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EDITED BY
Fabio Grati,
National Research Council (CNR), Italy

REVIEWED BY
Soibam Khogen Singh,
The ICAR Research Complex for North Eastern Hill Region (ICAR RC NEH), India
Martina Scanu,
University of Bologna, Italy

*CORRESPONDENCE
Elena Mengo
elena.mengo@cefas.gov.uk

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Exploring fishers' and fisherfolk's knowledge and perspectives on water pollution in India: insights from Chilika Lake

Elena Mengo[1]*, Rashmi Murali[2], Mini Govindan[2] and Danja Hoehn[1]

[1]Centre for Environment, Fisheries and Aquaculture Science (CEFAS), Lowestoft, United Kingdom, [2]The Energy and Resources Institute (TERI), New Delhi, India

Approximately 16 million fisherfolk in India depend on fisheries for their income, food, and nutritional security. However, aquatic ecosystems across India are heavily polluted, resulting in significant challenges for communities dependent on fisheries. While research on pollution and waste management in India has progressed, local coastal communities' knowledge and perspectives are still overlooked in environmental decision-making. To address this gap, we focused on the Chilika Lake area, employing a mixed-method approach. We surveyed 161 fishers and conducted focus group discussions (FGDs) in local communities. Our findings indicate that, although fisheries serve as the primary source of livelihood, water pollution adversely affects the quantity and quality of fish, ultimately impacting the household income. Tourism and agriculture, including aquaculture are considered major contributors to aquatic pollution. While fishing-related litter does contribute to pollution in coastal areas, fishers infrequently encounter derelict gear compared to plastic bags and bottles. Solid waste disposal and management issues are widespread, largely due to inadequate waste collection and disposal facilities, resulting in the prevalence of informal waste management systems. The outcomes of the research highlight the need for targeted education and outreach initiatives in coastal areas to address waste mismanagement, promote active participation among local communities to initiatives such as beach clean ups, as well as encourage practices of recycling and reusing materials. Similarly, developing alternative livelihoods can reduce dependency on fisheries and contribute to sustainable development and biodiversity conservation.

KEYWORDS

coastal pollution and management, sustainable fisheries, waste management & disposal, fishers' perspectives, local communities' knowledge, water pollution

1 Introduction

Worldwide, coastal pollution significantly impacts the provision of ecosystem services and the livelihoods they support (Wang et al., 2020 as cited in Urban and Ittekkot, 2022; Nair and Nayak, 2023). Combined with other environmental and anthropogenic stressors such as climate variability and overfishing, pollution has exacerbated ecological degradation and has adversely impacted coastal and marine fisheries, particularly small-scale fisheries (Shahidul Islam and Tanaka, 2004; Issifu et al., 2022; Kiran and Ramaraju, 2022; Wootton et al., 2022). Fisheries, nonetheless, also contribute to the contamination of aquatic environments, with

abandoned, lost, and discarded fishing gear (ALDFG) being a significant portion of fishing-related litter (FRL) (Borges et al., in Urban and Ittekkot, 2022).

India, the world's most populous country, with an estimated 1.45 billion citizens, has over 25% of its inhabitants living in coastal regions, and is rich in water bodies like lakes, coastal lagoons, and wetlands which support livelihoods, nutritional security, and cultural well-being (Ray and Garada, 2018; Wang et al., in Urban and Ittekkot, 2022; Sahoo and Goswami, 2024). The fisheries sector plays an important role within the national economy, providing employment and income for more than 16 million fishers (Rajeev and Bhandarkar, 2022). Fish has been a staple in the Indian diet for centuries; the average annual per capita fish consumption increased by over 80%, from 4.9 kg in 2005 to 8.9 kg in 2021 (Padiyar et al., 2024). Pollution from urbanization, industrialization, and agriculture, however, severely threatens biodiversity in India's coastal waters (Kiran and Ramaraju, 2022) and a risk to the health and the quality of fisheries (Bashir et al., 2020).

Water quality and water pollution are a central components of several Sustainable Development Goals (SDGs) targets (UN, 2015). SDG 6, target 3, focuses on reducing pollution and release of hazardous chemical and materials by 2030, while SDG 14, target 1, aims to reduce all forms of marine pollution by 2025. Additionally, water quality intersects with SDG 1, which focuses on eradicating poverty and building resilience (target 1.5), and SDG 2, which calls for an end to hunger and ensure access to healthy food (target 2.1) (Alcamo, 2019). The 2030 Agenda for Sustainable Development aims to address societal challenges and achieve its targets by integrating scientific and traditional knowledge, emphasizing the importance of stakeholder engagement and community participation in achieving the SDGs (Magni, 2017; Bansal et al., 2024).

While significant advances have been made in understanding the levels, abundance, and sources of coastal water pollution in India (for a comprehensive list of studies on litter pollution along the Indian coast, see Barik et al., 2024), the knowledge and perspectives of coastal fishing communities regarding pollution, its impacts, and their waste management practices and awareness remain underexplored, as recently highlighted by Kneel et al. (2023).

To the best of our knowledge, only two studies examined fishers' knowledge of water pollution and their waste disposal behaviors in India, specifically focusing on FRL. Daniel and Thomas (2023) conducted a survey of fishers' perceptions in Kerala to investigate the fate of marine litter caught in fishing gear, the drivers of gear abandonment, and the disposal practices of derelict gear. Similarly, Nelms et al. (2021) used a structured questionnaire to examine the behavioral drivers of ALDFG among fisher households in the Ganges River system.

The present paper aims to address this gap by investigating the perceptions, knowledge, and waste management practices of Indian coastal communities concerning pollution and waste management. Using Chilika Lake as a case study, our work focuses specifically on three objectives: (1) to explore the importance of fisheries for the Chilika Lake communities; (2) to investigate the views and perspectives of fishers and coastal villagers regarding pollution drivers in Chilika Lake; and (3) to understand waste management practices, particularly the disposal of solid waste and end-of-life fishing gear, within these communities.

2 Research methods

2.1 Study area

The study was conducted around Chilika Lake, east coast of India, the largest brackish water lagoon in Asia and the second largest in the world (Nair and Nayak, 2023; Dash and Balamurugan, 2024). Designated as a RAMSAR-listed wetland, the lagoon has a total length of 64.3 km and a maximum breadth of 18 km (Parida, 2018) spanning the Puri, Khurda, and Ganjam districts of Odisha state (Nag et al., 2020). The Chilika Lake ecosystem is an important biodiversity hotspot and supports large and diversified resources of aquatic plants and animals, including fisheries (Baliarsingh et al., 2014; Nag et al., 2020). There are approximately 337 villages, including 132 fishing villages (Nayak, 2017; Ray and Garada, 2018), which support the livelihoods of over 0.2 million fisherfolk (Parida, 2018).

The Chilika lagoon is subjected to pressures from both natural processes and anthropogenic activities which have resulted in the deterioration of the socio-ecological system (Dujovny, 2009). The number of tourists visiting Chilika annually has grown considerably, rising from 0.12 million in 2005–2006 to 0.75 million in 2019 (Dhineka et al., 2025). In the 2022–2023 period, the total plastic waste collected from all districts of the Odisha state has been estimated to generate 820 tonnes/year of plastic waste (Dhineka et al., 2025). The growth of tourism, plastic pollution from both land-based and sea-based sources, and effluent discharges from domestic, industrial, agricultural, and aquaculture activities—including untreated sewage, chemical fertilizers, and pesticides—have all contributed to the worsening pollution in the lake (Dujovny, 2009; Mishra and Griffin, 2010; Singh et al., 2023).

2.2 Fieldwork and data collection

Data were collected through a combination of quantitative and qualitative methods, including a semi-structured survey and focus group discussions (FGDs). The survey was administered in January 2023 across 8 villages (see Figure 1) in the three districts around the Chilika Lake: Puri (Balabhadrapur and Berhampur), Khurda (Balipatapur, Bhusandapur and Jagannathpur) and Ganjam (Keshpur, Odiaalapur and Upulialapur). Prior to finalizing the survey, members of the research team visited fishing villages in Puri and Khurda districts and interviewed 12 fishers between 26th and 30th September 2022 to collect detailed information to fine tune the survey questions and the choice of survey implementation strategy. The survey was hosted online on Survey123 for ArcGIS.[1] All interviews were conducted face to face by local interviewers who were trained in the use of the Survey123 data collection tool and data collection protocol, ensuring a standardized approach throughout. The interviewers also translated the questions in the local language (Odia). The interviews took place at the fishers' households, and respondents were recruited purposively across the Chilika Lake districts based on availability, meaning that respondents were at home during their time-off fishing. Because the sample of fishers in the survey was selected non-randomly,

1 https://survey123.arcgis.com

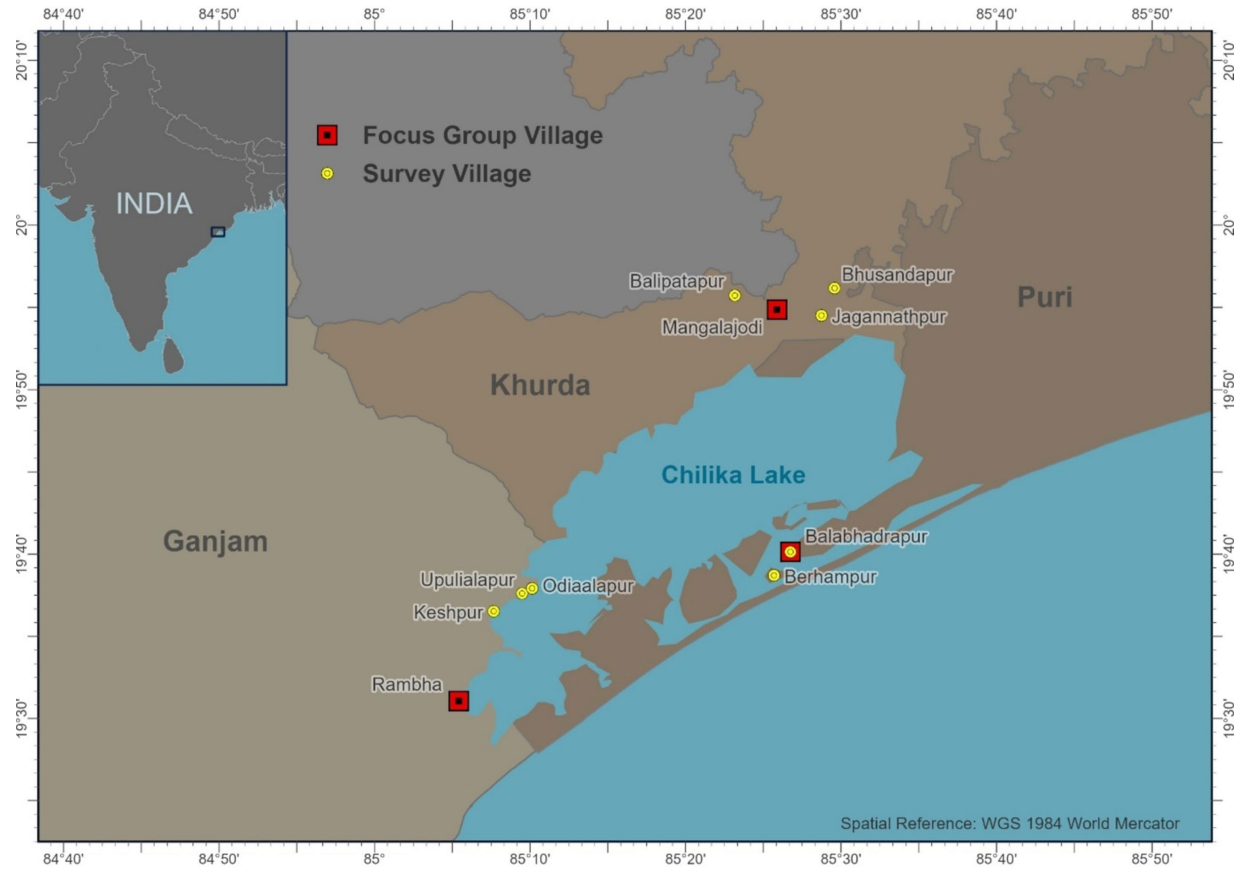

FIGURE 1
Map of study area.

our findings cannot be generalized to all fishers operating around Chilika Lake. Interviewers obtained verbal consent from fishers before starting the interview. Respondents were assured anonymity to minimize response bias and social desirability pressures.

The survey consisted of a combination of open and closed questions and was structured into three different sections. In the first section, respondents were asked to provide their sociodemographic details (gender, age, highest education level completed and household composition) and fishing activity related information. The second and third section included open questions, single and multiple-choice questions, and structured Likert-type questions. These sections aimed to elicit respondents' perspectives on pollution in and around Chilika Lake and to collect information on waste management practices.

In addition to interviews, focus group discussions (FGDs) with groups between 6 and 12 people were conducted by the research team between the 9th to the 13th of January 2023 with local fishing communities to verify and complement the information collected through the survey. The first focus group was held in Balbhadrapur village in the Puri district, the second took place in Rambha village in the Ganjam district and the third FGD was held in Mangalajodi in the Khurda district (Figure 1). Participants gave oral consent before starting the discussions. FGDs were conducted in local Odia language and translated by the local partner to English.

Descriptive statistics were used to describe the sociodemographic profile of the fishers who took part to the survey and their fishing activities. Statistical differences between districts were examined by Kruskal-Wallis test. The Kruskal-Wallis was followed by a *post hoc* Dunn test to identify which specific districts differ from each other. Qualitative data collected through open-ended questions in the survey and notes taken during the group discussions were manually coded to identify and summarize recurring topics.

3 Findings

3.1 Fisheries roles, characteristics, and fishing reliance

A total of 161 fishers engaged in capture fisheries spread over three districts participated in the survey: Puri ($N = 58$), Khurda ($N = 55$), and Ganjam ($N = 48$). The Supplementary Material presents descriptive statistics of respondents' sociodemographic profiles by district. The great majority of fishers in our sample - 93.2% - are males. From group discussions, it emerged that female engagement in the fisheries sector varies across different districts. In Balbhadrapur, women's role in fisheries is limited to tasks like fish drying and occasional selling. Similarly, in Mangalajodi, women support the household income by participating in agriculture and postharvest fishing activites (i.e., fish drying). Additionally, some women in Mangalajodi are involved in making and repairing fishing nets. Conversely, in Rambha women actively engage both in harvest and

TABLE 1 Fishing activity profile of the respondents by district.

		Total %	Puri %	Khurda %	Ganjam %
Fishing remuneration system (N = 160)	Fixed salary	8.1	22.8	0.0	0.0
	I fish alone	23.1	33.3	20.0	14.6
	Shared remuneration system (proportional revenues, i.e., value of catches)	23.8	5.3	32.7	35.4
	Shared remuneration system (proportional to revenues minus operating costs)	45.0	38.6	47.3	50.0
Role in fisheries (N = 161)	Boat owner and fisher	90.1	82.8	92.7	95.8
	Only fisher	9.9	17.2	7.3	4.2
Fishing gear ownership (160)	I am the only fishing gear owner	87.6	96.6	85.5	79.2
	I share ownership of fishing gear	12.4	3.5	14.6	20.8

TABLE 2 Mean total household and fisheries income reported by respondents and standard deviation in 2022 by district.

	Total household income (INR)-2022		Fisheries income (INR)-2022	
District	Mean	SD	Mean	SD
Puri	52,053	15,612	33,500	9,782
Khurda	66,611	17,038	43,519	19,175
Ganjam	69,688	14,998	46,234	14,997

post-harvest activities. Here, women reported that although men are the primary fishers, they assist with fishing during the rainy season and participate in sorting and selling the catch at markets. In Balbhadrapur and Rambha women reported also their involvement with Self Help Groups (SHGs)[2] where they received specialized livelihood training, such as packaging and selling of local food, fish drying and processing.

As shown in Table 1, fishers are overall mostly remunerated through shared remuneration systems, either with a share of the revenues proportional to the value of landings (23.8%) or with a share of the revenues minus operational costs (45%). The latter is the main system used in all the districts covered by the Chilika Lake – Puri (38.6%), Khurda (47.3%) and Ganjam (50%) – followed by fishers in Khurda and Ganjam (32.7 and 35.4% respectively), who are remunerated based on the value of the catch. In Puri, conversely, 33.3% of respondents reported to fish alone, hence keeping all profits. Puri is also the only district where a portion of fishers (22.8%) stated to be paid with a fixed wage, suggesting they may be employed under a formal arrangement. The great majority of fishers sampled across the three districts are both owners of the fishing boat and fishers, and all respondents catch fish using motorized boats. The great majority of fishers interviewed reported individual ownership of fishing gear. Very few participants in Puri - 3.5% - share fishing gear ownership, while in just under 15 and 21% or fishers in Khurda and Ganjam, respectively, share gear ownership.

In 2022, the average overall household income in the study area, derived from the income reported by fishers in our sample, was INR 62,321, (SD = INR 17,648.94). Among the districts, Puri had the lowest household income in 2022, while Ganjam had the highest (Table 2). Mean income in 2022 generated solely through fisheries in the study area was INR 40,293 (SD = INR 15,943.60). The mean fisheries income figures by district mirror the household income findings (Table 2), with Puri having the lowest average income generated through fisheries, while Ganjam stands out as the district with the highest annual (2022) fisheries-generated income.

FGDs confirmed that fisheries constitute the primary economic activity. In Balbhadrapur, tourism and agricultural production also contribute to a part of the community's livelihood. It was noted here that fishers often take loans from fisheries cooperatives to cover expenses related to boats and nets. Similarly, the Rambha community primarily depends on fishing for their livelihood, with some villagers also engaging in agriculture.

3.2 Fishers' and local communities' views on and experience with pollution

Most fishers (78%) said they discuss pollution in Chilika Lake within their communities, and nearly all (96.9%) believe it negatively affects their fishing activities. The majority of

2 Self-help groups (SHGs), established in 1992, consist of 10–20 women who meet regularly to contribute funds to a shared group account, enabling members to access loans during times of need. Over time, the program's scope expanded to include social services such as promoting health and nutrition awareness and addressing social issues like domestic violence and discrimination based on gender and caste (Kumar et al., 2021).

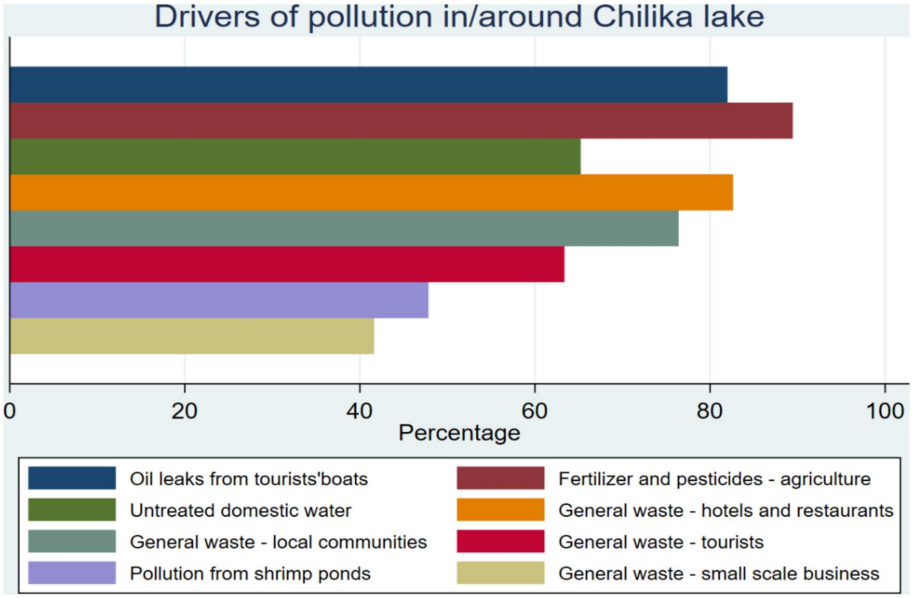

FIGURE 2
Perceived drivers of pollution in/around Chilika Lake across the sample of respondents - percentage distribution.

fishers - 42.9% - among those who elicited that fisheries are adversely impacted by the deteriorated quality of the Chilika waters, mentioned in a follow up open question that this led to both decreased number of fish catches and reduction in their earnings, followed by 25% of fishers reporting only lower income as a result of the contamination of the lagoon and 19.2% of respondents who just mentioned the local fisheries decline as connected to pollution. Livelihood losses resulting from contaminated lagoon waters were confirmed also by women during FGDs in Balbhadrapur. Finally, 7.7% of fishers reported to spend longer hours fishing in order to maintain their catch quantities.

One survey respondent reported that poor water quality also led people to migrate to other cities in search for better work opportunities. Participants in group discussions in both Rambha and Mangalajodi also mentioned that fishers migrate to cities to find alternative work opportunities to support their families due to a decrease in fishing activities. Another respondent stated that the polluted waters of the lagoon contribute to skin infections/diseases.

Fishers were provided with a list of potential factors contributing to water contamination in Chilika Lagoon and were asked to select multiple relevant drivers based on their views. This list of drivers was derived from the literature and other studies relevant to the study area (see Mishra and Griffin, 2010; Sahu et al., 2013; Baliarsingh et al., 2014; Nag et al., 2020). Figure 2 details the distribution of responses for each of the items presented to our sample of respondents. The option "*Fertilizers and pesticides used in agriculture*" was selected by almost 90% of fishers, followed by the option "*Waste generated by hospitality industry dumped into the lake*" and "*Oil spills from motorized boats used for tourism transportation around the lake*" was selected by 82.6 and 82% of respondents, respectively. General waste, such as plastic bags and bottles dumped into the lake by the local communities, was selected by 76.4% of fishers, whereas just under 50% of respondents think that shrimp farms contribute to the pollution of Chilika Lake waters. Furthermore, the graph illustrates that other contributors to pollution include sewage discharge from nearby settlements (65%) and waste (e.g., bags, bottles) dumped into the lake by tourists visiting Chilika Lake (63%). Participants in FGDs from three communities also identified tourism and agriculture (including prawn farming) as primary drivers of pollution.

All interviewed fishers agreed that fishing activities negatively impact the water quality and shorelines of Chilika Lake, corroborating findings from a similar study conducted in Kerala (India) by Daniel and Thomas (2023). Just under 45% of respondents think that fishers contribute to pollute the Chilika and its shorelines by either accidentally or voluntarily dumping ALDFG, followed by 26.1% of respondents who indicated that fishers pollute the lake by dumping general waste from fishing boats (either unintentionally or voluntarily). Oil leaks from motorized fishing boats and illegal use of ZeroNets[3] were selected by 18.6 and 11.2% of respondents, respectively. Discussions in Rambha revealed that zero mesh nets contribute to pollution by accidentally trapping solid waste during fishing activities which is later discarded in the Chilika Lagoon. Most respondents (60.6%) who stated that lake water pollution is caused by ALDFG also consider their occurrence a serious issue.

Figure 3 presents the distribution of seeing/observing marine litter items in and around Chilika Lake by all respondents, which was investigated using a five-point Likert scale ranging from 1

3 The Chilika Development Authority banned the use of small and zero mesh size nylon nets (zero nets) which caused wanton killing of larvae and were catching juvenile fish species of a number of commercial fish species (Suresh et al., 2018).

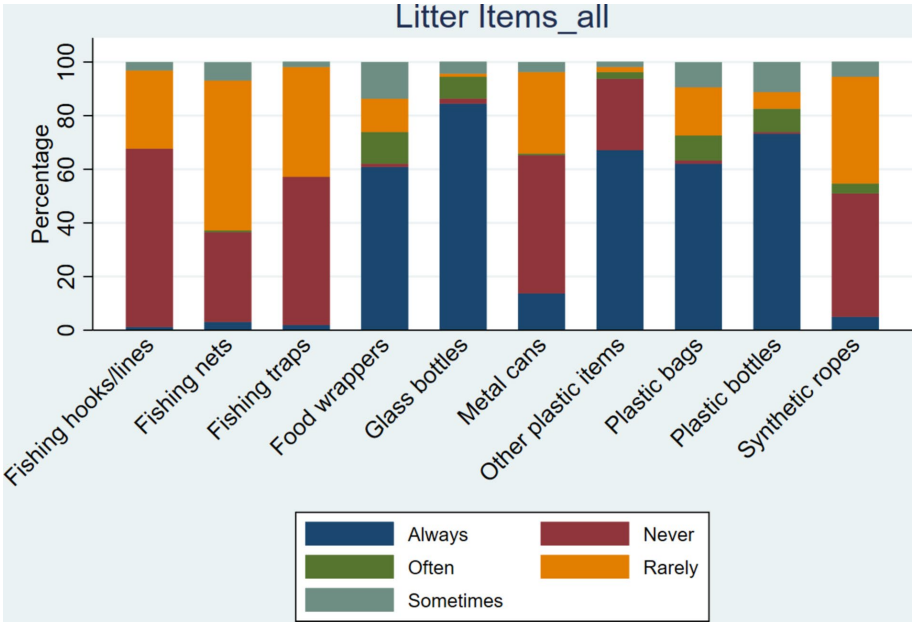

FIGURE 3
Percentage distribution of responses across the sample of respondents in the study area for each littering item observed in Chilika Lake.

("always") to 5 ("never"). The items were selected and adapted based on the information provided to the research team by the fishing communities during the initial visit to the fishing villages (as detailed in the methods) as well as the marine litter composition studies by Krishnan et al. (2022) and Mugilarasan et al. (2021). Results indicate that ALDFG items, such as fishing hooks and lines and pots and traps are never encountered by 66.5 and 55.3% of fishers, respectively, and fishing nets are rarely observed by 55.9% of fishers. Similarly, synthetic ropes are either never – 46%- or rarely – 39.8% - observed by fishers in our sample[4]. Metal cans are almost never encountered (51.6%). Conversely, plastic bottles (73.3%), plastic bags (62.1%), glass bottles (84.5%), food wrappers (60.9%), and other plastic items (67.1%) are frequently observed.

As shown in Figure 4, the analysis of ALDFG across the districts of Puri, Khurda, and Ganjam shows a substantial concentration of responses in the "*never*" and "*rarely*" categories, aligning with aggregated results.

Figure 5 presents the percentage distribution of non-ALDFG items across districts. The large majority of fishers in Puri - 87.9% - always encounter plastic bags in the Chilika Lagoon, while in Khurda just above half of fishers in the sample - 50.9% - always see this litter item, followed by 29.1% of respondents who stated to rarely encounter plastic bags. In Ganjam, 43.8% of respondents said they always saw plastic bags in/around the lagoon, while 22.9 and 20.8% of fishers, respectively, stated to rarely or sometimes see this item. An overwhelming majority of fishers in Puri - 96.6% - reported to always come across plastic bottles compared to the percentage of fishers in Khurda - 61.8% - and Ganjam - 58.3% - who stated to always encounter plastic bottles. Responses across Ganjam and Khurda show more variation in the frequency of encountering plastic bottles; 18.8 and 16.4% of respondents, respectively, reported to see sometimes plastic bags, followed by 14.6% of fishers in Khurda and 12.7% of fishers in Ganjam, respectively, who stated to often encounter carrier bags in the Chilika Lagoon. Nearly 83% of Puri fishers always observe other types of plastic items, compared to just under 60% of fishers in Ganjam and Khurda always encountering them. Nearly 42% of fishers in Ganjam and 31% in Khurda, on the other hand, reported never observing other types of plastic items. Food wrappers are always observed by the greater percentage of fishers in Puri and Khurda (81 and 61.8%, respectively). On the same item, fishers in Ganjam are spread across between those who always see food wrappers - 35.4% - and those who reported coming across this item either often - 25% -, sometimes - 16.7% - or rarely, 20.8% while fishing in the Chilika Lake.

A Kruskal-Wallis test revealed statistically significant differences in overall median scores across the three districts surrounding Ch*ilika Lake for four litter items: plastic bags* ($\chi 2 = 21.0$, $p < 0.001$, d.f. = 2), *plastic bottles* ($\chi 2 = 14.8$, $p < 0.001$, d.f. = 2), *food wrappers* ($\chi 2 = 13.7$, $p < 0.001$, d.f. = 2) and *other plastic items* ($\chi 2 = 5.9$, $p < 0.05$, d.f. = 2). Subsequently, we conducted a *post hoc* Dunn test with Bonferroni correction to further investigate differences between districts. The post hoc analysis indicated that the respondents in Puri had significantly higher median scores for the item "*plastic bags*" and "*plastic bottles*" ($p < 0.001$) compared to respondents in Khurda and Ganjam. Similarly, respondents in Puri scored significantly higher on these items on "*food wrappers*" ($p < 0.001$) compared to respondents in Ganjam and Khurda. It was also found that the respondents in Khurda had significantly higher scores than respondents in Ganjam

4 Synthetic ropes and strings come from different sources but are frequently mainly related to fishing and therefore are here considered as fishing litter related item (Source: https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/indicator-assessments/beach-litter/).

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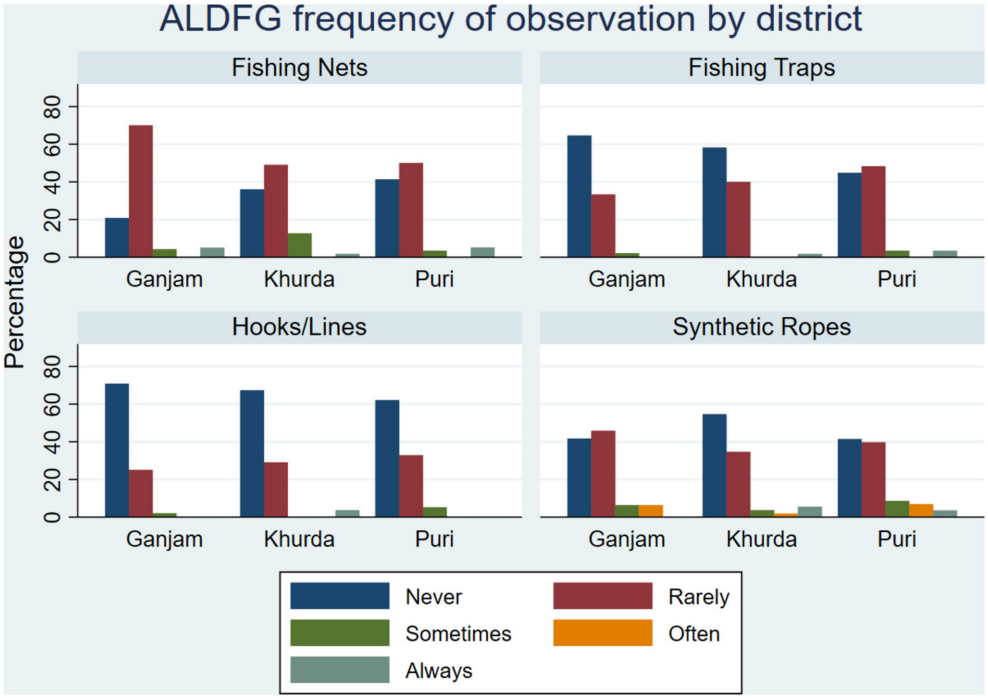

FIGURE 4
Percentage distribution of responses across the sample of respondents by district for each ALDFG item observed in Chilika Lake.

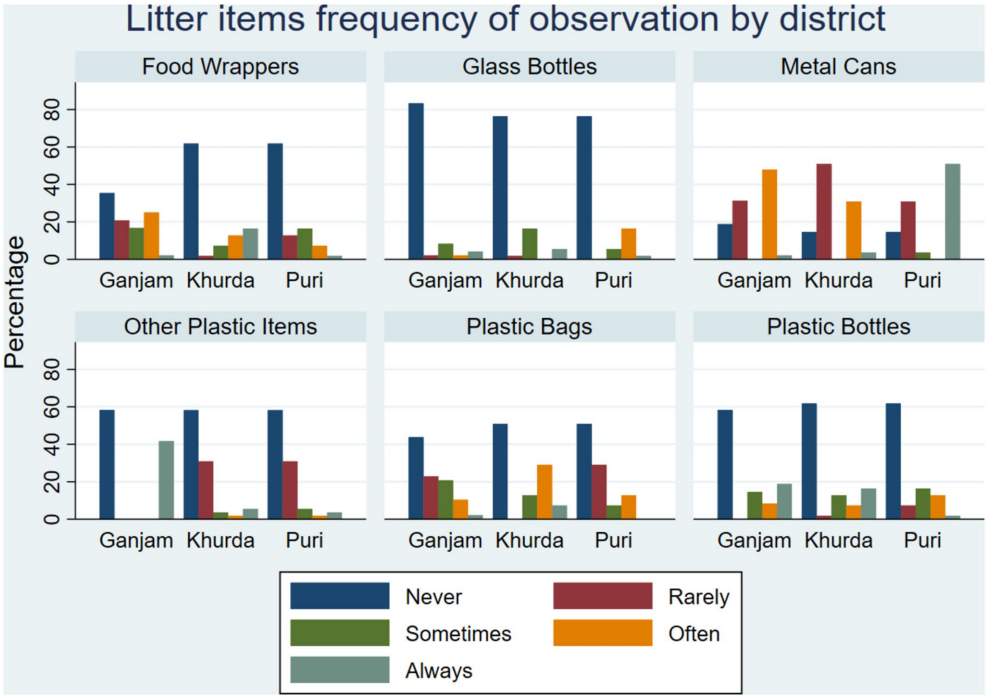

FIGURE 5
Percentage distribution of responses across the sample of respondents by district for each non-ALDFG item observed in Chilika Lake.

($p < 0.05$) for the "*food wrappers*" item. There are statistically significant differences for "*other plastic items*" between Puri and Khurda ($p < 0.01$) and between Puri and Ganjam ($p < 0.05$). Additionally, significant differences in median scores were observed between Puri and Ganjam for "*fishing nets*," and between Puri and Khurda for the item "*glass bottles*" ($p < 0.05$).

3.3 Waste management practices

3.3.1 Solid waste

Almost 90% of the fishers interviewed reported being unaware of any initiatives or practices aimed at reducing, reusing, and recycling general waste. Additionally, 80% of fishers surveyed reported the absence of facilities for solid waste disposal in their respective villages, while only 15.6% of fishers reported the presence of collection facilities (Figure 6A). This trend is mirrored at the district level to some extent. The large majority of respondents in both Puri and Khurda, 94.8 and 92.7% respectively, confirmed the lack of waste bins in their villages as shown in Figure 6B. Group discussions in Balbhadrapur (Puri) and Mangalajodi (Khurda) reiterated the shortage of dustbins for waste collection.

In contrast, 52% of fishers surveyed in Ganjam reported having waste collection facilities in their villages (Figure 6B). When asked in a follow up open question what collection services or facilities are available for the disposal of general waste, 13 out of 25 fishers in the surveyed communities in Ganjam mentioned that there are vehicles for waste transport, while the remaining 12 respondents indicated that there are dustbins available for solid waste disposal.

The remaining 4.3% of respondents from the overall sample stated to be unsure about availability of waste collection or disposal facilities (Figure 6A).

When fishers among those who reported lack waste collection facilities were questioned about solid waste disposal methods, the majority - 75.9% - indicated burning waste, followed by 18.1% who reported burying solid waste in ground holes, and 6% who admitted to dumping waste along the Chilika Lagoon shores (Figure 7A). Across all districts, a considerable portion of respondents—86% in Puri, 70.4% in Khurda, and 63.6% in Ganjam—cited open burning as a common waste management practice (Figure 7B). Insights from group discussions confirmed that household waste is commonly burnt by local communities. Sometimes, as reported during groups

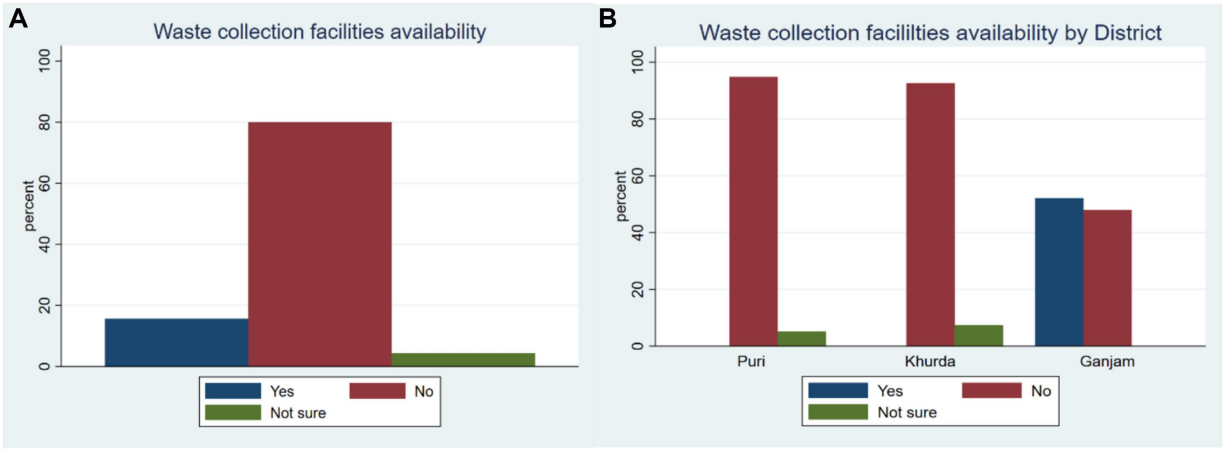

FIGURE 6
(A) Availability of waste collection facilities (total sample). **(B)** Availability of waste collection facilities (by district).

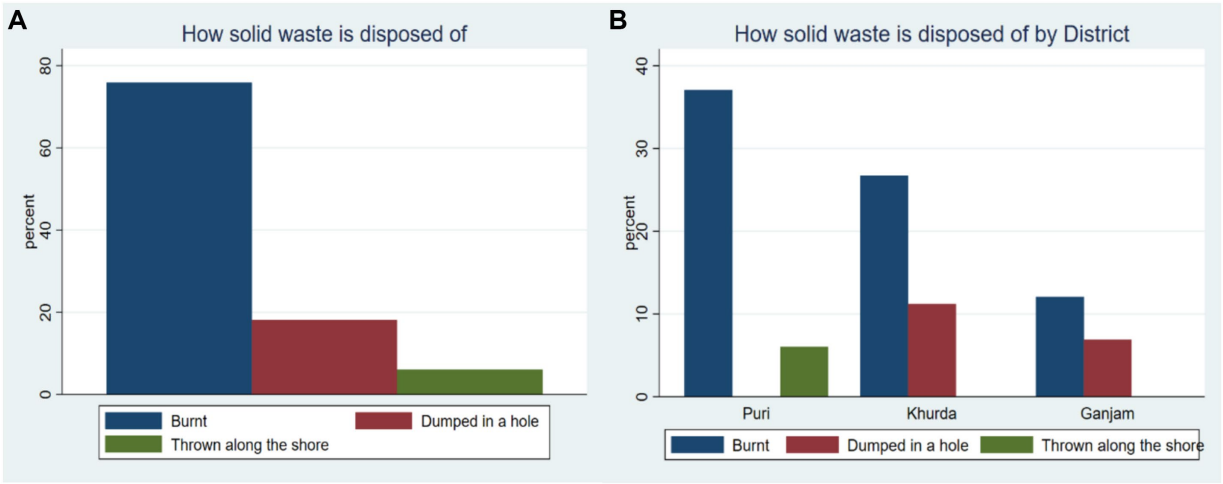

FIGURE 7
(A) Solid waste disposal methods - total sample. **(B)** Solid waste disposal methods across surveyed districts.

discussions, the collected reusable/ recyclable waste is given to waste pickers. Interestingly, only fishers in Puri reported dumping waste on lagoon shores, as illustrated in Figure 7B. Conversely, respondents in Ganjam and Khurda, 36.4 and 29.5% respectively, mentioned burying solid waste in holes dug in the backyard of their households.

3.3.2 End of life fishing gear

Over 90 % of fishers reported a lack of awareness regarding projects or schemes aimed at repurposing end of life (EOL) fishing gear. In terms of disposal practices of used fishing gear, as displayed in Figure 8A, the majority of fishers −55.6% - reported that EOL fishing gear is either reused or repurposed, while 36.9% of respondents store their used gear at home. Only a small proportion, comprising 7.5% of respondents, stated that they dispose of their old fishing gear using collection facilities such as bins or dumpsters available in the villages or at fish landing stations (Figure 8A).

The majority of respondents in Puri, 67.2%, reported storing the fishing gear that they no longer use at home, while a considerable majority of respondents in Khurda and Ganjam, 72.7 and 87.5% respectively, stated to reuse and recycle materials from fishing gear (Figure 8B). Just under 20% of fishers in Puri dispose of their EOL fishing gear by dumping it in bins for general waste collection available at fishing landing sites or in their villages (Figure 8B). A smaller portion of fishers - less than 2% - in Khurda dispose of EOL fishing gear using waste collection facilities (e.g., bins or dumpsters), while this option was not selected by any of the respondents in Ganjam (Figure 8B).

Among the 90 fishers who reported repurposing their EOL gear, the majority (55%), indicated that the fishing gear no longer used is repurposed for use in fencing houses (see Figure 9A), followed by those who stated to use ropes from retired fishing gear (19.1%) to craft decorative items, such as doormats, which are then sold in the local markets. Thirteen fishers (14.6%) mentioned that the EOL fishing gear is dismantled to separate the individual materials, with plastics sold to informal buyers from surrounding villages for recycling into new items. Twelve respondents (13.5%) use EOL gear instead to decorate their homes. A small percentage of fishers (4.5%) claimed to repurpose unusable fishing gear to secure thatched roofs and improve cyclone

FIGURE 8
(A) EOL fishing gear disposal across the sample of fishers. **(B)** EOL fishing gear disposal by district.

FIGURE 9
(A) EOL fishing gear repurposed as fencing for a house (image on the left). **(B)** EOL fishing gear used to reinforce the roof (image on the right).

resistance (Figure 9B). Similarly, during group discussions it was frequently mentioned that fishing nets no longer in use are repurposed for various household purposes, including as boundary walls, floor mats, roof protection, and fencing. Additionally, ropes from fishing nets are often utilized to tie cows.

4 Discussion

This study aimed to enhance the understanding of the fisheries sector's significance, the drivers and impacts of water pollution, and waste management practices by investigating the perspectives and knowledge of coastal communities in developing countries, with a focus on Chilika Lake on India's east coast. This area has seen limited social science research, particularly concerning the sources of pollution and the responses of local fisheries (Acharyya et al., 2023).

Small-scale fisheries play a pivotal role in the livelihoods, nutritional needs, and socio-cultural well-being of fishers living in and around Chilika Lake (Sahu et al., 2014; Parida, 2018; Ray and Garada, 2018; Sethi and Patra, 2021). As stated by Baral, (2019 p.636) "*fishing at Chilika is a part of the everyday life of the community, and fishing is as much an economic necessity as it is a social and cultural reality*." According to the Chilika Development Authority Report (2009, cited in Ray and Garada, 2018), fisheries output accounts for more than 71% of the total economic value of the lagoon. Our findings indicate that in 2022, over 65% of the total household income was derived from fisheries, hence confirming the key role of fishing for the Chilika Lake communities. Predominance of income from fisheries is reflected at district level with Ganjam being the district with highest yearly fisheries earnings in 2022 (INR 46,234), followed by Khurda (INR 43,519) and Puri (INR 33,500). In line with the global pattern in the fishing sector (Guillen et al., 2017), a shared remuneration system is used for the fishers in our sample across the Chilika Lagoon.

Fish harvesting in Chilika is predominantly a male activity. Women typically engage in roles such as fish processing, sorting, drying, packaging, and marketing. This division of labor reflects patterns observed in other villages across Odisha, where similar gender roles in fisheries have been documented (Pradhan and Flaherty, 2008; Khan et al., 2018; Ray and Mukherjee, 2022). Our findings also align with other studies on gender roles in the fisheries sector in India, which have similarly reported that women often engage in post-harvest activities, such as fish preservation and market sales (Busby, 1999; Samuel, 2007).

Fishers and local communities agreed that water pollution is a major threat to fisheries in Chilika Lagoon, posing a risk to their livelihoods due to declining catches. This decline in fish catches has led to out-migration of fishers in Chilika as a livelihood adaptation strategy, seeking alternative and more lucrative employment opportunities (Khan et al., 2018). The main drivers of water pollution identified by the fishers in our sample are pesticides and chemicals used in agriculture that are washed into the Chilika Lagoon. About half of fishers reported also the contribution of shrimp aquaculture to the lake water degradation. Similarly, in the focus group conversations, participants expressed strong concerns about the adverse effects of prawn culture on water quality of the Chilika Lake. As reported by (Dujovny, 2009) "*fishers have long claimed that prawn aquaculture undermines the ecosystem*." Other studies documented the adverse impacts of use of pesticides and chemicals in agriculture and aquaculture on the environmental conditions of Chilika Lake and on the local small-scale fisheries sector (Sekhar, 2004; Sahu et al., 2014; Mishra, 2015; Nair and Nayak, 2023). Plastic materials, such as nets, used in aquaculture also contribute to the contamination of the Chilika Lagoon (Ramanamurthy et al., 2018).

Tourism was as well identified as major source of pollution in Chilika Lake. Fishers noted that improper disposal of plastics, food waste, and oil leaks from motorized boats contribute to the contamination of the lagoon waters. This substantiates previous findings in the literature (Ray and Garada, 2018; Sambandam et al., 2022; Singh et al., 2023). Fishers, however, noted that mechanized fishing boats pollute the lagoon waters too. This observation aligns with the results of a household survey conducted by (Ray and Garada, 2018), which found that respondents believed the introduction of mechanized boats resulted in pollution of the Chilika Lake waters.

The results regarding the scale of fishing-related litter occurrence in Chilika indicate that ALDFG are infrequently encountered by fishers in our sample. Fishers acknowledged however that fishing activities also play a role in polluting the Chilika Lagoon, either via dumping of used or damaged fishing nets (see Sahu et al., 2014) or – to a lesser degree- via dumping from their boats of any other type of solid waste. These findings contradict Barik et al. (2024), who observed fishing-related litter such as nets, floats, strings, and ropes at popular tourist beaches in Ganjam in 2021. Likewise, research on the typology of marine litter in Digha coast and Sagar Island (West Bengal) (Mugilarasan et al., 2021), Kachchh coastline (Gujarat) (Behera et al., 2021) and Kerala Coast (Daniel et al., 2020) indicates that FRL[5] is one of the main sources of beach litter.

Furthermore, recent studies have indicated that the primary polymers in microplastic fragments from Chilika Lake sediments and water samples are polyethylene (PE), polypropylene (PP), and polystyrene (PS) (refer to Sambandam et al., 2022; Singh et al., 2023; Kumar et al., 2024). These synthetic fibres are commonly utilized in the manufacturing of fishing nets (Karadurmuş and Bilgili, 2024). Microplastics observed at the sample sites likely originate from deteriorated ropes, fishing gear, and other FRL (Sambandam et al., 2022; Kumar et al., 2024; Dhineka et al., 2025).

On the contrary, the categories of litter most frequently encountered, overall, by fishers include plastic and glass bottles, plastic bags, other plastic items and food wrappers. Plastic litter, including ALDFG, has significantly harmed biodiversity and ecosystem function in Chilika (Das et al., 2020). At district level, a significantly larger majority of fishers in Puri, compared to Ganjam and Khurda, always come across these items. This is consistent with findings from a recent analysis of beach litter abundance at Puri, which revealed that almost 59% of the total litter collected was categorized as plastic waste (Barik et al., 2024).

Other studies (Jayasiri et al., 2013; Daniel et al., 2020; Behera et al., 2021; Mugilarasan et al., 2021) indicate that plastics are the most prevalent component of litter along the Indian coastal areas, largely deposited due to activities such as tourism, fishing (including aquaculture), coastal settlements, and recreational activities.

Puri is a prominent destination for tourism and recreational activities, including large-scale cultural festivals (Singh et al., 2021) which have been

5 Mugilarasan et al. (2021) categorised marine litter items according to OSPAR standards, while Behera et al. (2021) and Daniel et al. (2020) categorised marine litter items according to the UNEP guidelines (Cheshire et al., 2009).

identified as major sources of litter along with fishing activities (Paul et al., 2023). However, further research should be undertaken to compare distribution, quantification, characterization, and potential sources of macro litter across the districts of Puri, Khurda, and Ganjam.

Fishers across the study area lack of awareness regarding initiatives or projects in the Chilika Lake area aimed at repurposing or recycling fishing gear when it reaches the end of its usable life. Nonetheless, EOL gear is either repurposed or material from fishing gear is reused by the majority of fishers who took part in our survey. The information gathered from the survey and validated through FDGs indicated that when fishing nets reach their end of life, they are repurposed in various ways by local fishing communities, such as for boundary walls, roof protection, and fencing. Plastics from old nets are recovered to make floor mats for the household or other decorative objects and old plastic ropes are also reused to tie cows. If it is not reused or repurposed, EOL gear is kept by fishers at home. These results echo the findings of Nelms et al. (2021) who reported that fishers along the Ganges commonly repurpose old fishing gear into items such as fencing and ropes.

The issue of solid waste disposal and mismanagement has emerged across all districts surrounding the Chilika Lagoon, were a considerable majority of fishers lack of awareness regarding waste management. This aligns with the findings of a recent study conducted on tourist beaches in Puri and Ganjam, which identified the lack of awareness about pollution prevention and management among beach visitors as a major cause of pollution in these areas (Barik et al., 2024). A significant portion of fishers reported a lack of proper solid waste collection and disposal facilities in their villages, as also noted by Sahu et al. (2014). Open burning and waste dumping are prevalent practices in India, as documented by Kumari et al. (2019), Ferronato and Torretta (2019), and Kibria et al. (2023). Our findings from the survey and group discussions indicate that these practices are also common around the Chilika Lagoon area. Informal recycling was identified as another recurring practice for managing solid waste by the fishing communities on Chilika Lake. The informal waste pickers buy recyclable materials (e.g., newspaper, plastic, glass, etc.) from households and sell, at a higher price, sorted and cleaned material to specialized waste merchants who then sell the materials to recycling plants (Nandy et al., 2015). Informal waste management systems are widespread in in developing economies such as India where many people depend on it for their livelihoods (Chaudhary et al., 2021; Kala and Bolia, 2022).

5 Conclusive remarks: coastal communities and sustainable coastal management

Pollution is one of the biggest challenges in developing countries like India (Nelliyat, 2016). Fisheries in India have been for centuries a considerable source of income and a vital protein source for rural coastal communities (Mcgregor et al., 2014; Viana et al., 2023). Water quality and marine pollution reduction, important requirement for subsistence, small scale and commercial fisheries (Alcamo, 2019), are part of the 2030 Agenda and explicitly included in the SDGs (Target 6.3 and 14.1). Thus, addressing water pollution is an urgent priority for the effective management and conservation of current fisheries and aquatic resources (Shahidul Islam and Tanaka, 2004).

Addressing pollution in aquatic ecosystems requires holistic, region-specific approaches and participation of coastal communities' insights and views. By incorporating insights from India's fisherfolk, we aimed with this work to inform strategies for managing fisheries and conserving natural resources, ultimately protecting coastal livelihoods.

The lack of awareness among fishers and fisherfolk regarding waste reduction, reuse, and recycling, including EOL fishing gear, accentuates the need for targeted education and outreach initiatives to encourage circular economy practices and community involvement in litter management. Local community engagement is key to effective waste management and achieving long-term sustainability targets (Suryawan et al., 2024). Old fishing gear should be collected, managed, and recycled through a buy-back system involving the fishing community (Mishra et al., 2023). Equally, regular coastal clean-ups, guided by standard protocols such as OSPAR (Wenneker and Oosterbaan, 2010) and UNEP (Cheshire et al., 2009) can contribute to community resilience and foster a sense of ownership and empowerment among community members (Purba et al., 2023; Suryawan et al., 2024).

The prevalence in our study area of solid waste mismanagement practices, such as open burning and dumping, calls for improved waste management infrastructures and policies. While informal recycling initiatives play a crucial role in ensuring sustainable waste management in densely populated countries like India (Kala and Bolia, 2022), they should be complemented by formal waste management systems to effectively address solid waste pollution.

It is also recommended to implement programs promoting alternative livelihoods in coastal communities, following the example of the Alternative Livelihoods - Community-Based Ecotourism Enterprise in the village of Mangalajodi (Nair and Nayak, 2023). Such initiatives, with proper stakeholder involvement and community participation, can create job opportunities for local communities and reduce their dependence on fishing, thereby minimizing migration among fishers seeking more lucrative livelihoods (Sethy and Senapati, 2023; Dash and Balamurugan, 2024). Moreover, they create more opportunities for women to contribute to household income generation and, most importantly, participate in sustainable economic activities (Samal and Dash, 2024). These programs not only diversify income sources but also contribute to sustainable development and biodiversity conservation efforts in coastal areas.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors upon request.

Ethics statement

This research was conducted in accordance with the 'Ethical Assurance for Social and Behavioural Research in Government' guidelines ensuring that all participants' rights and privacy were protected. Before obtaining written informed consent, participants were provided with a clear explanation of the research objectives. They were informed that their participation was voluntary and that they had the right to withdraw at any time without any consequences. Participants were also assured that all information collected during the study, as well as any findings published, would remain completely anonymous. No personally identifiable information was collected to protect participants' privacy and confidentiality.

Author contributions

EM: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Writing – original draft, Writing – review & editing. RM: Investigation, Methodology, Resources, Writing – original draft. MG: Investigation, Methodology, Resources, Writing – original draft. DH: Conceptualization, Funding acquisition, Writing – original draft.

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Supplementary material

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