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Fishing Gear Recycling: Minimizing Waste and Promoting Sustainability

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Abstract

The indiscriminate disposal and loss of synthetic fishing gear in marine environments has emerged as a critical ecological and socioeconomic challenge. With over 640,000 metric tons of fishing gear entering the oceans annually, ghost gear—abandoned, lost, or discarded fishing gear (ALDFG)—poses severe threats to marine biodiversity, navigation safety, and coastal livelihoods. This review explores the lifecycle of fishing gear, from end-of-life management and environmental impacts to innovative recycling, upcycling, and biodegradable solutions. Gear waste is categorized into End-of-Life and ALDFG, each requiring unique recovery approaches. Ghost gear contributes to habitat destruction, marine animal entanglement, and fish stock depletion, adversely affecting small-scale fisheries. Globally, legal instruments like MARPOL and the FAO Guidelines, alongside regional policies such as India's Marine Fishing Regulation Acts and emerging EPR frameworks, aim to address the issue. Technological innovations—including drones, sonar, satellite mapping, AI, and smart nets—enhance gear detection and retrieval. Recycling techniques for nylon, polypropylene, and metal components support material recovery, while upcycling initiatives such as backpacks, sunglasses, and skateboards from ghost nets offer high-value alternatives. The transition to a circular economy is further advanced by "gear-as-a-service" models and community engagement through awareness campaigns and citizen science platforms. Case studies from the Philippines, Chile, Spain, and India demonstrate scalable solutions for sustainable gear management. However, challenges persist due to high processing costs, infrastructure gaps, and limited market demand. Policy recommendations include enforcing EPR, subsidizing R&D for biodegradable gear, and mandating port waste facilities. A multi-stakeholder, circular approach is essential to mitigate ghost gear impacts and promote marine sustainability.

Keywords: Ghost fishing gear, Minimizing waste, Promoting sustainability, Recycling

Introduction

Fishing gear has evolved significantly, transitioning from traditional biodegradable materials like hemp and cotton to modern synthetic polymers such as polyethylene (PE), polypropylene (PP), and nylon. While these synthetic materials offer greater strength, durability, and resistance to environmental degradation, they also pose a serious ecological

threat due to their non-biodegradable nature—persisting in marine environments for up to 600 years. This shift has contributed to the growing problem of Abandoned, Lost, or Discarded Fishing Gear (ALDFG), also known as ghost gear. An estimated 640,000 metric tons of fishing gear are lost to the oceans annually, continuingto trap and kill marine life long after its intended use. Ghost gear accounts for roughly 10% of all marine plastic pollution but is far more damaging due to its entanglement and ingestion risks. It causes the death of over 136,000 marine mammals and countless other species each year, while also damaging coral reefs, reducing fish stocks, and endangering navigation. This crisis extends beyond environmental concerns, affecting the livelihoods of coastal fishers and increasing operational hazards. In response, sustainable management of fishing gear has become a global priority. Recycling, recovery, and upcycling of gear, along with the development of biodegradable alternatives, represent promising solutions. The transition to a circular economy in fisheries, emphasizing gear collection, reuse, and responsible disposal, supports the United Nations Sustainable Development Goals (SDG 12-Responsible Consumption and Production, SDG 14-Life Below Water, and SDG 17- Partnerships for the Goals). Collaborative efforts among governments, industry, and communities are essential to mitigate ghost gear impacts and promote long-term marine sustainability.

2. Categories of Fishing Gear Waste

Fishing gear waste can be broadly categorized into two main types: **End-of-Life (EoL) gear** and **Abandoned, Lost, or Otherwise Discarded Fishing Gear (ALDFG)**. Both categories significantly contribute to marine pollution but differ in their origin, condition, and management requirements.

A. End-of-Life (EoL) Gear

End-of-Life fishing gear refers to equipment that has reached the end of its usable life due to damage, wear and tear, or obsolescence. These gears are intentionally removed from use and disposed of by fishers or gear owners.

Characteristics:

- Intact or partially damaged gear
- Disposed through onshore pathways (e.g., dumping, landfill, or ideally, recycling)
- Can be collected and managed systematically

Examples:

- Old nylon gillnets with multiple tears
- Rusted or broken hooks from longlines
- Worn-out trawl cod-ends that no longer retain catch efficiently

- Decommissioned plastic buoys or floats

Management Possibilities:

- Recycling into plastic pellets, doormats, or footwear
- Upcycling into art or furniture
- Repurposing as materials in aquaculture cages

B. ALDFG – Abandoned, Lost, or Otherwise Discarded Fishing Gear

ALDFG includes fishing gear that is no longer under the control of the fisher due to operational or accidental reasons. It may continue to drift in the ocean, sink to the seabed, or entangle marine life, posing a long-term threat to ecosystems.

Subcategories:

1. **Abandoned** – Deliberately left behind (e.g., illegal fishing or economic reasons)
2. **Lost** – Unintentionally separated from the vessel (e.g., storms, snagging)
3. **Discarded** – Thrown overboard due to space issues or regulations

Examples:

- A gillnet torn from its anchor during a cyclone and left drifting
- A trawl net cut loose to prevent capsizing in rough seas
- A longline set that broke mid-operation and could not be retrieved

Impacts:

- Ghost fishing: Continued capture of fish and other marine life
- Navigation hazards for vessels
- Habitat destruction (e.g., coral reefs)

Management Challenges:

- Difficult to locate and retrieve
- Requires collaborative monitoring and reporting systems like GPS tagging, gear marking, and retrieval programs

3. Environmental and Socioeconomic Impacts of Ghost Gear

Ghost gear means abandoned, lost, or discarded fishing gear (ALDFG), represents one of the most harmful forms of marine debris due to its durability and persistent presence in the ocean. Its impacts span ecological, economic, and social dimensions.

A. Entanglement and Ingestion Risks

Ghost gear poses severe risks to marine fauna through:

- **Entanglement**: Marine mammals (e.g., dolphins, seals), seabirds, turtles, and fish become trapped, leading to injury, drowning, or starvation.

- **Ingestion**: Fragments of gear (nylon filaments, hooks, floats) are mistaken for prey and ingested by species like turtles and seabirds, leading to internal injuries, digestive blockage, or death.

B. Navigation Hazards and Fish Stock Depletion

- **Navigation Hazards**: Large floating or submerged nets can foul boat propellers or damage rudders, posing serious safety threats to fishing and transport vessels.
- **Fish Stock Depletion**: Ghost gear continues to trap and kill fish indiscriminately ("ghost fishing"), which:
    - Wastes commercially important species
    - Reduces recruitment rates
    - Distorts catch data used for fisheries management

C. Livelihood Losses for Small-Scale Fishers

- Lost gear can represent a significant investment for artisanal fishers who often lack backup equipment or access to formal insurance.
- Ghost fishing reduces the availability of target species, leading to reduced catch and income.
- Navigation hazards increase operational risks and repair costs, especially in traditional vessels.

D. Ecosystem-Level Threats

Ghost gear threatens the structural and functional integrity of marine ecosystems:

- **Coral Reefs**: Nets dragged across reefs cause breakage, smothering, and long-term habitat degradation.
- **Seabirds and Marine Turtles**: Breeding and feeding populations suffer population-level impacts due to increased mortality.
- **Seafloor Damage**: Heavy gear such as trawl doors or longline anchors disrupt benthic habitats when left on the seabed.

4. Global and National Legal Framework Addressing Ghost Gear

The issue of abandoned, lost, or discarded fishing gear (ALDFG) is addressed globally through treaties, guidelines, and national policies aimed at prevention, recovery, traceability, and accountability. MARPOL Annex V, a legally binding treaty, prohibits the discharge of plastics, including synthetic fishing gear, into the sea and mandates proper disposal at port reception facilities. However, enforcement is limited and primarily targets deliberate disposal. To promote gear traceability, the FAO's Voluntary Guidelines on the Marking of Fishing Gear (2019) recommend standardized marking with unique identifiers to trace gear ownership and origin. Though not mandatory, these are increasingly adopted in

national fisheries plans. The European Union's Directive 2019/904 on Single-Use Plastics recognizes fishing gear as major marine litter and enforces Extended Producer Responsibility (EPR). Under this law, producers must fund gear collection, disposal, and public awareness campaigns, shifting responsibility from fishers to manufacturers and supporting circular economy goals. In India, while the Coastal Regulation Zone (CRZ) Notification, 2019 doesn't directly address ghost gear, it contributes to broader marine conservation. Each coastal state enforces Marine Fishing Regulation Acts (MFRAs) controlling gear types and fishing practices, though most lack specific ghost gear provisions. India is now considering EPR norms for fishing nets under its Plastic Waste Management Rules, which would require manufacturers to manage collection and recycling, making India a pioneer among developing nations in regulating end-of-life fishing gear.

5. Gear Collection and Sorting Mechanisms

Efficient collection and sorting of end-of-life and abandoned fishing gear is vital to reducing the environmental impact of fisheries. Port-based collection centers, located at major harbors and landing sites, serve as drop-off points where fishers can voluntarily deposit used or damaged gear. These centers are often managed by government agencies, cooperatives, or NGOs.

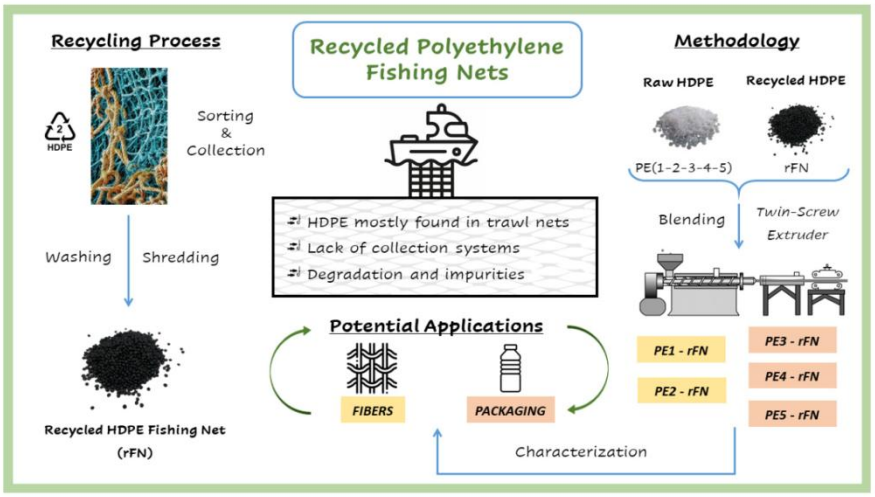
To boost participation, incentive-based schemes are increasingly adopted, offering cash rewards, discounts on new gear, or recognition to fishers who return old nets. Such initiatives encourage responsible disposal and reduce gear abandonment.

Once collected, gear is segregated by material type to facilitate recycling. Nets made from nylon or HDPE are separated from ropes, while metallic components like hooks and chains are set aside for metal recovery. Rubber items such as floats are sorted accordingly. This initial sorting ensures that each material stream is directed to the appropriate processing facility—whether for plastic shredding, upcycling, or metal smelting.

6. Material Recovery and Recycling Processes

Recycling fishing gear involves specialized processes tailored to each material type, promoting circularity and reducing environmental harm. Nylon nets, commonly used in fishing, are cleaned, shredded, melted, and extruded into plastic pellets. These are repurposed into products like carpet tiles, with companies such as Interface Inc. leading industrial-scale applications.

Ropes and monofilaments, made from polyethylene (PE) or polypropylene (PP), follow similar steps—cleaning, chopping, and pelletizing—to be used in outdoor furniture, construction materials, and even new gear. Advanced methods like chemical recycling or pyrolysis can convert complex polymers into fuel or base chemicals.



Metal components such as hooks, chains, and sinkers are separated, cleaned, and smelted for reuse in various industries. Rubber items, like floats and insulation pads, are ground into crumb rubber for flooring and track surfaces or safely discarded if unrecyclable.

These recovery methods reduce dependence on virgin resources, cut marine litter, and provide economic value through industry partnerships—turning marine waste into marketable materials.

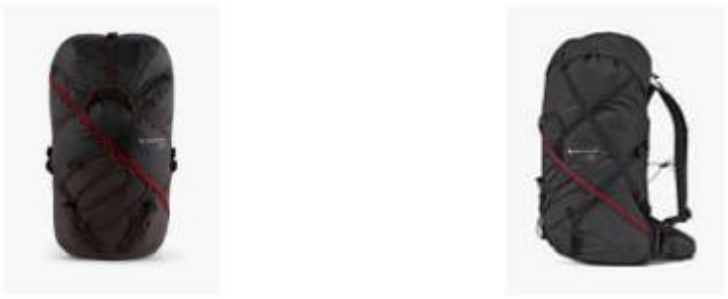
7. Upcycling and Repurposing Innovations

Upcycling fishing gear offers creative and high-value alternatives to traditional recycling, turning marine waste into functional and artistic products. This not only reduces ocean pollution but also raises awareness and supports circular economy practices.

Artistic repurposing uses discarded nets and ropes to create sculptures, installations, and crafts that promote marine conservation. These are often displayed in museums, aquariums, and public spaces, symbolizing sustainability through art.

In industrial design, ghost gear—especially nylon and PET nets—is upcycled into durable consumer goods:

- Parley and Timbuk2 produce eco-conscious backpacks from recycled marine plastics.



Backpack from recycled polyamide

- Bureo creates skateboards and surf fins from nets collected in Chilean coastal communities.

Skateboard from the recycled fishing gear

- Sea2See makes sunglasses using marine waste from the Mediterranean.
- 3D printing filaments derived from nets and monofilament lines are being marketed for sustainable prototyping.

These innovations demonstrate the value of fishing gear waste when creatively repurposed. They also support livelihoods in coastal communities, providing economic incentives for waste collection and local craftsmanship.

8. Circular Economy in the Fishing Sector

A circular economy in fisheries shifts from the linear "take-make-dispose" model to a closed-loop system where gear is used longer, repurposed, and recycled—reducing marine pollution and maximizing resource value.

Central to this model are the 4R**s**:

- **Reduce** gear loss through better maintenance and retrieval systems.
- **Redesign** gear to be biodegradable, durable, or smart (trackable).
- **Reuse** old gear in aquaculture, construction, or shading.
- **Recycle** synthetic materials into new products or raw materials.

An emerging model is **"**gear-as-a-service", where gear is leased instead of owned. Manufacturers remain responsible for collection, repair, and recycling, easing the financial burden on small-scale fishers while ensuring proper end-of-life management. With collaboration among governments, industries, fishers, and NGOs, the fishing sector can lead the way in integrating circular economy principles into marine sustainability.

9. Community Engagement and Education

Active engagement of coastal communities, particularly fishers, is crucial for effective ghost gear management and circular economy success. Fisher awareness programs, held at landing centres and harbours, educate on the impacts of abandoned gear, promote recycling, and inform about support systems like collection bins and incentives. These

initiatives are led by governments, NGOs, and research institutions. Outreach also targets youth, with school campaigns using clean-ups, art contests, and marine education to foster environmental responsibility. Educational tools like posters, comics, and games help instil a conservation mind-set early. NGOs and citizen science platforms play a major role in ghost gear recovery and data collection. Organizations such as MCS, Ocean Clean-up, and India-based groups like SNEHA Trust and TREE Foundation conduct beach clean-ups and public engagement activities. Platforms like Ghost Gear Reporter and Dive Against Debris enable volunteers to report ghost gear via GPS apps, contributing data to global networks like the Global Ghost Gear Initiative (GGGI).

10. Technological Advancements in Ghost Gear Detection

Advanced technologies have revolutionized the detection and tracking of ghost gear, enabling quicker, more efficient interventions.

- Drones (UAVs) are used for aerial surveillance of nearshore areas, identifying floating nets or entangled marine life through high-resolution cameras and thermal sensors. They are ideal for coastal monitoring due to their mobility and affordability.
- Satellites equipped with synthetic aperture radar (SAR) and multispectral imaging provide wide-area coverage offshore. These systems detect floating gear based on reflectivity and thermal signatures and assist in mapping drift patterns and accumulation zones.
- Sonar and echo sounders, particularly side-scan sonar, are employed to detect submerged gear entangled on reefs, wrecks, or seafloors—critical for deep-sea retrieval operations.
- Artificial Intelligence (AI) enhances detection by analyzing aerial and satellite images to automatically identify ghost gear. AI is also integrated into mobile apps that allow users to tag and report debris via citizen science initiatives.
- A key innovation in prevention is “smart nets”—gear equipped with GPS, RFID, or acoustic pingers. These allow real-time tracking and alert fishers of damage or detachment, minimizing gear loss.

11. Biodegradable Gear Research

Biodegradable fishing gear offers a sustainable alternative to synthetic materials like nylon and polyethylene, which persist in oceans for decades. Designed to degrade naturally in marine environments, biodegradable gear helps reduce ghost gear pollution. Researchers are exploring polymers such as Polylactic Acid (PLA), Polybutylene Succinate (PBS), Polyhydroxyalkanoates (PHA), and biodegradable nylon. These plant-based or microbially derived materials balance strength and elasticity during use but break down in seawater

within weeks to months. Field trials in Norway and Japan have shown promising results. For example, PBS-based gillnets in Norway degraded within 24–36 weeks. India, led by ICAR-CIFT, has initiated small-scale trials of biodegradable twines in Kerala and Tamil Nadu. However, challenges remain in higher production costs, reduced durability, and inconsistent biodegradation in varying ocean conditions. Despite these limitations, ongoing research is working to enhance performance and affordability.

12. Case Studies

Global and local initiatives show how collaboration can transform fishing gear waste into sustainable solutions:

- Interface + NetWorks (Philippines): Coastal fishers collect discarded nylon nets, which are recycled into ECONYL® yarn used by Interface Inc. for carpet tiles. The project supports both environmental goals and community livelihoods.
- Bureo (Chile): Through its "Net Positiva" program, Bureo collects fishing nets and turns them into skateboards, surf fins, and sunglasses using 100% recycled nylon, setting a precedent for circular economies in South America.
- Sea2See (Spain): Sourcing marine waste from Mediterranean ports, the company upcycles nets and debris into high-end eyewear and watches, combining sustainability with luxury.
- India – Tamil Nadu Net Buy-Back Scheme: Offers monetary incentives for returning damaged nets, reducing ocean dumping and enabling early recycling.
- India-Norway Projects: Technical collaborations support detection of ghost gear, biodegradable trials, and coastal clean-up under the Marine Litter Action Plan.

13. Challenges and Gaps

Despite progress, major obstacles remain:

- Inadequate infrastructure in coastal villages for gear collection and recycling.
- Mixed-material gear complicates sorting and reduces recycling value.
- Low market demand for upcycled products and high processing costs, especially in remote areas.
- Lack of incentives discourages fishers and recyclers from sustainable practices.

14. Policy Recommendations

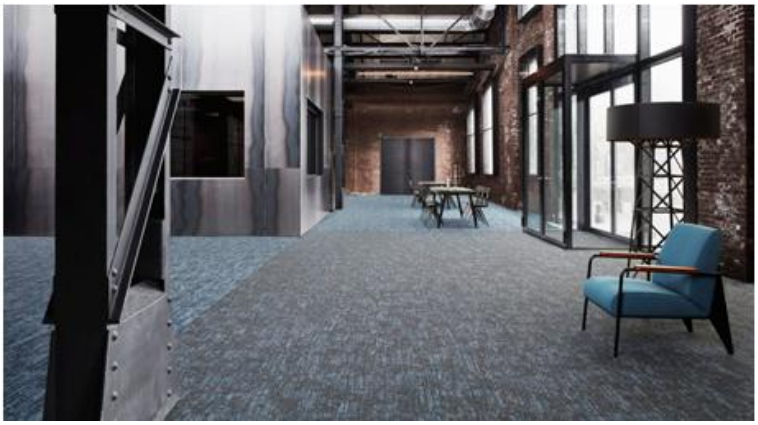
To overcome the above said barriers:

- Implement Extended Producer Responsibility (EPR): Make gear producers accountable for end-of-life recovery and recycling.
- Subsidize R&D for cost-effective biodegradable gear suited to tropical waters.

- Mandate port-based waste management facilities at all fishing harbors.
- Enable gear traceability via QR codes, RFID tags, or serial numbers for better monitoring and enforcement.

15. Conclusion

The growing crisis of ghost gear and marine plastic pollution presents an urgent environmental and economic challenge, especially for nations with expansive coastal fisheries like India. As synthetic fishing gear continues to degrade marine ecosystems, harm biodiversity, and threaten coastal livelihoods, transforming the current linear fishing model into a circular system has become imperative. While technical and financial barriers exist, the opportunities are substantial. Recycling, upcycling, biodegradable alternatives, and gear recovery systems can together build a sustainable fishing future. Progress is already visible through pilot programs, international collaborations, and innovative product development. Ultimately, success will depend on collaborative solutions involving fishers, policymakers, scientists, NGOs, and the private sector. By combining local action with systemic support, the fishing industry can not only reduce its environmental impact but also unlock new livelihood and market opportunities in the blue economy.



Retired fishing gear is being transformed into raw materials for new products like these blue-jean inspired carpet tiles

Rope made from Nylon monofilament gillnets

98% Econyl regenerated polyamide from fishing nets

Household product from Recycled fishing gear

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