Project Report Cover Page

UVic Sustainability Scholars Program

Project Title:

Researching Fishing Gear Pollution Types, Sources, and Supply Chains in BC Coast Fisheries to Support Policy Reform Proposals

Scholar's Name:

Shima Akar

Mentor Names:

Erin Gray, Staff Lawyer, West Coast Environmental Law

Lucas Harris, Executive Director, Surfrider Canada

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Disclaimer

This report is a product of the UVic Sustainability Scholars Program, a partnership between UVic and various on- and off-campus organizations offering internship opportunities to graduate students working on sustainability-focused research projects that advance sustainability in the region. This project was conducted under the mentorship of Erin Gray, Staff Lawyer at West Coast Environmental Law and Lucas Harris, Executive Director at Surfrider Canada.

Territorial Acknowledgement

I acknowledge and respect the lək̓ʷəŋən peoples on whose territory the university stands, and the Songhees, Esquimalt, and WSÁNEĆ peoples whose historical relationships with the land continue to this day. This author recognizes that the work for this project took place on these unceded ancestral lands and expresses gratitude for the privilege to conduct research in this beautiful and culturally significant area.

Abstract

Ghost gear, also known as abandoned, lost, or discarded fishing gear (ALDFG), poses a significant environmental threat both in Canada and globally. This problem encompasses fisher-specific gear, including both the methods—such as nets, lines, traps, and pots—and the equipment utilized, such as ropes, buoys, and foam floats, which are often abandoned or lost in marine environments. These abandoned items continue to capture and harm marine life long after being discarded. The initial phase of this project focuses on identifying and categorizing various types of debris collected from clean-up efforts along the BC Coast, using data primarily from 2021 and 2022. This phase involves cleaning the dataset for accuracy, analyzing it to identify the most common debris types and their locations, and providing a foundational understanding of debris distribution. Subsequent phases aim to identify the origins of these debris types by examining fisheries operating along the BC Coast and their gear usage through Integrated Fisheries Management Plans (IFMPs). This analysis establishes a link between the debris found and the responsible fisheries, aiding in the development of targeted mitigation strategies for gear used in British Columbia. The final phase centers on identifying the supply chain of fishing gear, including producers, distributors, and retailers. By mapping out these relationships, the project aims to understand how fishing gear reaches the market and propose measures to mitigate the impact of ghost gear, thereby supporting sustainable marine resource management. The findings will inform policy proposals to foster producer responsibility and promote environmental stewardship.

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Introduction to Ghost gear and project objectives

Introduction

Ghost gear, also known as abandoned, lost, or discarded fishing gear (ALDFG), is a significant environmental issue in Canada and globally. This problem involves fishing gear and equipment such as nets, lines, traps, and pots that are left in marine environments, continuing to catch and harm marine life long after they have been abandoned (1; 2; 3; 4). ALDFG significantly impacts shorelines, contributing to marine pollution and environmental degradation. Data from the Clean Coast Clean Waters clean-up show that ALDFG constitutes the majority of collected material. This gear, made from durable synthetic materials, can drift with currents and be deposited on beaches, affecting aesthetics, posing threats to wildlife, and introducing microplastics into ecosystems.

In Canada, ghost gear is recognized as a major threat to marine ecosystems. The country's extensive coastline, spanning 25,000 kilometers, makes it particularly vulnerable to this issue (1). Ghost gear can be lost or abandoned for various reasons, including:

1. Entanglement with other fishing gear or underwater obstacles
2. Severe weather conditions sweeping away equipment
3. Accidental cutting by marine traffic
4. In rare cases, intentional discard during illegal fishing operations (1; 2)

The amount of ghost gear entering the oceans annually is staggering. Globally, it is estimated that between 600,000 and 800,000 metric tonnes of ghost gear enter the oceans each year (2). While specific data for Canada is not readily available, the problem is significant enough for the country to have implemented a dedicated Ghost Gear Program in 2019, allocating over $26 million to fund 91 ghost gear projects (1)

Ghost gear contributes significantly to marine plastic pollution. Recent studies indicate that ghost gear may constitute up to 70% of all macro-plastics in the ocean by weight (2; 3; 4) . As plastic-based fishing gear degrades over time, it breaks down into microplastics, further exacerbating the impacts of plastic pollution in marine environments(2).

The environmental impact of ghost gear on ecosystems is severe and multifaceted:

1. Continued catch: Ghost gear is designed to capture marine life and continues to do so indiscriminately long after being abandoned. It is estimated that between 5% to 30% of harvestable fish are caught by ghost gear globally (2).
2. Entanglement: Marine mammals, sea birds, and various fish species can become entangled in ghost gear, leading to injury, starvation, or death (1; 2; 3; 4).
3. Habitat destruction: Ghost gear can damage sensitive marine habitats such as coral reefs and seagrass beds when dragged along the ocean floor by currents (1).
4. Food chain disruption: As ghost gear captures and kills marine life indiscriminately, it can disrupt local food chains and ecosystems (1) .

5. Species at risk: species at risk are vulnerable to ghost gear. Indeed, some ghost gear retrieval projects in Canada specifically target areas known to be habitats for species at risk, highlighting Canada's awareness of this threat (3) .
6. Economic impact: Ghost gear can lead to significant declines in harvestable fish stocks, with some estimates suggesting up to a 30% decline in certain fish populations due to ghost gear (4) .

The persistence of ghost gear in marine environments is particularly problematic due to the durability of modern fishing equipment. Many of the gear types is designed to last for decades, meaning their impact on marine ecosystems can be long-lasting if not addressed (1) .

In response to this issue, Canada has initiated programs to address ghost gear. The country has implemented a mandatory, no-fault gear loss reporting program for all fisheries and is involved in international efforts such as the Global Ghost Gear Initiative (4) . These efforts aim to prevent, retrieve, and responsibly dispose of ghost gear, mitigating its impact on Canada's marine ecosystems.

Project Objectives

This project aims to understand the fishing gear types and equipment used by the fisheries in BC and delving into the supply chain of fishing gear and identifying key actors involved. The findings will serve as the foundation for crafting policy proposals geared towards fostering producer responsibility and promoting environmental stewardship. The project objectives encompass several key components:

Analyzing Debris Data: Examining data from beach clean-ups in BC to gain insights into the types and quantities of ALDFG present.

Identifying Fishery and Gear Types: Identifying major BC fisheries and the gear types associated with them to assess their contribution to marine debris.

Investigating Supply Chain Actors: Conducting a thorough investigation into the supply chain of fishing gear used in BC fisheries, including mapping out manufacturers, distributors, and retailers involved in the gear's production and sale.

The outcomes of this study will ultimately be utilized to achieve the following goals

1. **Clarifying Legal Boundaries:** Examining who should regulate certain fishing gear and what responsibilities producers and distributors have in reducing abandoned gear.
2. **Proposing Regulatory Measures:** Crafting policy proposals, such as producer responsibility schemes, labeling requirements, and take-back initiatives, aimed at encouraging better fishing practices and reducing gear loss.
3. **Informing Stakeholders:** Providing policymakers, environmental organizations, and industry stakeholders with actionable insights and recommendations derived from thorough research and analysis, thus empowering informed decision-making and fostering collaboration towards sustainable marine resource management.

Project Plan

The project seeks to conduct a thorough examination of the dynamics surrounding ghost gear within the marine environment of British Columbia. The specific tasks outlined within the project's scope are detailed as follows:

Phase 1: Debris Type Data

- Utilize various sources of information regarding ALDFG collected during beach clean-ups in British Columbia.
- Provide data to understand the granularity of debris classification, ranging from broad categories like "plastic pieces" to specific types such as "Hard plastic fragments (#2 HDPE, #4 LDPE, #5 PP)" and "Hard plastic buoys (#2 HDPE, #3 PVC)."
- Identify the quantity and types of marine debris found on the BC Coast.

Phase 2: Fishery and Gear Types

- Identify major fisheries operating off the coast of BC.
- Determine the primary gear types used within each fishery and their associated equipment, emphasizing those showing up on BC Coasts like ropes, netting, and hard plastic buoys.

- Gather insights from resources such as the study in Marine Pollution Bulletin (5) provided by the mentors and potentially engage with fishers or fisheries experts for additional data.

Phase 3: Gear Supply Chains (main part)

- Investigate the supply chain of each type of fishing gear, with a focus on understanding manufacturing, distribution, and retail processes.
- Determine manufacturing locations, distribution channels and retail outlets for gear items.
- Explore the correlation between gear manufacturing/distribution/sales in BC and the debris found on BC beaches.
- Aim to differentiate ALDFG originating from non-Canadian vessels versus Canadian vessels through shoreline cleanup data analysis.

Potential future study

- Consider case studies to track specific pieces of gear, potentially involving direct communication with fishers or fishing vessel operators.
- Determining the volume of each gear and equipment type used in BC fisheries, providing a comprehensive understanding of the scale and usage patterns within the industry.

Phase 1: Identifying the debris type

1. Introduction

In Phase 1 of this project, the primary objective is to identify and categorize various types of debris collected from clean-up efforts along the BC Coast. This phase begins with a dataset obtained from the Clean Coast Clean Water Initiative (CCCW) (6) which documents information from multiple clean-up projects conducted in 2021 and 2022, predominantly focusing on 2021. The dataset includes detailed records of 13 different types of debris, along with methods of disposal.

The first step of Phase 1 involves cleaning the dataset to ensure accuracy and consistency. Once cleaned, the dataset was analyzed to determine distinct categories of materials. By exploring this data, we aim to identify the types of debris most commonly found and their prevalent locations. This analysis provides a foundational understanding of debris distribution, which will inform

subsequent phases of the project, where the focus will shift to identifying the origins of the debris and the responsible actors.

2. CCCW dataset

The dataset includes various types of debris found offshore on the BC Coast by CCCW, a provincial government initiative dedicated to cleaning up debris from the shoreline. During their cleanup efforts, the CCCW initiative discovered several derelict vessels and provided detailed data regarding these findings. The dataset contains:

1. Shoreline and Project Details: Information about the specific locations and the length of the shoreline that was cleaned. This includes data from two types of projects: shoreline cleanup projects and derelict vessel projects.
2. Number of Vessels Found: Data on the number of derelict or lost vessels found during ocean searches.
3. Total Debris Collected: Comprehensive data on the total amount of debris collected, with an emphasis on 13 different categories of debris materials. These materials range from foam floats to various types of fishing gear such as nets and ropes.
4. Debris Disposal and Reuse Methods: The debris is categorized based on its disposal or repurposing method:
    - Landfill Category
    - Recycled Category
    - Non-Recycled Debris
    - Reuse or Repurposing

This dataset provides valuable insights into the types of debris found along the BC Coast and their subsequent handling, helping to inform future cleanup and environmental protection efforts.

2.1. Exploring the data: debris categories

Foam Floats (PVC and Polyurethane): Foam floats, made from polyvinyl chloride (PVC) and polyurethane, degrade into small, lightweight fragments due to sunlight and physical abrasion. These fragments contribute significantly to microplastic pollution. The microplastics can absorb

harmful chemicals and be ingested by marine organisms, leading to health issues and bioaccumulation of toxins in food chains.

White Styrofoam (Expanded Polystyrene, EPS): Expanded Polystyrene (EPS), commonly known as white Styrofoam, breaks into small, buoyant pieces that persist in marine environments. Marine animals often mistake these pieces for food, causing internal injuries, blockages, and exposure to pollutants.

Hard Plastic Buoys (HDPE and PVC): Hard plastic buoys, made from high-density polyethylene (HDPE) and PVC, fragment over time due to UV radiation and physical wear. These microplastics are resistant to degradation and can remain in the environment for extended periods, accumulating in the guts of fish and seabirds, causing malnutrition and other health issues.

Hard Plastic Fragments (HDPE, LDPE, PP): Hard plastic fragments from HDPE, low-density polyethylene (LDPE), and polypropylene (PP) are ubiquitous in marine environments, originating from larger debris that has broken down. These persistent microplastics can travel long distances, posing a threat to filter-feeding organisms and other wildlife that ingest them.

Single-Use Plastic Packaging (HDPE, LDPE, PP): Single-use plastic packaging, such as containers and wrappers made from HDPE, LDPE, and PP, breaks down into microplastics through environmental exposure. These small particles are easily ingested by marine organisms, leading to physical harm and chemical contamination, exacerbating microplastic pollution.

Beverage Bottles (PET): Polyethylene terephthalate (PET) beverage bottles fragment into smaller pieces when improperly disposed of and exposed to environmental conditions. Lightweight PET microplastics can travel long distances by wind and water, posing a risk to marine life through ingestion and acting as carriers for toxic substances.

Oyster Baskets and Crab Pots (HDPE, PP): Oyster baskets and crab pots, made from HDPE and PP, break down into microplastics when damaged or discarded. These fragments can disrupt the feeding and reproductive behaviors of marine organisms and contribute to the overall microplastic load in critical aquaculture habitats.

Netting (HDPE, LDPE, PP, Nylon): Netting materials, made from HDPE, LDPE, PP, and nylon, degrade into microplastics through mechanical wear and environmental exposure. These microplastics can entangle marine life and be ingested, leading to physical harm and chemical contamination.

Ropes (HDPE, LDPE, PP): Ropes used in maritime activities, made from durable plastics like HDPE, LDPE, and PP, break down into microplastics over time. These small fibers can be ingested by marine organisms, leading to physical harm and potential exposure to toxic substances, contributing to persistent microplastic pollution.

Plastic Barrels (HDPE): Large plastic barrels, made from HDPE, break down into microplastics when degraded, contributing to marine pollution. These microplastics can be ingested by marine life, leading to physical injuries and chemical contamination, posing a long-term threat to marine ecosystems.

Tires with Styrofoam (Rubber and EPS): Rubber tires with Styrofoam break down into microplastics through wear and environmental exposure. Both rubber and EPS fragments are harmful to marine organisms that ingest them, leading to physical injuries and exposure to toxic chemicals, spreading widely due to their persistence.

Tires without Styrofoam (Rubber): Regular rubber tires, sometimes with metal or wooden parts, degrade into microplastics over time. These rubber fragments are a significant source of marine pollution, leading to physical harm and potential exposure to toxic substances for marine life.

Unclassified Items (Metal, Appliances): Various unclassified items, such as metal objects and discarded appliances, contribute to microplastic pollution when their plastic components degrade.

Fig. 1 illustrates the different categories of debris found during the Clean Coast Clean Water cleanup and the materials that these categories are composed of. For instance, it can be seen that hard plastic buoys are made of HDPE and PVC. Additionally, it is shown that HDPE is the most common material found, while LDPE and PP are the second most common materials in the debris collected on the BC Coast.

There are 13 different debris categories in the dataset. However, in this figure, unclassified debris has been eliminated, and tires with and without tire foam have been merged into one category, resulting in 11 categories of material.

Based on this figure, the following types of debris can be identified as resulting from the fisheries: hard plastic buoys, which are used for identifying the location of fishing gear; foam floats, used in fishing nets or lines; white Styrofoam, used as floats for fishing nets; oyster baskets; crab pots; netting; and rope. These items are typically associated with fishing activities. However, there is some uncertainty regarding the classification of plastic barrels and tires with and without tire foam. Plastic barrels can be used for various purposes, such as storing oil or other fluids, and may be found on fishing vessels, and they also can be used as buoys in fish aggregation devices by fisheries, meaning some portion could be fishing-related debris. Tires, on the other hand, are less directly associated with fishing activities but could still originate from fishing vessels or equipment.

Additionally, there is a category of hard plastic fragments, which are difficult to trace back to a specific origin in the dataset. These fragments are often too degraded or broken to identify their original purpose. Other debris categories such as packaging materials, hard plastic fragments, and beverage bottles are most likely the result of general individual use rather than specific to the fisheries.

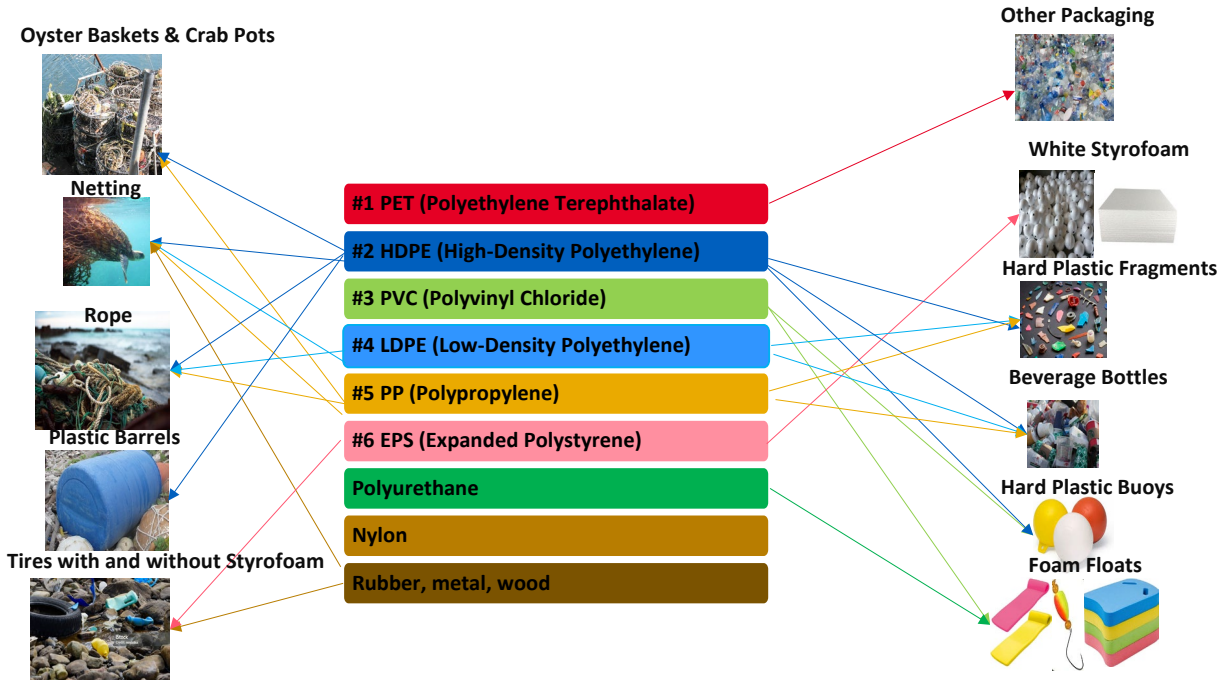


Figure 1 the debris classification and the associated material

2.2. Cleaning the dataset

Cleaning the dataset had several issues: some cells were empty and required filling. The main problem was the coordinates column for the start and end points of the cleaning sites, which lacked a unique or uniform format for location representation. For instance, some locations were recorded in DD (Decimal Degrees) format, while others used DDM (Degrees Decimal Minutes) format, and some were mixed. To resolve this, the data was cleaned and the latitude and longitude coordinates for both the start and end points of each site was standardized. This standardized data was then used as input for visualization in Tableau software.

3. Data visualisation: debris distribution analysis

In the first bar chart, **Fig. 2 (a)**, representing debris collected in 2021, the data indicates a substantial number of unclassified debris, including metal and appliances, leading the categories with close to 120,000 kg collected. Rope made of various plastics (#2 HDPE, #4 LDPE, #5 PP) and hard plastic buoys (#2 HDPE, #3 PVC) also featured prominently, with significant quantities collected at approximately 80,000 and 60,000 kg respectively. Other notable categories included tires without Styrofoam, hard plastic fragments, and netting, each contributing tens of thousands

of units to the overall debris. Foam floats, oyster baskets, and plastic barrels, although lower in quantity, still presented significant pollution challenges, while beverage bottles and other single-use hard plastics were collected in smaller, yet notable, amounts.

In contrast, the second bar chart, **Fig. 2 (b)** for 2022 shows a marked decrease in the total amount of debris collected across most categories due to the lower number of cleanup projects reported in the provided dataset. The unclassified debris remained the highest but saw a significant reduction to about 35,000 kg . Tires without Styrofoam were the second highest debris category, while in 2021, they ranked fourth. This discrepancy could be attributed to an outlier in the dataset: in 2022, a large number of tires were dumped on an island that fell within the cleanup area, significantly increasing the tire count for that year. As a result, the unusually high number of tires found in this year is not representative of the typical distribution and should be considered an outlier. Consequently, we cannot expect the same high number of tires without Styrofoam in 2023 under normal circumstances. Rope and hard plastic buoys continued to be major contributors, but at reduced levels of approximately 15,000 and 10,000 kg, respectively. Other categories – including plastic barrels, oyster baskets, and foam floats – also saw decreased reported amounts, resulting from fewer cleanup programs occurring in 2022. The data highlights a positive trend in reducing marine debris from 2021 to 2022, suggesting enhanced waste management practices or increased effectiveness of cleanup initiatives.

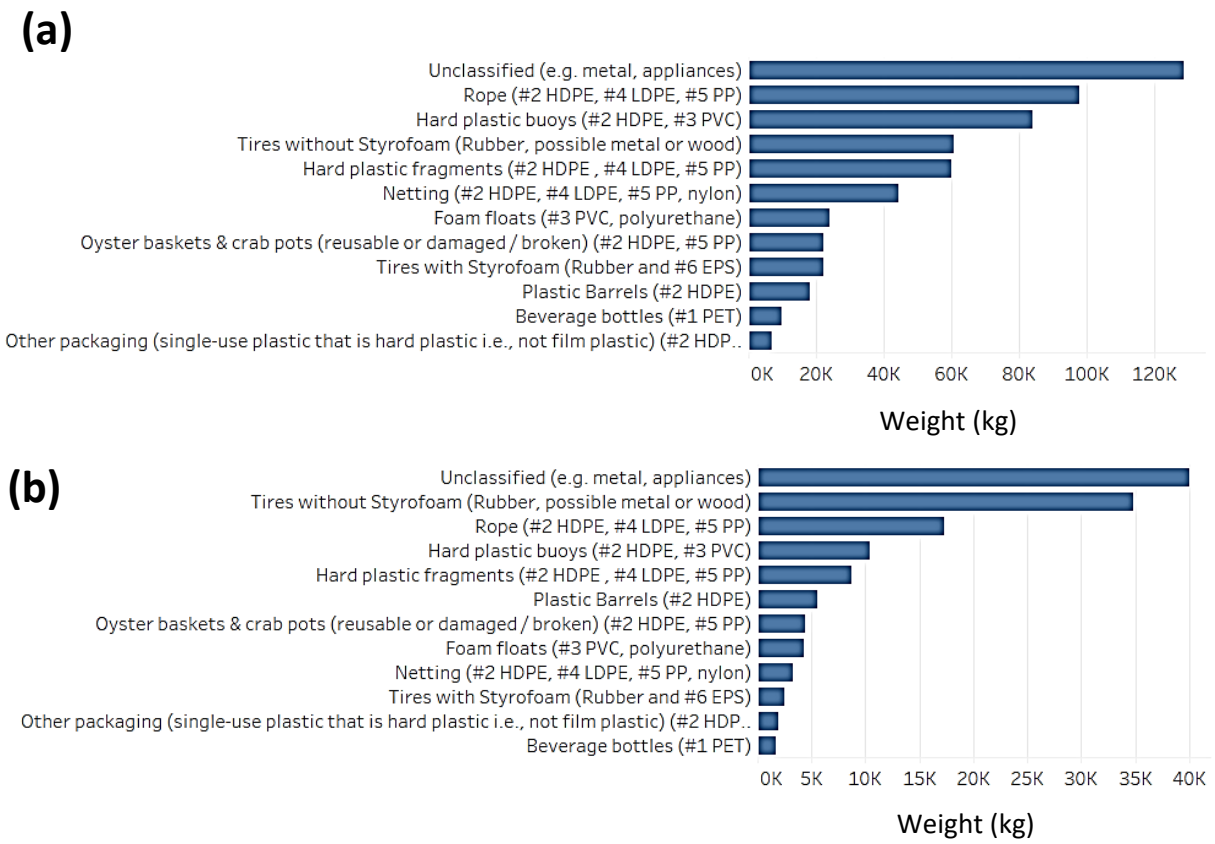


Figure 2 the quantity of debris collected in each debris categories in (a) 2021; CCCW dataset (6) and (b) 2022; CCCW dataset (6)

The bar chart illustrates the total amount of debris found on the shoreline of the BC Coast and how this debris is disposed of using three methods: landfilling, recycling, and repurposing or reusing. The data reveals that the majority of the debris is disposed of through landfilling. The combined total of debris that is recycled and repurposed or reused is nearly equivalent to the amount landfilled. This indicates that about half of the debris can be reintegrated into use, highlighting significant efforts in recycling and repurposing

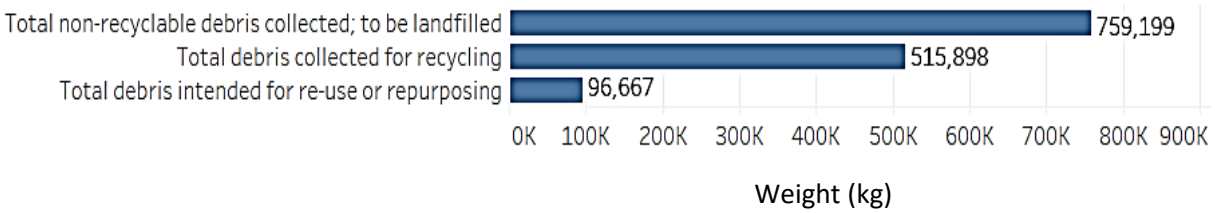


Figure 3 The total amount of debris collected by CCCW program and the disposal method (2021-2022; CCCW dataset (6))

Figure 3

Fig. 4 (a) and **5 (b)** provide insights into debris and lost fishing gear on the BC Coast. **Fig. 4(a)** shows the results of the CCCW dataset analysis, highlighting the locations where debris was found and cleaned in 2020, 2021, and 2022. The dataset indicates one point in 2020, over 70 locations in 2021, and 13 locations in 2022. The size of the points in each circle represents the volume of debris found. Notably, the majority of the debris was found near Tofino, Powell River, and Aristazabal Island. **Fig. 4 (b)**, based on the study by Caitlin M. Frankel [6], which shows the locations of lost fishing gear. Although it is possible that there is less debris in other areas, the absence of cleaning efforts there may account for the lack of data. By comparing the locations of lost fishing gear from Frankel's study with the CCCW data in **Fig. 4(a)**, we can identify several common hotspots where both debris and lost gear are found. It should be noted that the map diagram in **Fig. 4 (a)** illustrates the locations where debris was found, not where it was originally lost or produced. The map highlights the points of recovery during clean-up efforts, showing where the debris eventually settled. It is important to note that the actual origins of the debris may be different from the recovery locations, as items can travel significant distances due to ocean currents and other environmental factors.

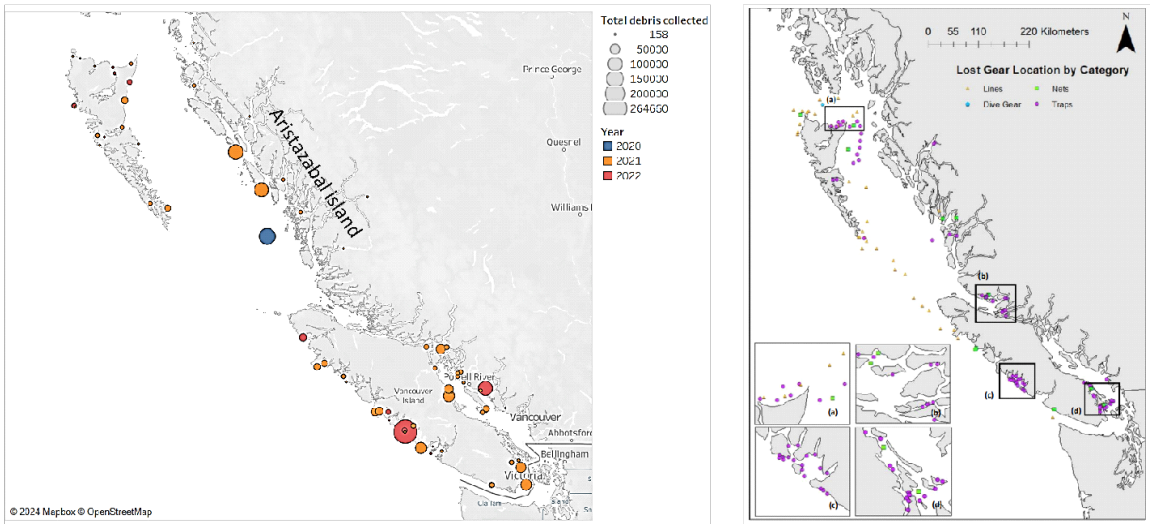


Figure 4 (a) the map diagram of collected debris on the BC Coast (2021; CCCW dataset (6)), (b) the location of fishing gear loss reported by Frankel (7)

Figure 4

Fig. 5 illustrates the most common locations where each category of debris is found on the BC Coast. For example, oyster baskets are primarily located near Powell River, while nets are more commonly found near Aristazabal Island. Similar to nets, ropes are most frequently found around Aristazabal Island. Plastic barrels are more uniformly distributed across Vancouver Island and Aristazabal Island. The distribution of hard plastic buoys mirrors that of ropes but with a greater concentration on the western part of Vancouver Island. Tires with Styrofoam are predominantly found near Powell River and various other islands. This detailed categorization helps identify specific debris hotspots, aiding targeted cleanup efforts.

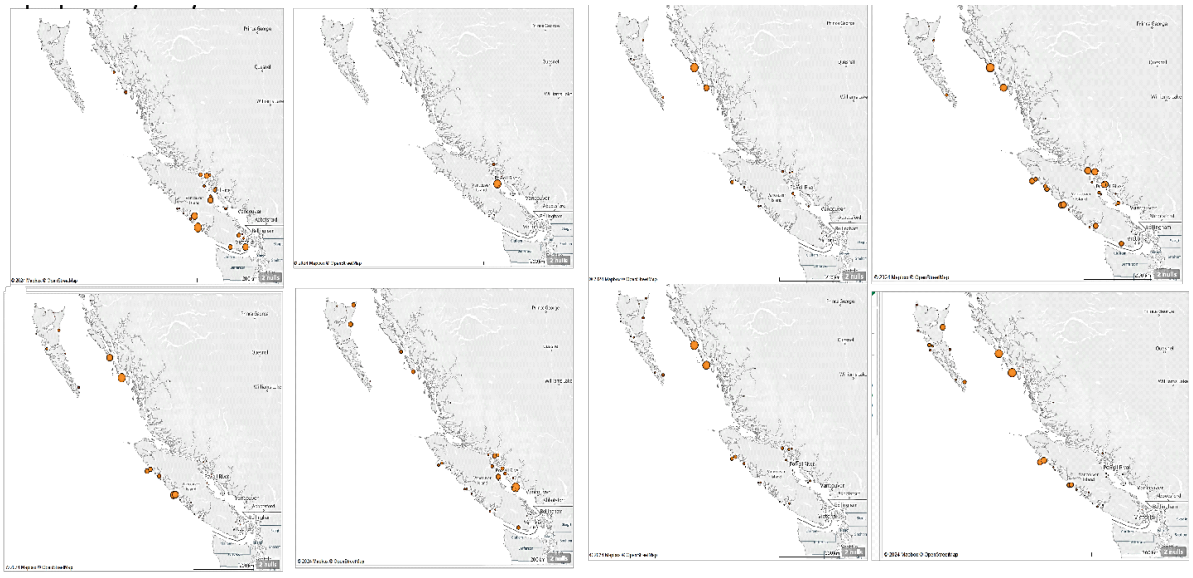


Figure 5 *The most common locations where each category of debris is found on the BC Coast, (2021; CCCW dataset (6))*

Phase 2: Fishery and Gear Types

1. Introduction

The next step of the project is to identify the key actors involved in producing the debris, with a primary focus on fisheries that may have lost their gear. In this section, we aim to identify all the fisheries operating along the BC Coast of Canada using data from Fisheries and Oceans Canada (DFO). After identifying these fisheries, we examined their Integrated Fisheries Management Plans (IFMPs) to determine the types of gear they use. By analyzing the gear types, we can establish a relationship between the debris found in the previous phase of the project and the fisheries that may be responsible for it.

2- Fisheries and associated gear

In this section, the fisheries operating on the BC coast were determined from IFMPs available on the DFO website. Additionally, the gear that is used in these fisheries, was also determined by the IFMPs, which are categorized by species and shown in **Table.1** (8). These plans provide the names of the fisheries and detailed information about the gear types they use. Most IFMPs do not, however, provide specific information about the equipment (such as rope and buoys). For the few that do, unique citations related to those IFMPs have been added in the table below. In other instances, the equipment details have been inferred from general information about the gear, which is likely consistent across BC fisheries. Notably, there are three fisheries—Ladysmith, French Creek, and Baynes Sound—that do not yet have an IFMP, so the gear types for these fisheries are not included.

Each fishery is divided into three sections: commercial fisheries, First Nation fisheries, and recreational or sport fisheries.

Table 1 The fisheries and gears type based on IFMPs [7]

Species	Fisheries	Gear	Equipment
Shellfish	crab-by-trap (9)	Trap, Dip nets, ring nets, or handpicking (9)	Rope: retrieve the trap from the sea floor (37) Buoy: mark the location of the rope and trap (37) Bait hard plastic cup: as baits container (9) Foam float: Marks submerged traps and provides buoyancy (37) ** hanging bait is prohibited (9)
	Euphausiid (11)	Plankton trawl nets (11)	Ropes: to tow the nets and the deploy and retrieve the gear (37)
	Geoduck and Horse Clam (12)	Divers using stingers (12)	Container: Clam shall remain in the container while taken to the surface and loaded onto the catcher boat, and then removed from the

			first container and immediately placed in another container (12) Buoys: Marking Fishing Areas (not mention explicitly (12))
	Intertidal clam (13)	Hand digging (13)	Container: Waterproof tags are required for all containers of clams harvested in the fishery (13)
	Prawn and shrimp by trap (14)	Trap (14)	Rope: retrieve the trap from the sea floor (37) Buoy: mark the location of the rope and trap (14) Container: all containers of frozen prawn tails to be marked or tagged (14) Foam float: Marks submerged traps and provides buoyancy (37)
	Razor clam (15)	Hand digging (15)	Container: All containers holding clams shall be marked or tagged (15)
	Scallop by dive (16)	dive and trawl gear (16)	Buoy: mark the location of trap (16) Ropes: to tow the nets and the deploy and retrieve the gear (37) Containers: Scallops containers or sacks must be individually tagged
	Sea cucumber by dive (17)	Hand picking by SCUBA divers (17)	Containers: used to Hold or Transport Sea Cucumbers (17)
	Green sea urchin by dive (18)	Dive (18)	Containers and Pick Bags: must be marked or tagged (18)
	Oyster (19)	Hand picking (19)	Container: Tagging of Oyster Containers for holding oysters (19)

	Geoduck and Horse Clam by dive (20)	Diver using stingers/wands (20)	Containers: used to Hold or Transport Geoduck and Horse Clam (20)
	Red sea urchin by dive (21)	Hand picking by SCUBA divers (21)	Containers: Used to Hold or Transport Red Sea Urchins (21)
	Shrimp by trawl (22)	Trawl beam trawls or otter trawl	Ropes: to tow the nets and the deploy and retrieve the gear (10)
	Ladysmith (23)	NA	NA
	French Creek (23)	NA	NA
	Baynes Sound (23)	NA	NA
Salmon	Southern Pacific Salmon (24)	Gillnets, Purse seines Troll gear Hooks and lines (trollers) Seine nets (with skiff) (24)	Rope: for encircling and towing nets, attaches floats and weights for gillnets and purse seine (10) Buoy: Keeps nets afloat and marks positions. (10) Foam float: Provides buoyancy to keep nets vertical and used for rudders(10) Containers: Used to Hold or Transport (24)
	Northern Pacific Salmon by various methods (25)	Gillnets Purse seines Troll gear (25)	Rope (10) Buoy (10) Foam float (10) Container (25) Float: attached to fishing gear for buoyancy and inside gears for rudders

	Transboundary Rivers Salmon by various methods (26)	Gill nets, troll, and seine nets. (26)	Rope (10) Buoy (10) Foam float (10) Container (26)
	Yukon River Salmon (27)	Fish wheels, Gillnets (27)	Rope used in gillnets (10) Buoy used in gillnets (10) Foam float used in gillnets (10) Containers (27)
Pelagic	Albacore tuna (28)	Surface gears (troll, pole-and-line), longline gear (28)	Rope: Mainline for branch lines with baited hooks (10) Buoy: Marks position of longlines for retrieval. (10) Foam float: Marks location and maintains gear at desired depths. (10)
	Pacific herring (29)	Roe Herring Fishery (seine nets, gillnets), Spawn on Kelp Fishery (enclosures), Food and Bait Herring Fishery (seine nets), Special Use Herring Fishery (rakes, dip nets, gill nets, hoop nets, enclosures). (29)	Buoy: Gill nets must be marked on both ends with buoys of similar colour (29) Rope used in gillnets and purse seine (10) Foam float used in gillnets and purse seine (10) Containers (29)
	Fraser River eulachon (30)	Gillnet (Indigenous) NA (for the rest) (30)	The commercial Eulachon fishery remains closed in all tidal waters and freshwater, including the Fraser River. (30) Rope (10)

			Buoy (10) Float: attached to the gillnets
	Sardine (31)	Purse Seine (31)	Rope (10) Buoy (10) Foam float (10)
Groundfish	Groundfish (32)	Hook and line gear (specifically longline, jig, and troll (32)	Rope: serve as the mainline to which branch lines with baited hooks are attached (Longlines) Buoys: to mark the position of longlines, hook and line and trap in the water Float: attached to fishing gear for buoyancy and inside gears for rudders (midwater & bottom trawl)

In addition to the mentioned equipment, cables are commonly used in Pacific commercial trawl fisheries, including those targeting euphausiid, scallop, shrimp, and groundfish. These cables are employed to attach nets, which are typically made of rope, providing a secure and robust connection necessary for trawling operations.

Moreover, some fisheries, such as Pacific Herring, Sardine, and Groundfish, are further divided into smaller subsections. **Table 2** presents the gear types used in the Pacific Herring subsection fisheries Sardine fisheries, and Groundfish fisheries.

Table 2 The Pacific herring, sardine and groundfish fisheries and gears type based on IFMPs (8)

Pacific Herring Fisheries	
Fisheries	**Gear**
Roe Herring Fishery	seine nets, gillnets
Spawn on Kelp Fishery	enclosures
Food and Bait Herring Fishery	seine nets

Special Use Herring Fishery	rakes, dip nets, gill nets, hoop nets, enclosures
Sardine Fisheries	
Sardine	Purse Seine
Anchovy	Purse Seine
Mackerel	Purse Seine
Herring	Purse Seine
Groundfish Fisheries	
Sablefish	Hook and line, Trap gear
Pacific Halibut	Hook and line gear (specifically longline, jig, and troll)
Rockfish	Hook and line gear (specifically longline, jig, and troll)
Lingcod	jig, and troll
Spiny Dogfish	Hook and line gear (specifically longline, jig, and troll)
Skate	Hook and line gear (specifically longline, jig, and troll)
Sole and Flounder	Hook and line gear (specifically longline, jig, and troll)
Pacific Cod	Hook and line gear (specifically longline, jig, and troll)

Based on the information found in the IFMPs, we have identified the types of fishing gear and equipment used by each fishery. By reorganizing this data, we can determine which fisheries utilize specific types of gear and ascertain the predominant gear types used within various scopes of commercial fishing. **Table 3** presents this information in a detailed and accessible format.

Table 3 The primary fishing gear types and equipment utilized on the BC Coast and the fisheries that employ this gear (8)

Fishing gears	**Fisheries**
Trap	crab-by-trap, Prawn and shrimp by trap, Sablefish
Trawl	Scallop by dive, Euphausiid, Shrimp by trawl
Purse seines	Southern Pacific Salmon, Northern Pacific Salmon, Sardine, Anchovy, Mackerel, Herring
Troll gear	Southern Pacific Salmon, Northern Pacific Salmon, Transboundary Rivers Salmon, Albacore tuna, Sablefish, Pacific Halibut, Rockfish, Lingcod, Spiny Dogfish, Skate, Sole and Flounder, Pacific Cod, Ground fish

Gillnets	Southern Pacific Salmon, Northern Pacific Salmon, Transboundary Rivers Salmon, Yukon River Salmon, Pacific herring, Fraser River eulachon, Special Use Herring Fishery, Roe Herring Fishery
Seine nets (with skiff)	Southern Pacific Salmon, Pacific herring, Food and Bait Herring Fishery, Roe Herring Fishery, Transboundary Rivers Salmon
Pole and line	Albacore tuna
longline	Albacore tuna
dip nets	Special Use Herring Fishery, Spawn on Kelp Fishery, Special Use Herring Fishery
enclosures, rakes,	metal mostly
hoop nets	Special Use Herring Fishery
Equipment	
Buoys	Crab-by-trap, Geoduck and Horse Clam by dive, Prawn and shrimp by trap, Scallop by dive, Southern Pacific Salmon, Northern Pacific Salmon by various methods, Transboundary Rivers Salmon by various methods, Yukon River Salmon, Albacore tuna, Pacific herring, Fraser River eulachon, Sardine, and Groundfish.
Rope	Crab-by-trap, Euphausiid, Geoduck and Horse Clam, Prawn and shrimp by trap, Scallop by dive, Salmon (Southern Pacific Salmon, Northern Pacific Salmon by various methods, Transboundary Rivers Salmon by various methods, Yukon River Salmon), Albacore tuna, Pacific herring, Fraser River eulachon, Sardine, and Groundfish
Float foam	Albacore tuna, Fraser River eulachon, Northern Pacific Salmon, Pacific herring, Sablefish, Sardine, Southern Pacific Salmon, Transboundary Rivers Salmon, Yukon River Salmon, ground fish
Container	Crab-by-trap, Geoduck and Horse Clam, Intertidal clam, Prawn and shrimp by trap, Razor clam, Scallop by dive, Sea cucumber by dive, green sea urchin by dive, Oyster, Geoduck and Horse Clam by dive, red sea urchin by dive, Southern Pacific Salmon, Northern Pacific Salmon by various methods, Transboundary Rivers Salmon by various methods, Yukon River Salmon, Pacific herring.

In the next section, these gear types are explained in greater detail.

2.1. Fishing gears details

There are various types of gear employed by the fisheries, and this section provides a comprehensive explanation of each type. This classification helps in identifying the specific debris associated with each gear type. The reference for this section is based on the study conducted by Chopin et al (10).

2.1.1. Traps

Traps are stationary devices designed to capture fish by allowing them to enter through openings but preventing their escape. Common types include pots and pound nets. Pots are often used for crustaceans like crabs and lobsters, whereas pound nets are fixed installations used in coastal waters.

- **Configuration**: Traps typically consist of a frame covered with netting or mesh, featuring funnels or non-return mechanisms. They are set on the seabed and marked by buoys for retrieval.
- **Operation**: Fish are lured into traps using bait. Once inside, they cannot escape due to the trap's design. Traps can be left in place for varying durations, depending on the target species and fishing practices.
- **Debris Concerns**: Lost or abandoned traps, often termed "ghost traps," continue to catch marine life indiscriminately. The materials used in traps, such as metal frames, ropes, buoys and plastic netting, contribute to marine debris if not retrieved.

2.1.2. Trawls

Trawls are large, cone-shaped nets towed behind one or more vessels. They are categorized into bottom trawls and midwater trawls based on the fishing depth.

- **Configuration**: Trawls consist of a codend (where the catch accumulates), wings, and otter boards or beams to keep the net open. Bottom trawls have heavy ground gear to maintain contact with the seabed.
- **Operation**: Trawls are towed at varying speeds, depending on the target species. Bottom trawls disturb the seabed to capture demersal species, while midwater trawls target pelagic fish.
- **Debris Concerns**: Trawls can lose netting sections, ropes, and other components during operations, contributing significantly to marine debris. Additionally, bottom trawling can cause habitat destruction and resuspend sediments, impacting benthic ecosystems.

2.1.3. Purse Seines

Purse seines are large nets used to encircle and capture schools of pelagic fish. They are particularly effective for species like tuna and mackerel.

- **Configuration**: The net is equipped with floats on the top edge and weights on the bottom. A purse line threaded through rings along the bottom edge allows the net to be closed like a drawstring purse.
- **Operation**: Purse seines are deployed around a school of fish. Once the fish are encircled, the purse line is pulled to close the bottom, trapping the fish. These nets can be very large, with lengths exceeding 2000 meters and depths of over 200 meters.
- **Debris Concerns**: In addition of risk of purse seine loss, the use of Fish Aggregating Devices (FADs) to attract fish to purse seines can lead to significant debris if these devices are abandoned or lost. FADs often consist of plastic and other non-biodegradable materials.

2.1.4. Troll Gear

Troll gear involves towing baited lines behind a moving boat. This method is commonly used for species like salmon and tuna.

- **Configuration**: Trolling involves multiple fishing lines, each with hooks and bait, deployed from outriggers or directly from the stern of the vessel.
- **Operation**: The boat moves at a steady speed to drag the baited lines through the water, attracting and hooking fish. The lines are periodically checked and retrieved to collect the catch.
- **Debris Concerns**: Troll gear generally contributes less to marine debris compared to net-based methods. However, lost hooks and lines can still pose environmental risks.

2.1.5. Gillnets

Gillnets are vertical nets that entangle fish by their gills as they attempt to swim through.

- **Configuration**: Gillnets consist of fine mesh netting stretched between a float line and a weighted bottom line. The mesh size is chosen to target specific fish sizes.

- **Operation**: Gillnets can be set at various depths, from surface to bottom, depending on the target species. Fish swim into the net and become entangled, usually by their gills.
- **Debris Concerns**: Gillnets are prone to being lost or abandoned, resulting in "ghost fishing," where the nets continue to capture and kill marine life. This can lead to significant marine debris accumulation.

2.1.6. Seine Nets (with Skiff)

Seine nets, used from the shore or boats, encircle fish and draw them towards the net. Beach seines and boat seines are two primary types.

- **Configuration**: Seine nets have long wings and a central bunt or codend. The top edge is buoyed, and the bottom edge is weighted.
- **Operation**: Beach seines are deployed from the shore and hauled back manually or with machinery, while boat seines are set and retrieved using vessels. The net encircles fish, which are then herded towards the center.
- **Debris Concerns**: Seine nets can become marine debris if large sections are lost or abandoned during operations.

2.1.7. Pole and Line

Pole and line fishing uses a rod to cast baited hooks, particularly effective for tuna.

- **Configuration**: A fishing rod with a line, hook, and bait. Multiple rods can be used simultaneously.
- **Operation**: Fishers cast the baited hooks into the water and manually retrieve them when a fish is hooked. This method is highly selective and minimizes bycatch.
- **Debris Concerns**: Pole and line fishing results in minimal debris, primarily limited to lost hooks and lines.

2.1.8. Longline

Longlines consist of a main line with numerous baited hooks, set horizontally in the water to catch both pelagic and demersal species.

- **Configuration**: A mainline with branch lines (snoods) attached at intervals, each ending in a baited hook. The line can be several kilometers long.
- **Operation**: Longlines are set in the water and left for a period before being retrieved. They can be anchored (set longlines) or allowed to drift (drift longlines).
- **Debris Concerns**: Lost hooks and lines from longlining contribute to marine debris, posing entanglement risks to marine animals.

2.1.9. Dip Nets

Dip nets are hand-held nets used to scoop fish from the water, often in small-scale and artisanal fisheries.

- **Configuration**: A net attached to a handle, used to manually scoop fish from the water.
- **Operation**: Fishers use dip nets to catch fish in shallow waters or near the surface. This method is typically used for small catches.
- **Debris Concerns**: Dip nets contribute minimally to marine debris due to their simplicity and manual operation.

2.1.10. Hoop Nets

Hoop nets are cylindrical nets held open by hoops, designed to trap fish as they swim into the net. They are used in freshwater and coastal fisheries.

- **Configuration**: Circular frames (hoops) supporting a conical net. The net narrows towards the end, preventing fish from escaping.
- **Operation**: Hoop nets are set in the water and left for a period before being retrieved. Fish enter the net through the wide opening and move towards the narrow end.
- **Debris Concerns**: Hoop nets can contribute to marine debris, especially if the hoops or netting materials are lost or abandoned.

These fishing gears are integral to global fisheries, but their environmental impacts, particularly regarding marine debris, necessitate sustainable practices and effective management to mitigate negative effects.

2.2. Fish Aggregation Device (FAD)

A Fish Aggregation Device (FAD) is an artificial structure designed to attract pelagic fish such as tuna, mahi-mahi, and marlin. These devices leverage the natural behavior of fish to gather around objects in the water, making them easier to locate and catch. FADs can be either floating or anchored, and they vary significantly in size, complexity, and cost.

2.2.1. Types of Fish Aggregation Devices

1. **Anchored Fish Aggregation Device (aFAD)**

aFADs are secured to the ocean floor using a line or chain attached to a concrete or metal anchor, with a floating component, such as a buoy or raft, tethered to the seabed. These devices are commonly deployed in shallow coastal waters but can also be used in deeper offshore areas. Since aFADs remain in a fixed location, they allow fishers to return to known productive spots. Examples include buoys anchored in regions with high fish activity, used in both traditional and commercial fisheries (10).

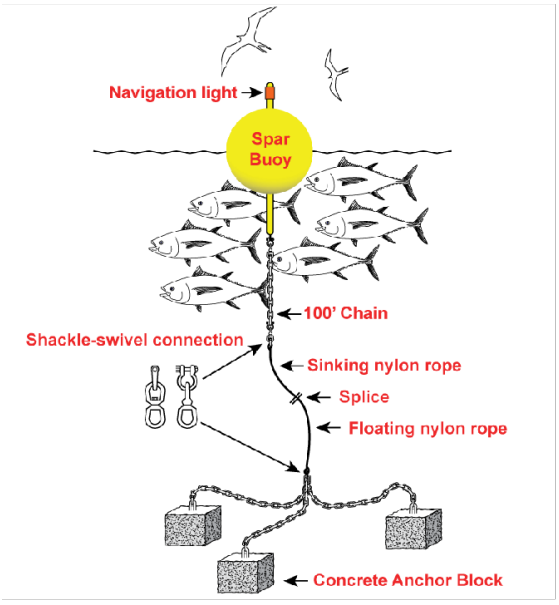
2. **Drifting Fish Aggregation Device (dFAD)**

dFADs, on the other hand, are not anchored and float with ocean currents. They often include floating objects with netting and ropes hanging below the surface to create shade and structure. Utilized in open ocean areas, dFADs exploit currents to cover larger fishing grounds. The mobility of these devices can be advantageous or disadvantageous depending on the fishing strategy. Examples of dFADs include floating buoys or rafts equipped with satellite tracking devices to monitor their positions as they drift (10).

2.2.2. Key Differences

1. **Positioning:**
    - **Anchored FADs:** Fixed in one location, familiar to fishers.
    - **Drifting FADs:** Move with currents, locations vary.

2. **Deployment Area:**
    - **Anchored FADs:** Used in strategic locations, such as near coral reefs or migratory routes.
    - **Drifting FADs:** Deployed in open oceans, covering wide areas as they drift.
3. **Targeting Strategy:**
    - **Anchored FADs:** Suitable for consistent fishing in a known productive area.
    - **Drifting FADs:** Ideal for fishing over large, less predictable areas.
4. **Tracking and Management:**
    - **Anchored FADs:** Easier to manage due to their fixed location.
    - **Drifting FADs:** Often equipped with GPS or satellite trackers to monitor their movement.



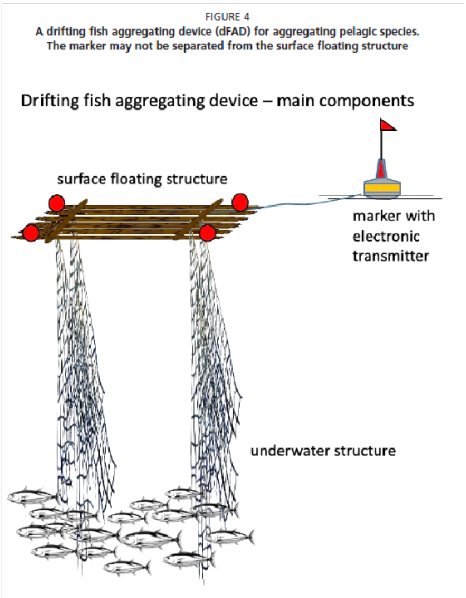


Figure 6 Fish Aggregation device (a) Anchored (b) Drifting (10)

FADs typically consist of surface components, underwater components, and a marker to indicate or report their position. Drifting FADs often have markers with electronic transmitters linked to satellite communication, while anchored FADs have a rope leading to an anchor or weight on the seabed. Earlier FADs were mostly made from natural, degradable materials, but the use of plastics in FAD construction has increased in recent decades (10) . This contributes to marine plastic litter when FADs are abandoned, lost, or discarded. Both actively fished and derelict FADs may entangle and kill non-target fish and other animals, including endangered, threatened, and protected species. Reviews by Fonteneau et al. (35) and Dagorn et al. (36) have examined the impact on marine ecosystems and the benefits of using dFADs in tuna purse seine fisheries. Important purse seine fisheries using FADs include the anchoveta fisheries in Peru and Chile, Atlantic herring and Atlantic mackerel fisheries in the Northeast Atlantic, and skipjack tuna fisheries in all major oceans.

2.3. The Connection Between Debris Types and Fisheries

The relationship between debris types found in the CCCW dataset, such as netting, oyster baskets, and crab pots, is more clearly linked to the fisheries available in the Pacific region compared to other debris types like rope, buoys, plastic barrels, and tires (with or without Styrofoam). Some other debris, like packaging and beverage bottles, is mostly due to individuals, and is out of scope of this study. White Styrofoam and foam floats can originate from individuals, recreational fisheries, and commercial sources. To gain a deeper understanding of the relationship between fisheries and debris, it is essential to examine the structure of each type of gear and the debris it might produce, and then identify the fisheries that use this type of gear. The following section describes the relationship between debris and gear types, while the subsequent section identifies the fisheries responsible for the debris, based on their known use of specific gear types.

2.3.1. Netting

- **Gillnets**: Netting is used in gillnets to create a wall of netting that entangles fish. The netting is held vertically in the water by a headrope with floats and a footrope with weights. Fish are caught when they swim into the net and get gilled, wedged, or entangled (10).

- **Purse Seines**: Netting is essential in purse seines, which are used to encircle and capture schools of fish by drawing the net closed from the bottom like a purse (10) .
- **Beam trawlers:** Beam trawlers and outrigger trawlers utilize large nets that are designed to be dragged along the seafloor or through the water column to capture fish and other marine organisms. The netting is crucial as it forms the main component of the trawl, enabling the capture of a wide variety of fish. Beam trawlers use a horizontal beam to keep the mouth of the net open, while outrigger trawlers deploy nets from extended arms. The design and durability of the netting are essential for efficient and effective fishing operations.
- **Trammel Nets**: These nets use multiple layers of netting to entrap fish. The outer layers have larger meshes while the inner layer has smaller meshed, creating pockets that entangle fish (10).

2.3.2. Oster baskets and Crab pots

These are used primarily in pot fishing, a method employed by potters targeting shellfish such as crabs, lobsters, and oysters. Oyster baskets and crab pots are designed to allow entry of the shellfish but prevent their escape, ensuring they are caught alive and intact. The sturdy construction of these pots is necessary to withstand underwater conditions and repeated use (37).

2.3.3. Rope

- **Purse seine and Trawl:** Rope is a critical component in various fishing methods, including purse seining and trawling. In purse seining, ropes are used to encircle a school of fish with a large net, which is then drawn closed like a purse. In trawling, ropes are used to tow the nets and to manage the deployment and retrieval of the gear. The strength and flexibility of the rope are vital for handling the significant forces encountered during fishing operations and for ensuring the nets are effectively managed (37). In the Fish Aggregating Devices (FADs) used in combination with purse seines, the rope is one of the components and can contribute to plastic debris.
- **Gillnets**: Ropes are used to anchor the nets to the seabed and to attach floats and weights that keep the net vertical in the water.

- **Longlines**: Ropes serve as the mainline to which branch lines with baited hooks are attached. These ropes can be several kilometers long, depending on the scale of the operation (10).
- **Pots (Traps)**: Ropes are used to connect the pots to surface markers, allowing fishermen to locate and retrieve the pots (10).

2.3.4. Hard plastic buoys

- **Purse sein and gill nets:** Hard plastic buoys are used in many types of fishing, including purse seining and gill netting, to keep nets afloat and to mark their positions. These buoys are essential for maintaining the vertical position of the nets in the water column, ensuring they are set at the desired depth to target specific species. Gill nets must have a buoy floating on the surface of the water attached to each end if the net is not attached to a vessel. For commercial fishing of salmon, these buoys must be orange and at least 125 cm in circumference. Additionally, if used for roe herring, all buoys attached must be of the same color and at least 125 cm in circumference (38). In the Fish Aggregating Devices (FADs) used in combination with purse seines, the Buoys is one of the components and can contribute to plastic debris (37).
- **Longlines**: Buoys are used to mark the position of longlines in the water, ensuring that the gear can be located and retrieved (38; 39).
- **Pots (Traps)**: Buoys are connected to the ropes of pots to mark their positions on the surface for easy retrieval (10). .

2.3.5. Foam float:

Foam floats are commonly used in various fishing gears and are indeed a common equipment in commercialized fisheries (10).

- **Gillnets and seine nets:** Foam floats are widely used in gillnets and sein nets to keep the net suspended vertically in the water column. They provide buoyancy to the upper portion of the net, allowing it to remain upright and effectively catch fish (40; 23).
- **Longlines:** In longline fishing, foam floats can be used to mark the location of the line and keep certain sections of the gear at desired depths.

- **Trap fishing:** Foam floats can be used to mark the location of submerged traps and pots, as well as to provide buoyancy for the gear.

Foam floats are popular in commercial fisheries due to their durability, low cost, and versatility. They come in various sizes and shapes to suit different fishing methods and conditions. For instance, round foam floats are commonly used for trout fishing and can be cast over long distances while still allowing anglers to detect strikes. In commercial fishing operations, foam floats are often used in conjunction with other types of floats and buoys to optimize gear performance. They are particularly useful in deep-water fishing and can be found in various fishing environments, including seas, lakes, and streams.

2.3.6. Plastic Barrels

- **Drift Nets**: Plastic barrels are sometimes used in drift nets as buoys to keep the nets afloat and to mark their positions.
- **FADs**: Plastic barrels are commonly used in Fish Aggregating Devices (FADs) to provide flotation and structure. These devices attract pelagic species, making them easier to capture with surrounding nets like purse seines.

2.3.7. Tire with and without Styrofoam

- **Various Small-Scale Gears**: Tires, sometimes filled with Styrofoam for added buoyancy, are repurposed in various small-scale fishing gears as markers, floats, or even as weights depending on the design of the gears. It should also be noted that, based on general knowledge, they are not typically associated with standard fishing gear. Instead, they are more likely to be used in the construction of Fish Aggregating Devices (FADs) or artificial reefs.

2.3.8. White Styrofoam

- **FADs**: White Styrofoam is often used in the construction of FADs for its buoyant properties. This material helps keep the devices afloat, attracting fish and facilitating capture by fishing nets like purse seines.

2.3.9. Hard plastic fragment

- **Various Gears**: Several types of fishing gear can produce small fragment hard plastics in the ocean: As these items degrade in the marine environment, they break up into smaller and smaller pieces, eventually becoming microplastics. This process continues indefinitely, as plastics do not fully decompose in the ocean. Plastic lures, like other fishing gear, are made from durable plastics such as polyethylene, polypropylene, and polyamide. When these lures are lost or discarded in the ocean, they can break down into smaller plastic fragments over time, contributing to the microplastic pollution problem (41; 42; 43; 44).

By integrating the information in **Table 3** which outlines the associated fisheries using different types of gear, with the above details about the types of debris each fishing gear can produce, we have compiled **Table 4.** Table 4 illustrates the relationship between the types of debris and the associated fisheries responsible for producing this debris. This comprehensive approach provides a better understanding of the impact of different fisheries on marine pollution.

Table 4 The relation between debris type and fisheries

Debris type	fishing gears	Fisheries
Netting	beam trawling gillnets Trammel nets Surrounding nets Purse seines	Anchovy, Euphausiid, Food and Bait Herring Fishery, Fraser River eulachon, Herring, Mackerel, Northern Pacific Salmon, Pacific herring, Roe Herring Fishery, Sardine, Scallop, Shrimp, Southern Pacific Salmon, Special Use Herring Fishery, Transboundary Rivers Salmon, Yukon River Salmon
Oyster baskets and Crab pots	potters for shellfish.	Prawn and shrimp by trap, Sablefish, crab-by-trap
Rope	Gillnets Longlines Pots (Traps) purse seiners seine-netters trawl nets.	Albacore tuna, Anchovy, Euphausiid, Food and Bait Herring Fishery, Fraser River eulachon, Herring, Mackerel, Northern Pacific Salmon, Pacific herring, Roe Herring Fishery, Sardine, Scallop, Shrimp, Southern Pacific Salmon, Special Use Herring Fishery, Transboundary Rivers Salmon, Yukon River Salmon
Hard plastic buoys	Gillnets Longlines Pots (Traps) purse seining and other net fisheries.	Albacore tuna, Anchovy, Food and Bait Herring Fishery, Fraser River eulachon, Herring, Mackerel, Northern Pacific Salmon, Pacific herring, Roe Herring Fishery, Sardine, Southern Pacific Salmon, Special Use Herring Fishery, Transboundary Rivers Salmon, Yukon River Salmon
Foam float	gill nets Longlines Pots (Traps) seine nets	Albacore tuna, Food and Bait Herring Fishery, Fraser River eulachon, Northern Pacific Salmon, Pacific herring, Roe Herring Fishery, Sablefish, Sardine, Southern Pacific Salmon, Special Use Herring Fishery, Transboundary Rivers Salmon, Yukon River Salmon

Plastic Barrels	Drift nets FADs (purse seine mostly) hook and line (some) longline (few)	Albacore tuna, Anchovy, Herring, Mackerel, Northern Pacific Salmon, Sardine, Southern Pacific Salmon
Tire with and without Styrofoam	FADs	Albacore tuna, Anchovy, Herring, Mackerel, Northern Pacific Salmon, Sardine, Southern Pacific Salmon
White Styrofoam	FADs	Albacore tuna, Anchovy, Herring, Mackerel, Northern Pacific Salmon, Sardine, Southern Pacific Salmon
Hard plastic fragment	Various gears, Troll (lures inside)	Albacore tuna, Northern Pacific Salmon, Southern Pacific Salmon, Transboundary Rivers Salmon
Other packaging	Individual	NA
Beverage bottles	Individual	NA

Phase 3: Identifying the supply chain

1. Introduction

Phase 3 is centered on identifying the supply chain of fishing gear. Following the identification of debris types and the fisheries responsible for producing this debris, this phase involves pinpointing the various actors involved in the supply chain. This includes identifying the producers of both commercialized and recreational fishing gear. The focus is on understanding the roles of suppliers, distributors, and retailers within the supply chain. By mapping out these relationships, we aim to gain a comprehensive understanding of how fishing gear reaches the market.

2. Fishing gears suppliers, retailers and distributors

Table 5 lists the fishing gear companies in Canada found through a web search, along with the product listed on their websites. Most of the fishing gear companies listed target recreational fisheries, rather than commercial fisheries. Only two suppliers of fishing gear cater to commercial fisheries: Pacific Nets and Twine Ltd., both headquartered in Vancouver, BC. Their products primarily include commercial fishing nets, such as seine nets, gill nets, and troller nets. Additionally, they offer multiple types of equipment, including ropes, buoys, and ground fish fleet equipment. The most important customers of this fishing gear company are commercial salmon and lingcod fisheries. Besides the commercial fisheries, they also serve customers from recreational fisheries. I was unable to find a retailer or distributor for Pacific Nets and Twine, but they operate three branches in BC and have a comprehensive website, where they sell their products (45).

The other company, Fipec, is headquartered in Quebec. This company supplies fishing gear for both commercial and recreational fisheries, and they also supply to fisheries researchers. Fipec is well known for custom-made fishing gear. Various types of custom-made gear are highlighted in the table, and their products are primarily targeted towards groundfish, pelagic, and shellfish fisheries. Fipec supplies to these sectors as well (46) .

Other companies, such as Westcoast Fishing Tackle, Gibbs Delta Tackle, and Fishing Tackle Store, are the main suppliers and distributors of fishing gear for recreational fisheries, as mentioned in the table. Gibbs Delta Tackle and Fishing Tackle Store sell many products for recreational fisheries from different brands. **Tables 6** and **7** show the brands and the suppliers of fishing gear they sell.

Table 5 The fishing gear companies in Canada, along with their products, specific target customers (recreational/commercial), and supply chain [22-28]

Company	Products	Commercial / Recreational	Target fisheries	Supplier, Retailer, distributor	Retailer, distributor
Pacific Net & Twine Ltd. (45)	Commercial fishing nets (seine net, gillnets and trollers), ropes, buoys, ground fish fleet	Both	Commercial Salmon and Ling Cod fisheries	Supplier	Three Branch in BC
Fipec (46)	Custom made fishing gears; Snow Crabs: Custom-made traps; Lobsters: Galvanized wire traps coated with vinyl; Rock Crabs: High-quality traps similar to snow crab traps; Hyas Crabs: Specialized traps; Pelagic Fishes (herring, mackerel, tuna, smelt): Various nets for pelagic fishing; Ground Fishing: Nets with different mesh sizes and twine in monofilament or nylon; Whelk: Pots made from high-quality Canadian steel	Both +Scientific	ground fish, pelagic and shellfish fisheries	Supplier	NM
Westcoast Fishing Tackle (47)	Custom Lure Marketplace Brand Ambassador's Top Picks Saltwater Trolling Lures & Flashers Saltwater Jigging Lures Saltwater Fishing Rods Freshwater Fishing Rods & Reels Crab/Prawn Traps & Accessories	Recreational fisheries	Custom Lure	Supplier	NM
Gibbs Delta Tackle (48)	Spoons, flashers, hoochies, jigs, and other accessories	Sport fishing / recreational	Recreational anglers targeting species like salmon, trout, and kokanee	Supplier Retailer	Table 6
Fishing Tackle Store (49)	Fishing lures, reels, rods, tackle	Sport fishing / recreational	NA	Retailer	Table 7
Liquid mayhem. (50)	Fish attractants	Sport fishing / recreational	lures and baits targeting species such as bass and pike	Supplier	Gibbs
Lunkerhunt (51)	Lures (limited)	Sport fishing / recreational	high-quality bait and trolling gear for salmon fishing	Supplier	Gibbs
Set the Hook (52)	Soft plastic lures (limited)	Recreational and sport	freshwater fishing, targeting	Supplier	Gibbs

			species like bass and walleye		
Freedom Tackle (53)	Interchangeable hook systems	Recreational and sport	Innovative lures and terminal tackle	Supplier	Gibbs
Lighthouse Lures (53)	Fishing lures, tackle	Recreational/ commercial	NA	Rretailer	Gibbs Delta Seadog O'ki Tackle Scotty Berkley Fishing Z-Man Blue Sea Systems Simms Fishing Silver Horde Luhr Jensen
Oki Tackle (54)	Trolling gear, lures	Recreational and sport	flashers used in trolling for salmon and other fish	Supplier	Gibbs
Rhys Davis (55)	Bait, lures	Recreational and sport	high-quality bait and trolling gear for salmon fishing	Supplier	Gibbs

Table 6 Brands Available at Gibbs Delta Tackle (48)

Manufacturer	**Gear Types**	**Headquarters**
Delta Tackle	Fishing tackle, lures	Canada
Gibbs	Lures, flashers, accessories	Canada
Lighthouse Lures	Fishing lures, tackle	Canada
Oki Tackle	Trolling gear, lures	Canada
Rhys Davis	Bait, lures	Canada
Silver Horde	Fishing lures, tackle	USA

Stinger	Fishing lures	USA
Yamashita	Fishing lures, squid jigs	Japan

Table 7 Brands Available at Fishing tackle store (49)

Manufacturer	**Gear Types**	**Headquarters**	**Manufacturer**	**Gear Types**	**Headquarters**
Daiwa	Reels, rods, accessories	Japan	Musky Mayhem	Musky lures	USA
Savage Gear	Lures	Denmark	Cal Coast Fishing	Rod holders, bait sacks, storage	USA
Strike King Lures	Lures	USA	Sunline	Fishing lines	Japan
Lunkerhunt	Lures (limited)	Canada	Seaguar	Fishing lines	Japan
Z-Man	Soft plastic lures	USA	Yo-Zuri	Lures, lines, accessories	Japan
Molix	Lures, accessories	Italy	Thermacell	Mosquito repellent	USA
Set the Hook	Soft plastic lures (limited)	Canada	Panther Martin	Spinners, lures	USA
Freedom Tackle	Interchangeable hook systems	Canada	Suick Lure Company	Jerkbaits, lures	USA
Drifter	Lures, rods, accessories	USA	Boomerang Tool Company	Tools, gear tethers	USA
EGO Fishing	Nets, storage, accessories	USA	McGathys Hooks	Hooks, tackle	USA
Owner Hooks	Hooks	Japan	Snag Proof	Weedless frog lures	USA

American Baitworks	Lures, tackle	USA	Accu Cull	Culling systems, accessories	USA
Roboworm	Soft plastic worms	USA	Esox Research Company	Lures, tackle	USA
Rapid Fishing Solutions	Tools, accessories	USA	Scum Frog	Topwater frog lures	USA
Liquid Mayhem	Fish attractants	Canada	Westin Fishing	Lures, tackle	Denmark

Conclusion

Ghost gear, or ALDFG, poses a significant environmental challenge on the BC coast and globally. It contributes heavily to marine pollution and environmental degradation, with a substantial portion of microplastics originating from these sources. Addressing ghost gear is crucial for mitigating its adverse impacts on marine ecosystems. This project aimed to explore the multifaceted issue of ghost gear by analyzing debris types, identifying their sources, and understanding the supply chain dynamics of fishing gear in BC fisheries. Our analysis for Phase 1 of the project was based on the CCCW dataset, which provided comprehensive data on debris found across various locations on the BC coast. We identified ropes and buoys as the most significant types of debris, followed by nets and crab pots. In Phase 2, we investigated the fisheries responsible for generating these debris types. Using IFMPs available on the DFO website, we identified the specific fishing gear and associated equipment used by different fisheries. One challenge we faced during the project was the difficulty in linking certain debris types directly to specific fisheries. While IFMPs provided details on the types of gear used by each fishery, they did not specify the associated equipment, such as ropes and buoys. This lack of detailed information created a gap in our ability to fully connect the debris found on BC shorelines to the fisheries responsible. As a result, some debris types, like white Styrofoam and plastic barrels, could not be definitively linked to specific fisheries. Addressing this challenge would require more granular data on the equipment used alongside each gear type and potentially direct input from fisheries to accurately trace the origins of all debris categories. This linkage between debris types and fisheries operations was critical for pinpointing the sources of ghost gear. In Phase 3, we examined the supply chain to identify the producers and suppliers of these fishing gear types. Our research focused on suppliers in BC, revealing Pacific Net and Twine Ltd. as a major supplier for commercial salmon and lingcod fisheries. Other suppliers primarily catered to recreational fisheries. While our web search provided valuable insights, a more in-depth study of the supply chains could yield a more comprehensive understanding of the actors involved in manufacturing, distributing and selling fishing gear and equipment, which ultimately results in generating ghost gear. In conclusion, by identifying key debris types, their sources, and the supply chain actors, we have laid the groundwork for developing effective strategies to

mitigate this pressing environmental issue on the BC coast. Continued research and collaboration among stakeholders will be essential to achieving significant reductions in ghost gear and its impact on marine environments.

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