

# The Environmental Risks Posed by the Oil and Gas Development and Its Potential Impacts on Mangrove Ecosystems and the Coastal Community's Well-Being

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## Abstract

Guyana is an oil-producing country with oil and gas exploration and production operations approximately 190 km offshore. The coastal communities selected as the study areas in Region 1 and Region 2 are adjacent to the coast and 5 to 10 km inshore. In the event of oil spills, Shell Beach Protected Areas and the other selected communities will be negatively impacted, particularly the mangrove ecosystems and the community's well-being. The research aims to investigate the potential environmental risks posed by oil and gas exploration and production activities. It followed a qualitative approach and employed semi-structured interviews with the Toshaos of the coastal communities. The data analysis strategy was thematic analysis using the Nvivo software. The major themes included community assets, the importance of mangrove ecosystems, and the impacts of mangrove ecosystem damage through oil spills. Oil spill pollution will negatively impact mangrove ecosystems and the coastal community well-being in Region 1 and Region 2. The major results include damage to cultural artefacts, saltwater intrusion of major creeks, reduced fish catch levels, and agriculture products, which are the main economic activities in the selected communities. Consuming contaminated agriculture and marine products will lead to adverse health problems. Mangrove ecosystems provide considerable benefits to coastal community residents, including shields against river bank erosion, natural habitats for wildlife and

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source of income, shared traditions, social values, recreational facilities, and tourist attractions. These benefits contribute to the overall coastal community's well-being. The mangrove forests must be protected and conserved to avoid environmental damage.

## Keywords

Biodiversity, Carbon Credit, Guyana, Health, Oil Spill

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## 1. Introduction

The coastal communities often struggle with numerous environmental challenges that negatively affect their socioeconomic lives. Diverse environmental challenges are related to oil and gas development, particularly exploration and production activities (Aung, 2017; Alemzero et al., 2021; Mejjad et al., 2022; Jeremiah et al., 2023). Offshore oil and gas exploration and production posed particular environmental challenges, such as oil spills caused by unplanned incidents. Oil spills may result in biodiversity loss and damage to mangrove ecosystems in coastal communities along the seashores (Cahyaningsih et al., 2022). These pollution consequences directly impact residents' livelihoods in coastal communities (Andrews et al., 2021; Adejobi, 2022) and similarly affect mangrove ecosystem services such as fisheries and coastline defence (Lopes et al., 2022). Negative environmental and health consequences often result from pollution by an oil spill during production or exploration and consumption stages (Henry et al., 2022). Examples of the negative impacts include flooding of coastal communities, damage to local economies, and threats to coastal residents' health and well-being (Andrews et al., 2021; Booi et al., 2022; Henry et al., 2022); pollution of air, water, soil, wildlife food sources, and other food sources (Karri et al., 2021; Manisalidis et al., 2020; Njoku et al., 2021) and diverse effects on rural communities' uniqueness and values (Kamat et al., 2019; Onyena & Sam, 2020; Malin & Kallman, 2022; Henry et al., 2022).

Guyana's biodiversity provides an essential basis for poverty reduction, enabling economic development and improvement in areas such as agriculture, forestry, and fisheries, compensation for forest climate services, and community-centered products in indigenous communities (Felipe Pérez & Tomaselli, 2021; Montambault & Missa, 2002). The creeks in the forest provide an abundant supply of fresh water for the Amerindian communities. Loss of biodiversity, habitats, and ecosystems such as mangrove ecosystems and any disturbances in providing ecosystem services would negatively impact the standard of living in the coastal communities and the economy (Lewis & Rosales, 2020; Nie et al., 2023).

The mangrove ecosystem service benefits include nurseries for juvenile fish, shrimps, and crabs (Li-Ying et al., 2022); provision of fresh water from creeks and rivers, medicines from local plants, raw materials from mangrove plants,

food, wild fruits, and fiber resources (Titumir & Paran, 2022; Mpelangwa et al., 2022) stabilization of the coastlines and protection of coastal communities from flooding and hurricane devastation (Le Xuan et al., 2022); sequestration of carbon dioxide (Ray & Jana, 2017); regulation of water services (Martin et al., 2022); ecosystem recreation and cultural heritage (Bimrah et al., 2022); supporting spiritual nutrition, educational improvement, and tourism (Holly et al., 2022).

In addition to threats to Guyana's biodiversity from climate change, threats specifically targeting mangrove forests include 1) challenges associated with offshore oil and gas exploration and production, particularly oil spills and other chemicals into the water (Henry et al., 2022) and 2) reduction of the mangrove ecosystems peripheral to the Region as a result of various human activities (Gonguet et al., 2021). An oil spill, deliberate or not, or illegal degassing, will result in the potential impacts and the widespread degradation of mangrove ecosystems and the coastal community's well-being, which could be difficult or even impossible to recover. Such an oil spill will thus likely cause, to varying degrees, negative environmental, socioeconomic, and health impacts (Ferreira et al., 2022; Nwaichi & Osuoha, 2022) on the coastal community's well-being. For instance, oil spills could limit the ability of mangrove forests to prevent erosion. They may eventually lead to floods (Palit et al., 2022) and thereby contribute to the destruction of important cultural artefacts. The mangrove forests serve as cultural symbols and artefacts; their destruction due to potential oil spills may lead to these communities losing important cultural elements.

Henry et al. (2022) present that Nigeria's Niger Delta, Indonesia's Balikpapan in 2018, and Brazil's north coast in 2019 have experienced the loss and degradation of mangrove ecosystems by pollution caused by several oil spills. In Nigeria, the impacts of oil spills included oil coatings on aerial and immersed roots from direct immersion, oil coatings on leaves, and submerged roots impeding salt exchange, upsetting soil chemistry and absorptivity. Oil could also interrupt salt exchange and decrease the time to absorb nutrients, causing the death of mangrove forests. These impacts resulted in the death of mangrove forests. Indonesia has experienced rapid loss and degradation of mangrove forests. Brazil also experienced negative impacts on 55 Marine Protected Areas, coastal ecosystems, and deadly effects on organisms in mangrove habitats.

Henry et al. (2022) present that Nigeria, Indonesia, and Brazil have collectively experienced negative impacts on the coastal community's well-being. These included impacts on socio-culture, such as changes in value systems, loss of aesthetic values, and unemployment. Health impacts included the death of fishermen, nausea, ingestion of polluted seafood, skin irritation, and limited access to coastal communities' health facilities. Livelihood structure's impacts included separating families seeking employment and reducing agricultural production. Further, there were tangible social, economic, and cultural impacts that affected the livelihoods of villagers. Their unique cultural history, traditional practices, and value systems are undercut and uprooted by the uncaring and exploitative

extractive industry elites (Kamat et al., 2019). Economic impacts included loss of tourism revenue and reduced harvest of farming.

In Nigeria's Niger Delta, the problem of oil spills has extensive consequences that need urgent attention. The harmful effects have resulted in irreparable environmental damage and many disadvantaged people (Ikhumetse et al., 2022; Egbe & Ikhumetse, 2022). Therefore, taking immediate measures to avert future occurrences while mitigating their impacts is essential. A critical analysis of this issue revealed several factors contributing to oil spills in the region, including unsatisfactory regulation by government agencies, corporate negligence by multinational firms operating in the area, and limited community participation in environmental matters (Crayton & Naher, 2023). These factors caused significant health problems such as respiratory diseases and skin rashes that impacted residents living near affected areas. Social challenges such as economic dislocation lead to the loss of livelihoods for fishing communities who depend on healthy ecosystems for subsistence. Consequently, more funding is required for research concerning new systems for cleaning contaminated environments effectively while encouraging sustainable practices within petroleum extraction activities (Udoh & Willard, 2023). There is a need for a more significant collaborative effort from governments at various levels and international organizations and working with communities for long-term solutions.

Indonesia's Balikpapan oil spill in 2018 adversely impacted the region's environment and socioeconomic conditions (Purnaweni et al., 2022). Moreover, wildlife suffered from exposure to toxic substances found in crude oil; coastal communities lost their livelihood due to pollution's negative impact on fish stocks and tourism revenue; and inadequate response efforts further worsened conditions on-site. A critical analysis of these consequences identified vital factors that intensified the disaster's destruction. The analysis revealed that oil spills have extensive implications beyond immediate environmental damage (Cahyaningsih et al., 2022). Consequently, there is an urgent need for collective intervention from all stakeholders to address future catastrophes effectively. Governments should take greater responsibility by ensuring better regulations before oil exploration (Bulandari et al., 2022). International oil companies must also be accountable for their actions.

Furthermore, proactive measures such as emergency response plans should be prepared instead of relying solely on reactive approaches after events strike. The participation of local communities is vital since they have often been affected most adversely (Purnaweni et al., 2022). The awareness campaigns will help educate them about potential hazards so they can take appropriate preventive measures. Consistent monitoring and assessment will enable better preparedness if similar incidents occur globally.

The oil spills that occurred off the north coast of Brazil in September 2019 have caused extensive harm to the environment, economy, and nearby communities. This spillage severely impacted marine life and ecosystems, while the

fishing industries and tourism faced financial losses. Furthermore, individuals residing in affected coastal areas had health problems due to exposure to harmful chemicals from the oil spill (Ferreira et al., 2022). The critical analysis revealed that better regulating and instituting contingency plans for managing such environmental disasters is crucial (Barbeiro & Inojosa, 2022). Oil companies should be accountable for their actions and adhere to adequate safety precautions to avoid future incidents. Additionally, providing support and compensation for those who suffered immediate and long-term consequences because of these events is vital. Therefore, proactive measures must be taken to prevent or mitigate such occurrences. Sustainable practices must be applied positively across all industries impacting our environment to safeguard the delicate balance between natural systems for future generations (Bastos Lima & Da Costa, 2022; Souto & Batalhao, 2022).

There has never been an offshore oil spill incident in Guyana. However, in the case of the oil spills in the countries above with the same tropical conditions and mangrove forests, Guyana will experience similar negative impacts related to the loss and degradation of mangrove ecosystems and the coastal community's well-being. This paper, therefore, seeks to address the research question:

1) Why is it important to address the environmental risks posed by the oil and gas development in Region 1 and Region 2 of Guyana?

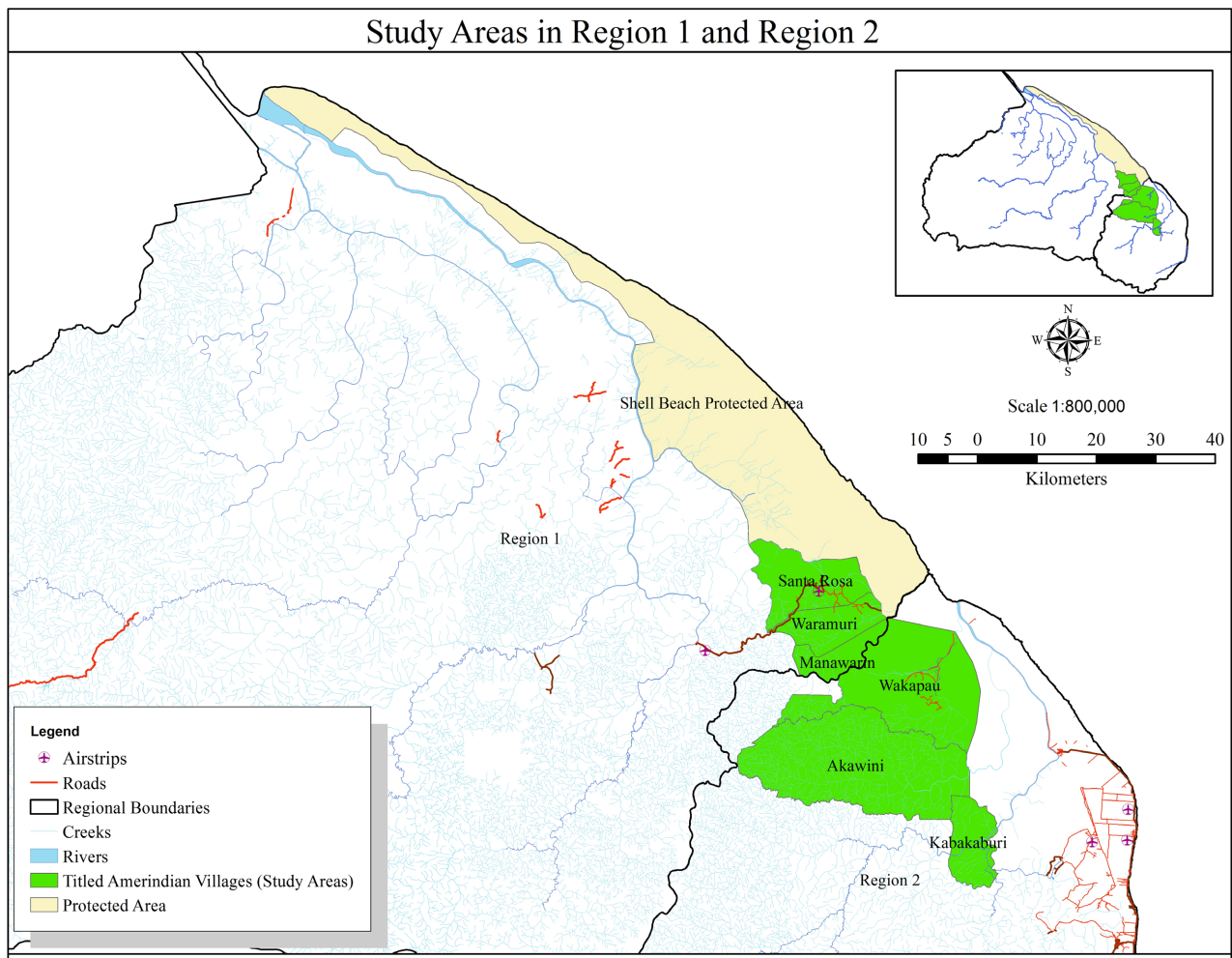
## 2. Materials and Methods

The research methods employed in this study involved qualitative data analysis. It aimed to interpret and analyse environmental risks posed by oil spills and their potential impacts on mangrove ecosystems and coastal community well-being in Regions 1 and 2, from the inhabitants' point of view. The data collection instrument employed was semi-structured interviews (Striepe, 2021), and the qualitative data analysis was thematic analysis using the NVivo software (Castleberry & Nolen, 2018). The findings from the field were contextualised with other published works.

### 2.1. Study Areas

The study areas selected were coastal communities in Region 1 (Barima-Waini) and Region 2 (Pomeroon-Supenaam). These two regions offer a unique perspective to explore the research question. The indigenous populations in the far-flung coastal areas of Regions 1 and 2 depend on various coastal resources for subsistence and livelihood. In Region 1, the study areas shortlisted are directly adjacent to the coast: Shell Beach, Santa Rosa, Waramuri, and Manawurin, located 5 to 10 km inland (Figure 1). Fishing and crabbing are predominantly done at the westernmost end of Shell Beach and on a smaller scale at the eastern end of Shell Beach (Blaha, 2017).

Region 1 (The Barima-Waini) is mainly forested highland, bordered north by a narrow strip of the low coastal plain. It has a population of 27,643 people



**Figure 1.** Study areas in Region 1 and Region 2.

living primarily in Amerindian settlements. The Region's coast, Shell Beach Protected Area, has a stretch of 120 km of beach and an area of 123 000 hectares. Shell Beach has a nesting site for four endangered sea turtle species, Leatherback, Green, Hawks Bill, and Olive Ridley, threatened with extinction by fishermen, turtle hunters, and plastic pollution.

It comprises the primary mangrove forests and Guyana's most intact diverse ecosystems. The vast mangrove forests offer nurseries for diverse fish species (Protected Areas Trust (Guyana), 2022), with fifty-nine species recorded in Shell Beach (Figure 1). This protected area is an internationally significant birding area that nests more than 200 migratory bird species. It is the only coastal protected area supporting these communities' livelihoods (Protected Areas Trust (Guyana), 2022).

Shell Beach Protected Areas is governed by the Protected Area Act 2011 (Parliament of Guyana, 2022a). It protects and conserves Guyana's natural legacy and natural resources through a broad network of protected areas. It establishes the Protected Areas Commission to oversee the management of this network. It

promotes the international importance of maintaining ecosystem services and encourages public participation in protected areas and conservation (Blaha, 2017).

In Region 2 (Pomeroon-Supenaam), the study areas are Akawini, Wakapau, and Kabakaburi (Figure 1). These Amerindian settlements are involved in various natural resource-based activities comprising agriculture, fishing, crabbing, shrimping, hunting, logging, mining, palm harvesting, and natural medicine harvesting on the coast. Region 2 (Pomeroon-Supenaam), which comprises forested highlands and a low coastal plain, has a population of 46,810 people. The main economic activity is rice farming for local consumption and export (Blaha, 2017).

Potential oil spills reaching the coast would hurt the supply of resources. The coastal communities in Regions 1 and 2 are highly dependent on the coastal habitats and have limited accessibility to substitute food, especially in Region 1. In mangrove forests and swamps alongside the coast, species like fish, crabs, and caiman, which provide protein for the indigenous people, could be severely affected (Blaha, 2017).

## 2.2. Governance Structure of the Coastal Communities

The governance structure of the indigenous villages in Regions 1 and 2 and the other indigenous villages in Guyana is in line with the stipulations in The Amerindian Act of 2006 (Parliament of Guyana, 2022b). The Act provides for the recognition and protection of the constitutional rights of Amerindian villages and communities, the accordancy of land to Amerindian villages and communities, and the establishment of good governance within Amerindian villages and communities (Parliament of Guyana, 2022b).

The National Toshias Council (NTC) is a semi-autonomous body, including all Toshias in Guyana. It has an executive committee including one Toshao from each of the ten administrative regions of Guyana. This body's responsibilities include promoting good governance in the villages and protection, conservation, and sustainable management of natural resources (Department of Public Information, 2019).

The community leadership is acutely aware of their duties and responsibilities, composition, and councils' powers to make rules, investigate breaches of these rules, and impose fines. The Toshias are Justices of Peace (Parliament of Guyana, 2022b), possess the powers of a rural constable, and ensure order in the community. Having interviewed each Toshao, it was clear these village leaders understood their responsibilities and were committed to working within a democratic framework to ensure the best possible outcomes for their communities. They demonstrated a vast knowledge of the terrain regarding geography and the people's aspirations. They were remarkably in touch with all matters currently impacting or likely to impact their community with outstanding tenacity. They demonstrated similar resolve, as characterised by their determined effort, to

continuously uplift their communities individually and as neighbouring communities.

Toshaos and the Council must ensure order in the community (Parliament of Guyana, 2022b). The vibrant and well-informed Community Councils manage all the villages, with between four (4) and twenty (20) community councilors who are democratically elected (Parliament of Guyana, 2022b). This number is generally proportional to the population size. The Community Councils are responsible for developmental projects, including water and energy supply, boats and engines, tractors, and other agricultural and developmental equipment. The communities received subventions from the government for developmental projects and money from the sale of carbon credit (Department of Public Information, 2022; Guyana Times, 2023; Gordon, 2023) to boost sustainable developments and communities' livelihoods.

### 2.3. Study Participants

The target population for this study was coastal community leadership, specifically the Toshaos of the indigenous coastal communities, with in-depth knowledge of their communities' environment, governance, and socioeconomic issues (that is, in Regions 1 and 2 of Guyana).

The participants' ages ranged from 30 to 60+ years, with working experiences directly in the environment, governance, and socioeconomic issues affecting the indigenous communities. Two (2) participants were teachers in addition to being farmers. However, all seven (7) participants interviewed were farmers of more than 20+ years. There is a great sense of commitment to the livelihood and well-being of their communities since farming and living off the natural land is their primary source of income and means of survival. Each participant was assigned a pseudonym, Participant (P)1 through Participant (P)7, to maintain their confidentiality and privacy in this study. Table 1 presents the pseudonym details of the 7 participants for this study.

The study's objectives were presented to all participants, and informed

**Table 1.** Participant's pseudonym details.

Participants' Code	Employment status	Region	Interview duration (Hour: Minute: Seconds)
P1	Toshao/Farmer	Region 1	01:40:32
P2	Toshao/Farmer	Region 1	01:34:40
P3	Toshao/Farmer/Teacher	Region 1	01:35:20
P4	Toshao/Farmer	Region 1	01:35:50
P5	Toshao/Farmer	Region 2	01:39:30
P6	Toshao/Farmer/Teacher	Region 2	01:40:15
P7	Toshao/Farmer	Region 2	01:30:10



consent was obtained from each participant through the signed letters of approval by the Community Councils to conduct the study.

#### 2.4. Sampling Strategy

In qualitative research, the researcher's samples are often chosen purposely, not randomly (Hendren et al., 2023). It permits researchers to choose participants based on pre-established criteria related to the research topic. These criteria include knowledge of the research topic, familiarity with the communities' governance structure, and conversant with environmental and socioeconomic issues arising from the oil and gas exploration and production activities (Alòs-Pereñíguez et al., 2022). These criteria improve the data collection (Mize & Manago, 2022). Based on the criteria above, a purposive sampling approach was adopted (Knott et al., 2022; Dunwoodie et al., 2023), and seven (7) participants were selected for this study.

#### 2.5. Data Collection

This study's primary data collection technique included face-to-face semi-structured interviews with 7 participants from the selected communities as the study areas. These communities are located adjacent to the coast and 5 to 10 km inland and could be negatively impacted by an oil spill incident. Consequently, the participants/Toshaos were interviewed because their communities are most vulnerable to the negative impacts of an oil spill incident. Semi-structured interviews were used with open-ended questions to collect data on governance structure, environment, and socioeconomic issues that could affect their communities during oil spills (Amghar, 2022).

Data collection in qualitative research contains selecting and structuring verbal data to analyse and understand problems and peoples' relevant experiences (Filliettaz et al., 2022). The data collection included archival documents and policy documents, which were subsequently interpreted (Hintz & Quigley, 2022). The techniques used to support the trustworthiness of the research comprised triangulation for cross-validating participants' answers and follow-up interviews for unclear answers (Hull & Whittal, 2023).

The EVISTR Digital Voice Recorder, interviews, field notes, archival documents, triangulation, and member checking were used to collect data. Rechecking the journals (diary of events during the fieldwork, especially the interviews), rechecking field notes (these are notes taken during the interviews), and replaying audio recordings assist the authors in becoming intimate with the data and subsequently connecting deeply with the research processes (Ningi, 2022). The use of field notes, transcripts, and audio recorders can complement each other to strengthen the results and trustworthiness of data (Jensen et al., 2022; Williams, 2022).

The data collected from all interviews and follow-up telephone conversations for clarifications (Byrne, 2022) were triangulated to produce reliable data. Further, a document was written based on the participants' responses and sent to

them for approval. In addition, steps such as allowing participants to review results, check for alternative explanations, and verify with more data sources were taken to avoid bias in the data collection (Knott et al., 2022).

## 2.6. Data Analysis

This study's data analysis strategy was thematic analysis, allowing researchers to analyze vast amounts of data collected from interviews, field notes, recordings, documents, and literature (Lassell et al., 2022; Osman et al., 2022). The thematic method underscores the systematic construction of the data, theoretical views, and perceptive elucidations from participants, documents, and literature. According to Robinson (2022), thematic analysis is the apposite method for recounting critical details of vast data. It coerces the researcher to use a methodical style for data analysis, creating a succinct and expressive interpretation and results. A similar study by Qin (2022) reveals that thematic analysis is used in qualitative research to analyze themes and construe the data's meaning.

The qualitative data analysis was conducted in the NVivo software version 20 to aid in the process of thematic analysis. Nvivo is a qualitative data analysis software that aids researchers in analyzing collected data from interviews, focus groups, field notes, open-ended survey questions, and documents (Dark et al., 2022). The advantages of the Nvivo software include efficiency in time, transparency, capturing of mixed data, and accommodating rich and large quantities of data (Harnois & Gagnon, 2022). On the other hand, the disadvantages of NVivo include that it is time-consuming for users to use the application and expensive for users to use (Dollah et al., 2017).

The six-step process of thematic analysis proposed by Clarke and Braun was followed in analysing the collected data from the semi-interview question responses. The six-step process of thematic analysis proposed by Clarke and Braun was followed in analysing the collected data from the semi-interview question responses. The six steps of the Nvivo software comprise familiarization, coding, generating themes, reviewing themes, naming themes, and final write-up (Clarke & Braun, 2018; Fryer, 2022).

1) Familiarisation involves reading the interview transcripts multiple times to be acquainted with the participants' overall feelings, perceptions, and opinions regarding the phenomenon under investigation. It also involves the researcher taking notes for reference during the thematic coding and generating themes (Clarke & Braun, 2013; Braun et al., 2022).

2) The coding process involves identifying the relevant codes and assigning names based on their meanings (Braun et al., 2022).

3) The generating of themes involves themes that contain information relevant to this study's objectives and are kept while the rest are excluded. These are placed in categories based on the similarities in meanings.

4) The review of themes generated determines two things. First, to determine whether each theme had a central organizing idea different from the rest. Second,

to determine whether each theme contained information that directly answered the research questions outlined in this study.

5) Names are assigned to each category of codes with similar meanings. The names are assigned based on the meaning of information conveyed by the categories forming that theme.

6) A report was generated to present the findings of the qualitative data collection and analysis (Clarke & Braun, 2018; Fryer, 2022).

### 3. Results and Discussion

Several themes emerged from the responses provided during the interviews and their analysis. The qualitative data analysis obtained seven major themes. The themes include community assets, the importance of mangrove ecosystems, the potential impact of mangrove ecosystem damage due to human activities and climate change, the potential impact of mangrove ecosystem damage through oil spills, the potential impact of coastal communities' well-being damage through oil spills, community subvention and payment from carbon sale to Amerindian communities. **Table 2** shows the summary of the major themes and sub-themes.

**Table 2.** Summary of themes and sub-themes used for analysis.

Theme	Sub-theme
Community assets	Collective community work Benefits of community assets Types of assets including natural capital, cultural Capital
Importance of mangrove ecosystems	Mangrove ecosystems prevent river bank erosion Mangrove ecosystems serve as habitat for wildlife Mangrove ecosystems' source of income alongside government stipends
Potential impact of mangrove ecosystem damage due to human activities and climate change	Damage to the environment caused by coastline erosions Damage to the environment caused by saltwater intrusion
Potential impact of mangrove ecosystem damage through oil spills	Damage to mangroves by oil spills may result in damage to cultural artefacts Death of mangroves disrupts biodiversity
Potential impact of coastal communities' well-being damage through oil spills	Economic problems of reduced production and increased poverty Adverse health effects
Community subvention	Insufficient subvention Financial contribution to the community
Payment from carbon sale to Amerindian communities	Government payment from carbon sale credit

## The Importance of Addressing Environmental Risks Posed by Oil and Gas Development in Region 1 and Region 2

### 1) *Community assets*

The first theme was community assets. This theme received the most excellent support from all seven participants compared to the other themes. They stated that their communities have various assets that benefit the residents. These assets include forests, rivers, creeks, animals, wildlife, farmlands, swamps, agriculture products, lumber, infrastructure, roads, trails, community playgrounds, buildings, equipment, skilled personnel, artisans, and social groups, shared traditions, shared identity, and attractive tourist sites. The participants shared similar perspectives and summarised the community assets in their responses aligned with natural capital, cultural capital, human capital, social capital, political capital, and built capital assets.

These coastal community's assets are aligned with Jan Flora and Cornelia Flora's asset framework, which focuses primarily on the community's assets rather than community needs and shortages. These assets may be underutilised but can be capitalised to generate more support (Green & Haines, 2015; Mattos, 2015; Mueller et al., 2020). The community asset framework includes:

a) The natural capital includes a community's environment, rivers, creeks, lakes, forests, wildlife, soil, weather, and aesthetic qualities of natural resources.

b) Cultural capital promotes creativity and innovation and influences voices heard and listened to, including traditions, heritage values, and a robust work ethic.

c) Human capital includes the knowledge and skills villagers acquire through external training in various areas such as education, health, skills, and youth development. Human capital enhances leadership's ability and assists community leaders in decision-making that benefits the communities.

d) Social capital includes the collaboration among people and organizations that fortify community cohesion and maintain the links among organizations and communities (Mattos, 2015; Mueller et al., 2020).

e) Political capital is the ability to encourage standards, adherence to rules, regulations, and related enforcement. It allows access to power for government officials and community leaders.

f) Built capital supports the community in telecommunications, roads, bridges, water, and sewer systems. It focuses on community development collaboration (Green & Haines, 2015; Mattos, 2015; Mueller et al., 2020).

The welfare of the coastal communities is determined by collectively recognising the benefits of their community assets combined with apposite leadership, which is structured and organized to deliver the best possible service to residents. This requires a considerable degree of community awareness based on constant assessment, evaluation, and adjustments wherever necessary (Green & Haines, 2015; Kavanagh et al., 2022).

### 2) *The importance of mangrove ecosystems*

The second theme was the importance of mangrove ecosystems. Several themes

were obtained from the qualitative data, each focusing on a specific element of the importance of the mangrove. Themes covered under this category include mangrove systems as shields against river bank erosion, mangrove ecosystems serving as the natural habitats for wildlife, and mangrove systems as sources of income. Each theme is discussed below:

*Mangrove forests as shields against river bank erosion:* The first theme under this category was that mangrove ecosystems act as shields against river bank erosion. The mangrove plants' roots keep the soil intact or hold it together along the banks of rivers and riverain creeks (Phan & Stive, 2022). This theme received support from all seven participants. For instance, P6 indicated that in their community, mangrove forests had served the important role of preventing erosion alongside river banks and riverine creeks banks in their community.

The core idea behind ecosystem services is that ecosystems provide a wide range of services that benefit humans in a multiplicity of ways (Millennium Ecosystem Assessment (MEA), 2005; Meacham et al., 2022). The services offered in this study are mangrove vegetation's ability to prevent or reduce erosions. Notably, mangrove vegetation provides a canopy that reduces the intensity of falling raindrops, thus effectively preventing splash erosion (MEA, 2005; Qiao et al., 2023). The mangrove forests also help reduce floods that could harm human life and survival. The canopy formed by forests provides a water catchment surface, thus lowering the amount of run-off that could result in floods (Egoh et al., 2012; Sklenicka et al., 2022). Thus, mangrove forests in Regions 1 and 2 are important for preventing erosion and reducing floods that could negatively affect the communities in these regions.

*Mangrove ecosystems serve as the natural habitats for wildlife:* The second theme under this category was those mangrove ecosystems serve as the natural habitats for wildlife (Iqbal & Mozahid, 2022). Six of the seven participants contributed to this theme, highlighting the importance of mangrove forests located in the coastal parts of Regions 1 and 2 as sources of natural habitat for wildlife. Three participants (P2, P5, and P7) indicated that mangrove ecosystems provide shelter and serve as habitats for fish, shrimps, crabs, snails, turtles, nesting homes for birds, and many other species.

From the biodiversity and ecosystems perspective, an ecosystem is essentially a complex and interconnected network of organisms that interact with each other and the environment (Cadman et al., 2010; Javanmardi, 2022). Thus, organisms within the ecosystem affect each other directly and indirectly. By serving as sources of habitation for wildlife, mangrove forests benefit community residents residing in Regions 1 and 2.

*Mangrove ecosystems as sources of income alongside government stipends:* The third theme under this category was that mangrove ecosystems are important assets to the communities living in Regions 1 and 2 as they serve as sources of income. When asked to indicate their source of income, all seven participants mentioned that the mangrove ecosystems are part of their income sources. However, many participants lamented that more than the income generated from the

ecosystems alone is needed; hence, they rely on the government's stipends. For instance, P6 stated:

*“Our source of income includes money from sales of lumber, coconuts, cassava, fish, wild meat, hunting, and craftwork. However, the money does not amount to any profit. The government offers a G.Y. \$45,000.00 or U.S. \$200.00 stipend monthly, which is used to supplement the income from the sales of local produce.”*

P4 also indicated that part of their income comes from selling agricultural produce: *“Income comes from the money from sales of coffee production, peanut, red peas, and cassava production. However, these products are for subsistence and do not amount to any reasonable profits.”*

P4 added, *“The government offers a G.Y. \$45,000 stipend to supplement the income”* P1 also responded similarly, indicating that a small part of their income comes from money from sales of *“coconuts, cassava, vegetables, wildmeat, fish”* P1 also indicated that the money does not amount to any profit and is just meant *“for survival”* P3, like P6, indicated that mangrove ecosystems provide income through the sale of lumber, farming, pineapple, fishing, hunting, and cassava production.

The minimum wage for workers in Guyana is G.Y. \$60,147.00 or U.S. \$300.00 per month. The monthly stipend is about 75% of the minimum wage. The stipend received is less than the minimum wage. As such, the leaders depend on income from the sale of agricultural products. Notably, the findings indicate that ecosystems provide natural capital humans can use to sustain their livelihoods. For instance, [Cadman et al. \(2010\)](#) and [Alemu \(2022\)](#) stated that ecosystems provide natural capital, which supports several socioeconomic activities and sustainable development that empower human communities to shape sustainable livelihoods and accomplish a satisfactory quality of life. [Egoh et al. \(2012\)](#) & [Morgan et al. \(2022\)](#) argue that ecosystems provide resources humans can harness to generate income. Consequently, the mangrove ecosystems in Regions 1 and 2 serve as important sources of capital, which the residents harness to generate income by farming and fishing.

### ***3) Potential impact of mangrove ecosystem damage through human activities and climate change***

The third theme focused on the consequences of coastline erosions and salt-water intrusion.

*Coastal erosion:* The first theme under this category was coastline erosions caused by human activities and climate change. Four participants contributed to this theme. P1 stated that they had lost a large portion of land and farm products due to the problems of coastal erosions and flooding.

*“Coast erosion threatens the mangrove plants and our crops, like coconuts, cassava, and vegetables. But mainly coconuts. The coconuts harvest is reduced because the land is washing away due to erosions.”*

P3, P6, and P7 shared similar experiences, indicating that the land was washing away, severely threatening our daily lives. The erosion caused flooding to the

farms, which reduced crop production. As a result, the coconut trees were destroyed, and crop production was reduced. A large expanse of mangrove forests and their ecosystems were damaged. Fish, birds, and other animals migrated to other parts of the mangrove forests. The families had to migrate to other villages for their safety.

The natural causes included wave erosion, sea level rise, and flood, but human activities are most responsible for the accelerated coastal land loss. The sea level rise enhances ocean dynamics and contributes to shoreline erosion and seawater intrusion (Dong et al., 2022). Nguyen & Takewaka (2020) posit that the collective effects of land subsidence and relative sea level rise contribute to coastal erosions. Similarly, Dada et al. (2019) and Alves et al. (2020) posit that the change in offshore submarine geomorphology due to natural processes and human activities results in significant and extensive muddy shoreline erosions, as evident along Shell Beach and Waini Beach. The coastline erosions resulted in the destruction of mangrove forests and the merging of muddy water with the freshwater at the mouth of the estuaries.

*Saltwater intrusion:* The second theme under this category was a saltwater intrusion in the study areas. Three participants contributed to this theme. P3, P6, and P7 shared their experiences where three major creeks have saltwater intrusion during the dry seasons, starting from the Pomeroun River Mouth and leading into the creeks. As a result, fish, animals, and plants die. Villagers usually fetch fresh water from the other villages to cook and drink. This phenomenon has occurred for the past five years.

The animals and plants in salt marshes differ from those in fresh marshes. Both human activities and natural forces create conditions allowing saltwater intrusion (Dhal & Swain, 2022). The dredging and excavation of navigation channels and oil field canals in the wetlands produce open channels through which salt water can easily infiltrate deep into freshwater or low-saline environments (Chala et al., 2022). Freshwater vegetation cannot tolerate these saltier conditions and die. As the plant roots are no longer there to hold soil in place, erosion occurs. Tidal action, storms, subsidence, and rising sea levels can hasten erosion (Nordio & Fagherazzi, 2022).

#### **4) *Potential impact of mangrove ecosystem damage through oil spill***

The fourth theme focused on the consequences of damage to mangrove ecosystems through oil spills. The key themes covered under this category include damage to cultural artefacts and the death of mangrove ecosystems that would disrupt biodiversity.

*Damage to Cultural Artefacts:* The first theme under this category was that oil spills cause damage to cultural artefacts (Ikhumetse et al., 2022; Egbe & Ikhumetse, 2022) when they damage mangrove ecosystems. All seven participants contributed to this theme in various ways. For instance, P6 indicated that oil spills would not only damage the mangrove forests but also destroy the beautiful environment that forms part of a robust cultural heritage: “*Some cultural problems include shared tradition and heritages, social values, religious practices, re-*

*creational facilities and damage to our naturally beautiful environment*” All the other six participants held similar observations.

According to Mondal et al. (2022), ecosystem resources attract tourism, with a community’s unique culture, thus helping communities generate income. Examples of resources that may form part of a community’s culture include wildlife, waterfalls, rivers, and forests. Mangrove ecosystems in Guyana are an important part of the coastal communities’ culture in Regions 1 and 2.

The Wai Wai community in Guyana recognised the significance of biodiversity, mainly through the culture, recreation, education, and ecotourism that biodiversity provides. These help the community promote a sustainable development plan for their community (Conservation International Guyana, 2010; Begg et al., 2022). For instance, the community attaches meaning to certain animal and plant species, which makes these ecological resources an integral part of their culture. In the coastal communities of the sampled regions for this study, the mangrove ecosystem allows the residents to remain connected with their culture. Any damage to the mangrove ecosystem would lead to the destruction of these important cultural artefacts.

*Death of mangroves disrupts Biodiversity:* The second theme under this category was the death of mangrove forests disrupting biodiversity. One of the primary effects of oil spills in mangrove ecosystems is the death of mangrove forests and subsequent disruption in biodiversity (Palit et al., 2022). Participants explained how mangrove forests could die from potential oil spills. All the participants explained that when oil spills occur, the oil clings onto the roots of mangrove vegetation, thereby blocking the absorption of water and minerals and resulting in the death of the mangrove forests. For instance, P1, P4, and P6 shared similar views that oil could destroy plants’ roots and stems and kill birds and animals.

These findings are consistent with knowledge existing in the literature regarding how mangrove ecosystems are affected by oil spills. For instance, Duke (2016) and Nomani et al. (2022) contended that oil spills are responsible for destroying thousands of acres of mangrove forests in coastal regions. According to Duke (2016) and Okeke et al. (2022), crude oil pollutes the roots and leaves of these mangrove forests, thus preventing these plants from effectively absorbing oxygen and taking up carbon dioxide.

##### ***5) Potential impact on coastal communities’ well-being through potential oil spills***

The fifth theme was the potential impact on coastal communities’ well-being through oil spills. The key themes covered under this category include economic problems of reduced production, increased poverty, and adverse health effects.

*Economic problems of reduced production and increased poverty:* This theme received support from all seven participants, who contended that reduced production is due to damaged mangrove ecosystems, which reduces income from sales and food available for consumption (Das et al., 2022). The direct result is a



rise in poverty rates. P1 indicated fishermen complained of reduced fish catch due to offshore oil and gas activities. P2, for instance, indicated that damage to mangrove ecosystems reduces the amount of fish caught for subsistence and commercial purposes. P2 also contended that damage to mangrove systems reduces ecotourism revenue. P4 also held that damaged mangrove ecosystems lead to increased poverty and reduced agricultural production: “Livelihood problems include increased poverty, increased crimes, reduced agricultural production, damage aquatic fishing ponds.” P7 further indicated that damage to mangrove ecosystems directly impacts the availability of food for consumption: “scarcity of food supplies and migration of families, anglers, and farmers moving to seek employment.”

Noise from seismic activities has been acknowledged as a source of pollution that can scare marine life and wildlife, mainly fish and birds (Lott, 2022). The participants stated that wildlife has migrated, and the fish catch has reduced in the communities. There were reports in the media that fisherfolk complained of the reduced fish catch in Regions 1, 2, 3, 4, 5, and 6. As such, they were unable to sustain their family’s livelihoods. Due to the hard time experienced by the fisherfolk, the Government of Guyana distributed a G.Y. \$150,000 or U.S. \$680.00 one-off relief grant to all the fisherfolk across the country (INEWS Guyana, 2022).

While ecosystems provide goods and services that humans depend on for daily survival, they become degraded through various human activities. The degradation of ecosystems reduces their capacity to provide enough goods and services that humans depend on (Useh et al., 2017; Raimi et al., 2022). Although ecosystems are sometimes resilient due to their ability to heal from past disturbances and return to equilibrium, persistent degradation may result in a permanent shift in the equilibrium (Olatunji et al., 2018; Falk et al., 2022). For instance, persistent logging and destruction of forest cover may eventually result in desertification (Useh et al., 2017; Kaspa, 2022). In the context of this study, disturbances to the mangrove ecosystems through potential and possible persistent oil spills may also lead to the degradation of these same systems. Since communities residing in Regions 1 and 2 depend on these ecosystems’ goods and services for survival, degradation of these ecosystems would result in adverse socioeconomic effects such as food scarcity and increased poverty levels. There is adequate evidence to conclude that Regions 1 and 2 may face adverse economic effects of food scarcity and increased poverty levels because of possible oil spills, which would significantly affect the regions.

*Adverse health effects.* The participants indicated that potential oil spills would pollute mangrove ecosystems and could also affect agricultural products generated in these ecosystems (Ikhumetse et al., 2022; Egbe & Ikhumetse, 2022). Consumption of these products may thus result in health effects such as cancers, liver diseases, and skin diseases. For instance, P5 stated that consuming polluted seafood might result in health problems such as nausea, dizziness, skin rashes,

breathing difficulties, cancers, and liver diseases. All other participants also held similar views.

Li et al. (2022) suggest that escalating global anthropogenic activities have influenced the planet in recent decades through the substantial impacts of nascent environmental pollution and climate change. These disturbances will impend the well-being of humans, plants, and animals and necessitate researchers and international community intervention. Similarly, Xu et al. (2022) posit that environmental pollution may result in various health problems for humans, and public health crises could indicate the offensive threat of pollution occurrences. The toxicological studies and other related ones could also provide vital data on the possibilities of the toxic compounds triggering adverse health outcomes.

Numerous health effects from the pollution of mangrove ecosystems through oil spills have been recorded in past literature. For instance, Masli (2018) and Jha & Dahiya (2022) indicated that consuming contaminated food at various levels in the mangrove ecosystems may lead to more health problems, such as vomiting and nausea. In another study, Upton (2011) and Hossini et al. (2022) held that people who come into direct contact with or consume foods polluted through oil spills or smoke might develop various health issues, such as breathing difficulties and stomach complications. Crude oil has also been classified as a possible carcinogen to humans, which implies that frequent consumption of food polluted through oil spills may catalyse the development of cancers in humans (Zhang et al., 2019; de Melo et al., 2022). Additionally, oil spill aftermaths are often characterized by clean-up exercises, which expose humans directly to oil and gas fumes, which may further increase the chances of developing health complications such as cancers and liver diseases (Zhang et al., 2019; Jha & Dahiya, 2022).

#### **6) *The community subvention***

The sixth theme category involved participants who were requested to give an amount of a direct financial contribution to the community from their subvention. The participants reported that the villages receive a yearly grant of G.Y. \$1,000,000.00 or U.S. \$5,000.00 for smaller communities and G.Y. \$2,500,000.00 or U.S. \$12,500.00 for larger communities. Participants considered these allocations inadequate, considering the projects and problems that must be addressed.

The potential oil spill could negatively impact mangroves and other vegetation and pollute flora and fauna's natural habitats. The village leaders across Regions 1 and 2 vacillated on the issue of quantifying an amount they would be willing to forego from their subvention to make a direct financial contribution to community efforts related to the potential negative impacts of an oil spill. The participants believe that ExxonMobil-Guyana should compensate for the potential damage to mangrove ecosystems and the adverse impact on the communities' well-being (Purnaweni et al., 2022).

Despite the inadequate subvention, four participants contributed to this theme. The collective perception of contributing money from their subvention towards deterring potential impacts on their communities by accumulating booms

and other mitigation equipment was remarkable. For instance, they underscored that the subventions were already inadequate and pointed to the fact that ExxonMobil is obligated to make adequate allocations for protective and defensive mechanisms in the event of an oil spill. They stated that the spending on projects is restricted, they must prioritise the community's interest, and ExxonMobil Guyana should compensate the community for environmental damage. Four Toshaos offered to contribute an average of G.Y. \$180,000 or U.S. \$900.00 to purchase clean-up gear and mitigation equipment for their communities.

It is outstanding that these participants are willing to give up a small portion of their subvention to deal with the consequences of any potential impacts of an oil spill negatively impacting their community's well-being. This positive behaviour of the participants underscored the importance they placed on their community's sustainable development and well-being.

**7) Payment from carbon sales to Amerindian communities:** The seventh theme was payments from carbon sales to Amerindian communities. All the participants reported that the government has committed to giving funds from the sale of Guyana's forest carbon credits to Amerindian communities. P1, P3, and P4 stated that the communities would receive 15 percent from the sale of carbon credit and emphasised that government funds would benefit their communities and promote sustainable development and livelihood. P2, P5, and P7 shared similar views and stated, "We are happy for the money that would help in the sustainable development, protection, and conservation effort of our forests and mangroves."

The Guyana government and Hess Corporation (ExxonMobil Guyana) signed an agreement to sell the country's carbon credits, US\$112 million, to benefit Amerindian communities (Department of Public Information, 2022). The Guyana government has committed to giving a total of G.Y. \$4.7 billion (US\$22.5 million), which is 15 percent of US\$150 million for the sale of Guyana's forest carbon credits to Amerindian communities (Guyana Times, 2023). The communities will receive between GY\$10 million to GY\$35 million payments, based on their population and size (Chabrol, 2023). The communities can disburse the funds into projects that promote sustainable development and communities' livelihood.

#### 4. Policy Implications

The critical challenges to coastal communities include mangrove ecosystem degradation, and anthropogenic chemical pollution, which disrupt the ecological equilibrium of the coastal communities (Cahyaningsih et al., 2022). Accordingly, the residents' well-being (Andrews et al., 2021) in coastal communities is impacted by the disruption of mangrove ecosystem services, including damage to cultural artefacts, reduced fish catch, and coastline protection (Nyangoko et al., 2022), prevention of flood and economic problems of reduced production and increased poverty (Gozie Ogbodo & Umadia, 2023). Further, oil extraction-related

impacts include adverse health effects should Guyana suffer an unmitigated oil spill offshore, which could pollute mangrove ecosystems and affect agricultural products (Ikhumetse et al., 2022). Consumption of these products may thus result in health effects such as cancers, liver diseases, and skin diseases in coastal communities and adjacent rural areas (Xu et al., 2022).

The relevant legal framework policy institution will undoubtedly prevent the degradation and loss of mangrove forests. Consequently, a robust legislative framework incorporating efficient mangrove policy management must be established. This framework will involve the relevant organizations, stakeholders, mangrove ecosystems, and other related ecosystems (Bell-James et al., 2023; Rakotomahazo et al., 2023).

## 5. Conclusion

This study examined the importance of mangrove ecosystems, the environmental risks posed by oil and gas development, and the potential impacts on mangrove ecosystems and the coastal communities' well-being in coastal Regions 1 and 2 by an unmitigated oil spill. The importance of data to this study was reiterated by providing specific details on data collection and the tools to gather, store, and analyze data. The mangrove ecosystems serve as a natural habitat for wildlife in Regions 1 and 2. Participants raised important benefits of the mangrove essentials based on the interviews, including mangrove systems as natural habitats for wildlife and mangrove systems as sources of income. Mangroves contribute significantly to the enhancement of the economy and the general standard of living of the Amerindian communities. For example, the Amerindian communities received money from the sale of carbon credit, a novel finding of this study. This is a historic and significant milestone achievement for developing sustainable livelihoods and protecting forests in their communities.

Healthy and correctly maintained mangrove forests have numerous environmental benefits and must be preserved, protected, maintained, and restored as required. This would reduce the incidence of environmental degradation, including plants, agricultural products, and domestic and wild animals.

Participants raised aspects regarding the consequences of damage to mangrove ecosystems through oil spills. These included the destruction of cultural artefacts, coastline erosions, death of mangrove ecosystems that disrupt biodiversity's health, contributing to adverse economic effects due to lower production, increased poverty rates, reduced fish catch, and adverse health effects from consumption of contaminated food. The seven participants indicated that the beautiful and natural environment shared traditions and heritages, social values, religious practices, and recreational facilities would be destroyed. Future research should be conducted to increase awareness of the valuable services mangroves offer coastal communities to protect and conserve mangrove ecosystems and provide mitigation strategies to efficiently manage the negative impacts of human activities on the mangrove ecosystems.

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## Declaration of Competing Interest

The authors have declared no conflicts of interest.

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