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Methods to Locate and Remove Lost Fishing Gear from Marine Waters

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CONTENT

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Cover photo: A surface-supplied air diver preparing to enter the water to conduct ALDFG operations. *Emerald Sea Protection Society*

PURPOSE AND BACKGROUND

The purpose of this document is to provide a general overview of methods and techniques used to locate and remove abandoned, lost, or otherwise discarded capture fishing gear and aquaculture gear (ALDFG). The document highlights organizations active in Canada and focuses on marine waters with some references to fresh water techniques. The document describes a number of methods available and provides general techniques, benefits, and limitations of the methods. Selected case studies highlighting location and retrieval methods described are included, and contact information is given for organizations experienced using the various methods explained.

Location methods discussed are focused on eventual retrieval of ALDFG. Some location methods are designed to inform managers of areas of accumulations, or to document ALDFG without any plans for eventual retrieval. These are not discussed here in detail. Trawling for marine litter, for example, has been used extensively to document accumulations of marine litter and ALDFG. Though this method does usually include retrieving the ALDFG, it is generally not used systematically and is not covered in this document, other than as a retrieval method[1,2].

The methods covered focus generally on locating and removing ALDFG from marine and fresh waters, rather than from intertidal areas or beaches. Retrieval of gear from intertidal habitats and beaches, while sometimes as easy as bundling gear and hauling it away, can also present unique challenges associated with sedimentation and entanglement with other debris. Removing large volumes of lost fishing gear and marine debris from remote beaches, for example, presents unique project management challenges around extractions, transport, and disposal. For guidance on these kinds of efforts, we recommend contacting the Fisheries and Oceans Canada (DFO) Ghost Gear Fund Program, Ocean Legacy, and the Coastal Restoration Society. Contact information is presented in Appendix 1.

While this document focuses almost exclusively on methods, considerations of any ALDFG location and retrieval project go beyond what methods to use. Permitting requirements, coordination with local indigenous groups, fishing organizations, and port authorities, disposal options, and data collection are all important. For insights and assistance with these considerations, we recommend contacting the DFO Ghost Gear Fund and practitioners listed in Appendix 1.

Abandoned, Lost and Discarded Fishing Gear in Canada

The negative impacts of ALDFG are a growing concern globally. Whether intentionally discarded or accidentally lost, ALDFG is one of the deadliest forms of marine litter. Lost gear can catch and waste target and non-target species (ghost fishing), damage habitats, and pose navigation risks[3–6]. The waste of target species can significantly impact the economics of a fishery, with 4% – 30% loss of harvest from ghost fishing documented in some fisheries[7–11]. In Canada, ALDFG has been documented in many fisheries and aquaculture locations[12–19]. As early as 1977, Miller found about an 8% loss rate of spider crab pots in Newfoundland [12]. More recent trawl surveys for marine litter in areas beyond Canadian national jurisdiction within the Northwest Atlantic Fisheries Organization Regulatory Area Division (Flemish Pass) found increasing amounts of litter, mostly ALDFG, at deeper depths[1].

Typical gillnet used in Canadian fisheries. *NRC*

Canada has recently taken steps to address problems of ALDFG in its fisheries. As president of The Group of Seven (G7) in 2018, Canada formally signed on as a government member of the Global Ghost Gear Initiative, a multi-sectoral a multi-stakeholder alliance of over 100 organizations, business and governments that drives solutions to ghost gear worldwide, develops and promotes best practice to inform policy and collects evidence. Also as in 2018, Canada launched an Ocean Plastics Charter and published its Strategy on Zero Plastic Waste which includes a Result Area specific to ALDFG solutions [20,21]. Canada-Wide Action Plan on Zero Plastic Waste: Phase 2, published in 2020, includes specific actions to reduce impacts from ALDFG [22]. Canada also announced significant investment in solving the problem, introducing the Sustainable Fisheries Solutions and Retrieval Support Program (Ghost Gear Fund) of the DFO with an initial $8 million dollar funding program aimed at reducing and preventing harm from ALDFG.

Fisheries in Canada are managed by the DFO, which currently requires fishers to report lost fishing gear. Recovery of lost fishing gear is not required, however. While most fishers do try to recover their lost gear, sometimes that is not possible. For many years, several local initiatives have focused efforts to locate and remove ALDFG from Canadian waters. DFO periodically removes lost crab traps from marine waters of Boundary Bay. The Lillooet Tribal Council collaborates with DFO to remove derelict gillnets from the Fraser River. And the Area A Crab Association regularly removes derelict crab traps from its fishing grounds during season closures [23]. The Fundy North Fishermen's Association has developed a manual of techniques to retrieve lost lobster pots [13,24].

With the inception of the Sustainable Fisheries Solutions and Retrieval Support Program (Ghost Gear Fund), these efforts have been amplified. Numerous funded organizations removed more than 730 tonnes of ALDFG from Canada's Atlantic and Pacific Coasts in 2020 and 2021 [25].

CAPTURE FISHERIES

British Columbia

The Pacific Fishery Regulations, 1993 under the Fisheries Act is the overarching regulatory framework under which Pacific fisheries are managed. The region is divided into 48 Pacific Fishery Management Areas (PFMAs) that provide boundaries within which the fisheries are managed, and several sub-areas exist within the PFMAs. Within these areas, DFO manages the commercial, recreational, and Aboriginal communal fishing activities through openings and closures of fishing effort in these areas. There are five major commercial fisheries in the Pacific Region of Canada; salmon, herring, shellfish, and groundfish.

Salmon fisheries in British Columbia target Chinook, Coho, Sockeye, pink, and chum salmon. This is a limited access fishery, managed mostly as a competitive fishery, with some portions operating under individual quotas. Throughout the last decade, salmon contribute to about 17% of the landed value of wild-caught seafood in British Columbia. In the most recent years, the commercial salmon fishery has seen the lowest harvests in history. The three commercial gear types licensed are: gillnets, purse seines, and troll. Gillnets typically fish in terminal areas, near coastal rivers and inlets. By regulation, gillnets cannot be longer than 375 m long, and net depths are restricted to either 60 or 90 meshes, depending on the fishery. This typically equates to net depths of approximately 6 m to 17 m deep. Seine nets typically fish further from shore than gillnets, with net depths ranging from 20 m to 80 m deep depending on fishing areas.

The west coast commercial herring fishery is made up of four components. The roe fishery is a limited access fishery with 252 seine licenses and 1,267 gillnet licenses. The Spawn on Kelp fishery includes harvesting herring roe off kelp, and does not include capture of fish with net, trap or line, however, these operations utilize ropes, lines, and buoys. There is also a food and bait fishery which the seine vessels have access to, and a special use fishery.

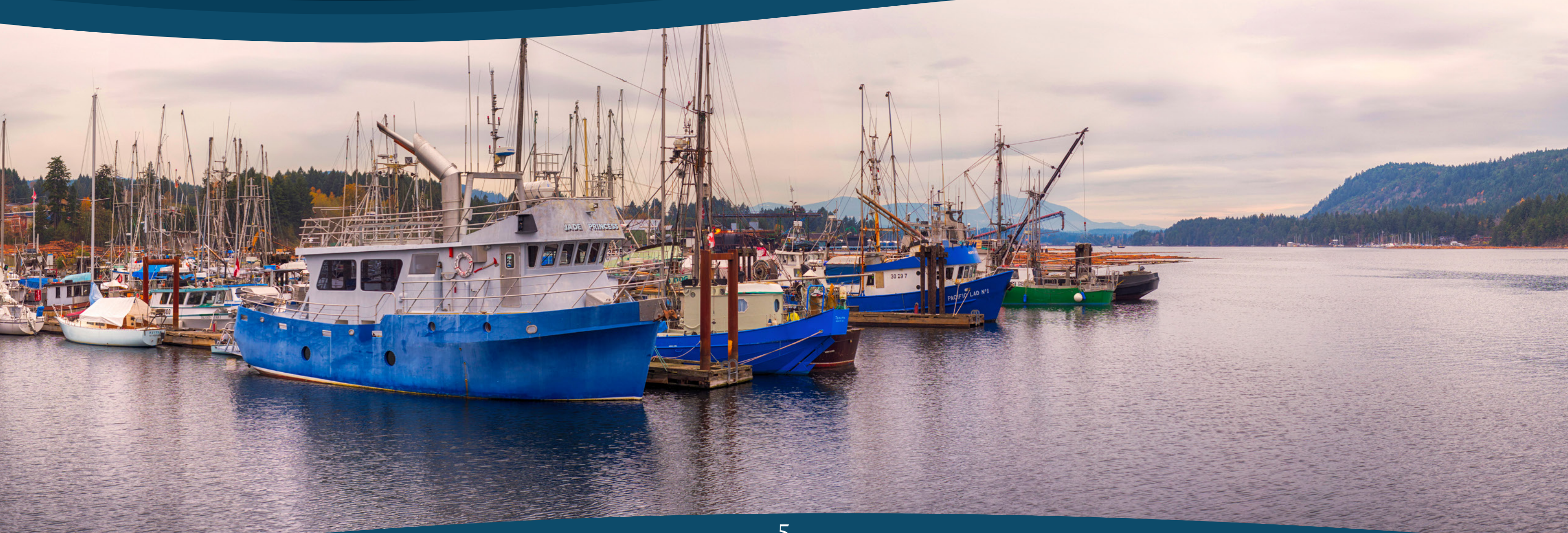
The two primary west coast shellfish fisheries are the crab and prawn trap fisheries, although other fisheries present in British Columbia waters are scallop trawl, shrimp trawl, and urchin/cucumber/geoduck harvest diving. The commercial crab fishery is dominated by the Dungeness crab fishery consisting of seven license areas. The fishery is executed with single buoyed traps with minimum harvestable size limits, limited licensing, trap limits, soak time limits, closed periods, and soft-shell restrictions. All traps are required to have escape rings for undersized animals to escape, and biodegradable rot cord to provide an egress route for entrapped crab if the trap becomes derelict. There is a substantial recreational crab fishery along the Canadian west coast, with fishers using single traps.

The prawn by trap fishery takes place in rocky nearshore areas at depths from 40 to 100 m. The commercial fishery is limited entry, with 245 eligible licenses; 59 of which are designated for First Nation participation. A majority of the commercial harvest (> 60%) occurs in the Strait of Georgia, and inside Vancouver Island. Traps are deployed attached to longlines, with about 50 traps per string, and up to six strings per license for a total of 300 traps per vessel. Traps are truncated conical shape with soft web mesh surrounding stainless steel frame.

The groundfish fishery consists of seven distinct sectors including: groundfish trawl (bottom and midwater), halibut, sablefish, inside rockfish, outside rockfish, lingcod, and dogfish. Besides the trawl gear, the primary gear used is longlines for the above listed species, as well as traps for sablefish. Trawling is substantial, especially outside the Strait of Georgia. The longlines used are anchored on each end and typically span about 550 m per skate. Two to six skates are often linked together to form longline sets. Halibut skates each consist of about 100 hooks per skate, while longlines targeting other species may have a higher density of hooks. The halibut fishery occurs on the upper continental slope in about 230 to 260 m water depths. The sablefish longline and trap fisheries are concentrated on the continental slope at depths up to 825 m. Sixty (60) to 80 traps are set on along a groundline with an average length of three km. The traps soak for up to four days before hauling.

Commercial fishing vessels docked at Ladysmith Marina on Vancouver Island, British Columbia.

Adobe Stock



Atlantic Canada and the Great Lakes

Atlantic fish stocks are managed under the Fisheries Act, Atlantic Fishery Regulations, Commercial Fisheries Licensing Policy of Eastern Canada, 1996 and the North Atlantic Fishing Organization (NAFO) Convention on Cooperation in the Northwest Atlantic Fisheries. NAFO treaties do not apply to shellfish harvesting. Region specific licensing policies for the Maritime, Gulf, and Newfoundland and Labrador Regions outline more specific licensing, gear, and other requirements.

The finfish fishery effort focuses mainly on herring, and groundfish. The herring fishery is split into inshore/fixed sectors, and offshore/mobile sectors. Inshore herring fishers can set or drift gillnets or use beach/drag seines. The groundfish fishery is predominantly a mobile gear fishery employing bottom trawl gear. A commercial halibut fishery operates in the Gulf of St. Lawrence but is largely limited to inshore, fixed gear fleet using set gillnets with a minimum mesh size of 152 mm (6 in).

The shellfish fishery primarily targets Queen crab, scallop, lobster and shrimp using a variety of gear types in waters less than 100 m deep. Both lobster and snow crab fishers use steel and mesh traps. Individual traps are attached to their own retrieval line and buoy but can be set along a groundline. These strings of traps are anchored at either end by metal or concrete anchors attached to retrieval lines and buoys. In the lobster fishery, it is not uncommon for more than 10 to 20 traps to be deployed on one line and a single license holder can set 100 to 300 traps depending on the region.

The shrimp fishery uses bottom trawls. Vessel size varies from 65 to 100' from which small bottom or otter trawls are deployed. The scallop fishery uses steel scallop dredges, generally two, 4 to 5m wide dredge to a vessel. In the Gulf of St. Lawrence, vessel size is generally less than 14 m long and fishers use Digby style dredges. A smaller scallop fishery also operates offshore of Nova Scotia, using similar dredges as inshore fishers but deployed from larger (38 m long) vessels.

In the Canadian Great Lakes, the Ontario Ministry of Natural Resources, in accordance with federal regulations, manages the largest freshwater fishery in North America. The fishery takes place in Lake Erie, Lake Huron, Lake Superior, Lake Ontario, and the St. Lawrence River. The fishery focuses primarily on walleye, rainbow smelt, yellow perch, lake whitefish, white perch and white bass using bottom set gillnets, trap nets and midwater trawls.

Aquaculture

Aquaculture activities in Canada are regulated by DFO through the Fisheries Act, Aquaculture Activities Regulations and Fishery (General) Regulations. Aquaculture activities are primarily regulated by provincial governments (except in British Columbia and Prince Edward Island) in accordance with DFO regulations. DFO is also in the process of updating existing Fisheries Act and other regional aquaculture policies, developing General Aquaculture Regulations, and working with legislatures and industry professionals on a federal Aquaculture Act. One such update to the Pacific Aquaculture Regulations places new requirements on aquaculture lease applications, requiring annual surveys, identification, retrieval, and reporting of any ALDFG within the lease site.

Canadian aquaculture systems use large nets, significant amount of polypropylene line, chain and buoys making lost aquaculture gear like more traditionally discussed ALDFG. However, unlike capture fishery gear, aquaculture lines and nets, especially in finfish operations, may be treated with antifouling compounds known to cause significant harm to marine organisms and habitats. ALD aquaculture gear may also require special permits or permissions for transport and disposal.

Salmon, mussel, and oyster aquaculture made up more than 85% of Canadian biomass production in 2020. The majority of salmon and other finfish aquaculture occurs in British Columbia while more than half of total shellfish aquaculture occurs along the Atlantic coast, specifically around Prince Edward Island. Most shellfish and kelp aquaculture occur in either intertidal waters or using long-line systems.

Canadian finfish aquaculture relies mainly on gravity-type cage systems (also referred to as net-pens). In these systems, individual cages consisting of nets hung from floating HDPE, rubber or steel collars are secured by upwards of 8 mooring lines to submerged mooring grids (Figure 1). For HDPE and rubber collar cages, a steel platform grid may be employed on the surface to ensure worker safety and access to the entire system. Cage collar diameter vary from 50 m to 120 m with net depths of up to 20 m. Additional predator netting may be deployed around the perimeter of the mooring system or individual collars.

Shellfish growers in Canada use intertidal bottom culture and off-bottom systems. Long-line systems are used along the east coast while a mixture of rafts and long-lines are used along the west coast. Off-bottom systems consist of large (35 m^2 to 75 m^2) floating rafts or individual 100 m to 200 m long-lines from which trays, cages, socks, or lines are suspended.

Polyethylene, or polystyrene floats provide buoyancy, and some growers may use common buckets and jugs to fashion homemade floatation. Large cement (>350 kg) or helical anchors anchor aquaculture gear to the surrounding substrate. Often, multiple cages are anchored in a group or flotilla (see photo). Raft systems provide greater production capacity but are more easily damaged and lost, especially in exposed areas — long-line systems are more resilient to exposed conditions.

Typical salmon aquaculture net-pen system in St. Mary's Bay, Nova Scotia. Note vessel in left of photo for scale. *Adobe Stock*

GENERAL CONSIDERATIONS

Considerations for locating and retrieving ALDFG go beyond which methods to use.

- *Practitioners should consider the local situation and need for actions in terms of what gear is being lost and why.*
- *The regulatory and cultural context of the area should be considered, and support from local fishers, indigenous groups, and aquaculture farmers should be sought.*
- *Required permits to remove ALDFG should be identified and acquired.*
- *Clear goals and objectives should be articulated and anticipated in order to measure success.*
- *Practitioners should determine what data should be collected to measure success, establish baseline information, and assess impacts from ALDFG and how the data will be managed to ensure easy access and dissemination.*
- *Recovered ALDFG reuse, recycling, or disposal options should be identified and secured before retrieval activities.*

There are several ways to locate ALDFG; some methods are systematic, utilizing technology to identify where gear is located, some use local knowledge from regional stakeholders, while others are the result of incidental sightings. Once ALDFG has been located, an important component of planning is determining whether ALDFG should be removed or not. Initial considerations should consider the safety of the retrieval team and the feasibility and cost effectiveness of the operation. In some cases, there is simply no feasible way to retrieve the ALDFG. This happens usually in deep water and/or areas with strong tidal currents. Sometimes, retrieving ALDFG can cause more harm to marine habitats than leaving it in place. This can be true in sensitive habitats, such as coral and cloud sponge reefs, or when ALDFG is causing little damage to habitats and species and would be best left in place, such as when ALDFG is fully sedimented into the seafloor. Sometimes, ALDFG can be disabled and left in place. For example, a crab trap's escape hatch can be removed or secured open to ensure animals are not trapped, or a billowing net can be weighed or pinned down to the structure where it is snagged, to avoid entanglement of animals in the water column. Each circumstance is different, but the flow chart below illustrates a simplified decision process for determining if ALDFG should be retrieved (Figure 1).

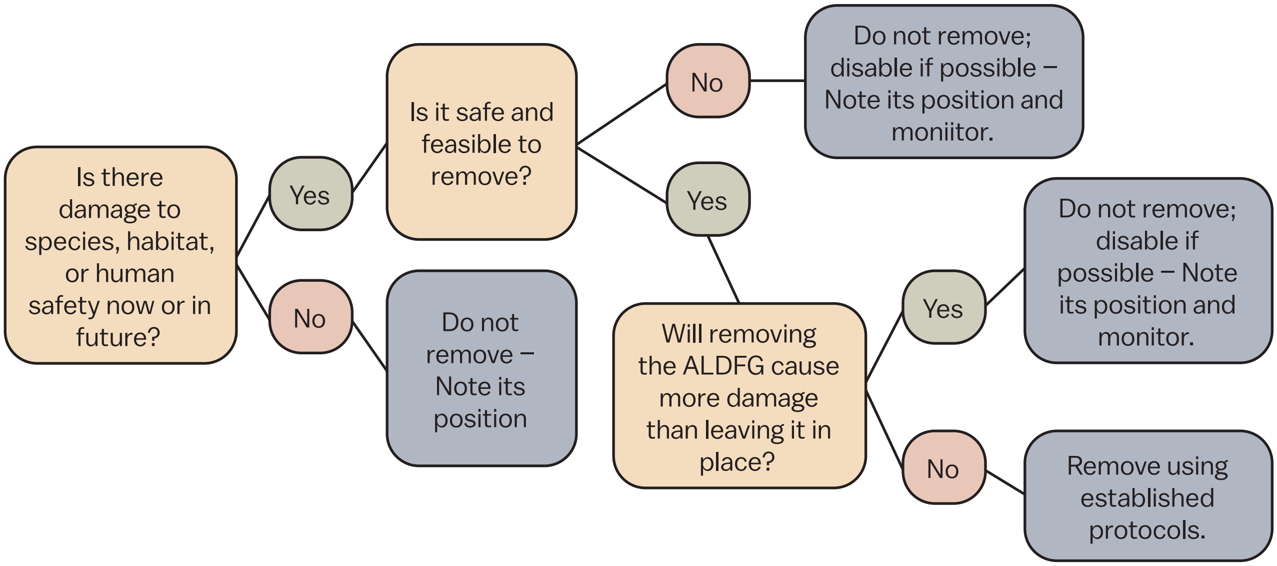


Figure 1: ALDFG retrieval decision process.

Once it has been decided to retrieve the ALDFG, the retrieval practitioners should develop an ALDFG Removal and Disposal Plan. The plan should include information about who will be sponsoring and participating in the retrieval operation, where the retrieval operation will be conducted, what types of ALDFG will be removed, the methods, procedures and equipment that will be employed, environmental impacts of the retrieval operation, documenting and reporting of activities and disposal/recycling options. In addition to choosing location and retrieval methods, this subsequent planning should include the specifications needed related to vessel size, deck space, stowage, crew size and lifting capacity.

A general safety procedures document should be prepared, that includes a description of the work being conducted, potential hazards, and operational methods used to avoid and address those hazards. Especially for diving operations, an Emergency Response Plan should be included in the ALDFG Removal Plan identifying an action plan in the event of an emergency (e.g., location of hyperbaric chamber, emergency contracts, maps/direction for evacuation).

See Appendix 2 for a general ALDFG Removal Plan outline. This plan outline helps to document the three phases of ALDFG retrieval:

- *Pre-retrieval planning*
- *ALDFG retrieval*
- *Post-retrieval activities*

In Canada, continued planning and coordination with local partners, including DFO permitting staff, indigenous groups, local harbour authorities and disposal operators should occur.

A note on data collection

Data collection is critical to efficient location and retrieval of ALDFG. Data should be collected before, and during location and retrieval activities and stored for easy retrieval. We recommend starting with a simple spreadsheet format. The use of mapping software combined with navigation software will enable practitioners to efficiently document where they have looked for ALDFG, where they have found ALDFG, and where they have retrieved ALDFG.

Systematic data on locations, or targets, of suspected ALDFG should be kept. We recommend assigning unique Gear IDs to each suspected target. As each target is investigated, note whether it is ALDFG or not. In addition, it is important to make a note of the area surveyed for ALDFG in order to avoid duplication of effort. This unique Gear ID should be used to track any data collected on the ALDFG during retrieval. Different funding programs require different kinds of data collection and reporting. For example, the DFO Ghost Gear Fund has specific requirements around data collection and reporting.

We recommend collecting the following data at a minimum:

- *Unique Gear ID*
- *Type of ALDFG removed*
- *Date*
- *Location*
- *Water depth*
- *Habitat affected by ALDFG*
- *Animals observed entangled in ALDFG*
- *Area/size of ALDFG removed*
- *Weight of ALDFG removed*


NRC

LOCATION METHODS

Retrieval of ALDFG is most efficient if the location of the ALDFG is known prior to retrieval operations. Especially for diving operations, knowing the exact location of the ALDFG to be removed maximizes the amount of time available for actual retrieval efforts and minimizes dive time spent searching for ALDFG. However, some retrieval methods are used effectively with general knowledge of locations of areas with concentrations of ALDFG. Additionally, some retrieval methods can be conducted in conjunction with locating ALDFG, through visual surveys for instance.

Initial information critical to locating ALDFG is identifying areas where capture fisheries and aquaculture occur or have occurred. While some ALDFG accumulates in areas far away from its source, such as ALDFG found on remote Pacific shorelines, starting your search in the areas where it is lost is advisable.

The ALDFG location methods discussed in this document include:

- *Assessing local knowledge*
- *Acoustic sonar surveys*
- *Remotely operated vehicle (ROV) and towed underwater camera surveys*
- *Diver surveys*
- *Surface visual surveys*
- *Aerial surveys*

Assessing local knowledge

Local knowledge is the first place to start when locating ALDFG. This knowledge can be defined in many ways. For general understanding of where ALDFG could be found, see maps of aquaculture facilities and fishery management areas and data related to previous retrieval efforts. This information can be combined with oceanographic information and other spatial data layers to develop simple predictive models of where ALDFG occurs. Such a model has been developed for British Columbia by Natural Resources Consultants[26] and has been a starting point for ALDFG surveys using various location methods.

Data on gear loss and locations can also be obtained from regulatory agencies. For Atlantic commercial fisheries, license holders must tag all gear. DFO maintains a gear tag database with information on commercial fishing license holders, allowing for more accurate tracking of gear location and loss. In 2020, to support new reporting requirements for lost gear, DFO launched an online Fishing Gear Reporting System. Data from this system can be obtained from DFO with some conditions.

Real time reporting systems for gear loss can be reliable sources of information on location. Sometimes these are opportunistic sightings and reports, such as reports to the DFO's Observe, Record and Report (ORR) Line. In the Washington Salish Sea, a real-time reporting system for newly lost nets has received over 70 verified reports of lost fishing nets resulting in an over 50% retrieval rate [27].

Formal and informal interviews with fishers and other maritime tradespeople (such as barge operators) about where they have lost gear or encountered lost gear are also an important method to obtain local knowledge. Nearly every organization surveyed for this report incorporated local knowledge from fishers and maritime tradespeople to identify concentrated areas of ALDFG. Titan Maritime and CSR GeoSurveys in Nova Scotia, and the T Buck Suzuki Foundation in British Columbia, begin ALDFG projects by interviewing local fishers and other maritime tradespeople, asking interviewees to annotate project area nautical charts. Local knowledge has also come from **marine and fisheries researchers** as ALDFG is sometimes collected in research trawls or detected in habitat surveys.

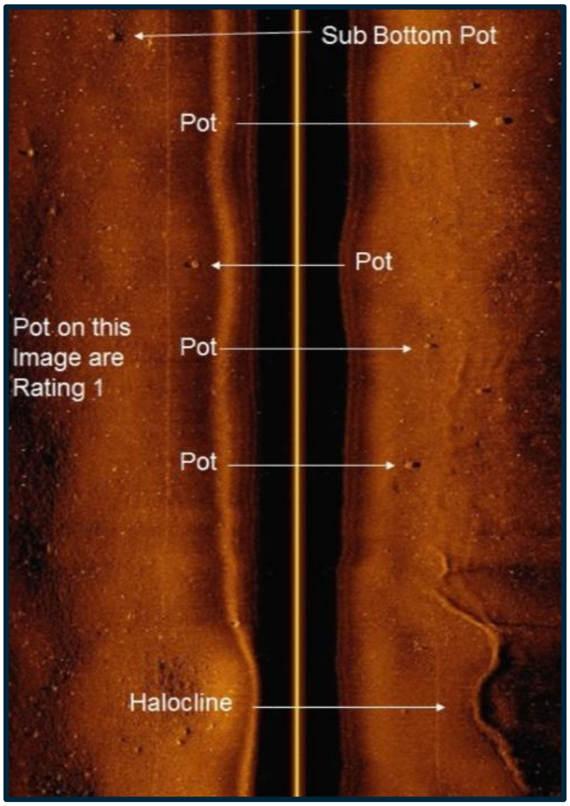
Online surveys distributed widely to target audiences, such as fishers and divers, are another useful method to obtain local knowledge. An online survey distributed to recreational divers in Lake Erie led to information on over 60 locations of ALDFG on shipwrecks in the lake [18,19].

Local knowledge should be a primary starting point when attempting to locate ALDFG. This information can sometimes be used to immediately attempt retrieval operations, such as after immediate reporting of loss by fishers. Usually, however, it is a starting point from which more focused surveys for ALDFG can be executed with other methods.

Acoustic sonar surveys

Underwater acoustic sonar surveyors can image predetermined areas of the seafloor. Sidescan sonar and multibeam backscatters systems are the most common acoustic sonar survey methods used by GGF partners operating in Canadian waters.

Sonar scanning can be deployed at a variety of depths and has been used to successfully locate ALDFG in shallow and deep waters worldwide. Both systems can and are deployed off a slow-moving vessel, with sidescan providing more detailed imagery for target identification. Sidescan sonar has been used effectively to locate ALDFG in a variety of locations worldwide. Sidescan sonar surveys have been used to detect lost crab traps in Boundary Bay and gillnets and shellfish pots in Washington Salish Sea (at depths to 100 m) [14,28]. Both side-scan and multibeam are employed by GGF partners operating on the Canadian Atlantic coast, with sidescan favored over multibeam for deeper waters, while multibeam is used in shallower areas (25 m or less). In British Columbia, Ocean Dynamics Inc. uses a combination of submersible ROV with mounted multibeam sonar for mapping and target identification. Sidescan sonar units can be mounted on ROVs to aid in directing the ROV to targets (see Appendix 3 and 4 for technical details on practitioner sonar and ROV). Sidescan sonar units can be mounted on ROVs to aid in directing the ROV to targets.



Sample sidescan sonar imagery showing individual crab pots. *NRC*

Sector scanning is appropriate for smaller areas of interest (like a harbor or rocky outcrop) and can be deployed from stationary tripods or poles placed on the seafloor. Sector scanning has been used effectively to locate ALDFG in the Adriatic Sea.

CASE STUDY

Bay of Fundy, New Brunswick and Eastern Passage, Nova Scotia

CSR GeoSurveys Ltd., Colin Toole, toole@csrgeosurveys.com

CSR GeoSurveys conducts ALDFG survey and retrieval operations in the Bay of Fundy and Eastern Passage targeting lobster traps and rope. While CSR does not intentionally target aquaculture gear it is often incidentally identified during location surveys and targeted for retrieval.

To begin a project, local fisheries knowledge is gathered to identify possible hotspots of gear loss. CSR then creates a survey grid at the possible hotspot location. Grid spacing is survey dependent, with transects typically run every 100 m to 200 m. Surveys are conducted using sidescan sonar and multibeam (with backscatter) technology. The vessel speed during survey operations is 4 – 5 knots. CSR GeoSurveys employs a Klein 3000 deep tow sidescan sonar system (see photo from CSR below) operating at 100 and 500 kHz to survey areas identified by local maritime tradespeople and DFO ALDFG data maps. The sidescan sonar system is attached to a depressor fin and towed from a 6 m tall A-frame on the stern of a 13.7 m long, Cape Islander style, scallop trawler. A winch and steel cable system allows the sonar system to be positioned approximately 10 to 20 m from the benthos in up to 100 m depths. Data is relayed back to the boat in real-time where a trained technician marks ALDFG targets for later retrieval efforts.

In waters less than 50 m deep, CSR mounts a Teledyne RESON SeaBat T20R multibeam echosounder attached to a rigid pole mounted to the vessel siderail. The multibeam unit operates at 200 or 400 kHz with a 500 m maximum depth at 200 kHz. Multibeam is used for bathymetry mapping in conjunction with grapnel tows for combined gear location and retrieval. CSR's multibeam system provides a high enough resolution for successful ALDFG identification in shallow water using real-time backscatter data.

ROV and towed underwater camera surveys

As ROV technology advances and costs decline, more organizations are employing ROVs for ALDFG target verification and location. ROVs can be equipped with cameras, USBL units and acoustic sonar systems, allowing for more targeted surveys of small areas without the need for a dive team. While useful, ROVs require calm conditions, adequate visibility (difficult as visibility less than 1 m is common). Most observational class ROVs are limited to a 3-knot maximum speed. Titan Maritime and Emerald Sea Protection Society use a combination of diver and ROV surveys to verify the presence of ALDFG in target areas, sometimes following sonar surveys. CSR GeoSurveys uses ROV surveys to develop valuable communications materials, in the form of video documentation of ALDFG magnitude and impacts.


Deep Trekker DTPod camera on cutom fabricated steel frame with concrete weights *Comité ZIP des Îles*

Drop camera surveys are most useful when the approximate location of ALDFG is known as the survey area is often significantly less than acoustic sonar surveys or visual surveys from divers. Ideally, drop camera surveys are conducted in areas with suspected high concentrations of ALDFG. While drop cameras may have a smaller survey footprint, their low cost makes them effective tools for smaller organizations. Cameras should have real-time video feeds to topside support crew.

Surveys should be conducted at slow speeds (<2 knots) and some practitioners use the tidal current flow as the primary source of propulsion. Visible swath width depends on water conditions but is typically ≤6.5 m in width. Swaths can cover the same distance at varying depth contours. When ALDFG is spotted on camera, topside personnel note the

GPS coordinates and any other information, such as gear type and depth. It is most helpful to mark these points on navigation software real-time.

Towed drop camera surveys have been used successfully by the Magdelen Island ZIP to locate lost lobster and scallop gear in target areas identified by local fishers, maritime tradespeople and the DFO. Natural Resources Consultants have successfully used towed camera surveys in the Salish Sea to identify ALDFG nets and crab traps in places where gear ALDFG was suspected.

CASE STUDY

Magdelen Islands and Adjacent Waters, Quebec

Comité ZIP des Îles, Émie Audet-Gilbert, audet@zipdesiles.org

The Comité ZIP des Îles (Priority Intervention Area Committee of the Magdelen Islands) uses a Deep Trekker DTPod submersible camera, mounted to a heavy-duty steel frame with attached concrete weights to locate ALDFG in areas identified by local fishers and maritime tradespeople. The camera system is deployed from a 13.5 m long and 4.5 m wide scallop boat, with load arms and a hydraulic winch capable of lifting 1,000 kg.

Depending on visibility, the camera is positioned 1 to 5 m above the seafoor. The camera system can tilt and pan 360 degrees and provides real-time video, temperature, and depth information to a small controller on the deck of the boat. Ideally, the camera is kept as far as possible from the seafloor, while maintaining good visuals on the area surveyed, to avoid collisions with rocky reef topography and to provide the greatest field of view. On average, the camera is towed 2.5 meters above the substrate, allowing a field of view of 9 m. If visibility is poor, the camera may need to be dropped to within 1 m of the seafloor, reducing the survey area to approximately 2.5 m. When ALDFG is identified, the boat captain marks the location using OLEX or Time Zero GPS systems. This point is offset from the true location of the ALDFG by a distance function of the depth and the angle of the camera, as well as the speed of the vessel. This error can vary between 15 and 35 meters.

All retrieval operations are accomplished via SCUBA diving. The average depth of ALDFG loss and retrieval is between 15 to 30 m with a maximum of 32 m. Retrieval operations are conducted off a 13.5 m long and 4.5 m wide scallop boat. Retrieval start locations, marked during location operations, are offset by an average of 25 m due to the use of a towed underwater camera. To deal with this offset, first a weighted line is dropped from directly above the marked GPS point. Divers descend to a minimum depth from which the seafloor is visible to maximize dive time. A 25 m rope is used to guide expanding circular searches to locate target ALDFG. Once the gear is located, the dive team descends to the seafloor and the diver positioned at the weighted dropline swims the weighted line over to the gear for use in retrieval. If possible, a hydraulic pot hauler is used to bring the gear to the surface before the line is transferred to load arms with a hydraulic winch capable of lifting 1000 to 1500 kg.

Comité ZIP des Îles crew heading home after recovering commercial lobster traps. *Comité ZIP des Îles*

CASE STUDY

Saanich Inlet and Southern Gulf Islands, British Columbia

Malahat Nation, Desiree Bulger, desiree.bulger@malahatnation.com

The Malahat Nation ALDFG location operations combines surface visual surveys and follow up ROV surveys with anecdotal local knowledge gleaned from the Malahat fishing community. During the crab and prawn fishing season, surface visual surveys of crab and prawn gear buoys in Saanich Inlet and around the Southern Gulf Islands identify fishing hotspots by marking GPS waypoints of active fishing areas. Survey data is then combined with the NRC predictive model data to identify areas for targeted ROV surveys.

The Malahat Nation employs a Deep Trekker Pivot Nav ROV. *Malahat Nation*

The ROV is deployed from either a 8.5 m thunder jet with side mounted davit and 2000 lbs capacity hydraulic lift or a 7 m long landing craft with a drop front and recreational, electric crab pot hauler. The ROV is outfitted with an Imagenex acoustic sonar unit to increase ROV survey capacity when visibility conditions would be otherwise prohibitive. A normal survey team consists of three to four members: ROV pilot, spotter and tether tender, and a vessel captain.

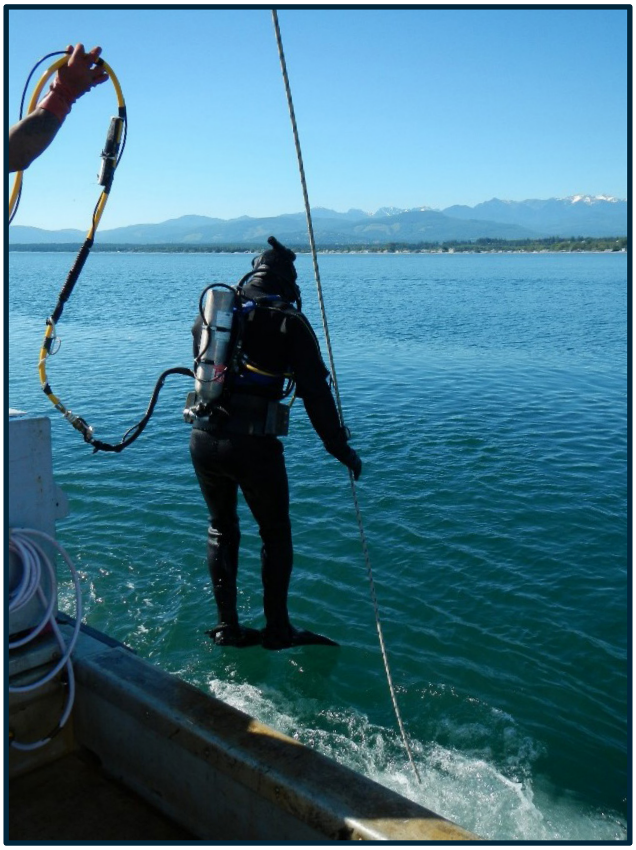
During surveys, the pilot monitors live video and acoustic sonar feeds, moving the ROV along transects through the previously identified hotspots. The ROV is equipped with a UBSL unit, enabling more accurate recording of ALDFG locations by negating the need to calculate offsets to account for the difference between vessel and ROV positions. When possible, ROV transect surveys begin upstream of local currents to avoid potential entanglement or interference from current interaction with the ROV tether cable. The Malahat Nation targets slack tide conditions for all ROV survey work. Current deepest extent of Malahat Nation surveys is 100 m though the project area includes waters of greater than 230 m depth. After survey completion, video and sonar data are reviewed in the office and all located ALDFG is reported to the DFO Lost Fishing Gear Tracking System.

Still image of a single crab pot captured during ROV location survey. *Malahat Nation*

Diver surveys

All diving associated with ALDFG should be carried out by trained divers certified to the level required by local legislation. In Canada, divers should generally be certified as Occupational SCUBA or Unrestricted or Restricted Surface Supply air divers (USS or RSS). Procedures for safe ALDFG dive surveys are consistent with current regulations and include having a three-person team with a standby diver and tender.

Diver surveys are best conducted in areas where concentrations of ALDFG are suspected after gleaning information from local knowledge. A limited survey area should be identified with depths within diver limits. Two methods are commonly used for diver surveys: jump dives and survey searches.



A Surface Supplied Air diver enters the water to begin ALDFG operations. *NRC*

A jump dive involves diving on an ALDFG target to verify whether it is ALDFG or not. Survey searches are more extensive dives to search a predetermined area for ALDFG. In some cases, survey searches also include ALDFG targets for verification and possibly even retrieval of gear identified.

During dive search surveys, systematic swaths of the area of interest should be covered with visual sight distance noted to ensure complete coverage. The diver may stay at a designated depth and follow the contour of a feature, such as a boulder field or reef. Or the diver may stay on a designated heading, staying at a consistent depth as much as possible.

Natural Resources Consultants uses diver surveys extensively to locate ALDFG in rocky reef areas where sidescan sonar is less accurate. For surveys in the Salish Sea, upon encountering a derelict net, the diver alerts topside personnel using 2-way radio communications with information on type and depth of ALDFG. The vessel operator positions the vessel above the diver (ensuring the air hose is as vertical as possible). Topside personnel then collect GPS coordinates once the vessel is positioned directly above the diver. As it is not always possible to ensure complete accuracy of this positioning method due to currents acting on the air hose and air bubbles, two or three positions might be collected using the same Gear ID. While jump dives are designed to verify presence of ALDFG, location position can also be updated using this method. This method can also be used if the diver helmet is fitted with a camera with topside video feed.

Surface Visual Surveys

Visual surveys from boats are an excellent method to locate the buoys of lost shellfish traps (See Malahat Nation case study on pg. 19). However, boat-based surveys are best conducted in areas of high concentration of lost gear as fuel costs will prohibit extensive surveying in large areas with low concentrations of lost gear. Rough sea conditions and marine fog can significantly limit surveyors' ability to identify buoys, therefore these types of surveys are most effective when weather is calm, and fog is not present. This method is best used after closures of shellfish or trap-based fisheries where traps are abandoned or drift away from set locations. Many fisheries enforcement agencies use this method to locate and remove gear left out after season closures.

In general, visual surveys for ALDFG are done simultaneously with retrieval operations. Locations of lost fishing gear reported can be a starting point for visual surveys. In the Area A Dungeness crab fishery in British Columbia, fishers keep note of sighted derelict crab traps or of locations where they have lost traps so they can provide those locations to retrieval teams after season closure.

Aerial Surveys

Visual surveys from airplanes or helicopters flying at low altitude have successfully located ALDFG in marine and riverine environments in Canada, Alaska, and Hawaii among other places[29,30]. This method has been used successfully off of the West Coast of Washington and Oregon to locate lost Dungeness crab traps where small planes are flown over the fishing area after season closure and buoy locations are noted for later boat-based retrieval operations. The Fraser River Sturgeon Conservation Society has successfully used this method to identify locations of ALDFG on the banks of the Fraser River. In this case, helicopters are flown following the path of the river. Locations are noted for later removal by field teams, or, in some cases the helicopter lands on the river bank and ALDFG is retrieved by hand.

Usefulness of aerial surveys for identifying submerged gear is visibility dependent and this should be taken into consideration when assessing the usefulness of this method.

Unmanned aerial vehicles (UAVs) have also been used successfully to survey for ALDFG in areas where boats cannot maneuver and in high visibility shallow nearshore areas[31,32]. This method could be useful to survey more remote areas of shoreline but requires highly specialized equipment and requires time-consuming analysis of raw data[31].

CASE STUDY

Fraser River, British Columbia

Fraser River Sturgeon Conservation Society, Sarah Shreier, sarah@frasersturgeon.com

The Fraser River Sturgeon Conservation Society is a small non-profit that has worked on Fraser River sturgeon research, conservation, and recovery issues for over 20 years. Gillnet ALDFG work began in 2018 along 200 river km from Stevenson, at the mouth of the Fraser River, to upriver of Yale. The Society focuses its ALDFG efforts in the Fraser River, a wild river with rapidly fluctuating flows and water levels. Because of these dynamic conditions, if ALDFG is not retrieved when it is located, there is a significant chance that it could be lost again before another retrieval expedition can be mounted. This necessitates a combined location and retrieval approach to ALDFG recovery in the Society's project area.

On-water location and removal efforts rely on the insights of indigenous and nonindigenous, professionally accredited angling guides and local fishers. During on-water expeditions, crews interview local fishers to identify search locations and conduct subsequent surface visual surveys to locate and retrieve encountered ALDFG.

Retrieval methods vary case by case, relying on professional expertise and employing standard fishing and angling equipment such as poles, boat hooks and small grapnels. Retrieval operations are conducted from jet powered guide vessels between 7.3 m and 8.5 m long. Twin engine vessels are used for especially technical waters.

The Society trialed aerial ALDFG surveys in 2022. Experienced search and rescue pilots from Valley Helicopters in Hope, British Columbia were hired to conduct low altitude, ~70 m to 152 m, low speed flights while Society personnel recorded location and gear type of sighted ALDFG. All helicopters used in survey operations featured pontoon skiffs to allow for aquatic landings and takeoffs. Helicopter surveys successfully located gear on large gravel bars and cliff faces that on-water boat surveys would otherwise miss and, in some instances, the aerial view allowed project personnel to peer into the water column enough to identify submerged snags at lost gear hotspots. In two instances, pilots were able to land on gravel bars, allowing Society staff to manually retrieve gear immediately.

RETRIEVAL METHODS

The ALDFG retrieval methods discussed in this document include:

- *Diving*
- *Grappling, trawling, dragging, or creeping*
- *ROV Retrieval*
- *Surface retrieval*

Diving

A SCUBA diver ties a retrieval line to a piece of ALDFG in the Gulf of St. Lawrence. *Comité ZIP des Îles*

Many programs around the world employ divers, both professional and volunteer, to remove ALDFG. All of these programs recognize the inherent danger of diving around lost fishing gear and usually have a separate dive safety plan or manual that they adhere to for all operations[33,34]. Nets pose increased risk for divers, especially gillnets, which are designed to trap and entangle animals. Very large and heavy aquaculture equipment also poses significant challenges to diver retrieval. However, even relatively simple retrieval of crab traps poses a danger, especially if lift bags are used. Therefore, our description of diver retrieval methods should be used as a guide to pursue deeper understanding of the methods and safety precautions necessary for safe retrieval operations. This document is not meant as a diver manual, but only as a reference for project proponents to help them determine if diver retrieval methods are right for their circumstances.

Diver retrieval takes three forms: free-diving using snorkel gear; SCUBA diving, and diving with surface-supplied air. Water depth and visibility, weight of gear, complexity of retrieval, and entanglement risk all play a part in determining the dive methods used. Each approach requires unique training and presents unique risks and benefits. While free-diving is used successfully in some areas of the world,[35] for the purposes of retrieving ALDFG from Canadian waters, we focus on SCUBA and Surface Supplied Air diving. In general SCUBA diving allows more freedom of movement since the diver is not tethered to the vessel. However, this method entails limited air supply and no verbal communications with the vessel crew. Surface Supplied Air diving provides longer working bottom time with unlimited air time and provides two-way communications with the vessel. Communications can also include a video feed if the diver helmet is fitted with a camera. The air hose does complicate mobility and can add drag in higher current areas. See Table 1 for a list of advantages and disadvantages of these different diving retrieval methods. Likewise, there are advantages and disadvantages to divers using fins or boots when retrieving ALDFG. Finning allows more vertical movement but can be less stable in currents. Boots limit the ability to transit around and over reefs and deeper areas but provide more stability.

In general, diving is avoided in areas with extreme currents and many divers do not work well when the currents exceed 1 to 2 knots. In areas with extreme tides, diving operations are most effective during slack tide and often work windows are very short. Depending on the substrate, areas with extreme tides can also have very low visibility due to shifting sediment. Deeper water also shortens the available work windows

Diving method	Certification required	Advantages	Disadvantages
SCUBA diving	Occupational SCUBA	Nimbleness; less drag; more flexible vessel requirements	Limited airtime; no communications
Surface Supplied Air diving	USS or RSS	Unlimited air time; audio communications	Less nimble; air hose can cause drag; requires air source on vessel

Table 1: Summary of the two most common diving methods employed in ALDFG operations and the advantages and disadvantages associated with each method.

due to bottom time limits. Use of mixed gas can lengthen available bottom time for experienced divers. In many areas, safety regulations prevent divers from working at certain depths without a hyperbaric chamber available on the dive support vessel.

Visibility is also a crucial factor when diving for lost fishing gear. While some very experienced ALDFG retrieval divers can work in very low visibility situations, in general, diver retrieval operations are safer and more efficient in waters with moderate to high visibility. In some areas, visibility is better in winter months because increased algae growth lowers visibility in warmer months. However, more rain in winter months increases sediment transport, which can also result in poor underwater visibility, especially near large river systems (i.e., Fraser River).

Diver retrieval requires advanced training and in Canada requirements mirror those for salvage divers. For example, Emerald Sea Protection Society uses industry standard commercial diving practices and a three-person team during ALDFG retrieval operations. A dedicated supervisor monitors air supply and live video feed from a helmet mounted camera worn by the diver. A diver on surface supply air descends to the sea floor and, if ROV surveys were not possible, conducts an underwater survey to identify and locate ALDFG or begins retrieval operations. The third member of the team acts as tender and backup diver, assisting the diver don and doff gear and help manage the diver's umbilical.

Prior to retrieval of ALDFG, it is important to conduct a thorough reconnaissance survey of the ALDFG to be retrieved. This could include marking the ALDFG location with dropline/clump weight (working line) from the vessel before diver enters the water. Then the diver descends the working line to the ALDFG and conducts a thorough assessment of the ALDFG and plans a retrieval approach.

Reconnaissance should include an assessment of the amount of ALDFG to be removed during a dive informed by how much ALDFG can be lifted by the vessel's hydraulics or by the crew if hand-hauling is the method used to get the ALDFG onto the support vessel. It is important to try to retrieve only the amount that can be safely and efficiently handled and processed on deck at one time. With very large targets, such as a whole gillnets, seine nets, or aquaculture nets, it is often necessary to partition the recovery of such gear items by cutting them into manageable pieces for recovery.

CASE STUDY

Coastal British Columbia and Salish Sea

Emerald Sea Protection Society, Burton Scott, bourton.scott@emeraldseasociety.ca

Emerald Sea Protection Society operates along the British Columbia Coast with projects in Prince Rupert Sound, Berkeley Sound, and the Discovery Islands. ESPS is led by a small team of commercial divers and uses surface supply diving with ROV support for all ALDFG retrieval operations. Target ALDFG in project areas are crab traps, gillnets, seine nets, and shellfish and finfish aquaculture gear (scallop, oyster, and salmon) at depths from 18.3 m to 33.5 m.

Methods to identify initial ALDFG locations include gathering information from the DFO on legacy fishing efforts and aquaculture lease sites, local knowledge from fishers and NRC predictive model. After identifying target areas, a Deep Trekker DTG 2, observation class, submersible ROV is deployed to locate and verify ALDFG targets. The ROV is an older model with a 150 m maximum depth, 2 knot maximum speed, and 720p digital camera. Due to its power constraints and relatively low-resolution imagery, high visibility, and low current speeds (less than 2 knots) are necessary for ROV reconnaissance.

For retrieval methods, Emerald Sea uses industry standard commercial diving practices with a three-person team. A dedicated supervisor monitors air supply and live video feed from a helmet mounted camera worn by the diver. A diver on surface supply air descends to the sea floor and, if ROV surveys were not possible, conducts an underwater survey to identify and locate ALDFG or begins retrieval operations. The third member of the team acts as tender and backup diver, assisting the diver don and doff gear and help manage the diver's umbilical.

Once gear has been identified, the tender sends a retrieval line down the diver's umbilical. The diver ties off or hooks into the ALDFG for retrieval via vessel mounted hydraulic winch. When retrieving strings of multiple traps or large nets, the diver exits the water once the retrieval line is secured and before the gear is brought to the surface to minimize diver risk. If the target gear consists of individual traps, the diver may remain in the water conducting visual surveys for additional gear while the deck crew recovers the trap and returns the retrieval line to the diver.

A note about gillnets

ALD gillnets are often laid out in spider web configurations, with portions being torn by rocks. It is important for divers to locate all ends of the net before attempting to retrieve the net. A successful method of retrieving nets that are spread out is to find one end of a 'leg' and bundle it up towards the center, securing it to a leadline with a choker. Then find another end of a 'leg' and follow the same protocol until you have a bundle at the center of the net. Attempting to lift a spread out net from the center without first addressing the 'legs' will result in a 'teepee' net. This leads to an unsafe situation with a bulk of the net suspended in the water column, with several points still attached to the seafloor in multiple directions that are difficult to find by divers in low to moderate visibility conditions. Causing a teepee net to occur can also significantly reduce efficiency in removal operations, as the diver must spend extra time searching for all branches, and the situation can run the risk of breaking off chunks of trailing net as it is being hauled onboard (Figure 2).

Always secure nets with chokers by the leadline rather than the mesh to avoid tearing net during lifting and losing portions. We recommend beginning work on ALD nets at the further distance from the vessel and working toward the vessel. This ensures that any net being lifted by the vessel is free and clear. Divers should note that a net is free and clear of snags before lifting it to the surface. If the ALDFG extends to areas deeper than the diver can work, do not try to 'haul' the net out of the depths as it is likely to break the net mesh and could damage habitat. It is better to cut the net at the appropriate depth and note its position for potential future removals with a different method. Essential tools for retrieving nets of any kind are a good knife (we recommend low cost Victorinox knives with serrated edges), carabiners, choker lines, mesh collection bags (for bones and small scraps).

A note about single shellfish traps

When retrieving multiple single shellfish traps, having accurate locations for those targets is critical. Targets should be plotted into navigation software, which is used to drop a clump weight onto the target location (Figure 3). An efficient method for this is to attach a clump weight to the terminal end of a working line which the diver will use as a tether. Attaching a float to the opposite end of the working line can be useful to deploy so that the clump weight does not drag if the vessel drifts further off target than the length of the line. The diver can then descend this line to the target. With the line moving freely through a carabiner attached to the clump weight, the diver can conduct a standard circle search for the target. Holding the working line close to the seafloor and working away from the weight is a reliable method to find a trap within about 15 m from the clump weight.

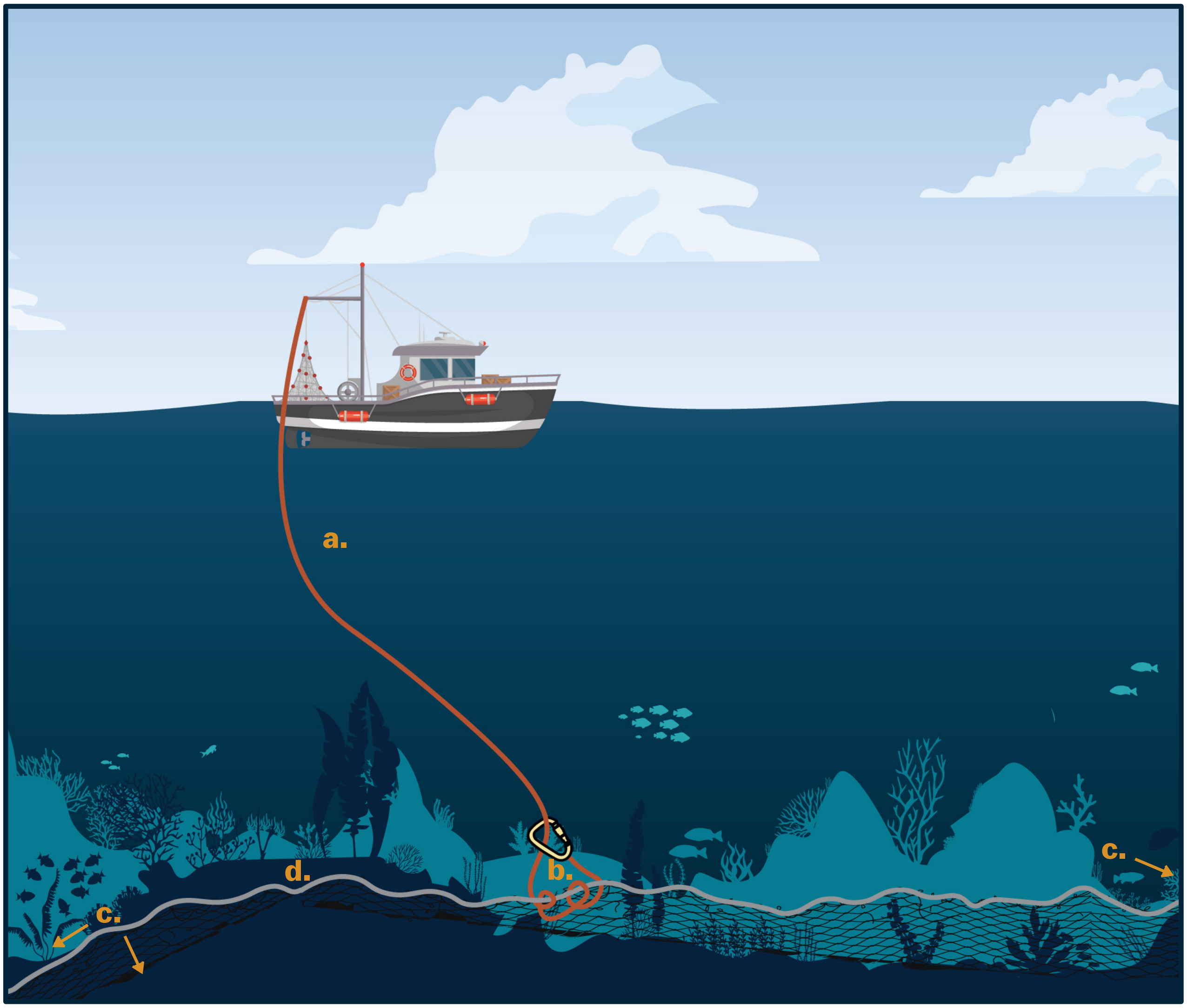


Figure 2: Simple diagram of ALD gillnet retrieval method. (a, b, c) The working line (a) is wrapped around the net *and* lead line, securing the working line back onto itself using a carabiner or choke (b). Floats can be added but should always be attached to the net and lead line. (c) Tails of net can travel up to 33 m (100 ft) from the main lead line, and can be pulled back to the main net and wrapped around the lead line to aid in retrieval. (d) Areas where only the lead line with little or no net remaining are good cut points to aid with large or particularly difficult gillnet recovery operations.

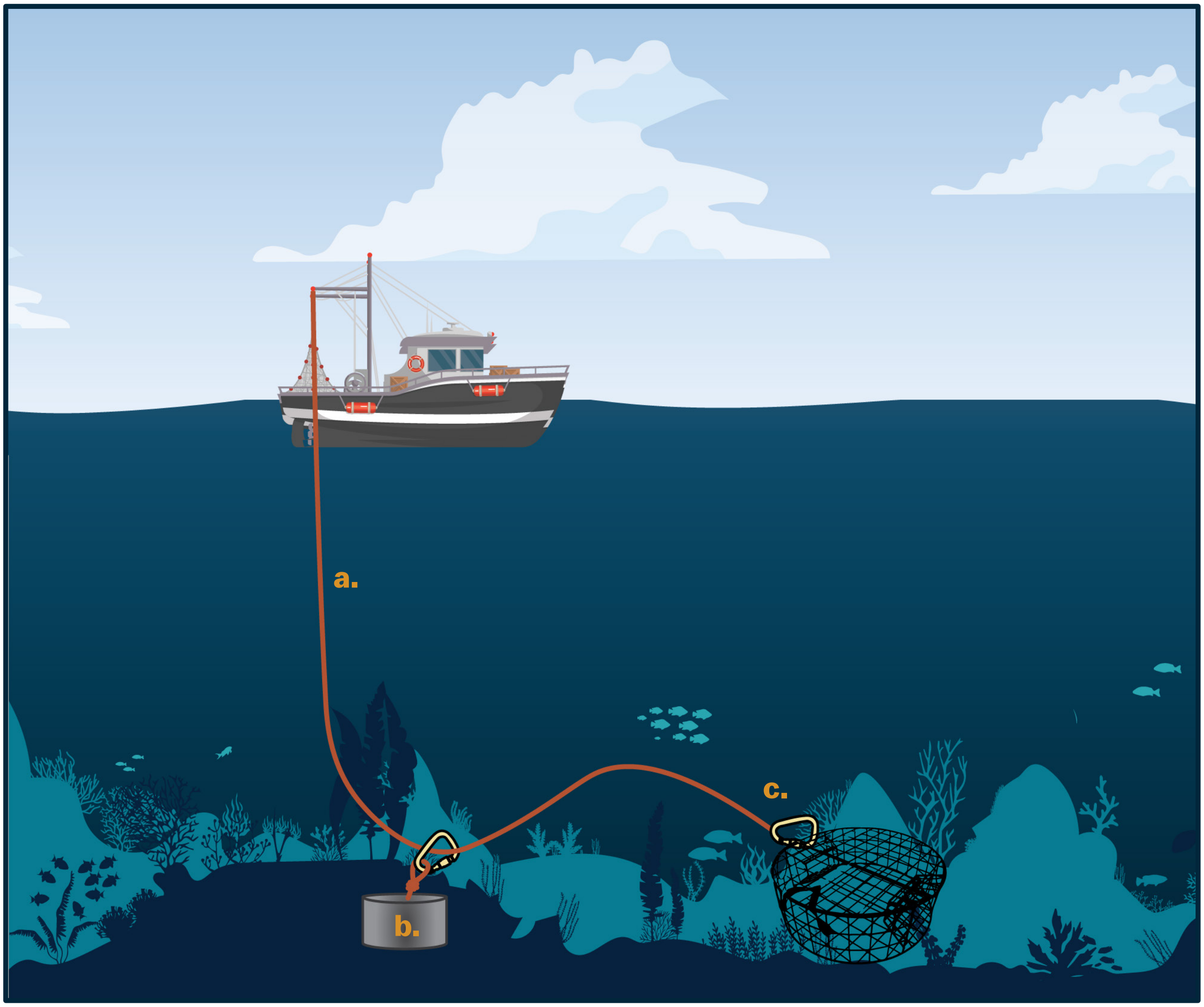


Figure 3: Simple diagram of ALD single shellfish retrieval method. Working line (a) is clipped to a previously lowered drop weight with attached carabiner (b). The diver can pull slack for circle search patterns. A second carabiner (c) on the end of the working line is not necessary but aids in trap recovery.

Towed grapnel system with recovered shellfish trap. *CSR GeoSurveys Ltd.*

Grappling, trawling, dragging, or creeping

Grappling, trawling, dragging, or creeping for lost gear is used extensively by fishers themselves when they lose their gear. It is an effective method when you know the location of where gear was lost and in areas where concentrations of lost fishing gear are known or suspected to occur. Systematic, or targeted, dragging of grapnels or arrays of hooks can effectively locate gear. In some instances, retrieval can be accomplished immediately after location using the same grapnels, or hooks to remove the gear. In other instances, locating the gear through dragging is followed by either noting the location of the gear or by marking the location in situ with buoys or other means for subsequent retrieval.

Grappling can involve deploying a single grapnel or array of grapnels to locate and retrieve single gear items. In the case of single shellfish pots with vertical lines, the grapnel may have a series of hooks aligned vertically on a working line. This method can be effective in habitats with sandy or muddy bottoms or rocky areas with little rugosity. In reef areas or seagrass beds, the method can cause excessive damage to marine habitats.

Practitioners exploring grappling, dragging, or creeping to locate or retrieve lost fishing gear should investigate the locations of underwater utilities and fiber optic cables in the project area. It should be noted that cables have been placed on the seafloor all over the world, including in some of the most remote ocean areas. Some cables are indicated on nautical charts. An internet search related to underwater cables in a project area should lead to maps of cable locations. One good general source for locations of underwater cables is http://www.submarinecablemap.com.

The Fundy North Fishermen's Association ghost gear retrieval manual includes recommendations around safety, towing speed, hauling equipment, and crew size as well as specific recommendations around building effective grapnels. Several noted key considerations for building the grapnels they use to retrieve lobster pots include:

- *Ensure configuration is designed to hook or squeeze rope as rope is often attached to lost pots and is a bigger target than the pot itself* (see photo*).*
- *For rocky ground, ensure the hooks are weak enough to straighten out if caught on rocks but strong enough to pull up the rope or gear.*
- *For deeper areas, ensure the grapnels are heavy enough to operate at depth in high currents*[24]*.*

Varieties of grapnels and arrays have been used throughout Canada to retrieve ALDFG. Below are photos of some examples.

Single grapnel designed to catch ropes and weighted to maintain depth and position. Used to retrieve Dungeness crab traps after trap locations were identified using sidescan sonar. *NRC*

Trawling or creeping for ALDFG is similar to grappling but involves towing a trawl or hook array along the seafloor to locate lost gear. It is an effective means in areas where bottom trawling or other gear that touches bottom is used [36].This method is also used extensively by fishers themselves when they lose gear. In deep sea habitats, this is often the only feasible method to remove ALDFG and has been used in deep sea habitats in South Korea and in Europe[37,38]. Trawling for ALDFG generally involves attaching hooks to a trawl warp weighted to maintain contact with the seafloor. The vessel then drifts at low speed (1.5 – 2.5 knots) through a target area where accumulations of ALDFG are suspected[38].

CASE STUDY

Bay of Fundy, New Brunswick and Eastern Passage, Nova Scotia

CSR GeoSurveys Ltd., Colin Toole, toole@csrgeosurveys.com

CSR GeoSurveys conducts ALDFG survey and retrieval operations in the Bay of Fundy and Eastern Passage targeting lobster traps and rope. While CSR does not intentionally target aquaculture gear it is often incidentally identified during location surveys and targeted for retrieval.

CSR GeoSurveys designed and fabricated a heavy grapnel for drag retrieval of ALDFG. For construction of the grapnel, CSR applied ideas published by Fundy North Fisherman's Association Lost at Sea: A Ghost Gear Retrieval Manual https://www.fundynorth.org/ghost-gear. The grapnel is constructed from a 3.6 m long, 450 kg steel bar with five, 180 kg grapnels affixed to the main bar. The grapnel is dragged at a constant speed of 3 to 4 knots in ALDFG hotspot areas previously identified and confirmed with sonar surveys.

When the grapnel encounters significant ALDFG it is common that the boat will drop in speed by 1 to 2 knots. Once ALDFG is hooked, the vessel continues at a fixed bearing at 1 to 2 knots and hydraulic winches are used to bring the grapnel and any ALDFG to the surface. Once at the surface, the vessel continues on its fixed bearing to ensure any retrieved gear does not entangle the vessel. The ALDFG on the grapnel is often a tangle of lines, pots, and nets that CSR refers to as a "gaggle" and CSR GeoSurveys relies on the expertise of experienced ghost gear operators and the fishing crew aboard the vessel for safe retrieval. First, the crew identifies and affixes a lead line to a portion of the gear that could likely be untangled from the whole. This portion is then carefully cut away and the lead line is run through a 6-ton capacity hydraulic pot hauler to bring the section of retrieved gear onto the vessel. This process is repeated until the grapnel is cleared and can take anywhere from 1 to 3 hours depending on the extent of hooked ALDFG.

In the Eastern Passage where the fishery is less intensive and focused in more shallow, nearshore waters, CSR employs a single, hand deployed grapnel and ROV technology for ALDFG retrieval of gear located via surface visual surveys.

CSR GeoSurveys Ltd. crew recovering ALD salmon net pen gear in the waters around Nova Scotia.

CASE STUDY

Area B Commercial Crab Fishery – Prince Rupert and surrounding waters, south to Bella Bella, British Columbia

Shift Environmental, Katie Smith, ksmith@shiftenvironmental.com

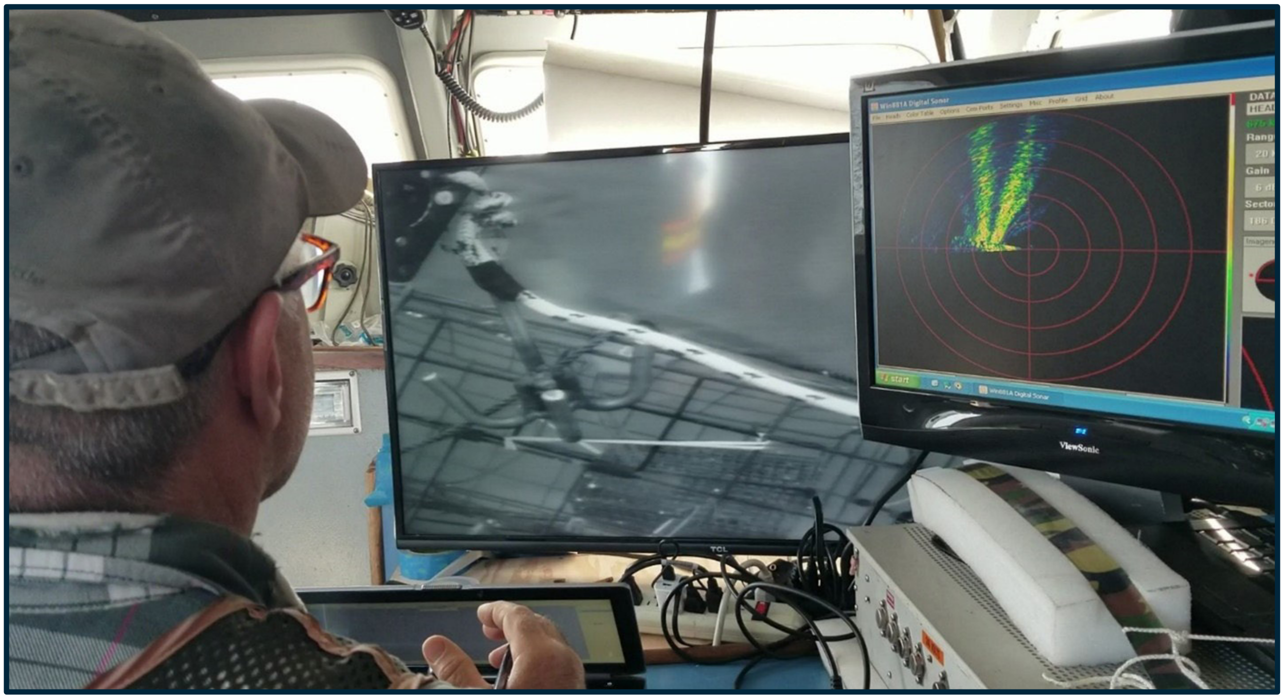
Shift Environmental Technologies conducts ALDFG retrieval in British Columbia's Area B Crab Fishery targeting commercial crab traps and developing methods for scalable shallow-water ALGFG retrieval.

ALDFG target locations are identified through conversations with local fisherman operating out of Port Rupert and from fishing effort heatmaps provided by the DFO Area B Crab Fishery. To pinpoint locations in the field, Shift uses a transom mounted Humminbird consumer sonar unit or an Imagenex Model 872 "YellowFin" sidescan sonar unit. Shift surveys regularly spaced parallel transects through the target area. During surveys, a technician monitors real-time live imagery, marking waypoints at potential targets for review during post-processing. Post-processing includes identifying targets and recording waypoints for the terminal ends of crab trap strings.

Retrieval efforts involve a custom fabricated towed grapnel, and 250 kg capacity davit with hydraulic winch. The grapnel consists of a 1.2 m long solid steel rod with welded spikes weighing approximately 22.6 kg attached by 5/8-inch (~16mm) Samson rigging rope towed at a 4:1 scope. The grapnel is dragged between the terminal waypoints recorded during processing a total of three times. The grapnel is recovered by means of a hydraulic winch after each pass and gear is stowed on deck when recovered. If no gear is captured after the third pass, efforts move to the next target. Using this method, Shift estimates a 30% to 40% success rate.

Shift works closely with Canadian First Nations on natural resource projects, contracting First Nation vessels for the majority of ALDFG operations when possible. Shift generally uses a 9.1 m vessel with davits and hydraulic capabilities for shallower, inshore projects and a 28.7 m long fishing vessel when working offshore.

ROV Retrieval



Pilot using ROV grapnel to hook a Dungeness crab trap for retrieval (left). Scanning sonar display (right). *NRC*

Retrieval of ALDFG using ROVs generally requires the ROV to be fitted with appropriate manipulative tools for retrieving the targeted ALDFG or for attaching a separate working line with which the ALDFG is hauled onto the retrieval vessel. There are three classes of ROVs, generally ranked by size, power, and technical capabilities. Work class ROVs are the largest; they typically have multiple articulating arms, and are equipped with the most specialized equipment for maintaining position while conducting operations in deep water under challenging conditions. In Washington state, a mid-size work class ROV was used to conduct deep water ALDFG retrievals [39]. Observation class ROVs are smaller than work class and are primarily used for surveys; they typically have one arm that may or may not articulate, and a manipulating clasp. Observation class ROVs have been used for ALDFG survey and removal, and in proper sea conditions (weather and currents) can be a good tool to recovery shellfish traps[39,40]. Compact or Micro ROVs are small observation ROVs which typically only have observation capabilities (i.e., camera, light, maybe sonar); using these ROVs efficiently requires calm sea conditions. They are typically used for surveying an area, but it could be possible to use a micro ROV to attach a working line with carabiner to a lost trap.

ROV retrievals can follow this general sequence: after the vessel has anchored near the target, the ROV is deployed within close proximity to the ALDFG target. Once on the seafloor, using topside controls, video feed, and sonar displays, the pilot navigates the ROV to the target. Once the target is in sight, a survey is conducted to determine if recovery is appropriate and feasible. Sometimes a large conglomeration of ALDFG (nets, ropes, etc.) can pose serious risk of ROV entanglement which can lead to breakage and even loss of the ROV. The ROV operator and team make the decision to recover the ALDFG, or sometime if it is partially buried, may choose to disable the gear and leave it in place.

Working class ROV fitted with grapnel being deployed to retrieve Dungeness crab pots from waters below diver depth. *NRC*

When recovery is chosen, the ROV either hooks onto the ALDFG with fitted tools or attaches a working/retrieval line to the ALDFG (see photo on page 36). The ALDFG is then either hauled up with the power of the ROV or with hydraulic lift supplied by the vessel. During trap recovery operations this can be a relatively simple task, especially when traps are present on the seafloor and not entangled in other gear. However, net recovery can be significantly more complicated when attempting to disentangle, bundle, choke, cut, and lift portion of net that may be spread in multiple directions. This can be very challenging and time consuming, even with the toolset and power of a work class ROV. In most cases, the ROV is deployed and recovered using the vessel's hydraulic lift, except for compact ROVs that can be hauled in by hand power.

ROVs can be an efficient retrieval technique when divers are unavailable or cost prohibitive and in waters too deep or treacherous for divers to safely operate [39,40].That said, effective use of ROVs requires careful considerations of cost and benefit. While ROV technology continues to increase, they are expensive pieces of equipment that are expensive to operate, especially work class ROVs. ROVs must have enough thrust to keep reliable positions at depth and in currents. Even with fairly powerful, mid-size working class ROVs, current speeds must be < 2 knots for work to be conducted efficiently without the ROV constantly contending the current [39,40]. Lightweight or compact ROVs will not be effective in most Canadian environments because of currents and weather. However, observation class ROVs have been successful at retrieving ALDFG in shallow bays during fair weather and could be an effective method in those situations [41].

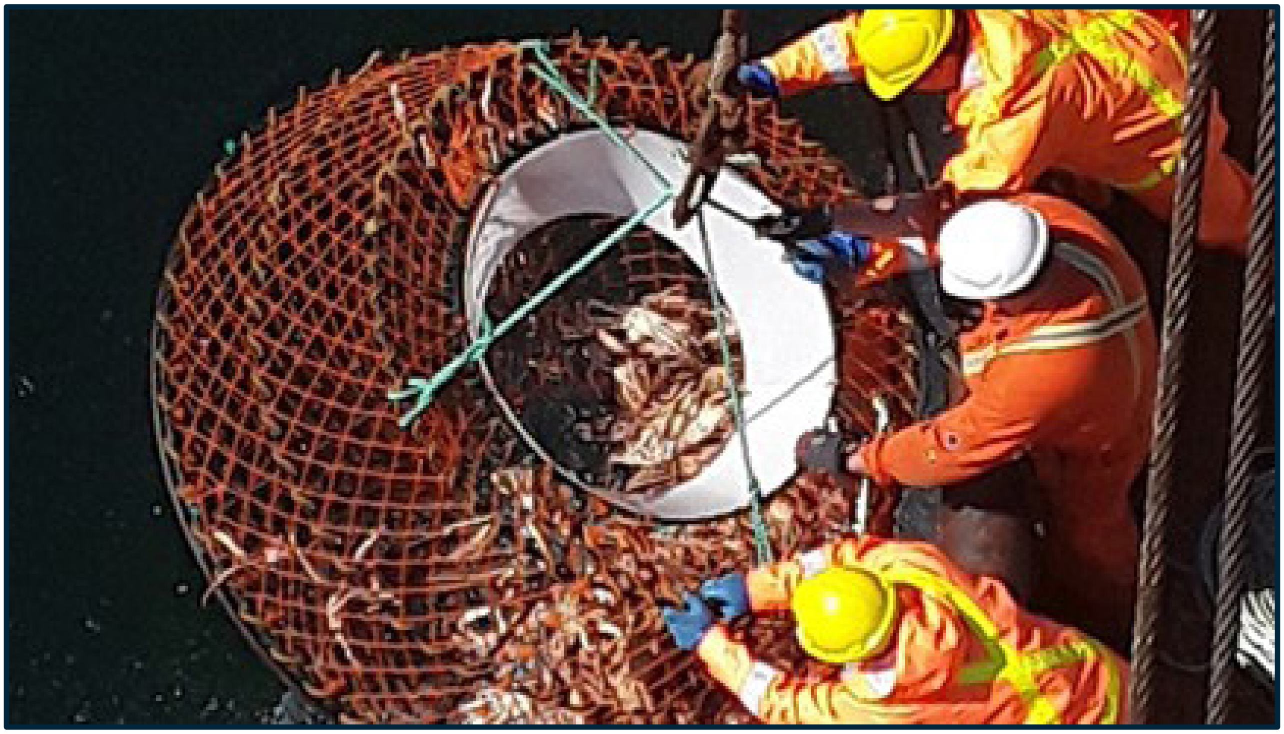
CERMIM, located on Quebec's Magdalen Islands, are working to develop new ALDFG specific ROVs and associated retrieval techniques.

Surface retrieval

Surface retrieval of ALDFG usually involves the retrieval of shellfish traps with floating buoys still attached. This method is used to retrieve shellfish traps of all sizes, from small recreational Dungeness crab traps to large snow crab traps (see photo on page 39).

While all retrieval methods require vessels with adequate lifting capabilities, surface retrieval is often an ideal method to conduct off of fishing vessels equipped with hauling equipment fit for the type of ALDFG to be retrieved. The floating buoy is approached slowly, and a grapnel or gaff is used to grab it and attach it to a hydraulic lift or pot hauler, which proceeds to haul the gear onboard. Entrapped animals can be released while the trap is suspended on the hauler or after the trap is brought onboard the vessel.

In the Area A crab fishery, fishers note locations of lost gear encountered during fishing. At the end of the season, the fisheries association hires a chartered vessel to retrieve stray crab traps at the same time the vessel conducts softshell surveys. Fishers provide noted locations to the captain of the chartered vessel to assist with targeting visual surveys and retrieval operations. Crew use binoculars to locate floating buoys. When a buoy is located, the trap is retrieved as described above and traps are generally returned to their owners. In the U.S. West Coast Dungeness crab fisheries, licensed crab fishers can acquire permits to retrieve out-of-season stray traps left on the fishing grounds following the fishing season.



Retrieving ALD snow crab trap from Gulf of Saint Lawrence waters. *Canada Department of Fisheries and Oceans*

REFERENCES

1. García-Alegre, A. et al. *Seabed litter distribution in the high seas of the Flemish Pass area (NW Atlantic)*. Scientia Marina 84, 93–101 (2020).

2. Grados, B. A*bandoned, lost or otherwise discarded fishing gear found in trawling at Tropical Sea of Grau Piura - Peru*. Presented at the 3rd International Conference of the YEAH. (2021).

3. Macfadyen, G., Huntington, T. & Cappell, R. *Abandoned, lost or otherwise discarded fishing gear.* UNEP Regional Seas Reports and Studies 185. FAO Fisheries and Aquaculture Technical Paper 523. Aquaculture vol. 523 (2009).

4. NOAA. *Impact of "Ghost Fishing" via Derelict Fishing Gear.* (2015).

5. National Oceanic and Atmospheric Administration Marine Debris Program. *2016 Marine Debris Habitat ReportHabitat Marine Debris Impacts on Coastal and Benthic Habitat*s. NOAA Marine Debris Program Report. 26 (2016).

6. Gilardi, K. V. K. et al. *Sea-Based Sources of Marine Litter - A Review of Current Knowledge and Assessment of Data Gaps.* Second Interim Report of GESAMP Working Group 43. (2020).

7. DelBene, J. A., Bilkovic, D. M. & Scheld, A. M. *Examining derelict pot impacts on harvest in a commercial blue crab Callinectes sapidus fishery.* Marine Pollution Bulletin 139, 150–156 (2019).

8. Gilardi, K. et al. *Marine species mortality in derelict fishing nets in Puget Sound, WA and the cost/benefits of derelict net removal.* Marine Pollution Bulletin 60, 376–382 (2010).

9. Humborstad, O. B., Løkkeborg, S., Hareide, N. R. & Furevik, D. *Catches of Greenland halibut (Reinhardtius hippoglossoides) in deepwater ghost-fishing gillnets on the Norwegian continental slope.* Fisheries Research 64, 163–170 (2003).

10. Tschernij, V. & Larsson, P.-O. *Ghost fishing by lost cod gill nets in the Baltic Sea.* Fisheries Research 64, 151–162 (2003).

11. Antonelis, K., Huppert, D., Velasquez, D. & June, J. *Dungeness Crab Mortality Due to Lost Traps and a cost – benefit analysis of trap removal in Washington State waters of the Salish Sea*. North American Journal of Fisheries Management 37–41 (2011) doi:10.1080/02755947.2011.590113.

12. Miller, R. J. R*esource Underutilization in a Spider Crab Industry*. Fisheries (Bethesda) 2, 9–30 (1977).

13. Goodman, A. J., Brillant, S., Walker, T. R., Bailey, M. & Callaghan, C. *A Ghostly Issue: Managing abandoned, lost and discarded lobster fishing gear in the Bay of Fundy in Eastern Canada*. Ocean and Coastal Management 181, 104925 (2019).

14. Drinkwin, J. & Antonelis, K. Lost Crab Trap Survey Project Boundary Bay, British Columbia. (2019).

15. Antonelis, K., Drinkwin, J. & Bertram, D. *Final Report Surf Scoter Restoration Project North Vancouver Island / Straits Region, British Columbia, Canada, derelict Net Surveys & Removals.* (2018).

16. Antonelis, K. L. *Derelict Gillnets in the Salish Sea: Causes of Gillnet Loss, Extent of Accumulation and Development of a Predictive Transboundary Model*. Unpublished master's thesis. University of Washington. (2013).

17. Drinkwin, J., Antonelis, K. & Edwards, D. *Final Report: Area A Lost Crab Trap Removal Project McIntyre Bay, British Columbia.* Prepared for World Animal Protection. (2017).

18. Wachter, G. & Wachter, M. A*bandoned Fishing Gear in Lake Erie*. (2021).

19. Antonelis, K. & Drinkwin, J. P*redictive model identifying locations of fishing gear loss or accumulation in Lake Erie, Canada.* (2021).

20. Canada. *Ocean Plastics Charter.* (2018).

21. Canadian Council of Ministers of the Environment. *Strategy on Zero Plastic Waste.* 14 (2018).

22. Canadian Council of Ministers of the Environment. *Canada-Wide Action Plan on Zero Plastic Waste Phase 2*. Canadian Council of Ministers of the Environment 1–9 (2020).

23. Drinkwin, J. *British Columbia Lost Fishing Gear Workshop Report*. (2019).

24. Fundy North Fisherman's Association. *Lost at Sea: A Ghost Gear Retrieval Manual.* (2016).

25. Department of Fisheries and Oceans Canada. *Canada's Ghost Gear Fund delivering results for cleaner oceans*. Canada.ca. https://www.canada.ca/en/fisheries-oceans/news/2021/12/canadas-ghost-gear-fund-delivering-results-for-cleaner-oceans.html (2021).

26. Antonelis, K. L. & Drinkwin, J. *Predictive model identifying locations of commercial fishing gear loss or accumulation in British Columbia, Canada.* Prepared for Department of Fisheries and Oceans, Canada Sustainable Fisheries Solutions and Retrieval Support Program CA No. 20-08-028/010. (2021).

27. Drinkwin, J., Antonelis, K. & Shipley, M. *Derelict Fishing Nets in the Washington Salish Sea : Impacts and Prevention.* (2022).

28. Natural Resources Consultants. *Deepwater Sidescan Sonar and Camera Surveys for Derelict Fishing Nets and Rockfish Habitat.* (2011).

29. Pichel, W. G. et al. *GhostNet marine debris survey in the Gulf of Alaska - Satellite guidance and aircraft observations.* Marine Pollution Bulletin 65, 28–41 (2012).

30. Morishige, C. & McElwee, K. A*t-sea detection of derelict fishing gear in the North Pacific: An overview.* Marine Pollution Bulletin 65, 1–6 (2012).

31. GGGI. Global Ghost Gear Initiative 2020 Annual Report. (2020).

32. *Proceedings of the Workshop on At-sea Detection and Removal of Derelict Fishing Gear.* (2010).

33. WDFW. *Derelict Fishing Gear Removal Guidelines.* (2002).

34. Seadoc Society. C*alifornia Lost Fishing Gear Recovery Project Policies & Procedures.* 52 (2009).

35. Donohue, M. J., Boland, R. C., Sramek, C. M. & Antonelis, G. A. *Derelict fishing gear in the Northwestern Hawaiian Islands: Diving surveys and debris removal in 1999 confirm threat to Coral Reef ecosystems.* Marine Pollution Bulletin 42, 1301–1312 (2001).

36. Hess, N. A., Ribic, C. A. & Vining, I. *Benthic marine debris, with an emphasis on fishery-related items, surrounding Kodiak Island, Alaska, 1994-1996.* Marine Pollution Bulletin 38, 885–890 (1999).

37. Cho, D. O. *Removing derelict fishing gear from the deep seabed of the East Sea.* Marine Policy 35, 610–614 (2011).

38. Humborstad, O. B. et al. *Catches in abandoned snow crab (Chionoecetes opilio) pots in the Barents Sea.* Marine Pollution Bulletin 173, (2021).

39. Natural Resources Consultants. *Documenting Rockfish Bycatch in, and Removing Derelict Shrimp Pots with a Remotely Operated Vehicle: Final Report*. Prepared for Northwest Straits Foundation and National Marine Fisheries Service, Protected Resources Division. (2019).

40. Natural Resources Consultants. *Project Report: Testing the viability of remotely operated vehicles for removal of derelict fishing nets in Puget Sound*. (2015).

41. Antonelis, K., Drinkwin, J. & Heller, C. *ROV Derelict Shellfish Pot Removal from Rockfish Critical Habitat.* (2022).

Appendix 1. Practitioner contact and methods summaries

Organizational Information			Location Methods									Retrieval Methods							
Name	Province	Email	Local Knowledge	Surface Visual	Surface Aerial	UAV	Acoustic Sonar	ROV	Towed Underwater Camera	Underwater Visual	Grapnel Drag	SCUBA	Surface Supply	Snorkel	ROV	Grapnel Target	Grapnel Tow	Shoreline Hand Removal	Shoreline Excavator
British Columbia Shellfish Growers Association	British Columbia	ed@bcsga.ca	×					×		×		×	×		×				
Capitaines Propriétaires	Québec	sbois@acpgaspesie.com	×	×				×			×					×	×		
Coastal Restoration Society	British Columbia	josh@coastrestore.com	×	×	×		×	×		×		×	×		×	×		×	×
COJO Diving Inc	New Brunswick	cojodiving@gmail.com	×	×		×		×		×		×	×						
Comité ZIP Côte-Nord du Golfe	Québec	fromero@zipcng.org	×								×								
CSR GeoSurveys	Nova Scotia	cgilbert@csrgeosurveys.com	×	×			×	×			×				×	×	×	×	
DFO Aquaculture	British Columbia	christopher.marrie@dfo-mpo.gc.ca	×	×				×		×		×	×					×	×
Ecotrust Canada	British Columbia	jennifer@ecotrust.ca	×	×															
Fraser River Sturgeon Conservation Society	British Columbia	helen@frasersturgeon.com	×	×	×		×				×					×	×	×	
Comité ZIP des Îles	Québec	audet@zipdesiles.org	×						×	×									
Les Cultures du Large	Québec	christian@lesculturesdularge.com	×				×				×					×	×		
Malahat Nation	British Columbia	desiree.bulger@malahatnation.com				×	×	×							×	×		×	
Ocean Dynamics Inc.	British Columbia	andy.clark@oceandynamics.ca	×				×	×			×	×	×		×	×	×		
Petty Harbour Fishermen's Producer Cooperative Society	Newfoundland	keithmooreminiaquarium@gmail.com	×								×						×		
Research Center for Island and Maritime Studies (CERMIM)	Québec	marc-olivier_masse@cermim.ca	×				×	×							×				
SHIPEK Fisheries	Québec	dir.shipek@ekuanitshit.com	×								×					×	×		
T Buck Suzuki Foundation	British Columbia	megan@bucksuzuki.org	×				×	×			×				×	×	×		
Titan Maritime	Nova Scotia	al@titanmaritime.ca	×	×			×	×		×	×				×	×	×		
UB Diving	British Columbia	seansmyrichinsky@shaw.ca	×							×		×	×	×				×	

Appendix 2. ALDFG Removal Plan Outline

ALDFG Removal Plan:

Project contact

Name:

Contact Information:

Date of form:

1. Location of planned ALDFG removal
2. Type of gear to be removed
3. Schedule
4. Project Team
5. Removal Vessel, Methods, and Equipment
6. Environmental Impacts
7. Insurace and Safety
8. Notification, Permits and Legal Access
9. Documentation and Reporting
10. Disposal
11. Attachments

Appendix 3. Sonar Technical Specifications

Organization	Gear Type	Make	Model	Max Operating Depth	Camera	ROV mounted sonar	USBL	DVL
CSR GeoSurveys	ROV	Seamor	300T	300 m	Color CCD 460+ TVL, 180° tilt	yes	no	no
Emerald Sea Protection Society	ROV	Deep Trekker	DTG2	150 m	Digital video 720p, 270° tilt	no	no	no
Comité ZIP des Îles	Towed Camera	Deep Trekker	Dtpod	305 m	Digital video 1080p, 360° pan and tilt, JPG 2 mp	—	—	—
Malahat Nation	ROV	Deep Trekker	Pivot Nav	305 m	Digital video 1080p, 200° tilt, JPG 8 mp	yes	SeaTrac X150	no
Natural Resources Consultants/ Fenn Enterprises	ROV	Phantom	HD2+2	300 m	Digital video, 90° pan and tilt; DOE 18:1 optical zoom high-resolution color camera, video feed	yes	yes	no
Natural Resources Consultants/ Global Diving and Salvage	ROV	Saab Seaeye	Cougar XT	2000 m	Digital video, 90° pan and tilt; high resolution cameras, video feed	yes	yes	yes
Research Center for Island and Maritime Studies (CERMIM)	ROV	Custom Proprietary	—	—	—	—	—	—
Titan Maritime	ROV	BlueRobotics	BR2 Heavy	330 m	Digital video 1080p, 180° tilt	yes	Cerulean Sonar	Cerulean DVL

Appendix 4. ROV Technical Specifications

Organization	Gear Type	Make	Model	Max Operating Depth	Frequency	Maximum Range	Survey Speed
CSR GeoSurveys	Sidescan Sonar	Klein	3000	1,500 m	100 kHz / 500 kHz	600 m / 150 m	4 - 5 knots
	Multibeam	Reson	T20R	500 m	200 kHz / 400 kHz	500 m / 200 m	4 - 5 knots
Malahat Nation	ROV mounted sidescan Sonar	Imagenex	Sidescan Sonar Kit for small ROVs	300 m	330 kHz / 800 kHz	Range scale/250 or 500 one or both sides	2 - 3 knots
Natural Resources Consultants/ Fenn Enterprises	Sidescan Sonar	Marine Sonic Technology	Custom	300 m	300 kHz / 600 kHz	Range used for ALDFG surveys: 50 m to 100 m	1.5-2.5 knots
Natural Resources Consultants/ InDepth Marine	Sidescan Sonar	Edgetech	4125	200 m	600 kHz / 1600 kHz	120 m / 35 m	4 - 5 knots
Shift Environmental	Sidescan Sonar	Imagenex	872 “YellowFin”	300 m	260 kHz / 330 kHz / 800 kHz	Range scale/1000	2 - 3 knots
	Depth Finder with Sidscan	Humminbird	Solix 15	NA	83 kHz / 200 kHz	457 m	2 - 3 knots
Titan Maritime	ROV mounted Sidescan	Ping360	BR2 Heavy	300 m	750 kHz	50 m	2 - 3 knots
	ROV mounted multibeam	CeruleanSonar	Insight240	300 m	240 kHz	150 m	2 - 3 knots