frontiers | Frontiers in Conservation Science

TYPE Original Research
PUBLISHED 23 September 2024
DOI 10.3389/fcosc.2024.1341434

OPEN ACCESS

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RECEIVED 20 November 2023
ACCEPTED 28 August 2024
PUBLISHED 23 September 2024

CITATION
Badola S, Gill AK, Dobriyal P, Patel S, Khan MZ and Hussain SA (2024) Haunting the Ganges: addressing the issues of ghost gear in the Ganga River through an incentive-based institutional mechanism.
Front. Conserv. Sci. 5:1341434.
doi: 10.3389/fcosc.2024.1341434

Haunting the Ganges: addressing the issues of ghost gear in the Ganga River through an incentive-based institutional mechanism

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Abandoned, lost, or otherwise discarded fishing gears, also known as ghost gears (GG), are major contributors to global marine and freshwater plastic pollution. GG can lead to the accidental entanglement of several threatened freshwater and marine species, especially the air-breathing aquatic vertebrates, which is a matter of global concern. There is a lack of know-how and mechanisms for collecting and recycling GG, leading to their constant accumulation in aquatic ecosystems. In this study, we have examined the mortalities of threatened aquatic species in fishing nets and have proposed an incentive-based standard operating procedure (SOP) for effective collection and disposal of GG based on field observations and extant national and international policies and made recommendations for a net buyback scheme as a possible downstream solution to reduce GG in the Ganga River Basin. It is proposed that the collection of GG can be done by the local level institutions of fishing community through the fair-price shops. The nets are then to be deposited at the block-level processing centres to be transported to the district-level consolidating centres. Recycling partners identified by the Government of India will then collect the nets directly from district centres for further upcycling and recycling. A multi-level, multi-stakeholder approach with strong upstream and downstream linkages backed with appropriate policy interventions is needed to tackle the ghost gear issue in the Ganga River basin.

KEYWORDS

plastic pollution, aquatic ecosystem, ghost nets, buyback schemes, grassroots institutions

Introduction

In the recent years, the burgeoning plastic use and the waste it generates have become a global concern due to determinant impacts of plastics on the ecosystem, biodiversity, communities and livelihoods (Lau et al., 2020; Rafey and Siddiqui, 2023; Sokolova et al., 2023; Pilapitiya and Ratnayake, 2024). Microplastics have become ubiquitous contaminants with the capacity to traverse diverse ecosystems. With plastic transported via rivers and coastlines, majority of marine plastics are considered to have originated from land-based sources (Wagner et al., 2014; Li et al., 2016; Lebreton et al., 2017; Andrades et al., 2021).

Fishing is among the oldest livelihood activities in the world (Tripathy et al., 2019), and a key source of income for the rural riverine communities. Historically fishing gears were made of biodegradable materials that were not harmful to aquatic biodiversity (Macfadyen et al., 2009; Stelfox et al., 2016). However, technological development has led to the use of fishing gears made of synthetic materials such as polyamide (nylon) that are non-biodegradable and may harm the environment (Stelfox et al., 2016). These modern fishing gears discarded after use, when lost in the rivers and oceans, are referred to as abandoned, lost or otherwise discarded fishing gears, or "ghost gears" (GG). A significant quantity of global marine debris can be attributed to GG (Gunn et al., 2010; Richardson et al., 2019; WWF, 2020; Simeonova and Chuturkova, 2020), which has also been recognized as a global concern by FAO (Stelfox et al., 2016).

Fishing nets, particularly monofilament gillnets, an essential fishing equipment for small-scale fishers globally, are the major contributors to GG. There have been significant evidences of plastic ingestion by freshwater species, ranging from invertebrates to mammals, in natural or semi-natural ecosystems (Azevedo-Santos et al., 2021b). GG also lead to entanglement of several freshwater and marine species (Azevedo-Santos et al., 2021a; Battisti et al., 2023).

India is the third largest fish and aquaculture producing country in the world. Nearly 75% of the total fish production of India (162.48 lakh tonnes) is from the inland fisheries sector (121.21 lakh tonnes), of which around 28.76% is produced in the five states along the Ganga River (Fisheries Statistics Division, 2022; Supplementary Table S1). The fishing activities contribute significantly to the GG accumulation in the aquatic ecosystem. After the Yangtze River in China, Ganga catchment is the second largest plastic pollution contributing catchment in the world (0.12 million tonnes of plastic discharged per year) (Nelms et al., 2021). Municipal and industrial effluents, fisheries (abandoned, lost and discarded fishing gears) and solid waste dumping have been identified as the major sources of plastic pollution in Ganga River (Raha et al., 2020; Nelms et al., 2021). Ganga is estimated to transport about 10–0.17 MT of plastics to the Bay of Bengal annually (Lebreton et al., 2017, Lebreton et al., 2018), but a large portion of this plastic waste such as flexible packaging and fishing nets are easily entangled and retained within the river (Schreyers et al., 2021) to further degrade to form microplastics.

Recent studies have revealed contamination of both water and sediment of the Ganga River with microplastics (Sarkar et al., 2019; Napper et al., 2021). Often associated with high population density and sewage discharge (Rajan et al., 2023), these contaminants enter the riverine environment from a variety of sources such as clothing, packaging materials, fishing lines, and ropes (Neelavannan et al., 2023). In the immediate future replacing plastic with sustainable alternatives is not a feasible solution. A combination of "sustainable production, conscientious consumption, efficient waste management and enabling policies" that addresses both upstream (production and pre-consumption) and downstream (post-consumption and waste management) issues needs to be in place (Bonanno, 2022). The high intensity of fishing and the lack of facilities and mechanisms for the collection and disposal of discarded fishing gear makes these a significant contributor to plastic pollution in the Ganga River (Nelms et al., 2021). Indian environmental and fisheries policies are non-responsive about the disposal of discarded fishing gears.

The objectives of the present study are to quantify the density and impacts of GGs and suggest impacts mitigation strategies to reduce the impact of GGs in Ganga River ecosystem.

Methodology

This study is a part of the long-term project "Planning and management for aquatic species conservation and maintenance of ecosystem services in the Ganga River basin for a clean Ganga" funded by the Government of India and implemented by the Wildlife Institute of India. The project has identified the volunteers from local communities that are trained in conservation related activities such as stakeholder mobilization, habitat restoration, biodiversity monitoring and ecological surveys. The information used for the present analysis was collected through river and socio-economic surveys conducted along the Ganga River between April 2018 and October 2023.

The Ganga River is among the largest transboundary rivers in Asia and was declared the National River of India on 4th November 2008 (Sanghi and Kaushal, 2014). The basin is spread across 11 Indian states and covers about 26% of the geographical area of the country (Sanghi and Kaushal, 2014). The river flows through one of the most densely populated regions in the world, with an estimated population density of 952.55 persons per sq. km (Census of India, 2011). The Ganga River serves as the lifeline to the millions residing along its banks, supporting a diverse array of livelihoods and the economies of both rural and urban agglomerations. Livelihoods centred around agriculture and fishing are the mainstay of the marginalized rural populace. Fishing is practiced by 2.82 million fishers in the Ganga River basin (Das et al., 2022). Literacy rate of the fishing community is lower than the national level (Tyagi, 2009).

Data collection

We conducted ecological and socio-economic surveys and supplemented them with a review of existing literature to identify critical gaps that require immediate intervention to address the issue of GG in the river. Boat based continuous river surveys (n= 6) for ecological studies were conducted along the Ganga River using inflatable boats. During the river surveys the fishing gears (both active and GG) encountered in the river and their type and material

was recorded at every 5 kms. Incidents of species entangled in the GG were also recorded. Frequency of encountering both fishing gears and species entangled was calculated. As high concentrations of fishing gears and their impacts on biota in the Ganga River was observed, the information was supplemented with the questionnaire-based survey, focus group discussions and personal observations.

For socioeconomic surveys, key informant interviews (n=150), focal group discussions with fishers (n=10), and personal observations, were used. We compiled detailed information on the types of fishnets used, their mesh-sizes, lifespans, prices per nets, and their impacts on aquatic species through field survey and secondary information such as government reports and databases. We surveyed grassroots administrative units viz., Block and Gram Panchayat (village councils) offices (n=20) for information on activities and facilities available to handle the GG.

Based on questionnaire surveys, focus group discussions and discussion with officials from government and non-government organizations, we proposed a fishing net buy back model.

Results

Quantification, density and impacts of fishing gears in Ganga River

Fishing intensity along the Ganga River

The intensity of encountered fishing nets in the Ganga River was assessed across six ecological surveys conducted between April 2018 and February 2021. We observed that the highest intensity of fishing nets was in the lower segment of the river with the highest number of fishing nets in West Bengal (n=4690) followed by Uttar Pradesh (n=2131), Bihar (n=1194) and Jharkhand (n=191). The presence of fishing gears was mapped on the scaled 1 to >100; where each number represented presence of fishing gears in every 5 kms stretch of the river e.g. 1 represented presence of one fishing gear per 5 kms stretch of the Ganga (Figure 1).

Entanglement of species in fishing nets

Based on the river and socio-economic surveys conducted, a total of 72 incidents of species entanglement (both dead and alive) in fishing nets were recorded. The highest (n=21) incident of entanglement was for "Vulnerable" Indian Flapshell Turtle (*Lissemys punctata*), followed by the "Critically Endangered" Gharial (*Gavialis gangeticus*) (n=11, Table 1). The reported numbers likely underestimate the true extent of the issue, as they only account for incidents documented during the survey period (~30 days per years) and incidents reported by local communities to our team. The cases recorded for entanglement are positively correlated with the presence of the volunteers along the river ($R = 0.91$, $p = 5.8e{-}06$; Figure 2).

About 25% of the respondents from fishing community (n=150), were aware of the impacts of GG on aquatic biodiversity. Fishermen (80%) also reported that one fishing net is used for about two years, although during heavy floods the nets are often lost. Hence, the average life span of a fishing net is generally less than 2 years. All the respondents confirmed that they previously (by respondents or by their elders in the past) used fishing net made of natural fibres (known as *pehra* in some parts of Uttar Pradesh). However, they have now switched to gears made of synthetic material due to their affordability and availability. They buy the fishing nets from the government subsidized depots and market, and the price varies with the mesh size. Minimum mesh size used is 0.5 inches that costs approximately US$8 per kg. Costliest net is about US$22 to 25 per kg.

About 40% of the respondents reported that they have witnessed aquatic species entangled in the GG. Low education level was the limiting factor regarding the awareness and access to information on GG and their impacts on environment and fishing as a livelihood. All the block level and panchayat offices (n=20) in Uttar Pradesh, Bihar, Jharkhand and West Bengal, lacked the facilities and mechanisms to collect, store and recycle the GG found in their respective areas.

Interviews with government officials, fishers and other local people, and review of government records and reports revealed that there is lack of mechanisms and standard protocols for managing the GGs.

A buyback model is proposed to encourage fishers to bring the old nets to a collection centre (Figure 3). Following are the steps for an effective implementation of buyback model in a mixed economy:

Collection

Considering the extensive network and reach of Government-owned Fair Price Shops (FPS), and the high visitation rates, FPS may be used as local/village level collection centres, where the fishers can drop off their old/damaged fishing nets for a price. The fishing nets from the FPS will be collected by the members of the Self Help Groups (SHGs).

SHGs comprising of female members of the fisher households and/or belonging to Fisheries Cooperative Societies (FCS) may be involved in the collection of old/damaged or discarded fishing nets. These SHGs will collect the nets directly from the fishers or FPS. The fishers will be paid a price for their nets and the operators of the FPS will be reimbursed the amount they paid for the fishing nets collected by them. The fishing nets will be collected by the SHGs regularly and taken to the block level processing centres for sorting and cleaning. Nets will be sorted and stored based on the type of polymer and the quality of the nets received. The centre may be set up in coordination with the block administration, preferably at the Block Office.

A district level consolidating centre may be established in the district headquarters to collect fishing nets from all the block fishing net processing centres in the concerned district. At these centres, the fishing nets will be sorted, baled and stored, ready to be transported for recycling. Trained individuals from the FCS or fishing community may be engaged for sorting, baling and storing of fishing nets, and overseeing of day-to-day operations. Additionally, linkages between the district administration and SHGs/FCS must be strengthened for the smooth functioning of the initiative through open channels of communication.

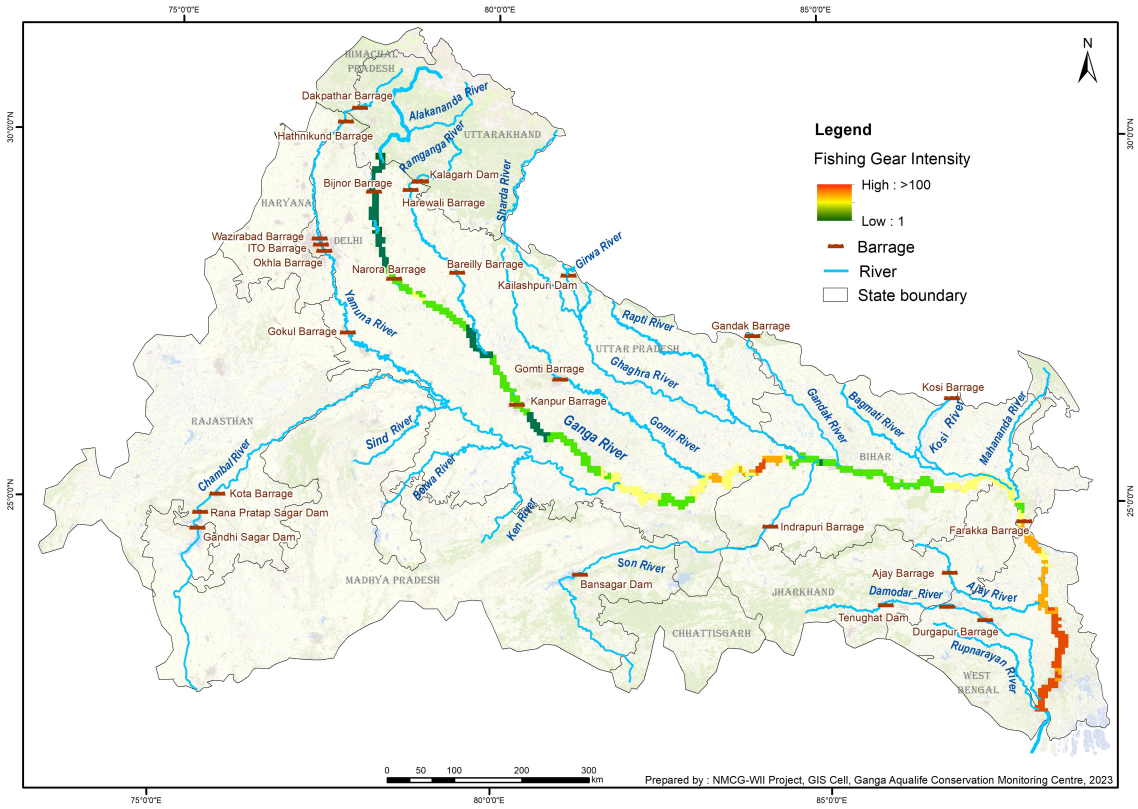

FIGURE 1
Fishing intensity in the Ganga River, India.

Pricing mechanism

Site-specific prices may be set for the fishing nets, with separate prices for old, damaged and/or discarded fishing nets and fishing nets damaged during rescue of aquatic fauna. The pricing policy and relative income shares at the level of the community may be determined in consultation with the communities themselves. Considerations while setting the price may also include supply of old, damaged and/or discarded fishing nets and fluctuation in market prices.

The subsidies on the fishing nets will be granted based on the time of usage, i.e., the longer the time of usage, the higher the subsidy on the

TABLE 1 Species and number of individuals rescued from fishing nets during 2021–2023.

Common Name	Scientific Name	IUCN Red List	Wild Life Protection Act, 1972	No. of Individuals
Gangetic Dolphin	*Platanista gangetica*	Endangered	Schedule I	3
Gharial	*Gavialis gangeticus*	Critically Endangered	Schedule I	11
Mugger	*Crocodylus palustris*	Vulnerable	Schedule I	1
Indian Flapshell Turtle	*Lissemys punctata*	Vulnerable	Schedule I	21
Indian Softshell Turtle	*Nilssonia gangetica*	Endangered	Schedule I	9
Indian Narrow Headed Softshell Turtle	*Chitra indica*	Endangered	Schedule I	4
Brown Roofed Turtle	*Pangshura smithii*	Near Threatened	Schedule II	2
Black Pond Turtle	*Geoclemys hamiltonii*	Endangered	Schedule IV	1
Indian Tent Turtle	*Pangshura tentoria*	Least Concern	Schedule I	1
Three Striped Roofed Turtle	*Batagur dhongoka*	Critically Endangered	Schedule I	1
Unidentified turtle species	––			18
Total				**72**

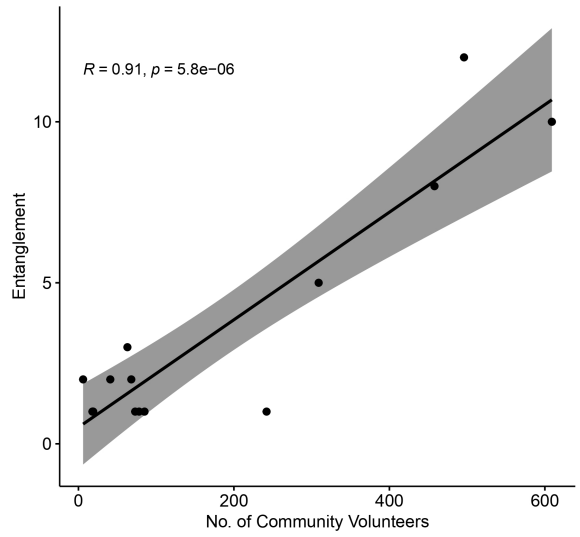

FIGURE 2
Correlation between presence of trained community volunteers and cases of entanglement reported from the Ganga River, India.

purchase of a new net. To determine the time of usage, a tracking system may be introduced such as biometry enabled magnetic cards that record every purchase of fishing net, similar to the documentation provided by the ration card. A revolving fund may be created for the SHGs to enable them to purchase the old, damaged and/or discarded fishing nets, with initial seed money provided by the Government. The revolving fund will also provide simple savings and loan facilities, and the accumulated profits may be distributed back to the members. Formal records of every fishing net collected, along with the name and other details of the fisherman, may be maintained digitally and in hard copy by the SHGs, Block processing centre, and District consolidation centres. Locally, every individual depositing a fishing net to the SHGs must be paid promptly. At the block processing centre, records from the SHG may also be shared with the district consolidating centre. Every SHG depositing the fishing nets must be paid promptly.

Building a circular economy

The collected, cleaned and baled fishing nets may be recycled through collaborations with national and international organisations working on recycling old, damaged and/or discarded fishing nets. Fishing nets can be recycled in two ways, mechanical and chemical. Although mechanical recycling, wherein the plastic wastes are processed into secondary raw materials or products without significantly changing its chemical structure, is more widespread, to build a circular economy, chemical recycling may be prioritised. Chemical recycling entails that the plastic is broken down and regenerated into new virgin-like plastic enabling recycling or even upcycling. Potential national partners that have existing infrastructure for chemical recycling may be identified. In the absence of said partners, the nets may be exported to responsible global markets. New opportunities to establish responsible chemical recycling in India may be explored and developed.

Formalising the fishing gear sector

Steps may be undertaken to formalise the fishing gear sector, especially in rural areas. Fishing gear vendors may be mandated to document and record the sale of fishing nets and other gear. Details to be recorded may include the type, length and weight of the fishing net, the name of the buyer and the date of purchase. This will enable the Government to upgrade the buyback scheme in the future wherein payments may be linked to the age of the fishing net, to incentivise fishers to use the net for a longer period of time.

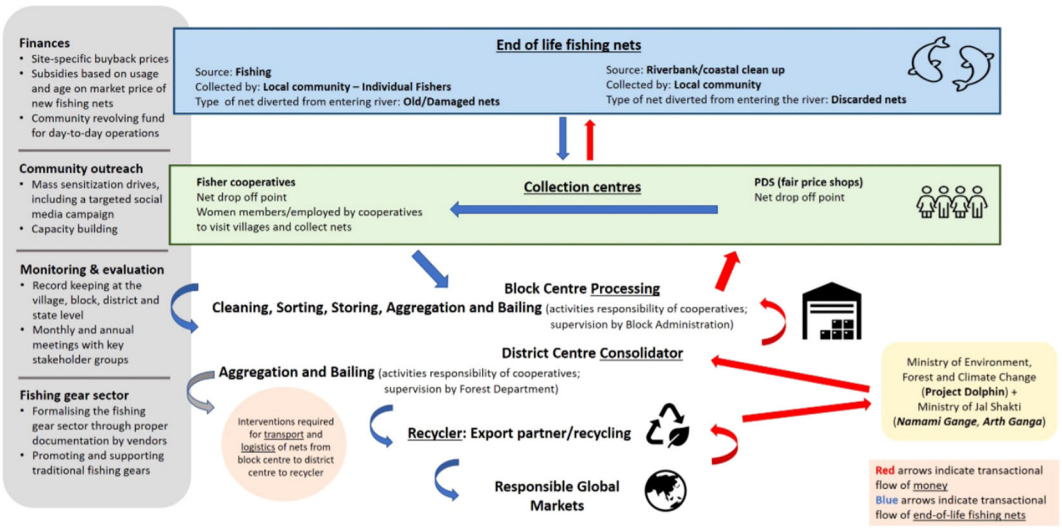

FIGURE 3
A detailed description of the proposed fishing net buy back model for the Ganga River System, India.

Building capacity of local communities and institutions for monitoring

It is suggested that capacities of local people and institutions such as village councils should be developed to conduct regular monitoring of the river for reporting the GG in their vicinity. Timely reporting can minimize the negative impacts such as entanglement of species.

Promoting and supporting traditional fishing gears

Along the Ganga River several indigenous communities such as the Santhals and the Nishads, used traditional low cost and biodegradable fishing gears. Although they have now shifted to modern gears, the traditional knowledge and gears should be revived and promoted. Local groups can be identified and their capacities should be developed to make the biodegradable traditional gears.

Monitoring and evaluation

The progress of the scheme may be evaluated at the monthly meetings with properly documented proceedings. This will enable effective implementation and monitoring of the progress of the fishing net buyback scheme, and also of the Plastic Waste Management Rules, 2016, 2021 and 2022, along with other interventions by the Government to combat plastic pollution or aid aquatic biodiversity conservation. In areas where buy back initiatives for old, damaged and/or discarded fishing gear are already underway, linkages may be established and/or strengthened with the implementing organisation. Efforts may be made to engage entrepreneurs and organisations by conducting workshops where they can learn about the scheme and expand the network.

Discussion

Ghost gears pose serious threats to biodiversity (WWF, 2020) at local, regional and global levels. Owing to the increasing demand, intensified fishing activities have led to a greater presence of GG in fresh and marine water ecosystems. Studies have revealed that plastic in rivers may be trapped in lower reaches for decades, which leads to formation of microplastics (Tramoy et al., 2020; Ryan et al., 2023). GG not only pose a significant threat to biodiversity but also impact human health and livelihoods (Nguyen and Bui, 2023). Despite the several reports of threats to aquatic species due to discarded fishing gear, the issue has not been addressed through policy.

Indigenous communities in many regions in the world practice fishing the traditional way. Indigenous fishing knowledge (IFK) is the knowledge of fishing techniques and practices passed on from one generation to another, mostly orally, over a period of time for the conservation of fish resources and is found to be useful in achieving continuous genetic diversity in fish (Kitolelei et al., 2021). To indigenous fishing communities, various key species are of cultural and ecological importance (Galappaththi et al., 2020; Loch and Riechers, 2021). Globally, local fisher communities have developed their own sustainable resource management systems and have the knowledge to avoid the destruction of spawning areas, consequently maintaining fish genetic diversity and ensuring that young fish are not caught by fishers; these should be documented and taken into consideration while planning (Obiero et al., 2023). Samajdar and Saikia (2014) had recorded 23 indigenous fishing gears that were made from bamboo, metal and nylon. Traditional gear made of locally-available organic material is more suitable and sustainable for the biologically sensitive floodplain playing a crucial role in fish recruitment, nursery ground and supporting the rural economy (Sandhya et al., 2019). Our results show that fishers nowadays prefer monofilament nets that are made of plastic as they are cost effective, lighter in weight and have longer lifespan. The adversity of situation increases as in Ganga River, areas with high fishing gear intensity correspond to the high biodiversity zones, underscoring the critical relationship between biodiversity and fish yield (GACMC, 2024). Therefore, efforts should be made at all levels to encourage and incentivise fishers to use traditional fishing practices and the use of organic indigenous gear should be promoted through appropriate policy mechanisms. These mechanisms should be in line with the needs and preferences of the fisher communities.

In the Ganga River basin there is lack of awareness and mechanisms to handle and manage the GG, hence, it is an urgent need to prioritize the issue of GG polluting the Indian marine waters. About 80% of the respondents reported that they have lost their fishing gears, still only one fourth (25%) of the respondents were aware of the impacts of GGs. Lack of alternative livelihoods and increasing demands clubbed with high poverty levels further aggravate the situation (The World Bank, 2023). Cost of fishing gears also plays an important role in determining the usage pattern. As the traditional fishing gear with bigger mesh size is costlier, it is suggested that strategies should be introduced to lower the price of sustainable fishing gears. Incentives can be introduced to promote the natural fibre based fishing gears.

Our results indicate that entanglement cases are recorded more in the areas with presence of active volunteers from communities. It is suggested that if more people are sensitized and trained at sensitive areas, more cases will be recorded, which may help in developing an informed strategy to handle the GG in the area.

As it is not possible to completely replace the monofilament fishing gear, a system, both at local and regional levels, should be in place to minimize the presence of GG in the fresh and marine ecosystem. Authorities should be identified, who may ensure capacity building of the FCS, SHGs and fishing community in the following areas: (a) aquatic biodiversity, especially aquatic fauna, and conservation issues; (b) provisions of the Indian Wild Life (Protection) Act, 1972; and (c) rescue and rehabilitation of aquatic species in distress. The concerned members of the FCS and SHGs must be trained in day-to-day management of the SHGs and fishing net collection, processing and consolidating centres, including data entry, book-keeping, micro-finance, cleaning nets and identification of nets for sorting. Relevant research institutions and non-governmental organisations may be engaged for the same.

Awareness about the scheme and the impact of GG on aquatic ecosystems and biodiversity may be generated through the engagement of volunteers from the local community, including the fishers. Signage, bill boards and wall paintings may be placed at strategic locations to create mass awareness.

United Nations Department of Economics and Social Affairs started the Global Ghost Gear Initiative in 2014 with the objectives of increasing awareness, investing in technologies, preventing equipment loss through responsible practices, and retrieval and proper disposal of GG. In 2018, the FAO Committee on Fisheries adopted Voluntary Guidelines for the Marking of Fishing Gear to fill the gap and provide support to assess, monitor and manage ghost gear-related issues (FAO, 2024). New global instruments such as the agreement made by governments during the Fifth session of the United Nations Environment Assembly (UNEA) in Nairobi, Kenya, on 28 February – 2 March 2022, where they agreed to adopt legally-binding provisions and obligations to prevent and remediate plastic pollution and its toxic impacts, are addressing the issue of plastic waste using a human rights-based approach due to the threats to human, animal, and environmental health.

During the Assembly an international legally binding instrument was developed to address plastic pollution in the marine environment "UNEA Resolution 14: End Plastic Pollution: Towards an International Legally Binding Instrument" (UNEP, 2024). More such guidelines and instruments need to be put in place at policy level as there are still various gaps in the legal framework. The National and International laws do not specify any GG collecting and discarding protocols and at the most promote recycling (Supplementary Tables S2, S3). The existing policies do not explicitly mention any form of buybacks, subsidies and circular economy models to address this issue, resulting in their failure to significantly alter the trends in plastic flows and pollution (OECD, 2023). Additionally, no policies address issues of disposal of ghost gears in riverine systems (Supplementary Table S3). Policies and laws are generally prohibitive in nature though the statistics on plastic pollution due to fishing gear makes it evident that this does not translate into grassroots level reality.

As per the OECD (2023) report, "Global ambition with early, stringent and co-ordinated policy action could cut plastic waste generation in 2040 by a quarter below baseline and virtually eliminate mismanaged waste by 2040 (from 119 Mt to 4 Mt)." This would result in plastic leakage being nearly eliminated. To make this a reality, governments need to adopt appropriate waste management practices with improved waste collection and recycling guidelines directed at reducing the leakage of plastics. In November 2023, representatives from 175 countries convened in Nairobi to work on potential diplomatic solutions to the global plastic pollution crisis. The draft zero of their discussion includes concerns about microplastics and ghost gear. There are high hopes for big moves globally aimed at combating the ghost gear problem through field action and diplomatic policy changes.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Permission for conducting the study was granted by the Chief Wildlife Wardens of Uttar Pradesh, Bihar, Jharkhand, and West Bengal Forest Department.

Author contributions

SB: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. AG: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. PD: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. SP: Visualization, Writing – original draft. MK: Formal analysis, Writing – original draft. SH: Funding acquisition, Project administration, Supervision, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This research was conducted as part of the projects "Biodiversity Conservation and Ganga Rejuvenation" and "Planning & Management for Aquatic Species Conservation an d Maintenance of Ecosystem Services in the Ganga River Basin" which received funding (No. B -02/201 5 -16/1259/NMCG -WI I Proposal and No. B -03/2015-16/1077/NMCG -New Proposal) from the National Mission for Clean Gang a (NMCG), Ministry of Jal Shakti, Government of India.

Acknowledgments

We would like to thank the Chief Wildlife Warden of Government of Madhya Pradesh, Rajasthan, Uttar Pradesh, Bihar, Jharkhand and West Bengal for providing and facilitating timely research permits to conduct the study. We acknowledge the help guidance and support provided by the Director and Dean at the Wildlife Institute of India in carrying out this study. We acknowledge the Frontiers journal team for their support at every step and also the important role played by the reviewers in improving our manuscripts with their constructive intellectual remarks.

Conflict of interest

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

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcosc.2024.1341434/full#supplementary-material

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