and current status of IUU fishing in the coastal and marine waters of Bangladesh (BD). Secondary, qualitative, and quantitative data were gathered using SWOT as the conceptual framework. Cluster analysis was performed using NVivo for quantitative and qualitative data analysis. This study found that, because of the lack of appropriate and robust governmental laws, regulations, and manpower, IUU fishing in BD has led to the extinction of important fish species, biodiversity loss, and increased poverty among fishers. Potential solutions include raising the standard of living for underprivileged fishermen, improving the management and oversight of artisanal and industrial fishing, motivating and training stakeholders, and coordinating across all stakeholder levels. This study serves as a crucial guideline for sustainably managing fisheries and developing legislation, rules, and regulations to prevent IUU fishing in BD.

KEYWORDS

IUU fishing, economic loss, management, monitoring, SWOT, NVivo, coastal and marine waters, Bangladesh

Introduction

Humans depend extensively on fish as a significant source of animal protein in their daily lives, even though future global food security is a major issue. The demand for fish protein is still increasing owing to the massive expansion of the global population; however, many of the world's fish populations are already degraded and unable to provide maximum

sustainable production (FAO, 2007; Agnew et al., 2009). In contrast to the rate of population growth, the consumption of fish as a food source has increased worldwide in the last six decades. The average annual increase in total fish consumption from 1961 to 2017 was 3.1%, exceeding the annual growth rate of the population, which was approximately 1.6% (FAO, 2020). According to estimates, 179 million tons of fish were produced globally in 2018, of which 156 million tons were used for human consumption (approximately 20.5 kg per person annually). In 2017, globally, fish accounted for 20% of the average per capita intake of animal proteins consumed by more than 3.3 billion people, reaching 50% or more in nations like Bangladesh (BD), Cambodia, the Gambia, Ghana, Indonesia, Sierra Leone, Sri Lanka, and several small island developing States (FAO, 2020). However, it is a matter of great concern that global fishery sectors are facing a potential threat due to such surging demand and continued illegal, unreported, and unregulated (IUU) fishing during the last few decades.

Fishing activities that contravene or disregard national, regional, or international fisheries' legal frameworks are referred to as IUU fishing. This can also refer to a lack of regulation or control in fisheries (DoF, 2019). According to the US National Intelligence Council (NIC, 2016: p5), illegal fishing refers to "*fishing activities by vessels from one country in the jurisdiction of another country without permission or other activities of fishing vessels that contravene fisheries laws*." Unreported fishing refers to "*activities that are unreported or deliberately misreported to proper authorities*." In addition, unregulated fishing refers to "*fishing activities in areas with no practical conservation or management measures, such as outside any country's Exclusive Economic Zone (EEZ) and not under the jurisdiction of Regional Fisheries Management Organizations (RFMOs)*".

Many studies have highlighted IUU fishing as a significant threat to global fishing (Le Gallic and Cox, 2006; Agnew et al., 2009; Polacheck, 2012; Helyar et al., 2014; Liddick, 2014; Petrossian et al., 2015; Leroy et al., 2016; Miller et al., 2016; Petrossian, 2018; Soyer et al., 2018; Sumaila, 2019; Fujii et al., 2021; Kadfak and Linke, 2021). It has become one of the most prominent issues worldwide because it threatens legitimate fishing livelihoods and operations, jeopardizes food and financial prosperity, aids international crime, skews markets, encourages human trafficking, and prevents efforts to implement sustainable fishery management practices (NIC, 2016). It also hampers marine biodiversity, natural fish stocks, and sustainable fishery management (Donlan et al., 2020). It is difficult to quantify the actual extent of IUU fishing. However, according to the most recent estimates, between 11 and 26 million tons of fish are harvested annually illegally and unreported worldwide, with a market worth $10–$23 billion (Widjaja et al., 2020). Moreover, owing to the increasing number of fleets, fish stocks are facing a record level of overfishing (Watson et al., 2013). Nevertheless, these fleets are up to 2–3 times larger than those generally needed to harvest fish, which the ocean can supply substantially (Joseph et al., 2010). Most importantly, modern fish detection systems and fishing equipment have made fishing boats more efficient, allowing them to accelerate the overexploitation of global fishery resources (Knauss, 2005).

Concerns have been raised in the international community since the 1950s. Any action that jeopardizes efforts to manage and rebuild fish stocks, such as IUU fishing, is no longer regarded as politically or economically acceptable from this perspective (Le Gallic and Cox, 2006). The Convention on the Conservation of Antarctic Marine Living Resources first formally used this term in a report published in 1997, highlighting the rising risk of fish overexploitation in the Southern Ocean. Since then, efforts to combat IUU fishing have gained international momentum (NIC, 2016). Many RFMOs, such as the North East Atlantic Fisheries Commission, Northwest Atlantic Fisheries Organization, South East Atlantic Fisheries Organization, South Indian Ocean Fisheries Agreement, South Pacific Regional Fisheries Management Organization, and General Fisheries Commission for the Mediterranean have been established over time by various groups to manage fishery resources (NIC, 2016) collectively. Nevertheless, at the global level, the first major international initiative to deter and eliminate IUU fishing, the Food and Agriculture Organization of the United Nations (FAO), developed the first International Plan of Action (IPOA) in 2001 to prevent and counter IUU fishing (FAO, 2001; Le Gallic and Cox, 2006). Moreover, the IPOA-IUU has supported many countries worldwide in adopting this plan at the national level, known as the National Plan of Action to Prevent, Deter, and Eliminate IUU Fishing, or, in short, the NPOA-IUU (Widjaja et al., 2020). Similarly, many regions have developed a Regional Plan of Action (RPOA), such as the RPOA-IUU of South Asia, under the IPOA-IUU, to control and properly manage fish stock (Fujii et al., 2021).

Concerns regarding IUU fishing are not new to the waters of the Indian Ocean, especially in the Bay of Bengal (BoB). Similar to many other developing countries in Southeast Asia, BD has been experiencing this issue to a greater extent for years. Despite having a large number of marine fish species (511, including shrimp) and a maritime zone in the BoB covering an area of approximately 118,813 square kilometers, including the 200 nautical miles-long EEZ and 354 nautical miles of the continental shelf, BD's marine fisheries account for a small portion of the country's overall catch (Shamsuzzaman and Islam, 2018). The fishery industry provides 2.06% of the total export revenue, 3.69% of the GDP, approximately 23% of the overall agricultural production, and 60% of the nation's total consumption of animal protein (Islam et al., 2017). Nevertheless, this sector is crucial because it supports the livelihoods of millions of people and ensures national nutrition and food security. However, the fishing sectors in BD experience many challenges because the stocks of several fish species, including shrimp, are decreasing. Consequently, the catch per unit effort is declining in coastal fisheries due to inadequate fish protection regulations, lack of knowledge, indiscriminate killing of juveniles, pollution, disease issues, and other factors (Kuperan and Jahan, 2010; Murshed-e-Jahan et al., 2014; Islam et al., 2017; Shamsuzzaman and Islam, 2018). A government-commissioned report revealed that the most important and valuable species, such as tiger prawns and Indian salmon, are nearly extinct because hundreds of vessels are overfishing at an unsustainable rate in the waters of BD (Azad and Pamment, 2020).

BD is ranked 85th among 152 countries worldwide based on the IUU fishing index (2021), which ranks nations based on their vulnerability, prevalence, and response to IUU fishing (Macfadyen and Hosch, 2022). The fishery sector of BD is adversely impacted by IUU fishing, which threatens the socioeconomic well-being of fishers. Foreign fishing vessels engaged in illegal fishing in BD waters endanger

the nation's security and engage in unhealthy competition with local fishermen. Likewise, illegal fishing by locals exacerbates social tensions between licensed and unlicensed fishermen, and between artisanal fishers and commercial fishing vessels encroaching on their territories (DoF, 2019).

BD has already developed several laws and regulations for fishery resource management (Supplementary File-Section 1), such as the Marine Fisheries Ordinance 1983, Marine Fisheries Rules 1983, and Protection and Conservation of Fish Rules 1985, but the application of these laws and regulations frequently results in disputes and stakeholder disobedience (Islam et al., 2017). Very recently (November 2019), BD ratified the 2009 FAO Port State Measures Agreement, and the Department of Fisheries (DOF) developed NPOA under the IPOA-IUU to control and manage IUU fishing to ensure the development of the Blue Economy, which is a crucial step towards the Sustainable Development Goal (SDG) 14: Life Below Water (DoF, 2019).

BD has diverse fisheries and fishing gear used in its waters (Table 1). The fisheries industry is essential to BD's economy and provides livelihoods for millions of people. However, some of these fisheries have been associated with overfishing, habitat destruction, and bycatch issues, including IUU fishing (Ghose, 2014; Shamsuzzaman and Islam, 2018).

The main objective of this study is to assess the status of IUU fishing in the BoB, focusing on BD's waters, and to generate a comprehensive report on the historical patterns and current status of IUU fishing in the coastal and marine waters of BD. This study also attempted to develop a comprehensive methodology to assess and quantify IUU fishing. Finally, this study provides a detailed proposal with specific guidelines to improve the current management practices, legislation, and compliance issues in response to IUU fishing, which will aid in combating IUU fishing and promoting sustainable fishery governance. Previously, many regional-level works by numerous researchers around the globe have focused on IUU fishing. Unfortunately, no noticeable scientific literature is available on BD, except for some newspaper articles. To the best of our knowledge, this is the first study of this kind.

Conceptual framework

SWOT analysis

In the study context, the Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis can be formulated to explore a change strategy by systematically identifying various factors. This analysis is based on logic that maximizes strengths and opportunities and minimizes weaknesses and threats (Rangkuti, 2015). The SWOT matrix illustrates how a company's external opportunities and threats can be matched with its internal weaknesses and strengths to produce four possible alternative strategies (Chaliluddin et al., 2021). This analysis method is used to evaluate the 'strengths, weaknesses, opportunities, and threats' involved in an organization, plan, project, person, or business activity (Gürel, 2017). SWOTs are frequently laid out in a 2-by-2 table or matrix (Figure 1), with internal performance enhancers labeled as strengths and internal performance inhibitors labelled as weaknesses. Likewise, external enhancing factors are categorized as opportunities, whereas external inhibiting factors are threats. Although each category may be broken out independently for practical purposes, this representation of SWOT considerations emphasizes a holistic view of the four categories. This is partly true because, at least in a traditional SWOT analysis, making comparisons between categories is not an express intent (Doug, 2009).

It is considered a crucial tool for structuring and outlining decision-making strategies. Such privileged and classified information is crucial for integrated and sustainable coastal management practices (Viegas et al., 2014). Rangsipaht and Thaipakdee (2012) used a SWOT analysis to identify co-management plans that improve the livelihoods of small-scale fishermen. This was accomplished using focus group discussions (FGD, as tools to assist participants in capturing the vital elements of co-management and obtaining a comprehensive understanding of communities during the analysis. Furthermore, using strategic SWOT analysis, Viegas et al. (2014) assessed the contribution of artisanal fishermen in small-scale fishing communities to the integration of sustainable coastal management. They believe that the fisheries administration can successfully employ strategic and prospective SWOT analyses in coastal management plans. To complete the matrix, data must be collected from a trustworthy source, along with a sampling plan that includes all actors in the territory. In addition, the fishery development strategies of the Biak Number for Regency were investigated by Wijayanto in Indonesia in 2016. A SWOT analysis was used to assess the strengths, weaknesses, opportunities, and threats of developing a fisheries development strategy for the Biak Number Regency (Wijayanto, 2016). In addition, a case study of the fishing communities of Cote d'Ivoire's Aby Lagoon demonstrates the relationship between

TABLE 1 Different fisheries, water bodies, and fishing gear used in Bangladesh.

Types of Fisheries	Water bodies	Gear types
Marine fisheries	Bay of Bengal	Trawling, purse seining, gill netting, long-lining, and trolling
Inland capture fisheries	Rivers, canals, beels (floodplain depressions), haors (large seasonal wetlands), and other water bodies	Gill nets, cast nets, seine nets, traps, and hook and line.
Aquaculture/Shrimp farming	Freshwater/Marine water	Pond culture, cage culture, and pen culture
Small-scale fisheries	Coastal water/Marine water/Freshwater (Inland water)	Hand lines, traps, and cast nets

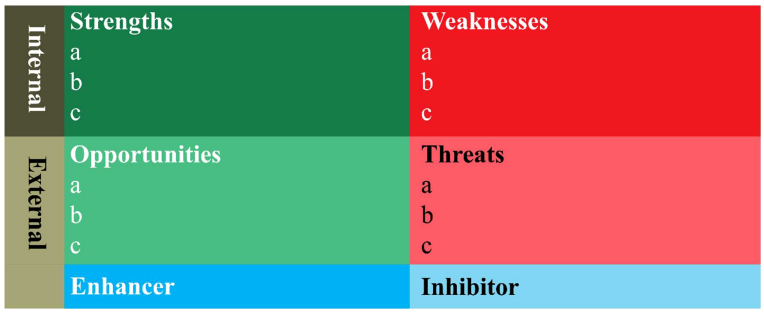

FIGURE 1
Conventional SWOT Table (Doug, 2009).

fisheries co-management and poverty reduction within the framework of a sustainable lifestyle approach. In the context of the sustainable livelihoods approach, which is emerging as a potentially helpful way of looking at policies and institutions to address poverty, the study used a combination of relatively standard and frequently overlapping participatory tools and techniques in addition to SWOT analysis (Njifonjou et al., 2006).

Moreover, in an article from BD, the authors used SWOT analysis to manage the fisheries of the Naaf River along the Teknaf coast, highlighting ongoing issues and related measures through the sustainable management of small-scale fishermen (Chowdhury et al., 2022). They identified several significant issues within the fishing community, including a high reliance on fishery resources, annual catch declines, catch price fluctuations, bycatch discards, and a lack of processing and preservation facilities, credit facilities, and training assistance, which led to a disorganized fishing community with low economic returns. Sunny et al. (2020) examined the sustainability of fishing communities in the Sylhet that are vulnerable to climate change. This study determined the demographics, mode of subsistence, challenges associated with fishing, coping mechanisms, and strengths, weaknesses, and opportunities of fishing communities using SWOT analysis. Consequently, several authors have used and implemented SWOT analyses in various studies, particularly in SSF research. While SWOT analysis can be a useful tool for strategic planning and decision-making, it also has drawbacks, including a lack of objectivity, limited scope, lack of prioritization, and lack of action orientation. Overall, while SWOT analysis can be a valuable tool, it should be used with other methods and approaches to ensure a comprehensive and balanced analysis (Pant, 2019; Lohrke et al., 2022).

Materials and methods

This study aimed to generate comprehensive knowledge of the historical patterns and current status of IUU fishing in the coastal and marine waters of BD. We conducted in-depth individual interviews in three coastal districts (Figure 2) of BD (Chittagong, Cox's Bazar, and Khulna) with relevant stakeholders(n-93), such as commercial fishers including small-scale and industrial fishers, academics, government and non-government officials (Ministry of Fisheries and Environment), police, journalists, coastguard officials, and BD Navy (BN) officials (Table 2). Individual interviews provided an understanding of details regarding each interviewee's perspectives on their lives, experiences, and situations, expressed in their own words (Lambert & Loiselle, 2008). Hence, we collected a significant part of the empirical data from in-depth interviews, each of which lasted approximately one hour on average. Primary data were collected using a pre-tested questionnaire consisting of direct and open-ended questions. The questionnaire was structured to capture the different dimensions of IUU fishing in BD coastal and marine waters. It mainly focused on factors that drive IUU fishing, information on relevant legislation and governance, IUU fishing influencing factors, monitoring, control, and surveillance (MCS) protocols and capacity, risk identification, quantification of IUU fishing by gear and fleets, and guidelines to reduce IUU fishing. The present status includes causes and methods in BD, disadvantages caused by IUU fishing in BD, the need for control, and existing laws and regulations to prevent it. For this purpose, open-ended questions were asked, such as how IUU fishing is taking place in BD, what is the present status of IUU fishing in BD, why it is essential to control IUU fishing in BD, what are the disadvantages of IUU fishing in BD, and what are the existing laws, rules, and regulations to prevent IUU fishing (See the Supplementary File-Section 2)?

NVivo version 12 was used for the quantitative processing and qualitative analysis of the data. It is one of the most advanced and effective tools for qualitative and mixed-method data analysis (Edhlund and McDougall, 2019). To determine the structure of the underlying concepts, it supports the analysis of qualitative content found in interviews, academic articles, texts, audio, videos, emails, images, spreadsheets, and online surveys. To explore the connections among various projects and create new models for future work, sentiments, themes, and attributes can be sorted using NVivo. The results can then be visualized (Amrutha and Geetha, 2020).

Cluster analysis was performed using the NVivo software (Figure 3). It was performed to confirm manually coded phrases. Cluster analysis results are generally presented through a dendrogram, which reveals the similarities and dissimilarities between the objects classified (Hair et al., 2010). Cluster analysis

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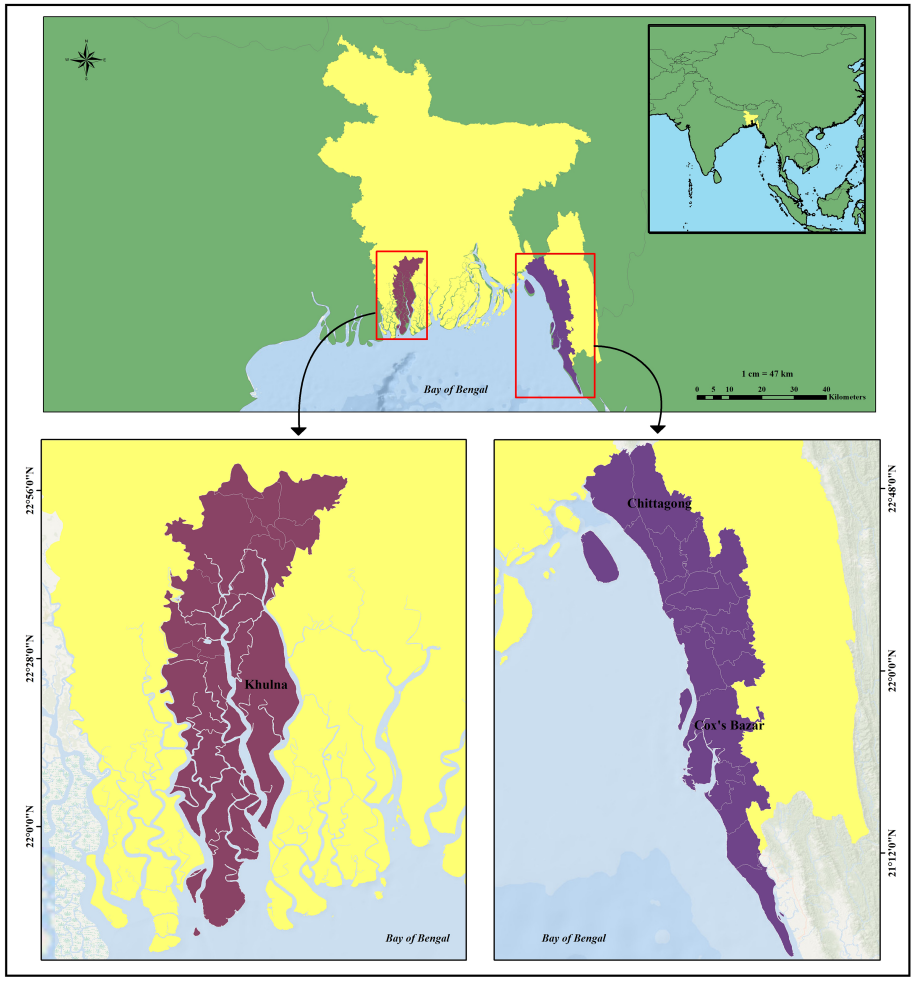

FIGURE 2
Study area map.

is an exploratory technique for visualizing patterns in a project by grouping sources or nodes that share similar words and attribute values or are coded similarly by nodes. The sources or nodes in the cluster analysis diagram that appear close together are more similar than those that appear far apart. Cluster analysis using a word tree was generated in NVivo 12 to exhibit the pattern of similarities within codes and subcodes. Based on the similarity of the words under the classification of various codes of parent themes, the respondents' reviews were analyzed cluster-wise and were closer. The machine algorithm uses simultaneous axial codes according to their group of contexts.

TABLE 2 Sample distributions of in-depth interviews.

Stakeholder groups	Number of respondents
Commercial fishers	45
Academicians	6
Government & non-government officials	15
Coastguard officials	6
Navy officials	6
Police	6
Journalists	3
Focus group discussion (FGD)	6

Steps for cluster analysis generation

First, semi-structured questionnaires with open-ended questions were used to conduct interviews. The responses were then transcribed and translated. Data analysis was initiated by coding using NVivo. Finding relevant text units (commonly referred to as "segments") and assigning these units descriptive labels, or "codes," is the process of creating codes in NVivo 12 from qualitative data or respondents' descriptive comments. A few steps were followed to create the codes. Parent codes were generated in the "Coding" tab by right-clicking on an existing code and selecting "New Parent Code," and child codes were created by right-clicking on the parent code and selecting "New Child Code." A descriptive name was assigned to child codes that reflected a subcategory or

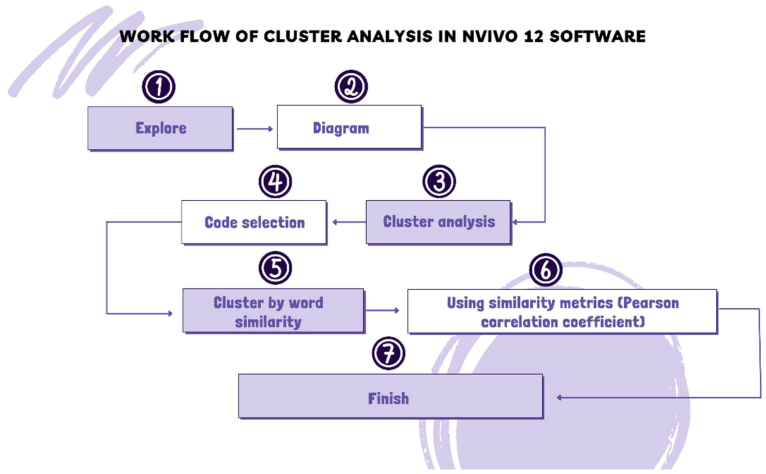

FIGURE 3
Workflow of cluster analysis in NVivo 12 software.

aspect of the overarching theme or concept represented by the parent code. The text segments were coded by dragging the selected text into an appropriate child code. The coding process was repeated for all relevant text segments and the coded data were evaluated and interpreted. The next step after coding was to perform a cluster analysis.

In NVivo 12, the procedure for conducting cluster analysis includes selecting the relevant codes for analysis, constructing a similarity matrix, selecting a clustering method, performing the analysis, evaluating and analyzing the results, improving the analysis as required, and saving and exporting the results. In the first step, cluster analysis was performed by clicking on the Explore tab in the diagram group to create the cluster analysis diagram. Subsequently, a cluster analysis wizard was created. Next, codes were selected to create a cluster analysis. In Step two, select was clicked to choose all codes. The author ensured that only child codes were selected for this analysis, because the parent codes were aggregated from the child codes. Subsequently, Next was clicked, and then OK. Next, word similarity was selected for the option *Clustered by*, and for *Using similarity matrix*, the Pearson correlation coefficient option was selected. The finish option was then clicked. Finally, a horizontal dendrogram showing similarities among the codes was obtained.

First, interview transcripts were processed using the NVivo software suite (version 12). The findings were cross-validated using cluster analysis, which provided an in-depth understanding. The general method for conducting a cluster analysis (Figure 3) that has been performed in NVivo 12 software is as follows:

Explore

Qualitative data in NVivo were explored, and relevant words or phrases for cluster analysis were selected. This stage involved examining the data in NVivo and choosing pertinent words or phrases for the cluster analysis. The tasks in this step involve determining the data pertinent to the research question and ensuring that they are suitable for analysis.

Diagram

A diagram is constructed to visualize the relationships between words or phrases in the data. In addition to helping discover patterns and trends, the diagram provides a visual depiction of the links between words or phrases.

Cluster analysis

The cluster analysis method was selected, and hierarchical clustering was conducted. Based on the research question and the data being examined, the best method was selected.

Code selection

The authors specified the codes to be included in the cluster analysis. The words or phrases in the data that are examined for patterns and relationships are represented by codes.

Clustered by word similarity

A similarity matrix was used to conduct cluster analysis based on word similarity. Based on the relationships between words or phrases in the data, a similarity matrix was used to determine their similarity. Clusters are formed from the words or phrases that exhibit the greatest similarity.

Using similarity matrix

Pearson's correlation coefficient was employed to organize similar words or phrases into clusters. A similarity matrix is utilized at this stage to organize the related words or phrases into

clusters. The most comparable words or phrases were grouped together to allow for a more in-depth examination of the relationships between them.

Finish

Cluster analysis results were analyzed and interpreted to make relevant judgments regarding the data. The findings were analyzed to detect patterns, correlations, and trends in the data and to provide insights into the study topic.

Results

Present status of IUU fishing in Bangladesh

Recently, several causes of IUU fishing have been identified in BD. A scientist from the BD Marine Fisheries Academy in Chattogram offered his perceptions of the causes of IUU fishing and how it is occurring in BD. He focused on the *illegal and unregulated* issues of IUU fishing in the following words.

"The main reason behind IUU fishing is that it does not follow the proper government rules and regulations of native fishermen. Owing to the tendency to earn more profits and catch more fish within less time, fishermen often use prohibited fishing nets or industrial fishing trawlers in shallow waters (less than 40 meters deep). However, there are many fish here because of the high quality of water. For this reason, fishermen from many neighboring countries, such as India, Myanmar, Sri Lanka, and Thailand, come here to fish illegally because they are more equipped with fishing instruments and trawlers. Many medicinal fish species are not typically consumed. Therefore, the fishermen do not catch the fish. However, fishermen from neighboring countries also catch those species and take them away, especially in the banned seasons."

Foreign fishing vessels or illegal incursions are most common in national waters from neighboring states, as stated by the Fishers Chief of the Marine Fisheries Academy when she was asked how IUU fishing is being conducted in our country.

During the FGD, some fishers (Md. Faruq, Md. Alauddin, and Md. Jasim, aged 55, 48, and 36 years, respectively, from the fishery ghat, Chattogram region) also argued about the illegal intrusion of foreign fishers. They said that "Fishing is off during the ban season. Even then, many fishers caught fish illegally. Indian fishermen have taken advantage of this opportunity. Although we could not catch fish, many Indian fishermen entered our waters at that time (mainly during the Hilsa ban period) to catch fish. Their boats are larger than ours; they have more powerful engines and modern technologies are installed in their vessels. Additionally, fishermen from Thailand often visit St. Martin Island to catch fish. However, their number is less than that of Indian fishermen."

From the perspective of the temporal evaluation of IUU fishing in BD, especially during different ban periods, the following conclusions can be drawn:

Several ban periods have been implemented in BD at different times of the year. The hilsa fishing ban was implemented for 92 days, from March 1 to May 31, whereas the juvenile hilsa (jatka) fishing ban was implemented for 61 days, from November 1 to December 31. The prawn fishing ban was implemented for 92 days, from June 1 to August 31. Additionally, the crab-fishing ban was implemented for 61 days, from July 1 to August 31. Additionally, there is a 65-day ban on fishing in the BoB implemented by the government of BD to protect the breeding and spawning seasons of marine resources. The exact dates of this ban may vary from year to year; however, it usually starts on May 20 to July 23. All fishing vessels in the BoB were prohibited from operating during this period. Violators are subject to fines and other penalties, including the seizure of fishing vessels and equipment. During these closure seasons, fishermen from neighboring states come with their boats and fish illegally (Figure 4).

Additionally, IUU fishing is generally carried out more often by local and external fishermen at night than during the day because there is a limitation in monitoring the activities of the navy and coast guard. Fishermen exploit this opportunity and fish illegally, sometimes to depths of 40 meters or less.

The lack of designated landing centers, reluctance to submit accurate catch information or provide misreporting, and a lack of rules requiring them to provide accurate catch information to the authorities are the causes of the *unreported issue*. An official from the Marine Fisheries Department (MFD) in Chattogram indicated some critical points in his speech regarding the unreported issue of IUU fishing, "The number of fish caught by Artisanal fishermen or local fishermen in BD is almost always unknown. No reports are available from them. Currently, the total number of engine-driven boats is 34000, with only 7000 are licensed. The rest of the fishing trawlers are not licensed, so no information comes from them."

According to the Survey Office of Chattogram and Cox's Bazar, "information on only 11 fish landing centers is available. The remaining 200 fish landing centers have no information on catch volume or data available on fish landing centers."

Lack of necessary sophisticated instruments is another reason why IUU fishing is happening by mechanized boat fishers as stated by Coast Guard East Zone Staff Officer (Operations), Chattogram, "Most of the time, the engine-driven wooden boats are fishing at 8–20 meters water depth region. They have no idea how deep the water is because they lack an echo sounder. Therefore, they cannot calculate their actual fishing depth and thus passively attend to IUU fishing." He also mentioned the lack of workforce and sophisticated modern equipment of the Navy and the Coast Guard for monitoring all industrial trawlers at a time in the sea. He argued this issue in his speech: "industrial fishing trawlers catch fish below 40 meters of water depth whenever they get a chance. Mostly at night, they have been seen fishing at 12 to 20 meters water depth regions. However, owing to our ineffective monitoring system, it was not possible to monitor everything simultaneously. Industrial merchant fishing vessels have echo sounders to monitor depth, but they illegally fish in shallow water by violating laws behind our eyes."

The permit required by the MFD for fishing in the sea for a specified period by industrial trawlers is known as the Sailing Permission (SP). The District Fisheries Officer (DFO), Chattogram expressed his experience on SP as follows

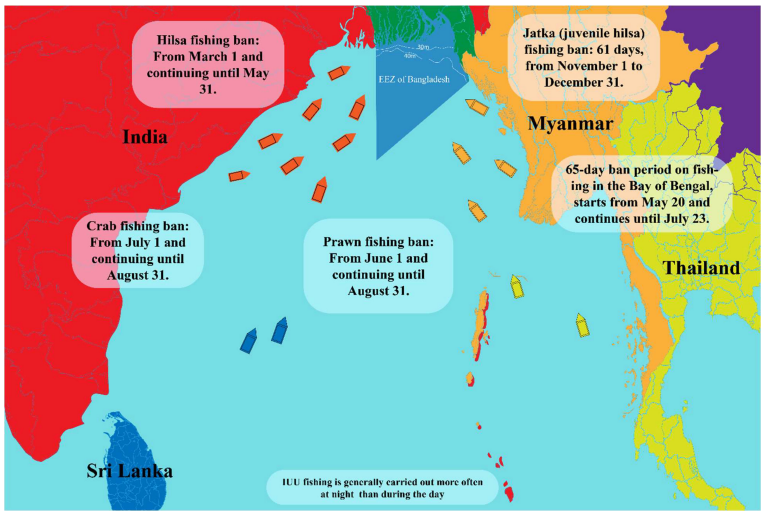

FIGURE 4
Temporal evaluation of IUU fishing in Bangladesh, especially in the different ban periods.

"Mechanized industrial fishing trawlers have SP with them. They submit a catch report, however, engine-driven small wooden boats, especially those under 15 tons, are not yet under the registration process, so they do not obtain SP because they do not need it. Furthermore, in doing so, they do not need to submit any reports about their fishing; consequently, the country's huge amount of extracted fishery resources remain unknown." As proper and accurate reports of a vast amount of fishing and catches remain unknown, IUU fishing and its marine resources are a major issue in BD.

One fisherman, Jasim, who uses a mechanized wooden boat and has been fishing in the BoB region for approximately 25 years, stated the following about SP and industrial trawlers, "We usually go fishing with 18–19 people in a trawler. We must obtain a license for the boat, but we do not have to obtain any SP for fishing. After fishing, we land the fish in a convenient place, because there is no specific fish landing station. Approximately 20 tons of fish are caught per trip. The DOF does not conduct any surveys. So, we do not have to give any reports of caught fish."

A government official from the DOF proposed a crucial aspect of IUU fishing in the deep sea. She stated,' "The country does not yet have the proper capability to monitor IUU fishing and collect all fish catch reports. Therefore, the illegal use of small mesh nets is currently the most serious issue. In addition, fishermen transfer their extra caught fish and illegal nets with the help of other boats or small boats in the deep sea to submit the correct fishing report. Consequently, the total catch data of the fisheries sector are not accurately available."

The Pearson correlation coefficient was used as a similarity matrix in the cluster analysis to quantify the similarity between distinct causes. The causes were classified into clusters based on word similarity. This technique aids in the identification of common patterns and relationships among causes, as well as the classification of causes into related groups based on their linguistic qualities. Cluster analysis allowed us to see and grasp the complicated linkages between the causes, and make intelligent decisions based on the findings.

The dendrogram (Figure 5) in this case shows that "Fishing in shallow depth" and "Using prohibited and illegal nets" are grouped together, indicating that they have similarities and are closely related. Similarly, "Foreign Fishers" and "High Water Quality and More Fish attract more fishers" are grouped together on the same branch, indicating that they also have similarities and are closely related. High water quality attracts foreign fishers. Various colors in the dendrogram were used to distinguish different branches and demonstrate the links between the elements. The more similar the components are, the closer they are to each other. The greater the distance between the elements, the less comparable they are.

Disadvantages of IUU fishing in BD

The country is experiencing IUU Fishing, which has a wide range of disadvantages. For example, one of the officials from the BN

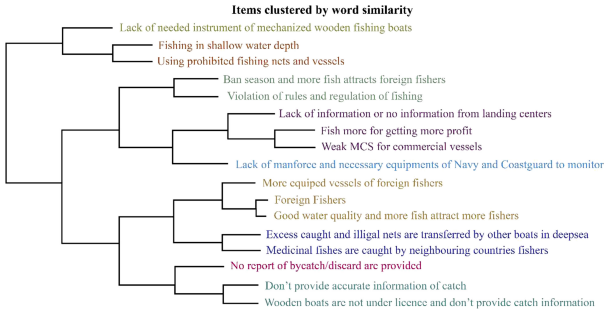

FIGURE 5
Cluster analysis of causes using Pearson correlation coefficient (similarity matric) and clustered by word similarity.

mentioned in his speech that "Due to the lack of proper fisheries statistics, it is difficult to gain proper knowledge of fish stock, which ultimately hampers the sustainable development plans of the government. Moreover, our country is experiencing economic losses."

Decreasing trends, extinction of important fish species, biodiversity loss issues, and increasing poverty due to IUU fishing have been highlighted by several scientists and professionals working in the fisheries sector in the Chattogram and Cox's Bazar region of BD. Their opinions are as follows:

"In BD, fishermen use illegal nets to catch fish before they are fully grown. Consequently, the number of fish species decreases daily, and some valuable fish species have almost become extinct. For example, lakkha, pomfret, and shrimp (Tiger Shrimp) are declining. Consequently, the government loses daily revenue."

"Due to disobeying the mesh size law of the fishing nets, bycatch fish are carried out in addition to the targeted species, threatening biodiversity."

"The loss of valuable wild brood stocks and over-exploitation of fishery resources causes degradation of the marine ecosystem. It also poses security threats to the country, as foreign intrusions generally occur. Finally, IUU fishing is a major threat to sustainable fishing, hampering fishermen's economic and social livelihoods. Consequently, poverty is exacerbated."

The analysis grouped similar causes based on context and word similarities. In this case, the causes "Hamper sustainable fishing and exacerbates poverty," "Food insecurity," and "Affect the livelihood and its change" were found to have similarities and were grouped into one cluster. The causes "Biodiversity loss" and "Degradation of marine ecosystem" were found to have dissimilarities with the previous cluster but still had context similarities and were grouped into another cluster (Figure 6).

Sustainable fishery development is hampered by IUU fishing, which destroys marine biodiversity. Additionally, the government is deprived of significant revenue. Several stakeholders have suggested the need for control measures to prevent IUU fishing. One of the officials from BD Fisheries Development Corporation, Chattogram, stated, "At present, it is vital to stop IUU fishing in BD to protect the ocean's biodiversity and maintain its sustainability. It is also necessary to obtain accurate catch reports from fishers, and then it will be possible to determine how much fishing will be sustainable in an area, or how many fish will be able to return to their previous state from a decreasing trend."

The Additional Director (AD) of the MFD expressed his perception of the need for control: "If IUU fishing continues like this, first of all, you cannot get an idea about fish population and stock. Consequently, it is impossible to determine the correct sustainable yield. Consequently, marine fishery management activities will not progress. Fish stock sustainability will be completely destroyed."

Essential to control IUU fishing in BD and some early examples

Recently, the government took the initiative to combat IUU fishing and introduced the Marine Fisheries Act of 2020. Several

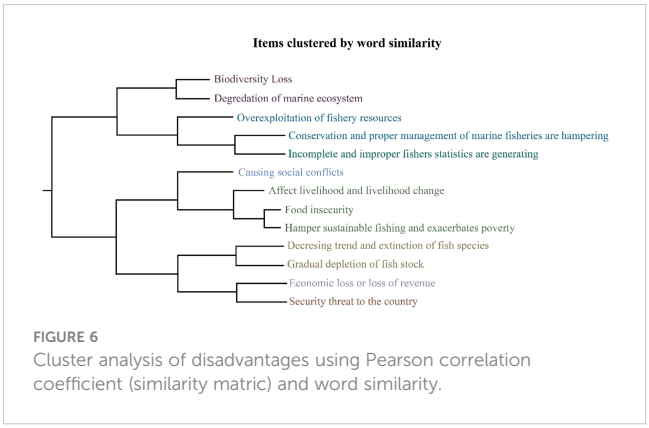

FIGURE 6
Cluster analysis of disadvantages using Pearson correlation coefficient (similarity matric) and word similarity.

scientists, academics, policymakers, and government officials are currently developing this technology. The present act came up several times in different in-depth interviews. Some of these are as follows:

"In the National Plan of Action (2020), some laws regarding IUU fishing have been passed. However, these laws have not been formulated yet. The BD Marine Fisheries Act (2020) includes several sections on IUU fishing. Currently, the Marine Fisheries Policy and Marine Fisheries Rules are drafted by the DOF (Ministry of Fisheries and Livestock) of BD."

"BD has already introduced laws to prevent IUU fishing. In particular, the Marine Fisheries Act-2020 has already been passed under the Marine Fisheries Survey Management Unit (MFSMU) and Fish Inspection Quality Control (FIQC), and currently, to combat IUU fishing rules are proposed. Currently, patrolling activities are being carried out by the DOF to prevent the illegal use of nets and comply with the Fisheries Protection Act. In addition, the ban period was 65 days during the breeding season of the hilsa. In addition, trawlers weighing more than 15 tons have been registered, and trawlers weighing less than 15 tons will be registered if the rules of the Marine Fisheries Act of 2020 are implemented."

One academician from Chattogram has specified IUU issues that were not clear in previous acts, and she stated, "Protection and Conservation of Fish Act, 1950 as well as the Marine Fisheries Ordinance of 1983 addressed the necessity of conservation of inland and marine fish. However, both laws lack comprehensive mechanisms to prevent and deter unauthorized fishing. These laws did not contain any provisions defining or recognizing IUU fishing activity as an offense."

Challenges and potentials of IUU fishing in BD

Challenges of IUU fishing in BD

By depleting fish stock, destroying marine habitats, and contributing to pollution through discarded fishing gear, IUU fishing has affected marine fishery resources in BD. Moreover, illegal fishers, such as artisanal fishermen, defraud local communities by catching fish. Consequently, they face food insecurity owing to their lack of income and sustenance.

Therefore, there is an urgent need to stop IUU fishing. However, there are some significant challenges to IUU fishing in BD, as revealed by different interviews with government officials and academicians.

The fisheries management officer of MFD in Chattogram expressed the significant challenges of IUU fishing: "Bringing all coastal fishing trawlers under license and registration is one of the challenges. Additionally, the lack of check-posts in the coastal belt complicates monitoring. In addition, workforce and vessel crises and a lack of Guarding Facilities are major challenges. One challenge is modernizing the monitoring system, such as by implementing a Vessel Monitoring System (VMS) for proper monitoring. According to the Marine Fisheries Act 2020, a law has been enacted to register all fishing trawlers based on a 15-ton weight. However, the biggest drawback was that the survey was not conducted properly because of IUU fishing. Another major challenge is a lack of patrol vessels for monitoring fishing trawlers."

One government official indicated some crucial challenges in his speech, "The major problem is the lack of alternative income-generating options. Therefore, many small-scale fishers are forced to fish illegally. In industrial fisheries, this is mainly caused by the greediness of businessmen/mahajans. In the absence of strict monitoring, industrial trawlers violate the rules and fish illegally."

In her talk, DFO Chattogram brought up the same issues: "Currently, a survey is being conducted under MFSMU. All fishing trawlers weighing > 15 tons are being surveyed. If these survey activities are unsuccessful, it would be nearly impossible to prevent IUU Fishing. Fishery Ghat and South Kattali Ghat are now considered fish-landing centers for artisanal fishers. Nevertheless, fishermen sometimes anchor fishing trawlers in different places, which does not provide accurate information on the total catch. In addition, many fishing boats sell fish while at sea. As a result, if the fish landing center is not specified, it will be difficult to prevent the unreported aspect of IUU fishing."

One of the top-ranked coast guards raised another issue regarding a more critical problem for combating IUU fishing: "In the coastal areas of BD, most people involved in fishing rent engine-driven trawlers from proprietors/vendors/Mahajan. Vendors collect money from fishermen and provide them with fishing nets and boats. The Coast Guard arrests fishers for illegal activities (e.g., IUU fishing). However, they release fishermen most of the time, because they are not directly involved in these activities and are forced to do so by vendors/Mahajan. So, the Coastguard cannot stop IUU fishing."

Navy officers and several government officials mentioned the following challenges for IUU fishing: the tendency to enter illegal fishing boats and their poaching in their EEZ, shortage of manpower and logistics of the DoF, lack of routine catch monitoring and database systems in the DoF, and lack of monitoring systems and VMS. A Captain in BN in Chattogram during his in-depth interview mentioned, "Due to inadequate human resources and advanced technology, the Navy and Coast Guard experience many difficulties during surveillance. The coastal guard can only maintain surveillance up to a contiguous zone. Owing to their technical limitations, they cannot conduct surveillance in the total EEZ. Moreover, they have no air support, which is one of the main obstacles to their operation. The radar used in coastal guard ships has a minimal range, generally 15–20 miles, which is unable to detect smaller ships."

The dendrogram shows interconnected codes grouped together and exhibits a pattern of similarities within the codes and subcodes. According to the dendrogram, the items "Change of approved gears and equipment of fishing vessels" and "Weak and weak logical support of fisheries department" are grouped together on the same branch. Thus, these items are believed to be similar and closely related. The items "Incomplete licensing of motorized wooden boats" and "Unauthorized construction of commercial vessels," on the other hand, are clustered further apart. This means that these items are less similar and less closely related to the items in the aforementioned cluster (Figure 7).

Monitoring, control, and surveillance to prevent IUU fishing in Bangladesh

The MCS activities were conducted through the MFD, Marine Fisheries Surveillance, related coastal districts, and Upazila fisheries officers to prevent IUU finning by mechanized fishing boats engaged in fishing in marine and coastal areas. If IUU fishing is committed by a fishing vessel during the operation of the MCS program, penal action is taken according to the Marine Fisheries Ordinance, 1983. Fisheries management expert and AD of MFD talked about MCS of Industrial fishing trawlers, "Each trawler carries a one-year fishing license for fishing, and each time they have to take SP to fish in the sea. After submitting the fishing report, SP must be renewed. Preserving system-implemented vessels (steel bodies) were given SP for 30 days and non-preserving vessels for 13–14 days. ID cards must be kept with skippers and crew. Each trawler was carefully monitored and inspected before and after fishing. Occasionally, inspectors monitor the offloading of fish from the trawlers. If fishing nets are imported, approval must be obtained from the Department of Marine Fisheries. A catch certificate is required for exporting fish to foreign fishing vessels and trawlers. Every time fish are caught from the sea, a report has to be submitted by the fishers."

He also talked about MCS for Artisanal/Mechanized fishing trawlers:

"Each trawler needs a license to fish. Artisanal trawlers do not need to sail to obtain permission to fish. If the rules of the Marine

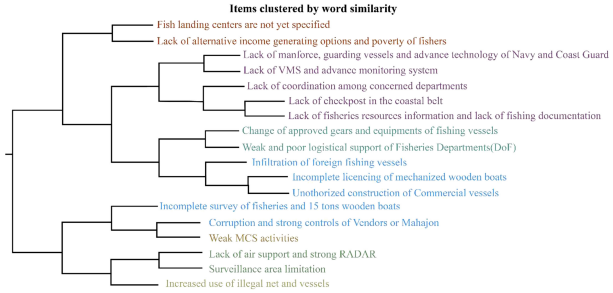

FIGURE 7
Cluster analysis of challenges using Pearson correlation coefficient (similarity matric) and clustered by word similarity.

Fisheries Act of 2020 are passed in future, they will be added with SP. However, they must obtain a fishing permit if the rules of the Marine Fisheries Act, 2020, are passed. Only one surveillance check-post at Patenga in Chittagong provides fishing information on engine-driven local trawlers. If this number does not increase, it will not be possible to obtain accurate information about local fishing trawlers. There has been a shortage of logistics support and manpower during the Corona period. For this reason, no data or reports of fish landing centers were available for the last year."

The 52-year-old industrial ship skipper of Ayub Monowara made the following comments about the existing MCS: "The MFD basically gives SP for one month. With this permission, industrial fishing trawlers can go fishing in the deep sea. If they get enough fish, they return it 15 days earlier. They must submit a report on fishing every time; otherwise, they will not obtain SP. The SP was renewed after each report was submitted."

To stop IUU fishing, it is necessary to stop fishing for certain species during their egg-laying or breeding seasons. Ban periods should be introduced, and the workforce should be increased to enforce it properly and for proper guarding activities. Therefore, appropriate monitoring systems must be implemented. All fishing trawlers were brought in with SP. Adequate numbers of check-posts should be established along the coast. Therefore, the number of patrolling vessels must increase. All of these can be considered potential solutions. An academician identified some essential points that could potentially prevent IUU fishing. She said, "The number of patrolling vessels and the workforce needs to be increased. Therefore, it is necessary to introduce Vessel Traffic Management Systems (VTMS). To protect critical species, it is essential to declare certain locations as fish sanctuaries. The spawning times/seasons of certain fish species should be identified, and a ban period should be implemented for each species. Finally, a sustainable fishing yield must be determined."

One government official used a strict voice when discussing alternative job opportunities for fishers so that overfishing and IUU fishing were under control (Figure 8). He said, "To reduce IUU fishing, the government must create more job opportunities, adapt existing rules and regulations, ensure strict monitoring, and build up the capacity of DOF officials."

A Navy officer said, "First, the monitoring system should be developed. An automatic identification system (AIS) should be introduced in larger fishing nets. The ship size should be different for mid-water and shallow-water fishing. All boats must have a communication system with the authorities responsible for fishing surveillance. Research on fishery resources and their management is vital. The capacities of the Navy and Coast Guard must be increased; simultaneously, the Coast Guard should be equipped with larger ships and helicopter support."

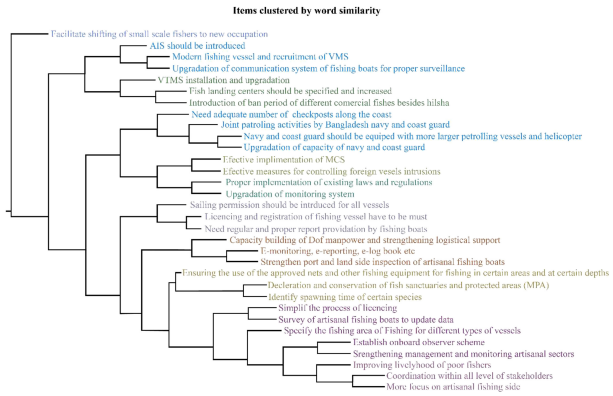

FIGURE 8
Cluster analysis of necessary needs for combating IUU fishing in BD using Pearson correlation coefficient (similarity matric) and clustered by word similarity.

Discussions

Currently, IUU fishing is a serious and growing concern in the global fishing industry because it disrupts the conservation and management objectives of sustainable Fishing without permission in national, regional, and international waters is illegal According to a survey conducted by FAO, IUU fishing accounts for 20% (one in five) of all the fish captured in national and international waters worldwide (FAO, 2022). Currently, IUU fishing is widespread and prevalent in BD national waters. There are several causes of IUU fishing in BD that have recently taken place, such as violation of rules and regulations of fishing, using prohibited nets and illegal nets, fishing in a shallow depth, less or no catch information from mechanized wooden boats, no reports of bycatch discards and actual catch after a single voyage, lack of landing centers and catch reports from landing centers, intrusion of foreign fishers, especially during the ban season, who are more equipped and catch nontraditional medicinal fish, weak MCS for commercial vessels, lack of man force, and lack of necessary equipment for the Coastguard and navy to control IUU fishing (Present Study). Other studies have found similar results, such as foreign fishers being responsible for the most prolific IUU fishing (Le Gallic and Cox, 2006; Mackay et al., 2020; Song et al., 2020; Fujii et al., 2021). These findings demonstrate that IUU fishing is not limited to foreign vessels as initially assumed. Le Gallic and Cox (2006) discovered that domestic vessels account for a significant proportion of IUU fishing in the Southern Ocean. Song et al. (2020) and Mackay et al. (2020) discovered that, while foreign vessels contribute to IUU fishing, domestic vessels account for a substantial proportion globally. According to Fujii et al. (2021), IUU fishing in Southeast Asia involves domestic and foreign fishing vessels. Dayem and Kuwait fishermen noted that immigrant fishermen, especially those from Egypt, were the main perpetrators of IUU fishing in Kuwait, taking advantage of poor immigration control (Alqattan et al., 2020). When fishing vessels operate against the rules of a fishery, such as by taking too many vessels or fishing outside the designated seasons, this practice is known as IUU fishing. As many crab and lobster species, especially those in limited supply, are valuable, IUU fishermen have financial incentives to engage in this practice. Coastal fisheries in poorer nations are particularly susceptible to IUU fishing because governments often fail to regulate or implement national or international rules (for instance, owing to a lack of resources or

ineffective levels of governance) (Force and Upton, 2006). Foreign fishing boats, typically Chinese or Korean, are particularly susceptible to the abuse of the marine resources of nations with weak or non-existent enforcement, such as Somalia, West Africa, and Madagascar (Petrossian et al., 2015). In the case of BD, the need for inland and marine fish conservation is addressed by the "Protection and Conservation of Fish Act 1950" and the "Marine Fisheries Ordinance of 1983." However, both laws lack adequate measures to stop and discourage unauthorized fishing. In addition, these statutes do not define IUU fishing as an offense. Although the Coast Guard Act of 2016's Section 10 refers to the constant role of law enforcement agencies in combating IUU fishing, several issues, such as the inspection of alleged foreign-flagged IUU vessels and the prevention of IUU catch products from entering ports, have not been addressed (Rahman and Rupom, 2020). In addition, owing to the lack of legal and administrative oversight, IUU fishing activities continued in BD's maritime zones. A large number of unregistered and unlicensed mechanical and non-mechanical fishing vessels in the BoB are causing gradual depletion of fish stocks. In addition, the conservation and proper management of marine fisheries are hampered by the violation of laws and regulations by commercial trawlers, which also puts pressure on fishery stock. Moreover, at present, no license fee is levied from unauthorized fishing vessels, and because of this, it is not possible to export the fish caught by such illegal fishing vessels to European Union countries; for this reason, revenue is not generated, and foreign exchange is not earned (DoF, 2014). Furthermore, fishing activities damage the marine environment and have detrimental effects on overall ecosystems, fisheries, and biodiversity. Moreover, fishing, legal and illegal, causes social conflicts between the two groups. If illegal fishing activities, such as IUU fishing, persist in the absence of an effective MCS, they are likely to become organized fishery crimes (DoF, 2019). Consequently, fish stocks will decrease and many fish species may vanish in the long run. Finally, the livelihoods of many small coastal fishing groups, including fishermen, vessel owners, exporters, and others involved in this sector, will be jeopardized, resulting in acute poverty and food insecurity, and sustainable development will also be impeded. Above all, the development of the Blue Economy, which is reliant on the sea, will be impeded. BD has a sizable coastal region rich in marine and aquatic biodiversity and is blessed with abundant natural resources. Fish production will increase if IUU fishing is curbed, boosting the GDP of the country. The IUU fishing hinders sustainable fishery management and the productivity of aquatic biological resources in a sustainable manner. There are many reasons for these threats, including poor MCS in the area, a lack of internal capacity to stop domestic fishing vessels from engaging in illegal fishing, a lack of coordination between relevant departments such as the DOF, a lack of checkpoints in the coastal belt for catch monitoring, a lack of technical support or facilities such as advanced RADAR, a lack of information about fisheries resources and fishing documentation, and poor or entirely no implementation of rules (SWOT analysis-Figure 9).

According to a three-year report commissioned by the government, IUU fishing has nearly eliminated the largest and most valuable species, including tiger prawns and Indian salmon (FAO, 2022). Fishers used to catch a variety of species but are no longer able to do so. Millions of underprivileged fishermen are affected by hilsa conservation, yet a substantial amount of the benefits go to industrial trawl operators, who capture tons of hilsa without much social benefit or taxable income for the government (Porras et al., 2017). The hilsa recovery has also begun to draw "super-trawlers" from other countries, which are outfitted with equipment to follow and target hilsa schools. The capacity of super trawlers is twice that of existing industrial vessels. Their size and engine power allow them to catch fast-moving hilsa, and they are outfitted with sonar technology to assist them in locating shoals (Islam and Walkerden, 2022).

To protect fishery resources, the government has formulated laws and policies regarding sustainable fishing. They are in the process of developing some laws, rules, and regulations to prevent IUU fishing in BD, such as the Marine Fisheries Act 2020 (Nakamura et al., 2022). The Marine Fisheries Act of 2020 is one of the many actions taken by the government to prevent IUU fishing. Laws were introduced to prevent IUU fishing in BD. In particular, the Marine Fisheries Act-2020 has already been passed under the MFSMU and FIQC, and fishing rules are currently proposed to combat IUU. Currently, patrolling activities are being carried out by DOF to prevent the illegal use of nets and comply with the Fisheries Protection Act. In addition, the ban period was 65 days during the breeding season of the hilsa. In addition, trawlers weighing more than 15 tons are registered, and those weighing less than 15 tons will be registered if the rules of the Marine Fisheries Act 2020 are implemented (this study). Mala (2020) said, "On January 29, 2020, the Marine Fisheries Bill 2020 was introduced to parliament. Marine Fisheries Ordnance-1983 will be replaced by the New Marine Fisheries Act 2020. Under the new IUU provisions, the Ministry of Fisheries and Livestock will have more authority to manage and monitor the maximum sustainable yield, establish permitted catch and hoarding limits, and conduct surveys on fish resources. The current ordinance has no legal provisions for issuing orders or instructions to stop illicit, unreported, or unregulated fishing. The country could unlock the potential of a blue economy with the help of the IUU and mariculture."

With limited exceptions, such as innocent passing, as defined by the 1982 United Nations Convention on the Law of the Sea, the proposed Act placed restrictions on the entry of foreign fishing vessels without a license. According to the proposed Act, registration is necessary for all automated fishing vessels, referred to as artisanal fishing vessels (Mala, 2020). One of the UN Nations' SDGs is to combat illegal fishing. Indicator 14.6.1 of the SDGs, which is related to SDG 14, 'Life Below Water,' is dedicated to evaluating progress toward the ambitious goal of eliminating IUU fishing by 2020 (Canton, 2021). BD experiences potential challenges in combating IUU fishing. However, time-consuming methods are required to overcome these issues. The livelihoods of fishermen will be severely impacted, and sustainable development will not be attained if the country fails to address this issue.

Recommendations

Dealing with all these challenges and resolving them strictly and efficiently is necessary to control IUU fishing in BD. Government

FIGURE 9
SWOT analysis of IUU fishing in BD.

and national agencies can take several steps to control and stop IUU fishing in national waters. At present, in BD, ban period activities are being carried out by the DoF to protect jatka and mature hilsa fish, and benefits are being experienced after implementation. The Coast Guard only supports the proper implementation of the ban period's activities. This implementation system also needs to be introduced to other commercial fish or targeted fish at sea. For this purpose, the number of patrolling vessels and the workforce must be increased. The VTMS must be introduced, where VMS and AIS will be used for domestic and commercial vessels (all trawlers), and AIS will be used for boats and vessels in other fisheries. To protect critical species, it is essential to declare certain locations as fish sanctuaries. The spawning time/season of certain fish species should be identified, and a ban period should be implemented for each species. Sustainable fishing yield must be determined by the DoF. Furthermore, to control IUU fishing in BD, everything related to fishing must be included in a stable operative system. Fisher and trawler proprietors/owners must be aware of the harmful aspects of illegal nets with small mesh sizes. Rural people in the coastal areas of BD are less aware of the effects of illegal net use. Therefore, they need to be aware of this to protect the future. In addition, fish landing centers should be specified. All fishing trawlers must be registered through a proper survey and brought under the SP so that they can be controlled by the MFD. Further research is needed to resolve this issue. Government organizations and institutions can conduct research to combat IUU fishing. In this regard, national and international collaborations are essential. The country's MOFL needs to collaborate with other nations, such as the USA, UK, China, and Indonesia, to know how they are successful in this respect. The Ministry can arrange international seminars and conferences to better understand how they do so. Appropriate research is the only tool for appropriate fishery stock assessment and management, which is vital for sustainable governance.

Moreover, from a scientific standpoint, the government should assess all major stocks in the BoB. Additionally, the government can introduce MSP into existing MPA to boost declining fish resources. To reduce the pressure on inshore waters, scientists of the BFRI and MFD must explore deep-sea fisheries. To update the FRSS data collection system, the concerned departments must make appropriate plans. The SSF fishers must be motivated to follow rules and regulations. There is a need to determine the amount of support each fisherman needs during the lean period caused by bans and other restrictions. A holistic approach or research package based on a socio-ecological perspective is required to combat IUU fishing. In addition, nets smaller than 60 mm mesh size cannot be used in the sea because marine fish fry are generally much larger. Research on multi-fish species needs to be initiated, which will facilitate proper net selection for catching the desired fish, making it possible to reduce the number of bycatch fish. Research should be conducted on different marine fish species' breeding seasons and growth. Research on selecting the ban period for important fish species such as hilsa, Vetki, Indian salmon, and shrimp (tiger shrimp and lobster) should be carried out. The recommendations are summarized in the following figure (Figure 10):

Conclusions

The consequences of IUU fishing include loss of revenue, environmental damage, economic loss for coastal communities, and reduction in fish stocks. This study focused on comprehensive knowledge of the historical patterns and current status of IUU fishing in the coastal and marine waters of BD. We recommend that relevant government and non-governmental organizations encourage and support coastal fishers to build resilience against IUU fishing effects and other human-made or natural threats to their existence. Such initiatives have allowed coastal fishermen to improve their lives and protect coastal waters. We also recommend strengthening the management and monitoring of artisanal sectors, as well as industrial fishing, training and motivation for stakeholders, coordination with all stakeholders, and effective implementation of MCS. We believe that this study will serve as a crucial guideline for sustainably managing fisheries and developing legislation, rules, and regulations to prevent

FIGURE 10
Recommendations to control IUU fishing in BD.

IUU fishing in BD. However, more research on this and related areas is needed to further improve the situation of fishers, obtain more data, and improve the surrounding processes to successfully combat IUU fishing in BD.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

Conceptualization, MM; Data curation, MM, DD, MH, SS; and A-AN; Formal analysis, MM, DD, MH, SS; and A-AN; Investigation, MM; Methodology, MM, PS; MU; Project administration, MM, and PS, MU; Resources, MM, and PS; Supervision, PS; Visualization, MM, DD, MH, SS; and A-AN; Writing—original draft, MM, DD, SS, MH, MU; and A-AN; Writing—review & editing, MM, MU, and PS. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2023.1150213/full#supplementary-material

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