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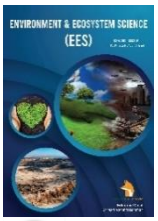

RESEARCH ARTICLE

SHIPBREAKING YARD AND ITS THREAT TO COASTAL AQUATIC AND TERRESTRIAL BIODIVERSITY: AN ENVIRONMENTAL IMPACT ASSESSMENT IN SITAKUNDA, BANGLADESH

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ABSTRACT

The rapid growth of shipbreaking yards in Sitakunda, Chattogram, Bangladesh, has raised concerns about its environmental and biodiversity impacts. This study examines the environmental flow and vulnerability of coastal ecosystems due to expanding shipbreaking activities, utilizing satellite imagery, historical data, and field observations. The industry's growth has led to significant major changes, with forests and agricultural land being transformed into shipbreaking yards, resulting in deforestation and habitat destruction. Multi-temporal Landsat imagery from 1989–2024 tracks this expansion, revealing an increase from 367 hectares in 1989 to over 5,600 hectares in 2024. The shipbreaking process, which occurs on the intertidal zone, releases hazardous pollutants like oil, chemicals, and heavy metals, degrading soil, water, and air quality. These disruptions have harmed marine and terrestrial biodiversity, especially affecting fish and aquatic habitats. The findings highlight the need for effective environmental management and policy interventions to mitigate the ecological damage. Recommendations include a sustainable ship recycling fund, environmental impact assessments, and stricter regulation enforcement. This research emphasizes the importance of balancing economic growth with ecological preservation in the shipbreaking industry.

KEYWORDS

Shipbreaking; Biodiversity; Environmental flow; Degradation; Water

1. INTRODUCTION

Bangladesh is located within the world's largest delta system, with a coastline stretching 710 km (Azad et al., 2009; Masum and Hasan, 2023). The largest coastal region of Bangladesh is not only a crucial habitat for diverse species but also a lifeline for approximately 30 million people who call it home (ESCAP, 1987; WARPO, 2004). The livelihoods of coastal residents are deeply intertwined with agricultural field, fisheries including shrimp farming, forestry and salt production, manufacturing industries with infrastructure development, and the tourism sector (CZP, 2005). Agriculture is the predominant land use in the country, occupying approximately 59% of the total land area, while rivers and other water bodies account for around 9% (Billah, 2023). The deep reliance of both humans and wildlife on coastal ecosystems highlights their significance, which cannot be overstated (Vardar and Harjono, 2002; Martinez et al., 2007). The region is ecologically diverse, featuring critical terrestrial and aquatic ecosystems such as mangrove forests, tidal floodplain, and both seasonal and perennial wetlands (Tomaselli et al., 2012). Each of these habitats contains distinct micro-environments that support diverse biological life, making the coastal ecosystem exceptionally important for maintaining biodiversity. These ecosystems also provide essential environmental goods and services that directly benefit human communities (Beaumont et al., 2007). However, the coast of Bangladesh faces significant threats from both natural and human-induced factors (MEA, 2005; CZP, 2005). This region is extremely susceptible to severe natural disasters, including cyclones, storm surges, and floods (McGranahan et al., 2007). Additionally, erosion, salinity, waterlogging, and pollution of soil and water resources further exacerbate the region's challenges (YPSA, 2011). Addressing these vulnerabilities is critical to safeguarding both the ecological integrity and the livelihoods that depend on this dynamic coastal environment.

Ship breaking, the process of dismantling and cutting down decommissioned vessels to recover scrap metal, is a common practice along the coast of Bangladesh. This activity releases various pollutants in liquid, gaseous, and solid forms (Hossain and Islam 2004; Islam and Hossain 1986; Zou and Wei 2010). The shipbreaking industry is primarily located along the extensive coastline of Sitakunda in Chittagong, where vast stretches of the seashore serve as a hub for dismantling decommissioned vessels. The shipbreaking industry in Bangladesh began to flourish in 1984, and since then, the country has become home to one of the largest shipbreaking hubs in the world. The rapid growth of this industry has been driven by the high national demand for iron, significant revenue generation, and employment opportunities for thousands of low-income workers. However, despite its economic benefits, the industry poses a serious threat to the coastal environment, causing severe ecological disruption. Multi-temporal remotely sensed data are used to monitor land cover changes, providing an accurate method to assess anthropogenic impact on the environment. Remotely sensed method serves as a powerful tool for assessing changes across different spatial and temporal scales (Chilar, 2000). Satellite-derived spatial and temporal data archives serve as a valuable resource for monitoring land use and land cover changes (USGS, 2011). Reliable and up-to-date land use information is crucial for effective environmental and ecological planning, as it significantly influences terrestrial ecosystems and contributes to advancing sustainable development goals (Wulder et al., 2007; Alphan, 2003). The shipbreaking industry poses a significant threat to the surrounding natural environment due to the improper disposal of

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hazardous waste from dismantled ships. Without an effective waste management system, toxic materials are released and dumped into nearby areas, leading to severe pollution of the soil, air, and water. This contamination endangers both terrestrial and marine biodiversity. Additionally, deforestation occurs as trees are cleared to make space for expanding recycling operations, further amplifying the industry's environmental impact. The once-pristine and biodiverse intertidal coastal areas of Sitakunda, Chittagong, have experienced severe environmental degradation, largely due to the unregulated ship-breaking activities. Despite the severity of the issue, research on coastal pollution caused by ship-breaking remains limited. To navigate the challenges we encountered, we took a more passive approach in our investigation, focusing on the following objectives:

- To analyze the trends in Sitakunda's shipbreaking activities and compare them with other countries using various data sources.
- Tracking about 35-year expansion of shipbreaking yards using temporal Landsat imagery.
- This study aims to document the degradation of environmental flows along the Sitakunda coast and its impact on biodiversity. By assessing the extent of flow disruption and its ecological consequences, we seek to highlight the challenges facing local ecosystems and contribute to informed conservation efforts.
- Based on the insights gained from these activities, develop practical strategies to transform ship-breaking operations into an environmentally sustainable and economically viable enterprise.
- Based on the insights gained from these activities, develop practical strategies to transform ship-breaking operations into an environmentally sustainable and economically viable enterprise.
- This research also brings together the findings of various researchers into a single platform, providing a comprehensive overview of environmental impacts.

2. Materials and Methods

2.1 Study area

Sitakunda is an upazila located within the Chittagong district of Bangladesh. This region lies in the southeastern part of Bangladesh and features a series of parallel hill ranges extending in a NNW-SSE direction (Billah, 2024). The shipbreaking industry in the country is primarily concentrated in the Barabkunda to Bhatiary region, which lies within Sitakunda (Abdullah et al., 2013). The strategic position of this region, situated at 22º37'99" N and 91º33'05" E, is further emphasized by the distinct curved form of the Bay of Bengal, has played a significant role in the growth and development of shipbreaking activities (Kutub et al., 2017). The industry is situated along the Bay of Bengal's shoreline, just to the west of the Dhaka-Chittagong Highway. This stretch of coast hosts the majority of the country's shipbreaking yards, which are clearly marked in red on the accompanying map (Figure 1). The area has an annual temperature variation between 32.5°C and 13.5°C, receiving around 2,687 mm of rainfall each year.

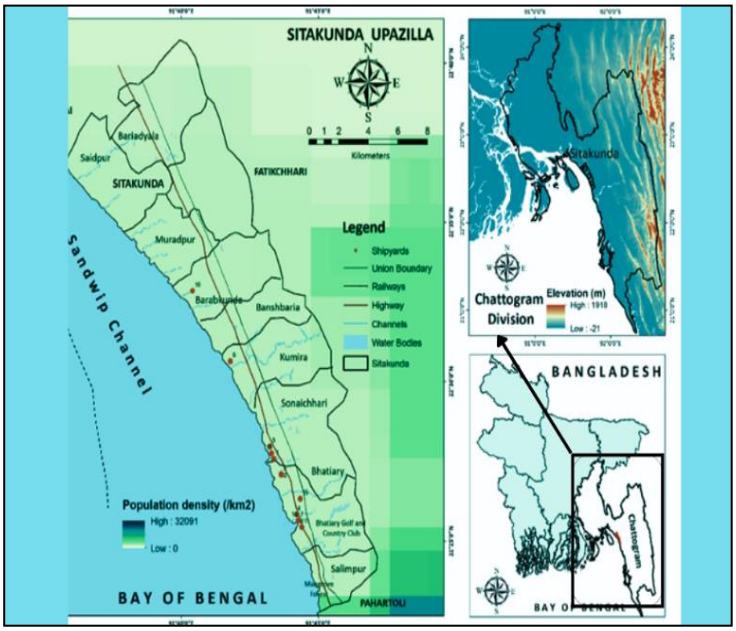

Figure 1: The location map of the ship breaking yards in Sitakunda Upazila

2.2 Landsat imagery and data acquisition approach

Landsat imagery, sourced from the Earth Explorer database, was utilized to assess shifts in land use and land cover (LULC) across the study area over a span of 35 years, from 1989 to 2024 A supervised classification procedure (Table 1 and Figure 2) was employed to quantify these LULC changes. Data regarding shipbreaking activities were primarily gathered from secondary sources, as no field visits were conducted. Key sources referenced include well-known journal publications, Clarkson's Ship Register, Lloyd's Register of Ships, the monthly shipbreaking reports by the Cotzias Group (NCSG 2024), and the Department of Environment's (DOE) 2007 report on Bangladesh's Coastal and Marine Environment.

For mapping land use, an object-based supervised classification technique was applied to Landsat TM satellite images. Reference data for validation were collected from field surveys and high-resolution images from Google Earth. Four land use categories were identified: agricultural land, forested areas, open beaches, and marine zones. A range of classification scales (2, 5, 10, and 20) were evaluated, with a scale of 5 providing the best results. The values for shape factor and compactness were set at 0.2 and 0.4, respectively.

Table 1: A comprehensive information about the imageries

Year	Acquisition Date	Satellite	Sensor	Path	Row	Source
2024	2024/02/03	Landsat 8	OLI/TIRS	137	044	USGS Landsat Level-1
2010	2010/03/03	Landsat 7	ETM	137	044	USGS Landsat Level-1
1999	1999/03/24	Landsat 7	ETM	137	044	USGS Landsat Level-1
1989	1998/03/04	Landsat 5	TM	137	044	USGS Landsat Level-1

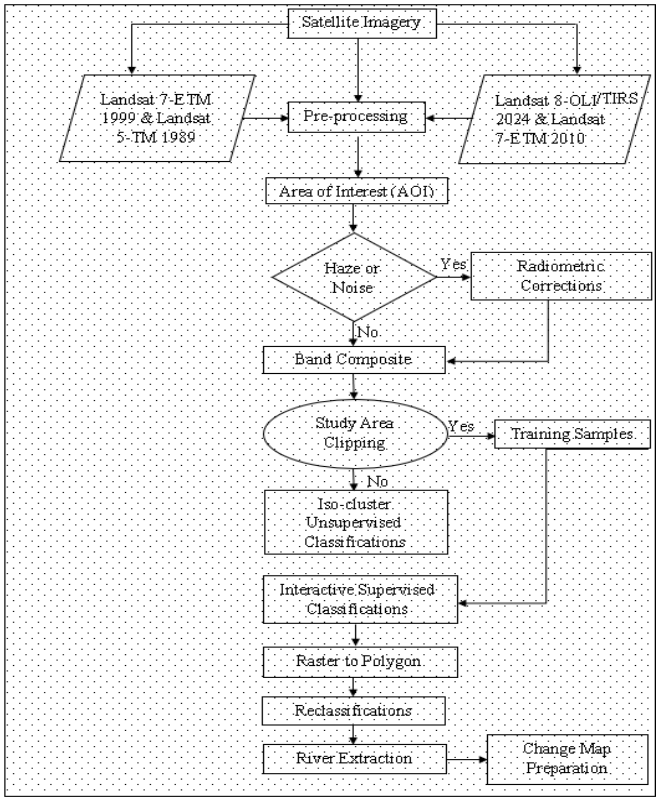

Figure 2: The whole working procedure flow chart

2.3 Statistical analysis

All data were processed in MS Excel 22 version to calculate average value. To evaluate the LULC over the study area was identified by ArcGIS 8. All these research parameters were evaluated and compared with EQS (Environmental Quality Standard) set in the Environmental Conservation Rules, 1997 (ECR, 1997).

3. Results and Discussion

The environment coast of Bangladesh has faced significant degradation due to the growth of the shipbreaking industry over the past two decades. The current operational practices of the industry are disorganized, outdated, and pose serious risks to both human health and the environment. Shipbreaking activities are commonly quantified in Light Displacement Tons (LDT), which represents the weight of a ship excluding its cargo. LDT is a key factor in determining the value of a ship for scrapping. As the financial worth of ship dismantling rises the fueled by low labor costs the industry expands, which in turn accelerates environmental damage.

The ship recycling industry in Bangladesh plays a key role in South Asia's industrial development, contributing to about 25% of the world's LDT processed in Sitakunda. This positions Bangladesh as the second-largest ship recycling nation (figure 3), following Turkey. In Sitakunda, the shipbreaking process takes place on the coastline, where around 90% of the ship is submerged in the intertidal zone, with its bow often resting on the beach. This arrangement increases the likelihood of oil spills and other forms of pollution, which are difficult to manage. While a dry dock system could help in containing liquid pollutants, it has yet to be implemented. The most pressing environmental concern continues to be pollution from oil and similar substances, especially in coastal marine regions. This includes the mishandling of oil-contaminated drilling muds, cuttings, and oil spills, all of which present serious threats to marine ecosystems (Gbadebo et al., 2009).

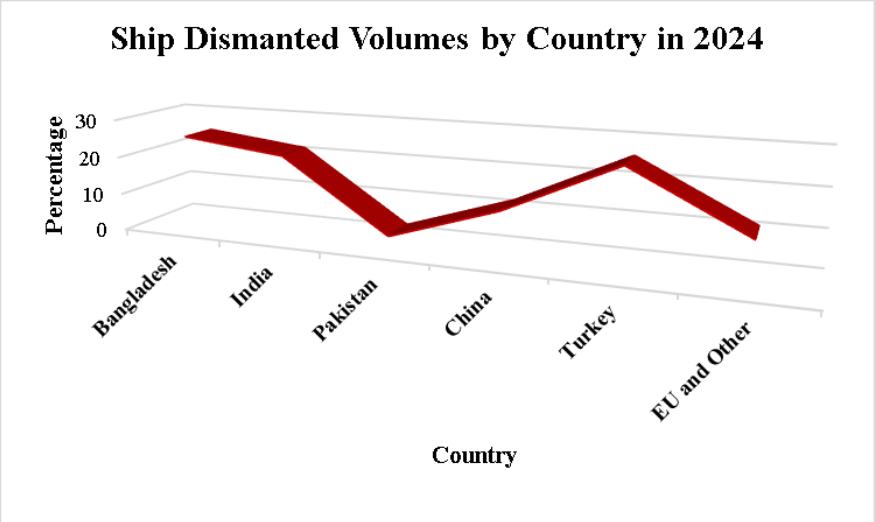

Figure 3: Worldwide ships dismanted total percentage (NGO, 2024)

3.1 The Effects of Ship Breaking on Coastal Ecosystems and Land Use in Sitakunda

The coast of Bangladesh is highly susceptible to both natural forces and human activities (MEA, 2005; CZP 2005). Recently, the environmental impacts of shipbreaking industries in the region have raised significant concerns. In Sitakunda, ships are dismantled in the intertidal zone, an area with low-lying beaches, releasing a range of pollutants including liquids, gases, and solids (Demaria, 2010; Hossain and Islam, 2004; Islam and Hossain, 2010; Zou and Wei, 2010). Preventing oil spills and other types of

contamination, both liquid and solid, is practically impossible. As a result, coastal soil, water, and biodiversity have become severely degraded due to these unregulated activities. With the increasing influx of oil tanker recycling to Sitakunda, more chemical pollutants are being introduced into the coastal environment. The extent of habitat degradation is not speculative; satellite imagery clearly shows these changes (Figure 4). Figure 5 indicates that the construction of new ships has led to deforestation to provide easier access to the open sea, and agricultural lands have been converted into shipbreaking yards. The circled areas provide clear evidence of this environmental transformation. The rapid growth of the shipbreaking industry in Bangladesh can be attributed to low dismantling costs, weak enforcement of laws, and inexpensive labor.

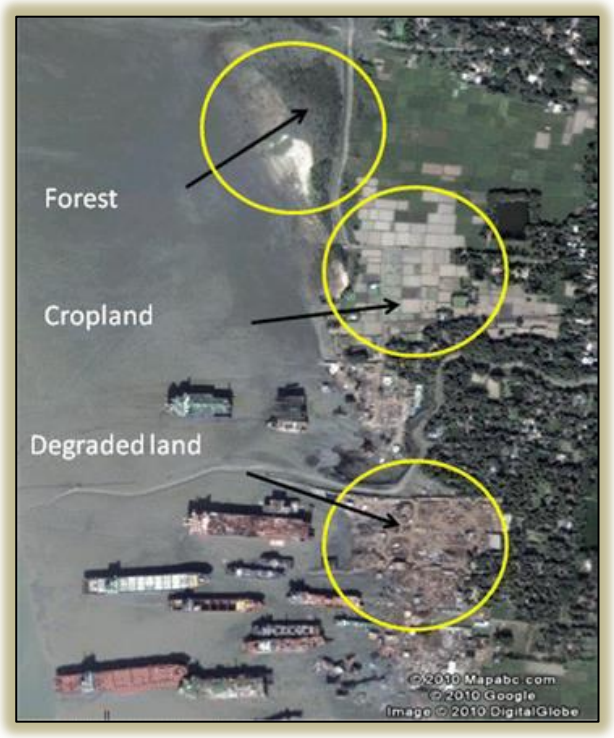

Figure 4: The deterioration of coastal areas caused by ship recycling, including forests, agricultural land, and other degraded areas, is highlighted by the circular markers (image source: Google Earth).

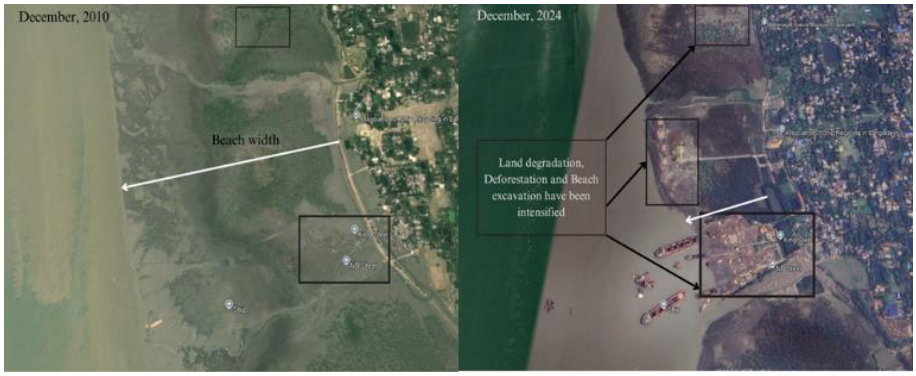

Figure 5: The rectangle in the image (source: Google Earth) illustrates the destruction of forests due to the establishment of new shipbreaking yards.

The shipbreaking yard grew significantly, expanding from 3.45 km in 1989 to about 30 km by 2024 (Table 2 and Figure 6). The impacted area in Sitakunda's coastal environment, initially covering 367 ha in 1989, expanded by an additional 5,600 ha, 1,500 ha, and 890 ha in 2024, 2010, and 1999, respectively (Table 2). Figure 7 illustrates land use and coastal changes in Sitakunda over several decades, specifically in 1989, 2010, and 2024. These maps, produced through supervised classification of Landsat imagery, underscore the growth of shipbreaking operations and their environmental consequences. A notable increase in cleared beach areas by 2024 is evident compared to 1989. Coastal agricultural and forested regions have decreased, while the area occupied by the shipbreaking yard has expanded, with large ships now being dismantled. It is anticipated that shipbreaking yard expansion will continue.

In 1989 to 2010 shows the shipbreaking yard expanded significantly, replacing forested and agricultural land. The red areas (open beach) grew noticeably along the coastline, indicating increased land clearance. Agricultural land (yellow) and forest cover (green) declined, making way for ship breaking yards expansion. 2024 analysis is the latest classification map which provides a more detailed view, incorporating "New Beach" (light yellow), "Vegetation" (green), and "Waterbodies" (blue). These trends highlight the ongoing growth of shipbreaking activities in Sitakunda, contributing to deforestation and significant changes in land-use patterns. This analysis underscores the need for sustainable coastal management to mitigate further ecological degradation.

Table 2: Total land-cover data illustrates the extent of the impacted area.

Year	Area (ha)	Length (km)
1989	368	3.4
1999	893	6.9
2010	15,00	12.78
2024	56,00	30

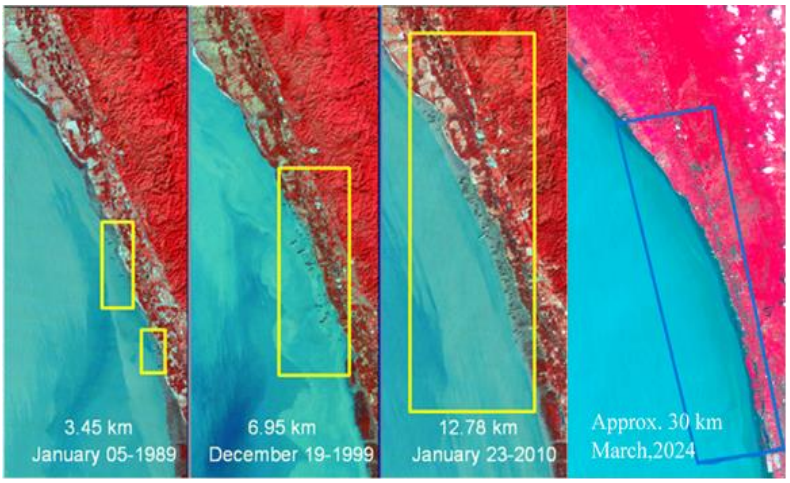

Figure 6: The growth of a shipbreaking yard over the past twenty years is evident in the increased number of ships on the beach, as captured in Landsat TM imagery.

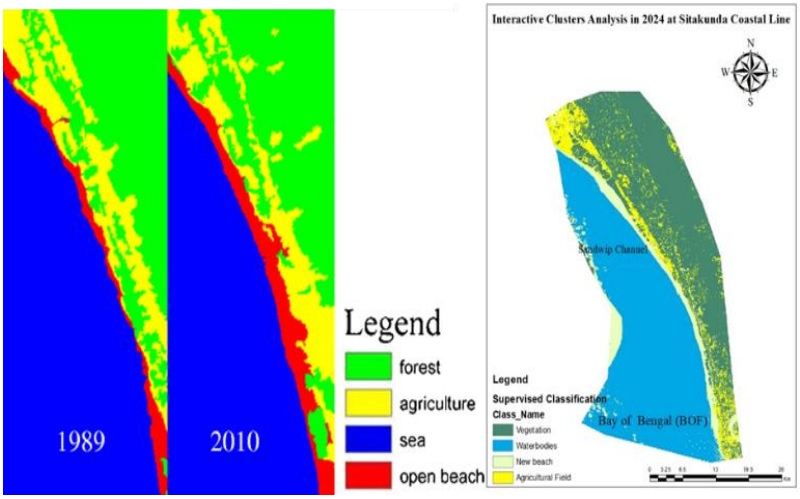

Figure 7: Land use maps of the Sitakunda shipbreaking region for the years 1989 and 2024, derived through object-based classification of Landsat TM satellite imagery

3.2 Impact on Ecosystem Functions

Following a thorough review of existing literature, nine distinct ecosystem types were identified in the coastal region of Sitakunda Upazila: the open sea, estuaries, mangroves, tidal mudflats, coastal dunes, rivers, sandy beaches, seashores, and hill areas (Figure 8). These ecosystems not only support the livelihoods of local coastal populations but also contribute both directly and indirectly to regional economic activities (Ahammad et al., 2022). However, the elevated levels of trace metals and hazardous substances in the vicinity of shipbreaking yards in Sitakunda have severely disrupted both marine and coastal ecosystems. These pollutants have reduced primary productivity by harming key organisms such as phytoplankton and zooplankton in intertidal zones. Furthermore, habitat destruction caused by deforestation, contaminated water, and toxic soil has significantly degraded the local environment, posing a serious threat to biodiversity in the area.

Table 3 presents an overview of environmental issues associated with the expansion of shipbreaking activities and other coastal developments in Sitakunda. The data highlights various environmental degradations, quantifying their approximate impact in percentage terms. Deforestation (27.42%) presents the highest reported impact is the loss of vegetation, primarily due to land clearance for shipbreaking yards and associated industrial activities. The removal of coastal forests has weakened the area's ecological resilience. Agricultural production decrease (8.29%) reflects the encroachment of industrial activities, soil contamination, and water pollution have contributed to declining crop yields. Black and polluted water (14.17%) shows the discharge of oil, heavy metals, and other contaminants from ship breaking has significantly deteriorated water quality. Less fish catching (13.89%) illustrates the pollution and habitat destruction have adversely affected local fisheries, reduced fish populations and impacting livelihoods. As a result, fish populations declined significantly due to a lack of adequate food sources (Table 4).

Table 3: Environmental flow degradations approximate scenario

Types of problems in the Environment	Percentage (%)
Deforestation	27.4
Number of fishing	13.8
Agricultural degradation	8.2
Water pollution	14.1
Land use and land cover degradation (farmlands and natural areas being converted into industrial zones)	2.2
Plants and animal (both terrestrial and marine degradation)	3.1
The presence of hazardous materials like asbestos, heavy metals, and oil residues on beaches contributes to toxic waste contamination.	7.05
Others (Includes various unaccounted environmental consequences, such as air pollution, shoreline erosion, and social impacts on local communities)	23.83

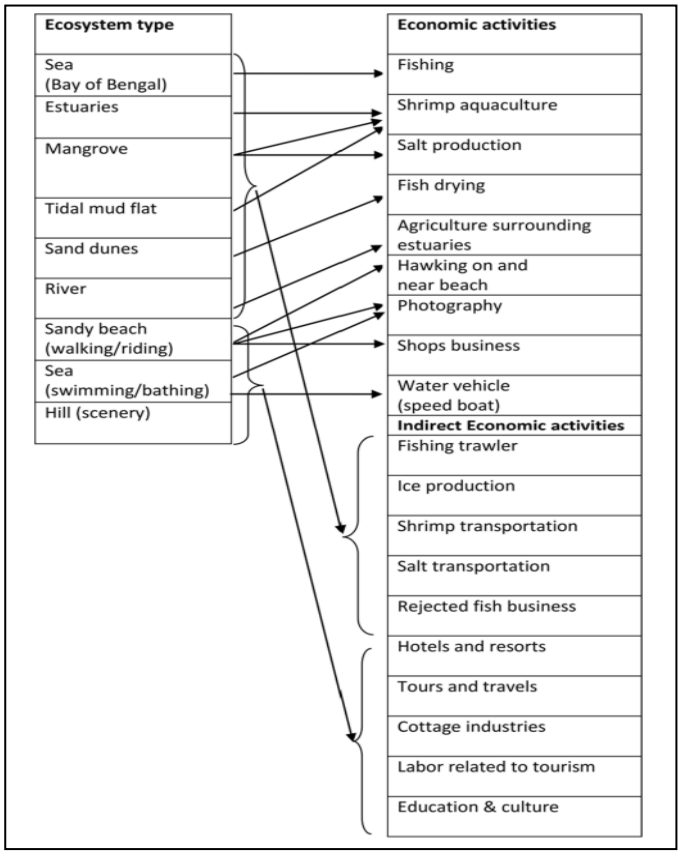

Figure 8: Visual representation of ecosystem types that facilitate diverse economic activities within shipbreaking yards.

Table 4: Absence of Fish Species in the Shipbreaking Zones of Sitakunda (Siddique 2004)

Scientific name of fish species	Local name	Scientific name of fish species	Local name
Osteogeniosus staenocephalus	Aspisoa katamach	Sphyraena obtusata	Khika mach
Scolopsis vosmere	Nemipscol mach	Carangoides malabaricus	Lohamuri mach
Eleotris fusca	Dora bailla	Carangoides melampygus	Bungda muri
Uranoscopus guttatus	Foton mach	Sauridia elongata	Tiktiki mach
Dendrophysa russelli	Kala poa	Anodontostoma chacunda	Koiputi mach
Bahaba chaptis	Chapti mach	Pricanthus macracavthus	Prica mach
Pomadasys opercularis	Grunti mach	Pricanthus tayenus	Prica mach
Polynemus sextarius	Kala tailla	Cynoglossus macrolepidotus	Lamba kukur jib
Gobuis sadanandio	Nandi bailla	Arius thalassinus	Kata mach
Gobuis melanosoma	Kalthu Bailla	Apocryptes serperaster	Dosa chau mach
Sphyraena forstegi	Khika mach	-	-

4. Conclusion and Remarks

The coastal plain is both extremely current and remarkable fragile. Unfortunately, shipbreaking activities in certain coastal regions have caused significant environmental degradation. To address this issue, Bangladesh urgently needs a comprehensive and well-structured policy to promote clean and sustainable ship recycling. This policy should incorporate robust measures for monitoring the environmental impacts of coastal operations. However, the development of an effective coastal monitoring program is currently impeded by a lack of adequate data. Further research is essential to bridge this gap. A comprehensive monitoring system would provide crucial insights to various stakeholders, including environmental advocates and policymakers, helping to safeguard the coastal ecosystem for future generations. Since the shipbreaking industry in Bangladesh makes a significant contribution to the country's GDP, it cannot simply be shut down. However, to ensure its long-term viability while minimizing environmental harm, the following recommendations have been proposed to make shipbreaking more sustainable and environmentally responsible.

- Shipowners and recyclers should collaborate to establish a dedicated ship recycling fund. This fund would support the transition from traditional beaching operations to a safer and more sustainable approach. It would be utilized to (a) implement comprehensive dismantling and pre-cleaning protocols, (b) ensure proper compensation for workers in the event of occupational incidents, and (c and (c) gradually replace the current beaching method by introducing a more organized, skilled, and properly trained workforce.
- Regular environmental impact assessments should be conducted periodically to monitor and regulate shipbreaking activities effectively.
- A sustainable coastal zone management plan must incorporate strategies to confine shipbreaking industries within designated areas along the coast. This approach helps minimize environmental damage, protect marine ecosystems, and ensure the safety and well-being of local communities while allowing the industry to operate responsibly.
- Establish an efficient pre-notification mechanism that ensures authorities are promptly notified in advance of any company's intention to dispose of a vessel. This system should provide key details, including how hazardous materials will be managed and disposed of, as well as the criteria used to select a dismantling facility. By enhancing transparency and oversight, this approach helps ensure compliance with environmental and safety regulations while promoting responsible ship recycling practices.

- National and coastal authorities must adhere to the International Maritime Organization's policies to ensure ship dismantling is conducted sustainably and with minimal environmental impact.
- The government must enforce stricter laws and prioritize minimizing environmental pollution when shaping policies for the shipbreaking industry.
- To ensure the transfer of proper ship dismantling knowledge to Bangladesh and other nations, it is essential that the government actively supports and enforces adherence to the regulations set by the International Maritime Organization (IMO). Additionally, the government must ensure adherence to the "Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships" to promote secure ship recycling practices.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

DATA AVAILABILITY

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

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