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Oil Spill in the Philippines: Its Impact, Response, Practices, and Challenges

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***Abstract*— The Philippines is an archipelagic state bounded by various bodies of water and has around 17.5 thousand kilometers of coastline; inside the territorial waters, there are also a total of 1.67 million square kilometers of fisheries that are abundant with marine products such as corals, pearls, crabs, seaweeds, and diverse fish species; in 2020, coastal and marine resource management established marine protected area (MPA); maritime activities in the Philippines pose threats and harm to these marine resources.**

From 1998-2023, the Philippines recorded 18 major oil spills; there were reported economic losses, with fisher folks losing their livelihood, and the operation of nearby tourist spots was restricted - resulting in tourism revenue lost; the marine environment was also affected. It also impacted the health of numerous households with complaints of respiratory illness, dizziness, dermatitis, and stomachaches. Sadly, on 28 February 2023, another oil spill incident transpired from a sunken vessel, M/T Princess Empress, carrying approximately 900,000 liters of industrial oil. This study aimed to investigate crucial oil spills in the Philippines, their impact, response practices, and challenges to provide innovative solutions that could immediately diminish the spread of oil spills and mitigate further losses and damages.

***Index Terms*— Aquatic Pollution, Oil Spill Mitigation, Oil Spill Response, Impacts, and Challenges**

I. INTRODUCTION

1.1 Background of the study

The Philippines is an archipelagic state bounded by various bodies of water such as bays, rivers, lakes, falls, gulfs, straits, and swamps. The Global Marine Species Assessment of the World Conservation Union highlights the Philippines' marine biodiversity as the center of marine biodiversity in the world significance in the Pacific Coral Triangle [1]. In the heart of the Coral Triangle lies the 7,641 islands of the Philippines [2], supporting a variety of ecosystems and a wide diversity of marine life, as shown in Fig. 1. It encompasses diverse Marine Protected Areas (MPA) and a great diversity of marine life, such as big schools of sardine fish, barracudas, dolphins, giant trevallies and parrotfish, and the famous thresher sharks, hawksbill sea turtles, whale sharks that the tourist divers enjoy as they explore the numerous magnificent sceneries of coral reefs. MPA's were also established for coastal and marine resource management, and based on records as of 2020, there are 1,923 MPAs nationally and locally managed [3]. Fishing is the main source of livelihood in the country.

The Philippines is an archipelagic state surrounded by bodies of water that serve as a gateway for vessels or routes for transportation of people and merchants. Its ports are busy with vessels docking, berthing, or anchoring, making it vulnerable and at risk of oil spills. Vessel activities in the Philippines pose threats and harm to these marine resources.

The key command responsible for oil spill response and operations in the Philippine Coast Guard (PCG) is the Marine Environment Protection Command (MEPCOM). The PCG has developed a National Oil Spill Contingency Plan (NOSCOP) manual that serves as a guide and contains policies and procedures in case of oil spill incidents. The sources of oil spills mentioned in the manual are vessels (domestic and international), power plants and barges, shipyards, oil explorations, refineries, terminals and depots, production activities, offshore mining activities, and industrial and manufacturing activities. Offshore response strategies include - mechanical (booms, skimmers, storage tanks), chemical dispersant, and in-situ burning. The response during oil spill operations is determined through the TIER response, which is determined based on the magnitude of the oil spill, the presence of the oil spill response center, and the availability of resources needed during the oil spill response. The activation of the command system, the national oils spill response team, is warranted on TIER III, which is described as the large volume of spill accounting for >1,000$m^{3,}$ brought about by large tanker accidents or offshore blowouts which could affect large bodies of water and vulnerable marine environment [4].

A total of four hundred sixty-six (466) incidents of offshore oil spills from 2000-2022 were reported by MEPCOM. Eight (8) major impacts of oil spills were reported from (2000-2013) which

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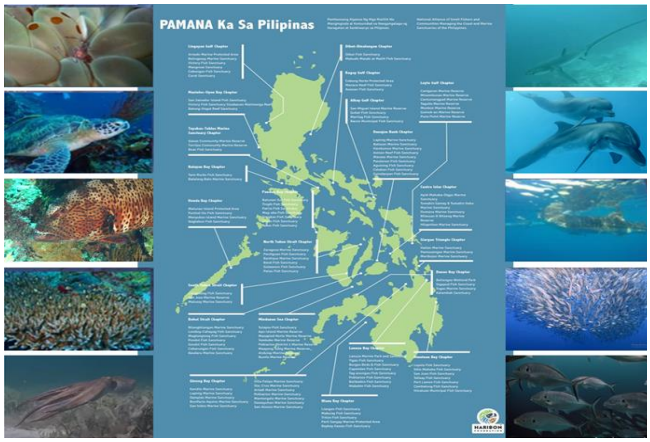

Fig. 1. Philippines Marine Biodiversity. (Source: Haribon Foundation: Marine Protected Area and Photographs by Mike Smith and Ruba Husari).

occurred in Pangasinan, Semirara, Guimaras Island, La Union, Polilio Island, Cebu City, and Iloilo. Sunken or capsize vessels were the major source of most of these oil spills; the other cause was leaking from the pipeline of the depot. An investigation of aquatic oil spills in the Philippines from 2000 to 2021 was studied by (Alea et al., 2022) [6]. One of the recommendations is to store records or data which is systematic, consistent, and comprehensive. Data on oil spill incidents should include date, locality, source, cause, and spillage amount.

Unfortunately, on 28 February 2023, another oil spill incident transpired from a sunken vessel, M/T Princess Empress, carrying approximately 900,000 liters of industrial oil. As of 17 April 2023, it affected 178,306 individuals from 37,872 families, with agricultural damages of about USD 5.27 million [7], [8].

1.2 Statement of the problem

The Philippines is encircled by waterways that have served as ports and routes of vessels for the transportation of goods. Climate change has brought detrimental damages not only to the Philippines but to several countries as well. Due to climate change, the weather forecast is unpredictable, which could result in the collision and capsizing of motorboats, ships, and vessels, resulting in oil spills. The impacts of oil spill pollution can affect or damage not only the coastal environment but also the socioeconomic status and health of human beings. Hence, several studies were conducted on how to contain or treat the oil spills and developed contingency planning to prevent further damages brought about by the oil spill. This paper aims to look into the impacts, response practices, and challenges met during the oil spill response.

1.3 Objective of the study

1. To describe the incidence of oil spills in the Philippines in terms of:
   a. Timeline of the major oil spill and its causes.
   b. Socio-economic, environmental, and health impacts.
   c. Oil spill response practices and challenges.
2. To determine sustainable solutions to address the challenges faced in oil spill response.
3. To promote Environmental Sensitivity Index (ESI) mapping as mitigation in oil spill response.

II. METHODOLOGY

2.1 Study Area

The “Pearl of Orient Seas” in Southeast Asia is the Philippines. It has 7,641 islands; it ranked seventh for having the most islands in the globe and second in Asia. The islands of the Philippines are divided into three groups: Luzon, Visayas, and Mindanao, with Luzon Island being the largest and Mindanao being the second largest. The Philippines has a total coastline of 36,289 kilometers or 22,548.94 miles and is surrounded by four marginal seas: The Philippine Sea, the South China Sea, the Sulu Sea, and the Celebes Sea. The maritime zone comprises internal waters, archipelagic waters, territorial sea, contiguous zone, and Exclusive economic zone. Minor peripheral seas, such as Bohol, Samar, Sibuyan, Camotes, and Visayan, are crucial navigational waterways within the nation's internal and archipelagic waters. The Philippine archipelago's straits, channels, and inlets divide islands and define coastlines. It facilitates the transportation of people, animals, and products. Diverse bodies of water are seen in the Philippine archipelago - gulfs, bays, coves, estuaries, and lagoons which provide leisure activities like swimming and diving. These contribute to the landscape and provide essential resources for the region's diverse ecosystems. The Philippines experiences warm to hot weather year-round due to its proximity to the equator, with dry and wet seasons [1].

Being part of the Coral Triangle, more than 2,500 species of spectacular fish of the world's coral species are found in the coral reefs of the Philippines. There are more than 500 coral species, making the Philippines one of the richest marine biodiversity in the world. Several reef fish find sanctuary in these dazzling underwater gardens, and the mangrove area is an important place to spawn small fishes, crabs, and shrimps [4]. The maritime industry in the Philippines has the most essential function to maintain and develop the social economy in the country [2].

2.2 Data Collection

The majority of the oil spill data utilized in data gathering came from the PCG report and National Oil Spills Contingency Plan Manual 2018. Additional information on the impacts, challenges, and situation report was collected from media or news reports (international, national, and local). Keywords searched on Google Scholar and other search engines were Aquatic Pollution, Oil Spill Mitigation, Oil Spill Response, Impacts, and Challenges to augment other information needed to complete this paper. The data collection process is shown in Fig. 2.

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2.3 Data Analysis

Information and data gathered were analyzed through figures and charts. Among the eight major oil spills, the National Power Corporation (NPC) Power Barge ran aground in Semirara Island (2005), MT Solar Tanker I, Guimaras Strait (2006), and MT Princess Empress (2023) has detailed situation reports on the impacts of oil spill on population, resources, socio-economic and health. DOTMPLFSI – (Doctrine, Organization, Training, Materiel, Personnel, Leadership, Facility, Sustainability, and Innovations) analysis

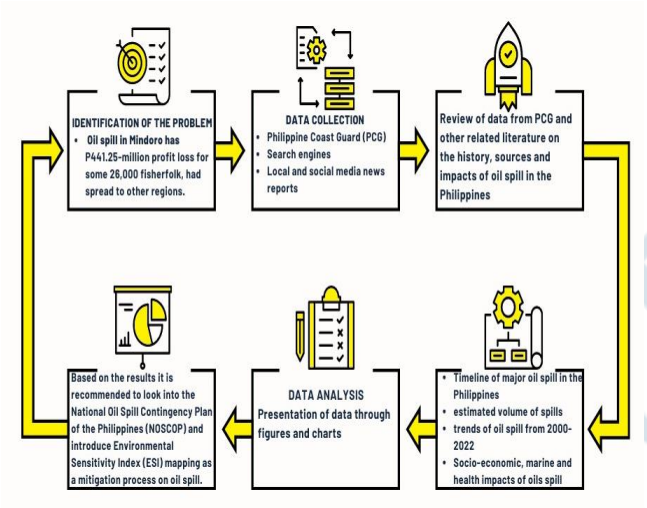

Fig. 2. Methodology and summary of reports of this study regarding the major oil spill in the Philippines.

was adopted to determine sustainable solutions and improvement areas to resolve the challenges met during oil spill operations in the Philippines. This analysis is often employed to determine gaps in the capabilities across military operations, either materiel or non-materiel approach [16].

III. Results

3.1 Timeline of Oil Spill in the Philippines

A total of four hundred sixty-six (466) incidents of offshore oil spills from 2000-2022 were reported by MEPCOM. Table 1 shows the timeline of significant oil spills in the Philippines from 1998-2023. Among the oil spills, the most devastating and worst impact on humans' socio-economic, marine life, and health was an incident in Guimaras Strait on 11 August 2006. The second largest volume of an oil spill is the recent incident last 28 February 2023 with an estimated volume of 900,000 liters. Most of the oil spill incidents are the sinking of vessels due to strong winds, bad weather conditions, grounded, and collisions. Other sources of oil spill mentioned were leakage from a pipeline accidentally and allegedly done by an assailant, which was leaked pipe of MT Panglao in La Union, Petron Corporation in Manila Bay Cavite, and cut-up hose from a tanker to Caltex depot in Illana Bay. Incidence of an oil spill was noted most in February – four (4) incidents of oil spills were noted, while three (3) for July and August.

Table I. Timeline of the Significant Oil Spill in the Philippines from 1998 to 2023. (*Source: PCG report, Philippine Inquirer News).*

Date	Place	Volume	Cause
18-Sep-98	Fortune Islands Batangas	600,000 L	MV Princess of the Orient capsized due to extreme weather conditions and human error (erroneous maneuver)
23-July-99	Mariveles Bataan	747,991 L	MT Mary Anne sank
27-Jan-00	Lingayen Gulf	57,000 L	M/V Nol Scheddar ran aground
29-Jun-00	Ilana Bay	18,000 L	An unidentified assailant sliced the hose that pumps diesel from a tanker to Caltex depot
17-July01	Davao Gulf	12,500 L	M/V Dingalan Bay sank due to a collision with a certain Singaporean vessel
06-Mar-05	Davao Gulf	128,000L	Oil tank of M/V Cala Piccola cracked
18-Dec-05	Semirara Island	364,000 L	NPC Power Barge 106 ran aground
11-Aug-06	Guimaras Strait	2,100,000 L	Oil tanker MT Solar I capsized
27-Feb12	Mactan Channel	10,000 L	M/V B&E Uno sank
21-Feb-12	La Union	10,000 L	Leaking of the pipeline of MT Panglao
03-Apr-12	Polilo Island	10,000 L	Leaked in the generator of NPC's power source
17-Feb-13	Bolinao	10,000 L	M/V Harita sank due to engine trouble
08-Aug13	Manila Bay Cavite	500,000 L	Leaking of the pipeline of Petron Corporation
16-Aug-13	Mactan Channel	160,000 L	Collision of M/V St. Thomas & M/V Sulpicio causing the latter to sink

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09-Nov-13	Estancia Iloilo	800,000 L	NPC Power barge was dislodged from its mount due to Typhoon Haiyan
03-July-20	Iloilo Strait	264,949 L	A power barge owned by AC exploded
28-Feb-23	Naujan Oriental Mindoro	900,000 L	MT Princess Empress sank

Based on the report, the Western Visayas region has the highest number of oil spill incidents [5], [6], [9].

3.2 Sources and Number of Incidents of Oil Spill in the Philippines

Fig. 3 shows the sources of oil spills in the Philippines; leading sources are from vessels accounting for 55% of 305 vessels either sank due to weather conditions or collision. Other sources mentioned were manufacturing and industrial, refineries, terminals, depots, power barges or power plants, shipyards, oil exploration, offshore mining, and others [5].

Fig. 4 and Fig. 5 show the trends and number of incidents of oil spills in the Philippines; as shown in the line graph, the greatest number of incidents of oil spills occurred in the years 2008, 2018, and 2021, with thirty-six (36) incidents while the least number of oil spill incident happened in the year 2000 with only four (4) incidents [5], [6].

3.3 Impacts of Oil Spill

The impacts of oil spill pollution can affect or damage not only the coastal environment but also the socioeconomic status and health of human beings. Common impacts mentioned were loss of livelihood and income revenue of fisher folks and tourism, and significant damages to coastal areas, coral reefs, mangroves, and beach areas were also reported. Further, it contaminated marine life, including seagrasses, coral reefs, shellfish areas, and livelihood seaweed projects.

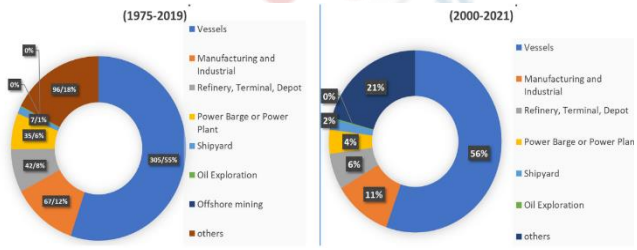

Fig. 3. Sources of oil spill from (a.)1975-2019 to (b.)2000-2021. (*Source: PCG records, from the National Operation Center for Oil Pollution).*

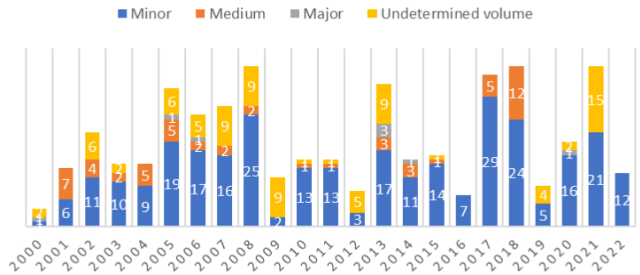

Fig. 4. Estimated volume and trends of oil spill incidence in the Philippines from 2000 to 2022.

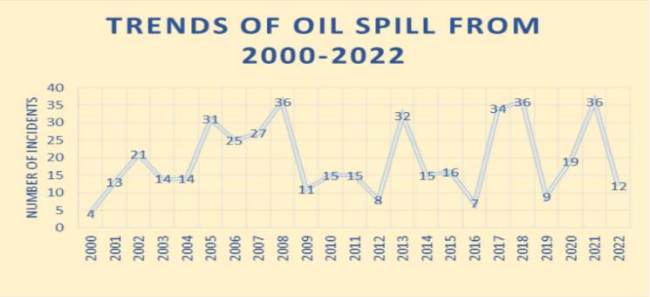

Fig. 5. Number of incidents of oil spill per year from 2000 to 2022.

Fig. 6. Impacts of the sinking of oil tanker MT Princess off the coast of Mindoro Island in the Philippines. (Source: Photograph by Francis R Malasig/EPA).

Report Health hazards that were noted or experienced among the exposed community were stomachache, dizziness, headache, cough, vomiting and watery stool, skin irritation, and mental health (anxiety and depression) as demonstrated in Table 2. [6] - [11].

Table II. *Impacts of Oil Spill* (*Source: PCG report, Philippine Inquirer News, Department of Environment and Natural Resources).*

Oil Spill	Population	Resources	Socio-Economic	Health
Semirara Island 2005	Approx. 184 families	40 sq.m of marine life	4.5 million pesos	stomachache dizziness

		(seagrasses, corals, and fish sanctuary) Mangrove: 236 ha	estimated costs of damage Seaweed	headache cough vomiting and watery stool, skin irritation
MT Solar Tanker 1 Guimaras 2006	7,870 families (39,004 people)	Fishpond: 823.5 ha DENR marine reserve: 1,143.5 ha Coastline: 245 km Mangrove: 1,128 ha Corals: 16 sq. km Seaweed plantation: 58 ha	3.95 million pesos estimated tourism revenue lost Php 9 billion pesos estimated economic loss	respiratory illness skin irritation stomachache dizziness headache cough vomiting and watery stool mental health (anxiety, depression)
MT Princess Empress 2023	42,487 families or 200,244 persons affected	Corals: 2,251.95 ha Seagrass: 1,040.66 ha Mangroves: 1,604.23 ha	4,918,287,957. 74 pesos production loss or cost of damage (Department of Agriculture) 6,727,298 pesos cost of damage to livestock, poultry, and fisheries, loss of income for fishermen, and loss of tourism revenue as swimming and other water activities are banned	Mental health (anxiety, depression) Contamination of sources of water Contamination of marine resources and decreased food sources.

Table III. *Definition of Tier Response (Source: National Contingency Planning Guidebook, PCG 2018).*

The volume of Oil Spill	**Tier**	**Response**
1 liter to 10,000 liters	I	An oil spill is small in magnitude and the affected area is local. The spill can be controlled by the spiller; no additional resources are needed. (eg. Smaller harbor spills and Relocation of fuel or bunker at a terminal).
10,001 to 1,000,000 liters	II	The spill is outside the limit of Tier I response, larger in magnitude, and needs additional resources such as public amenities and government resources. (eg. shipping incidents in ports/harbors, coastal water – pipeline or tank failures, or near-shore explorations and operation)
More than 1,000,000 liters	III	A spill with the largest volume can affect a large area and needs assistance and resources from the national government and international support. (eg. Large tanker accidents or offshore blowouts)

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3.4 Response Practices and Challenges

Response strategies are based on the tiered response concept, adapted from Net Environmental Benefit Analysis (NEBA). Factors that are considered are the spill's magnitude, location and extent, and number of resources needed to control and recover the spill. A description of Tier response is seen in Table 3 [5].

The Philippine Coast Guard (PCG) led the response operations with the assistance of Petron Corporation and international support in the oil spill that occurred in Guimaras Strait in 2006. Chemical dispersants were applied, and spray arms were mounted on tugboats and patrol vessels of PCG. Conventional and improvised booms such as banana leaves, bamboo, coconut husk, and rice straws were utilized to protect vulnerable areas and resources. Shoreline clean-up was done manually through scooping and conducted for three months. Oily waste was transported by small boats and was recycled at a cement plant on the island of Mindanao [9]. As seen in Table 4.

Challenges mentioned by the PCG during the oil spill response in Guimaras Strait in 2006 are limited resources, political pressure, and media attention. There was no proper waste storage of the collected debris from the spillage; it was temporarily stored in the nearby habitats of the community; others were stored in canoes and small pump boats while waiting for the next transport utilizing barges. Lastly, prolonged stay in evacuation centers among other villagers due to misinformation about health hazards requires further

Table IV. *Oil spill response strategies and challenges met* (*Source: Yender et. al, 2008, PCG accomplishment report, P. Nepomuceno, 2023).*

Oil Spill	Response	Challenges
MT Solar Tanker 1 Guimaras 2006	• The Philippine Coast Guard (PCG) led the response operation with the assistance of Petron Corporation.	• PCG has limited resources, and during the response, they experienced strong political pressure and focused media attention. • Oily waste was transported to Southern Guimaras to a cement plant in Northern Mindanao through barges with nine separate journeys. The temporary storage of the waste was on small pump boats and canoes. • One barge, unfortunately, sank while transporting waste. • . Several villages were forced to evacuate for an extended period due to misinformation about the health hazards posed by the oil leak, which also caused hardship for the social welfare department.[10]
MT Princess Empress 2023	• PCG vessels were deployed to respond to the oil spill incident • Manual scooping, use of oil skimmers, and deployment of absorbent booms were the methods used by the PCG to recover the oil spill. • Positioning absorbent, solid, and improvised booms to sensitive and vulnerable areas was also done.	During the incidence, no studies have yet been conducted to determine the challenges faced during the oil spill response in Mindoro.

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	• Report from the PCG last May 2023 stated that out of the 79.33 km (83.74 percent) of contaminated coastlines, approximately 66.433 km had been cleaned with only 12.89 km (16.26 percent) remaining for clean-up. • A total of 44,656.30 liters of oily water mixture, 648 1-tonner bags, 10,708 sacks, 997 drums, and 119 pails of contaminated sand/debris and oily waste were collected during the clean-up.

assistance from the government [9].

The recent oil spill incident in Mindoro 2023 has limited references to the challenges faced during the response and recovery of oil spills. Similar response and mitigation equipment were used, such as booms, skimmers, and dispersants. As seen in Fig. 7.

3.5 Sustainable Solutions

Consolidated solutions from other countries, reports, and studies. This paper utilized DOTMPLFSI analysis to determine solutions that could help mitigate and abate further damages brought by oil spills. The following

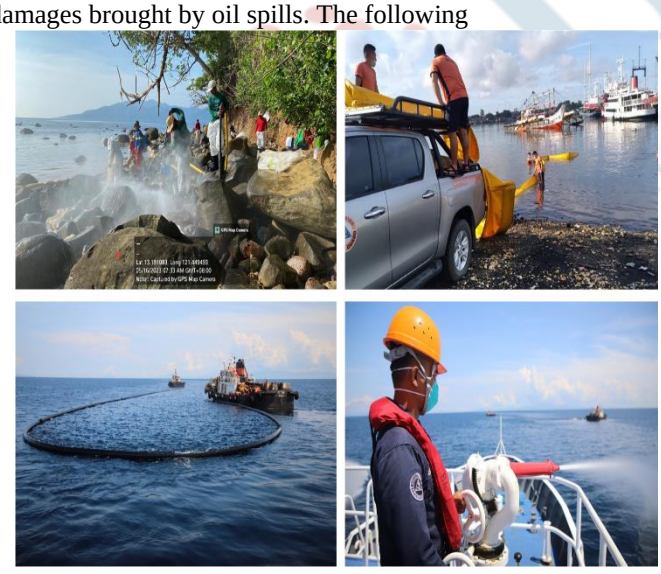

Fig. 7. Response Practices and Challenges. (Source: Philippine Coast Guard).

recommendations are as follows: a) review laws for stricter regulations and accountability on hazardous material vessels and routes; b) regularly conduct monitoring on ecosystems, water quality, and critical habitats; c) develop courses and training modules for personnel involved in oil spill operations; e) monitor materials, equipment, and vessels, and revisit logistics planning and purchasing to assess response capabilities [17]; f) propose ESI mapping using a Geographic Information System (GIS) approach to prioritize vulnerable areas, reducing oil spill impacts and minimizing losses and damages; g) implement modern oil spill trajectory modeling software to mitigate spill spread and damage [22]; h) identify personnel specializing in oil spill response, coordinate with non-government agencies, and establish buffers; i) implement leadership development programs, focus on structure, skillset, and mindset; and j) identify evacuation areas and equipment storage warehouses to prolong its shelf-life and operational capability.

IV. Discussion

Oil spills in the Philippines are inevitable due to the numerous islets that separate almost every region in the country. The National Government, PCG, Department of Environment and Natural Resources (DENR), Bureau of Fisheries and Aquatic Resources (BFAR), National Disaster Risk Reduction Management Office (NDRRMO), and the Local Government Unit (LGU) are responsible for the planning, response, recovery, and monitoring of oil spill incidence in the country.

The most devastating oil spill in the history of the Philippines was caused by the MT Solar I tanker, with an estimated volume of oil spill of 2,100,000 liters. Based on the report of the Philippine Coast Guard Board of Marine Inquiry (BMI), the captain failed to exercise attentiveness or diligence in ensuring that the tanker was seaworthy [12]. The Petron Corporation was also held liable for overloading the said tanker. It carried approximately 2,000 tons of intermediate fuel, which made the vessel stable, contributing to the sinking when it encountered strong winds and rough seas [13].

The main sources of oil spill incidence are the vessels, manufacturing industry, oil depots and refineries, power barge/plants, shipyards, oil exploration, and offshore mining. The causes of an oil spill can be due to collision, grounded,

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hazards to navigations, unseaworthiness of vessels, negligence and incompetence of the owner/operation, human errors caused by the Master or crew, improper lashing of cargoes, improper stowage, and aging of vessels at sea, presence of terminals and depots, size/type of vessel and operation, heavy vessel traffic [34]. Moreover, it can be brought about by the ship's movement and density, as well as tourist vessels and a concentration of fishing. The areas with high difficulty levels to safe navigation, trading patterns, volumes of oil carried as bunker fuel, frequency, and commercial cargo shipping size. The oil tanker's regularity, sizes, quantities shipped, and shipping routines. Properties of oil shipped as cargo, terminal/port design, type/amount of oil carried. Environmental factors such as sea conditions, including tidal flow, sea state, current, wind temperature, classification of shoreline, presence of oil terminal and depot, and capability and capacity of the response team [12], [13].

However, an unreported oil spill incidence came from Non-point sources, usually found in the estuaries and beach areas. It is observed that there are limited resources to contain the spread of oil spills; in most islands, there is no waste management plan and area to dispose of the collected spills, and limited manpower, and logistics. That is why most of the time when a major oil spill transpires, it will take time to respond and recovery period to the situation that causes more loss of income for fisher folks, loss of revenue from tourist spots, marine ecosystem destruction, respiratory and skin diseases, vomiting and seafood products contamination [8], [10]. The record showed that the major source of an oil spill is obtained from vessels, accounting for fifty-five and fifteen percent (55.15%) [5]. The impacts of the oil spill will affect the Socioeconomic, marine, and coastal environment and the mental health of humans.

The National Oceanic and Atmospheric Administration (NOAA) introduced the ESI mapping. It is described as a compilation of information that shows symbols and codes prioritizing highly vulnerable areas to oil spill pollution and serves as a guide in drafting contingency planning [19].

Several case studies were conducted utilizing Environmental Sensitivity Index (ESI) mapping as part of mitigation or strategic plans against oil spill pollution, such as South Sumatera Province in Indonesia, Cat Ba Island in Vietnam, Caspian Sea, Okhotsk Sea in Japan, Black Sea, and the Gulf of Thailand [25].

It is time to promote ESI mapping through GIS to all regions in the Philippines as a mitigation process in hampering the detrimental effects of oil spills in vulnerable areas. In the recent open forum, sustainable solutions can mitigate future oil spills more effectively. The methods above might effectively operate as a subsidy for the decision-makers concerning policy updates and modification or review of the current NOSCOP.

V. Conclusion

Based on data, there are a total of 17 major oil spill incidents in the Philippines from 1998 to 2023. The most detrimental was the incident at Guimaras Strait where MT Solar I capsized with an estimated >2,000m^3 vol. of oil spill/liter in 2006. Environmental factors such as sea conditions, including tidal flow weather current, wind temperature and sea state, type of shoreline, presence of oil terminal and depot, and capability and capacity of response team are vital elements in mitigating the spread of spill immediately. Vessels are the major source of oil spills. Oil spills could greatly affect the Socioeconomic status, marine and coastal environment, and mental health of humans if planning and immediate actions are neglected.

Fig. 8. Oil spill mitigation sustainable solutions.

Moreover, based on the review of the related works of the literature shows that the introduction of the ESI mapping with GIS approach supported by Synthetic Aperture Radar (SAR) images and modern oil spill trajectory model improves the NOSCOP in oil spill mitigation, detection, and monitoring. The oil spill mitigation sustainable solutions diagram is demonstrated in Fig. 8.

VI. Recommendations

This paper suggests focusing on the DOTMPLFSI analysis as presented in Table 5 and the following recommendations to immediately mitigate or decrease the spread of oil spills to vulnerable areas:

(a). Examine how the National Oil Spill Contingency Plan is currently being implemented. Propose extensive restrictions and accountability standards for vessels transporting hazardous products, power plants, barges, and shipyards responsible for the oil spill [17], [32].

(b). Conduct regular assessments of the marine environment or ecosystems, and monitor water quality and critical habitats in oil-spilled areas [32].

(c) Improve the management of maritime or shipping routes and marine protected zones to prevent overlapping and

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stop similar occurrences of oil spills in the future [32].

(d) Promote the development of environmental sensitivity index mapping using a geographic information system approach. This will help in protecting vulnerable areas and will serve as a guide on how to go about the response in the event of an oil spill [32]. A complete infographic poster of the study is well presented in Fig. 9.

Table V. *DOTMPLFSI Analysis.*

Doctrine	Review laws for implementation for more stringent regulations and accountability on hazardous material vessels and routes.
Organization	Meetings and collaboration among agencies should be done yearly to provide updates on the assessment of ecosystems and monitor water quality, and critical habitats in oil-spilled areas.
Training	Define the Identification of courses and training modules that could develop the skills of the personnel directly involved in the oil spill operations. These pieces of training will include the technicality in operational usage of the modern oil spill modeling system.
Material	Regular monitoring of materials, equipment, and vessels that are specialized for oil spill operations. Logistics planning and purchasing should be revisited yearly or quarterly to monitor and assess the capability to respond to oil spills First.
Personnel	Identification of personnel specialized in oil spill response, coordination with non-government agencies and community that will serve as a buffer in case the spread of spill is uncontrollable.
Leadership Development	Leadership development programs that will focus on structure (rules, procedures, and instruments for making decisions), skillset (technical knowledge and behavioral standards), and mindset (self-awareness, recognizing that attitudes and beliefs affect actions and behaviors).
Facility	Identification of evacuation areas for families that necessitate shelter during recovery of oil spill operations. Warehouse for storage of equipment to prolong the shelf-life of operational status.
Sustainability	Propose the development of ESI mapping with a Geographic Information System (GIS) approach through the use of the modern modeling system which could aid in prioritizing areas that are vulnerable to detrimental impacts of oil spill.
Innovations	Provide innovative solutions by introducing a modern oil spill trajectory modeling system and the practice of modern application software for ESI mapping with a GIS approach that could immediately abate the spread of oil spills and mitigate further losses and damages.

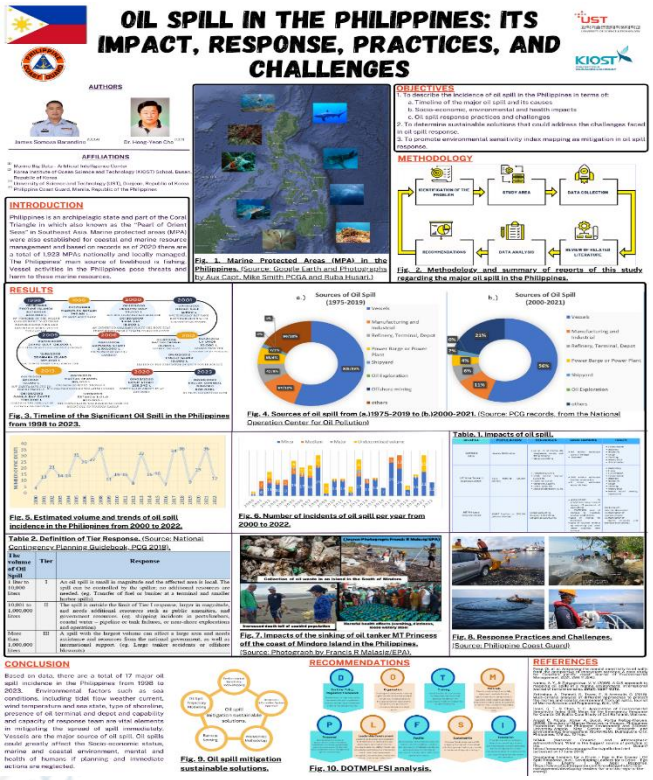

Fig. 9. Infographics| Oil Spill in the Philippines: Its Impact, Response, Practices, and Challenges.

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