# ALDFG Predictive Model and Retrieval Recommendations for Gulf of Saint Lawrence

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# ALDFG Predictive Model and Retrieval Recommendations for Gulf of Saint Lawrence

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Ocean Conservancy

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# FINAL REPORT

# ALDFG Predictive Model for Gulf of Saint Lawrence and Retrieval Recommendations

Prepared for:

Ocean Conservancy/Global Ghost Gear Initiative

Prepared by:

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May 30, 2024

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## Acknowledgements

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## Project Purpose

The purpose of this project task is to reduce harm from abandoned, lost, and discarded fishing gear (ALDFG) in the Gulf of St. Lawrence including reducing the risk of North Atlantic right whale (NARW) entanglement in ALDFG. This purpose is achieved by providing fisheries managers with an understanding of where ALDFG likely accumulates in relation to whale sightings and by providing a recommended approach to retrieve accumulation of ALDFG from areas of high risk to whales.

The first objective of the project is to develop a predictive model that identifies, at varying levels of probability, where fishing gear is lost, and where ALDFG is likely to accumulate in the marine waters of the Gulf of St. Lawrence, with an emphasis on the snow crab fishery in the southern Gulf of St. Lawrence, defined by the boundaries of Crab Fishing Area (CFA) 12.

The second objective is to develop recommendations on the future removal of accumulations of ALDFG, with specific attention to potential risk of whale entanglements. Recommendations presented here focus on strategic resource use on the most damaging ALDFG to NARWs to reduce the threat of whale entanglement in the Gulf of St. Lawrence.

## Introduction and Background

The negative impacts of ALDFG are a growing concern worldwide. Whether intentionally discarded or accidentally lost, ALDFG is one of the deadliest forms of marine litter. It catches and wastes target and non-target marine species through a process known as ghost fishing where animals continue to be caught in the gear after it is lost. It also damages marine and nearshore habitats, poses navigation risks, and is expensive and hazardous for fishermen and marine communities to deal with (GESAMP, 2021; NOAA MDP, 2016; NOAA, 2015). In the Gulf of St. Lawrence, ALDFG is of particular concern as the endangered NARW population continues to move through the area in new and unexpected ways, increasing risk of entanglement with both active and lost snow crab traps in particular. The potential for whale interactions with fishing gear poses a significant challenge to fishers, who often must endure fisheries closures when whales are in the area, and to right whales whose migratory patterns have changed in recent years, resulting in more entanglement events. A large portion of the NARW population uses the Gulf of St. Lawrence during parts of its life history and NARWs have been documented entangled and killed in lines and ropes associated with fisheries in the gulf.

Canada has 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 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 (Canada, 2018; Canadian Council of Ministers of the Environment, 2018). *Canada-Wide Action Plan on Zero Plastic Waste: Phase 2,* published in 2020, includes specific actions to reduce impacts from ALDFG (Canadian Council of Ministers of the Environment, 2020). Canada also announced significant investment in solving the problem, introducing the Sustainable Fisheries Solutions and Retrieval Support Program (Ghost Gear Fund) of the Department of Fisheries and Oceans (DFO) with several millions of dollars used to fund projects aimed at reducing and preventing harm from ALDFG. An early initiative of the DFO was to require fishers to report lost fishing gear. Recovery of lost fishing gear is not required, however.

This project compiles existing information about ALDFG in the Gulf of St. Lawrence and develops a predictive model to identify potential locations of loss of capture fishing gear, specifically snow crab and lobster pot/trap gear, and locations where lost fishing gear may be accumulating. Predictive models have been shown to improve efficiency of ALDFG management and removal activities (Martens and Huntington, 2012).

This report includes recommended snow crab trap ALDFG retrieval activities in the Gulf of St. Lawrence for the purpose of remediating harmful effects of snow crab trap ALDFG. These harmful effects include potential NARW entanglement, ghost fishing of target and non-target species, habitat damage, and threats to navigation safety. Recommendations include identification of primary and secondary retrieval areas and identification of retrieval methods and timing.

## Marine Fisheries of Gulf of St. Lawrence

The commercial fishing industry in the Gulf of St. Lawrence was historically dominated by the groundfish fisheries. However, management measures in the 1990s aimed to reduce overexploitation of certain species, led to industry expansion of other fisheries, such as the well-established lobster fishery, as well as the northern shrimp trawl fishery, and the snow crab pot fishery. Now snow crab and lobster pot/trap fisheries are two of the most economically important fisheries in the region. Other major fisheries in the region are groundfish (multi-species), tuna, mackerel, herring, scallops, and clams. Table 1 summarizes the primary gear types and associated target species in the Gulf of St. Lawrence.

Table 1. Primary gear types and associated target species in the Gulf of St. Lawrence commercial fisheries.

| Gear Type | Target species |
|---|---|
| pots and traps | snow crab, lobster, other crab, groundfish, hagfish (barrel), whelk |
| longlines | groundfish |
| rod and reel; angling | tuna |
| gillnet | groundfish, herring, mackerel |
| trawl nets | groundfish, shrimp |
| seine nets | herring, mackerel, capelin |
| dredges | scallops, clams |

Snow crab is fished using baited conical iron or steel, top-entry, pots that are placed on the seafloor, attached to a buoyed line for marking and retrieval. In some areas of Canada multiple snow crab pots are connected to a single groundline, however, in the Gulf of St. Lawrence pots are set primarily as singles. Fishing primarily occurs between May – June, in water depths from about 60 – 100 m, with buoy lines typically around 155 m in length (GOSAF, 2024). The primary snow crab fishery is in the southern Gulf of St. Lawrences in crab fishing area (CFA )12, and adjacent areas 18, 25, and 26 (Figure 1), with approximately 400 snow crab licenses and around 30,000 pots in the fishery (GOSAF, 2024). In the estuary and northern Gulf of St. Lawrence (CFA 12A-C, 13-17) there are around 205 active licenses, with between 1,000 – 2,150 pots in the fishery (Figure 1) (DFO, 2021).

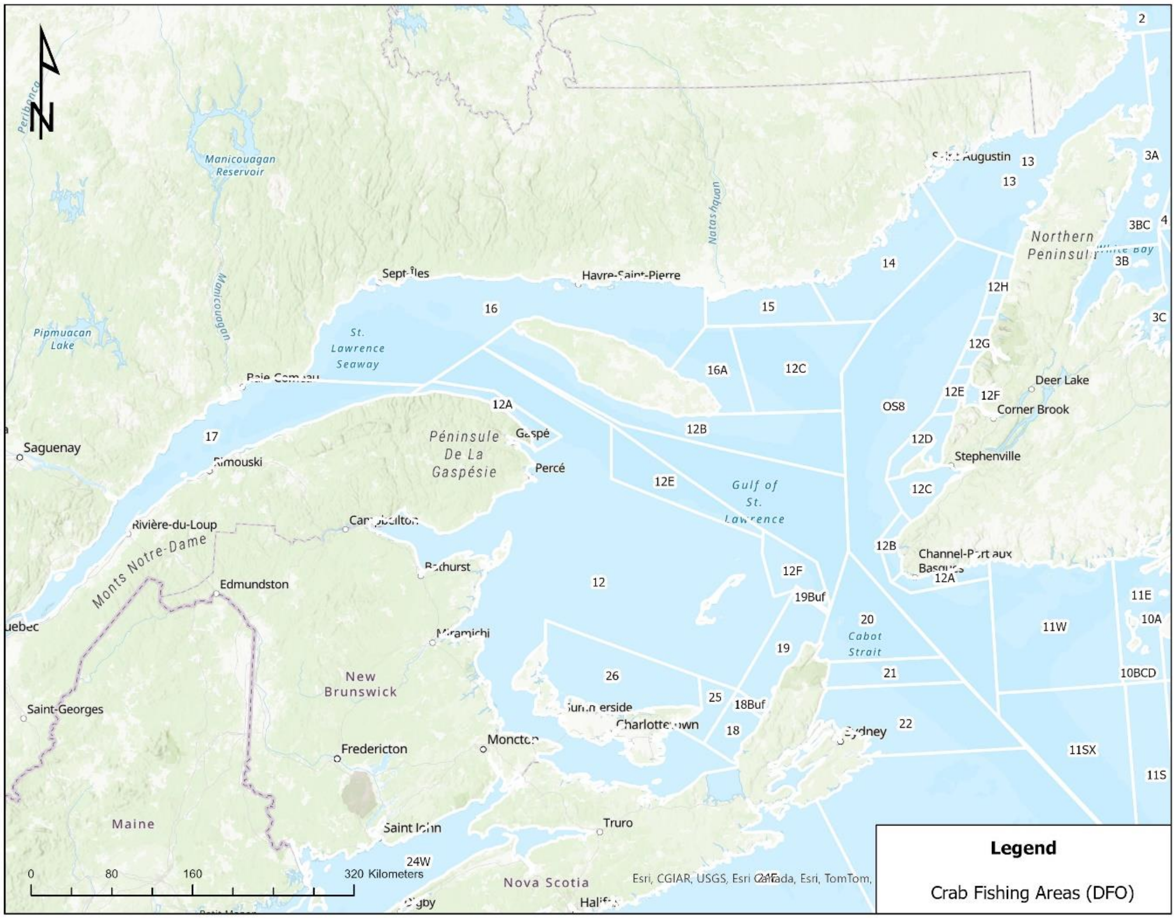


Figure 1. Crab Fishing Areas (CFA) in the Gulf of St. Lawrence.

Lobster fisheries in the Gulf of St. Lawrence also primarily occur in the southern gulf, in Lobster Fishing Areas (LFA) 23 – 26 and in LFA 22 around Magdalen Islands (Figure 2), however unlike snow crab, lobster is an inshore fishery which typically operates in water depths less than 40 m. Lobster effort occurs to a lesser degree in the northern gulf in LFAs 13-19 (Figure 2). Lobster traps are made of wire mesh or wooden lath, and contain a parlor entrance. They are set in singles or in "trawls" (two or more traps connected to a groundline), with a buoyed line attached.

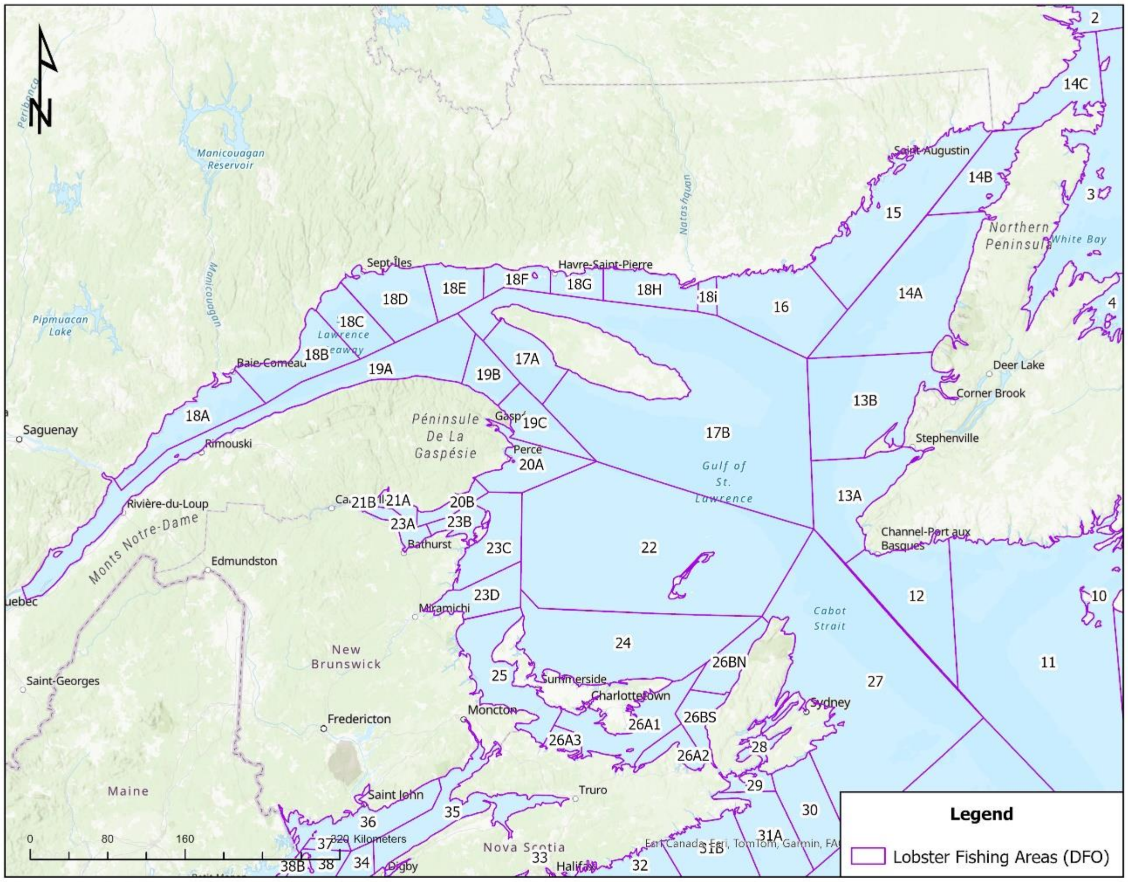


Figure 2. Lobster Fishing Areas (LFA) in the Gulf of St. Lawrence.

As the two primary fisheries in the study area, and the highest risk to NARW entanglement, the research reported here focuses on the snow crab pot and lobster trap fisheries.

# Methodology

## Predictive Modeling for ALDFG Accumulation

Developing a predictive model for identifying probability of presence of ALDFG is reliant on the input data that is available. The dependent variable in these models are locations of gear loss and/or accumulation. DFO provided a database of all reported gear lost by fishers, gear recovered by contractors, and lost fishing gear later recovered by fishers from 2020 through present (Figure 3). Explanatory variables representing primary reasons for gear loss that are well accepted in the global ALDFG community were used to develop predictive models for ALDFG from the snow crab and lobster fisheries in the Gulf of St. Lawrence. These are the two primary fisheries in the region, and the dominating gear types in the ghost gear database. Modeling began with establishing the study area as (a) the entire Gulf of St. Lawrence, including waters off the coastline of Quebec, the western coastline of Newfoundland, and the northern coast of Nova Scotia, and (b) the southern Gulf of St. Lawrence, including the Crab Fishing Area 12 and adjacent surrounding waters. A series of base layers, each used as exploratory variables to represent a specific reason for gear loss, were collated, and modified as needed to ensure proper coverage as raster datasets (Table 2) (Figure 4 & 5). All geospatial analysis and modeling were conducted in ArcGIS Pro and RStudio (ESRI, 2023; R Core Team, 2024). Following initial modifications, all explanatory variable rasters were projected into NAD83 UTM 20N coordinate system and underwent iterative cropping, resampling, and masking using the terra package in the software environment R (Hijmans, 2024). All targets of the appropriate gear type and target species in the lost gear reporting dataset formed the set of ALDFG presence points for the models. Known ALDFG targets were manipulated to develop a presence/background dataset for locations where ALDFG records are present in the study area. Background points were generated randomly within each of the study areas, with an equal number of background points as presence points, implemented in RStudio. Presence and background points were joined into one set and the values of each explanatory variable were extracted to each point.

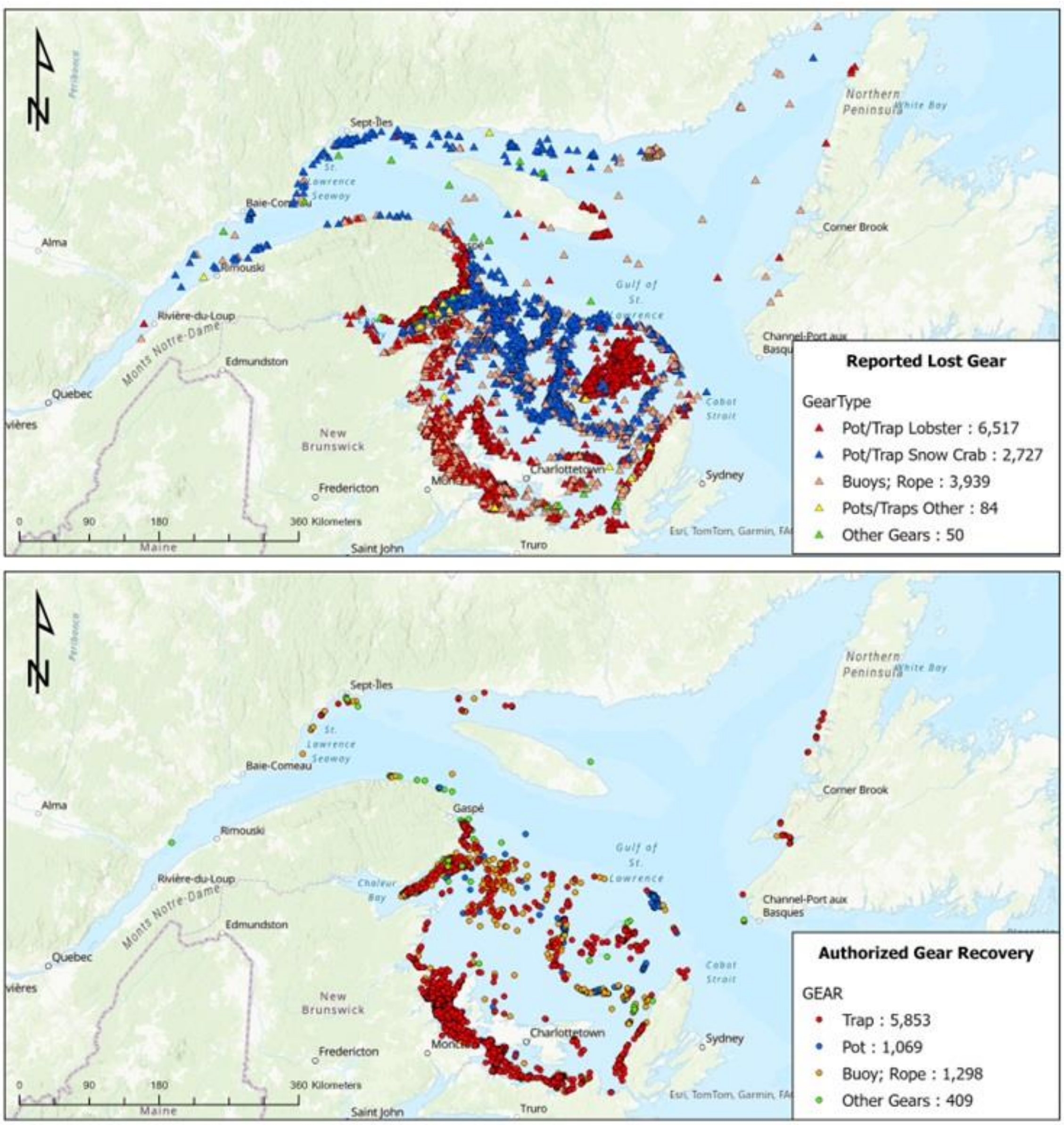


Figure 3. Reported gear loss by gear type from fishers (top), and authorized gear recovery records (bottom) from DFO Ghost Gear database 2020 – Jan. 2024. Source: DFO

Table 2. List and description of spatial datasets used to represent causes for fishing gear loss; used to as explanatory variables in final predictive models for ALDFG probability in Gulf of St. Lawrence.

| Cause of Gear Loss | Representative Dataset | Description & Source |
|---|---|---|
| Delineation of Fishing Areas | DFO – Fishing Management Areas | Shapefile map of fishing management areas in Atlantic Canada, including detailed coastline. Provided by DFO (DFO Atlantic Marine Mammal Hub, 2024) |
| Fishing Effort/Intensity | Lobster landings per LFA | Summary of lobster landings from years 2013-2022 by LFA per square kilometer in the GoSL (DFO – Stock Assessment and Status Reports). |
| | Crab fishing effort intensity raster | Cumulative intensity logbook and VMS data of offshore crab effort by percentile from years 2005-2014 by 1 km grid cell in the GoSL (Koen-Alanso et al., 2018). |
| | All fishing effort intensity raster | Cumulative intensity logbook and VMS data of all fishing effort by percentile from years 2005-2014 by 1 km grid cell in the GoSL (Koen-Alanso et al., 2018). |
| | Fixed-Gear fishing effort intensity | Point locations and intensity of fixed-gear effort and landings in southern GoSL 2013-2022 provided by DFO (J. Ryman) |
| North Atlantic right whale Distribution | Location and count of NARW sightings | Visual observations points of NARW from all GoC platforms 2018-2022 provided by DFO (K. Mckercher). |
| ALDFG loss and recovery locations | DFO – Ghost Gear Points | All data points from DFO Ghost Gear Database as of January 2024 provided by DFO (J. Ryman) |
| Bathymetric profile | Bathymetry | Raster data for water depth (m) at 15 arc-second grids for Atlantic Canada, obtained from GEBCO (2022) |
| Inclement Weather | Wind Speeds | Mean annual values (m/s) per 250 m grid cells within Atlantic Canada (Global Wind Atlas 2023) |
| Ocean Currents | Ocean Current Northward | Monthly mean northward current speeds (m/s) per 1/12° grid cell in GoSL extracted from the Copernicus-Global Ocean Physics Analysis and Forecast model, obtained from E.U. Copernicus Marine Service Information (CMEMS 2021) |
| | Ocean Current Eastward | Monthly mean eastward current speeds (m/s) per 1/12° grid cell in GoSL extracted from the Copernicus-Global Ocean Physics Analysis and Forecast model, obtained from E.U. Copernicus Marine Service Information (CMEMS 2021) |
| | Surface Temperature | Monthly mean surface temperature (C) per 1/12° grid cell in GoSL extracted from the Copernicus-Global Ocean Physics Analysis and Forecast model, obtained from E.U. Copernicus Marine Service Information (CMEMS 2021) |
| Conflict with Vessel Traffic | Vessel Traffic Density | Vessel Density Mapping of 2022 AIS Data in the Northwest Atlantic (DFO, 2023) |

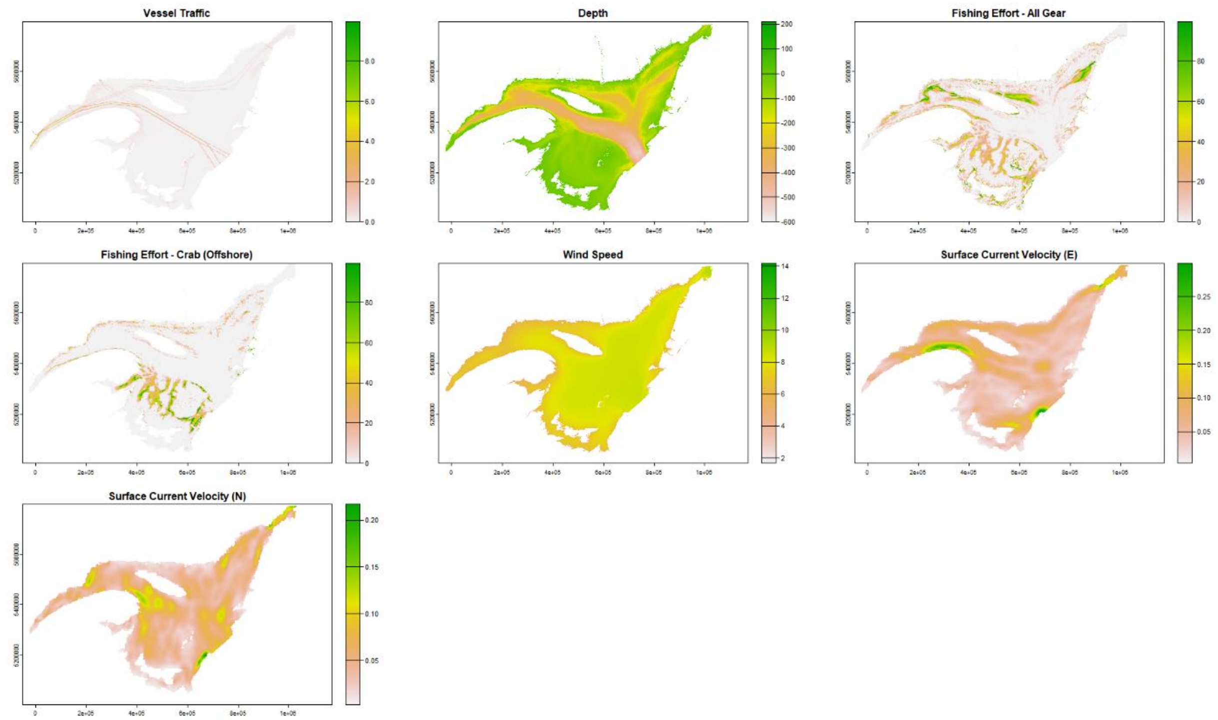

Figure 4. Rasters representing exploratory variables for snow crab gear predictive model prepared for analysis.

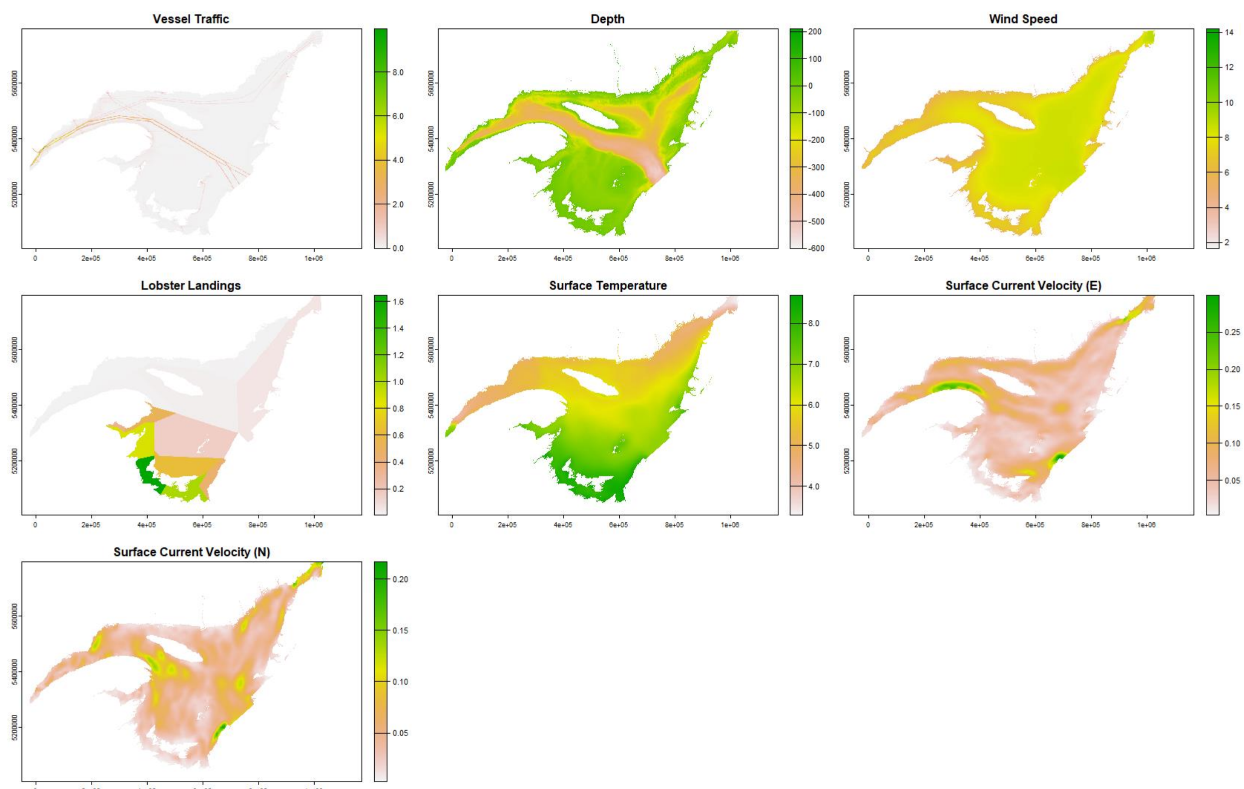

Figure 5. Rasters representing exploratory variables for lobster gear predictive model prepared for analysis.

To develop the predictive models, the sdm package was implemented in R using RStudio (Naimi and Araujo, 2016; Posit team, 2023). Variables were checked for collinearity; all variables used in the models passed with a variance inflation factor of less than 10 (Naimi et al., 2014). For each model iteration, the random forest method was employed with 5x5 cross-validation (k-fold cross validation where k = 5, with 5 replicates) for a total number of 25 replicates. For each model output, a predictive map was produced by ensemble of the trained replicates, weighted by AUC (Area Under the ROC Curve). Additional outputs include a chart of the relative importance of each variable to the model and the response curves for each variable. Models were evaluated based on their predictive effectiveness by their AUC, True Skills Statistic (TSS), and Correlation (COR) values.

## Recommendations for ALDFG Removal

Priority areas for removal of snow crab trap ALDFG accumulation were identified in the Gulf of St. Lawrence in specific areas of co-occurrence between high-probability ALDFG areas from the predictive model, and highly concentrated areas of NARW sightings (Figure 6). The process for identifying co-occurrence areas was two-fold.

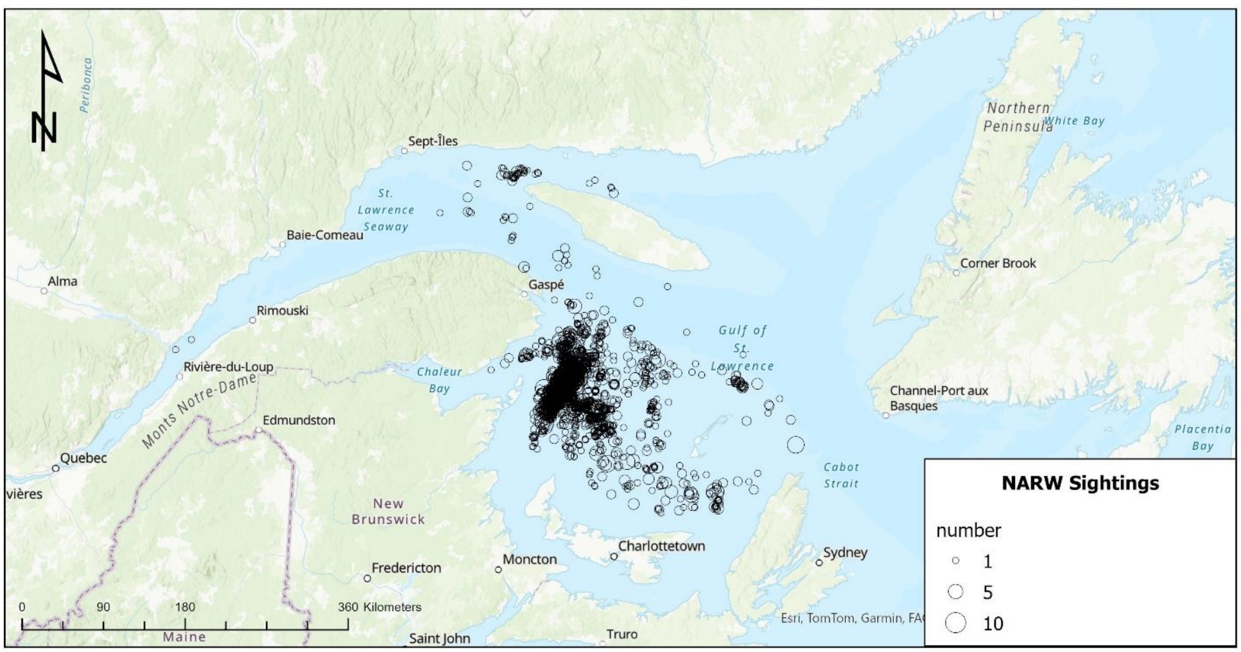


Figure 6. North Atlantic right whale sightings from Government of Canada (2018-2022). Source: DFO

First, to identify the highest priority areas (Priority 1a-d), the CFA 12 predictive model for lost and abandoned snow crab pot accumulation areas was converted from raster to point, and the mean probability value from those points were summarized within a series of 3km x 3km grid cells covering the extent of the southern Gulf of St. Lawrence. The cell size was chosen to reduce variability in model values for ALDFG presence within a given priority area, and ensure the greatest chances of locating ALDFG. The Hot-Spot Analysis tool with Getis-Ord GI* statistical model in ArcGIS Pro was used to identify statistically significant areas where clustering of high probability values was present for lost snow crab pot accumulation. Each cell, weighted by the mean probability values within that cell, was analyzed using the inverse distance function to ensure that the impact of a given feature on other features decays with distance (ESRI, 2024). Clusters of cells (hot spots) with significant spatial clustering values were categorized by degree of confidence into three categories: 99% CI, 95% CI, and 90% CI.

Using the dataset of NARW sightings from 2018 through 2022 provided by DFO-Canada, the total number of sightings were summarized within a series of 6km x 6km grid cells covering the extent of the southern Gulf of St. Lawrence. A larger cell size was used for the NARW sightings than the lost gear areas to account for NARW movement throughout any given region where an individual has been sighted. While a 36 $km^2$ cell may not representative of the range of a NARW, it was determined an appropriate size to ensure that recommendations could focus on areas manageable for gear recovery operations, and to limit the model value variability within a given work area (i.e., larger areas may include variation of both high and low probability characteristics). The Hot-Spot Analysis tool was used to identify statistically significant areas where clustering of NARW sightings have occurred, using the polygon contiguity conceptualizations (contiguity edges corners) to emphasize the spatial relationship between cells that share borders (ESRI, 2024). Clusters of cells (hot spots) with significant spatial clustering values were categorized by degree of confidence into three categories: 99% CI, 95% CI, and 90% CI. The Hot Spot Analysis Comparison tool in ArcGIS Pro was used to compare the two hot spot analysis result layers and measure their similarity and association, hence, identifying where hot spots of NARW activity and modeled gear accumulation co-occur. Overlapping hot spots were identified as Priority Areas, and ranked 1a – 1d based on the combinations of significance level for each input (Table 3).

Table 3. Categories for prioritizing primary removal Priority Areas where ALDFG and NARW hot spots co-occur. Identified through Hot Spot Analysis Comparison.

| **Hot Spot Significance Level** | **Priority Ranking** |
|---|---|
| 99%CI + 99%CI | 1a |
| 99%CI + 95%CI | 1b |
| 99%CI + 90%CI; 95%CI + 95%CI | 1c |
| 95%CI + 90%CI | 1d |

Second, to identify the next highest priority areas (Priority 2a-2c), throughout the Gulf of St. Lawrence, including outside CFA 12, areas where NARW were sighted, and reported snow crab pots were lost within the same 6km x 6km cells. Their rankings include a combination of the two values. Priority 2a includes areas where both NARW sightings and gear loss were relatively high, 2b moderate, and 2c low (Table 4). The two priority categories were developed to show that the data shows one clear priority where the highest concentrations of lost snow crab pots and NARW co-occur, while acknowledging that removal efforts may occur opportunistically, or by a particular group of fishers or others that are limited to their geographic range. In such cases, the secondary priority areas provide guidance.

Table 4. Ranking classification for NARW sightings and ALDFG counts per 6km x 6km cell to identify level 2 priority areas.

| **Ranking Category** | **NARW sightings per cell** | **Lost Gear per cell** |
|---|---|---|
| Low | 1 - 5 | 1 - 12 |
| Moderate | 6 - 10 | 13 - 39 |
| High | 11 - 87 | 40 - 90 |

To inform the recommendations on methods to retrieve ALDFG in marine waters of the Gulf of St. Lawrence, an online survey was developed and distributed to organizations that had received DFO Ghost Gear funding to locate or retrieve ALDFG from the Gulf of St. Lawrence. The survey solicited information about locations where the individuals worked, what types of gear they retrieved, what methods they used to retrieve gear, obstacles they encountered, and recommendations to increase success in derelict gear recovery in those areas. The survey questions were primarily short answer format to allow for individual details about retrieval work from each respondent, though some questions were multiple-choice format. The survey was distributed in both English and French to 33 individuals on April 5, 2024 with a one-week response deadline.

In addition, methods reported in *Methods to Locate and Remove Lost Fishing Gear from Marine Waters* (Drinkwin et al., 2022) were reviewed, with particular attention to methods used and case studies in the Gulf of St. Lawrence.

# Results

## ALDFG Predictive Models

### Snow Crab Gear

Two predictive models were developed for snow crab gear specifically, one for the entire Gulf of St. Lawrence, and the other focusing on southern Gulf of St. Lawrence (CFA 12, 18, 25, 26). Explanatory variables used in the final predictive models included offshore crab pot effort, all other fishing effort, ocean current speed, wind speed, vessel traffic density, and water depth. These were chosen based on their relative importance to the predictability of ALDFG presence and response curves which all showed positive relationships through a portion of their value ranges. The AUC, COR, TSS, and Deviance values for both models show values representative of good to excellent models (Mkala et al., 2023)(Table 5).

Table 5. Performance evaluation results for predictive models developed for snow crab gear and lobster gear. AUC=Area Under Curve, COR=Correlation Coefficient, TSS=True Skill Statistic

| Model | Area | AUC | COR | TSS | Deviance |
|---|---|---|---|---|---|
| Snow crab | GoSL | 0.95 | 0.84 | 0.82 | 0.53 |
| Snow crab | southern GoSL | 0.92 | 0.77 | 0.74 | 0.68 |
| Lobster | GoSL | 0.98 | 0.91 | 0.9 | 0.31 |
| Lobster | southern GoSL | 0.97 | 0.85 | 0.84 | 0.44 |

Offshore crab fishing effort was by far the most important variable in both snow crab gear models, followed by water depth, all other fishing effort, vessel traffic density, and northward ocean currents. Wind speed and eastward ocean currents were the least important of the variables used (Figure 7). Response curves for explanatory variables show steep positive slopes (strong positive association) within the lower values of the datasets, followed by a plateau or sharp decline (Figure 8). These patterns appear due to complexity of interactions and non-linear relationships between the predictors and response, which the random forest model can flexibly model without imposing rigid parametric assumptions (Fu et al., 2021).

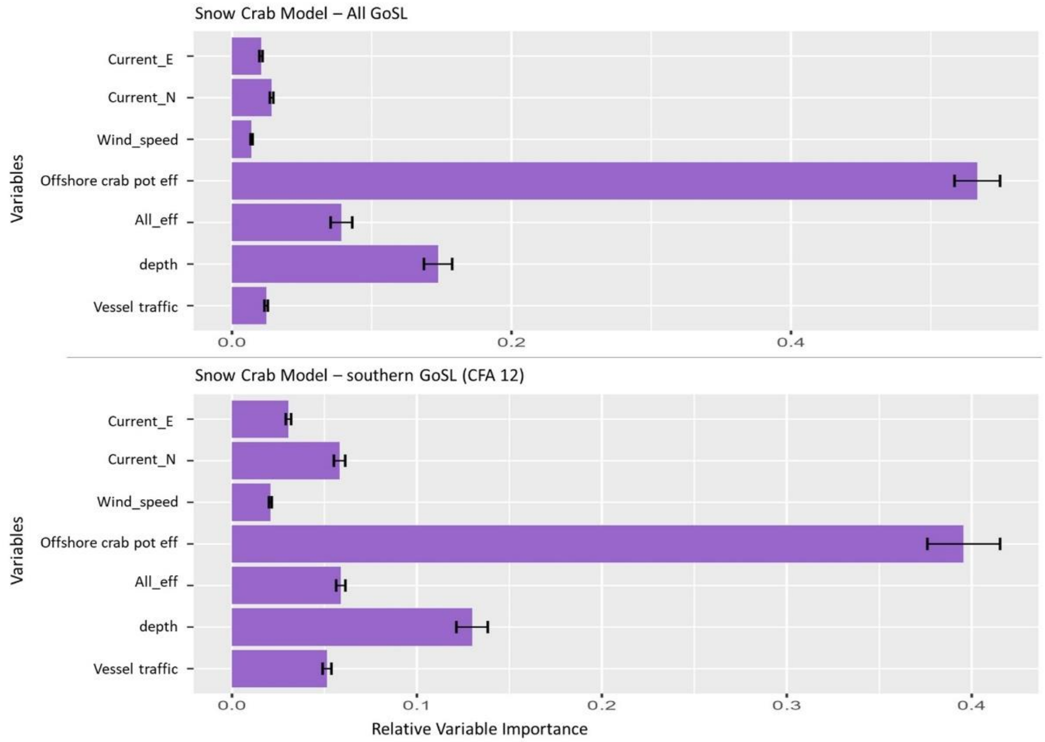


Figure 7. Relative variable importance for all explanatory variables used in the final predictive models for snow crab ALDFG in all Gulf of St. Lawrence (top) and southern Gulf of St. Lawrence (bottom).

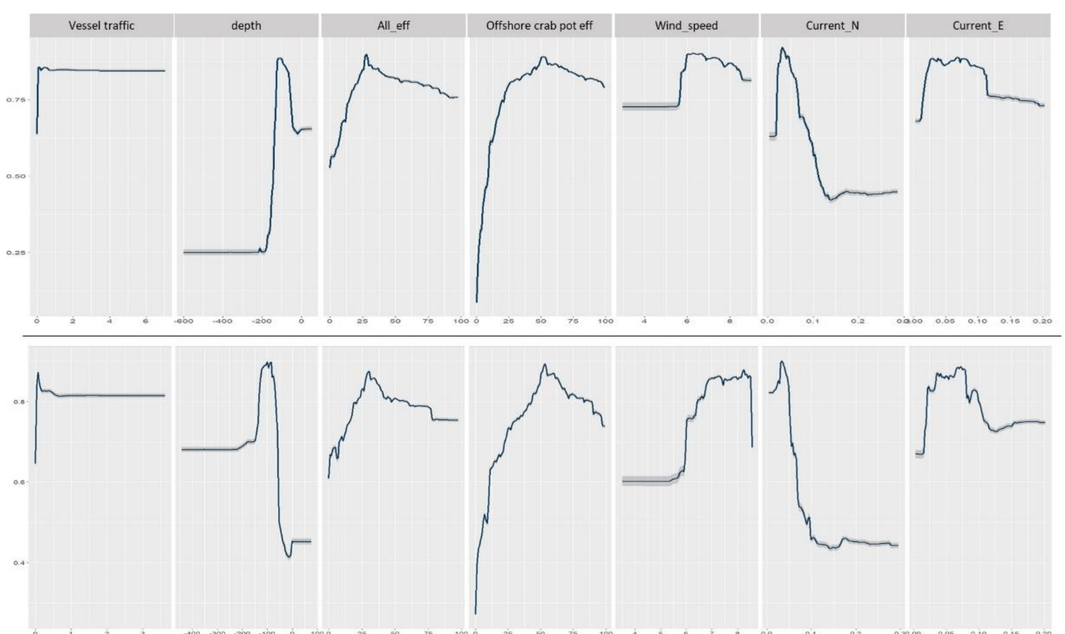


Figure 8. Response curve charts showing the effect of changing values on presence probability within each individual dataset used in the predictive model for snow crab ALDFG in all of Gulf of St. Lawrence (top), and for southern Gulf of St. Lawrence (CFA 12) (bottom).

The probability model outputs included 15 arc-second raster cells each with a value from 0.00 to 1.00, from lowest to highest probability for snow crab gear presence, respectively. For interpretation, these values were binned in equal intervals by 0.1, and each bin was reclassified as an integer value from 1 to 10 (lowest to highest probability) (Figures 9 & 10), and converted to vector format shapefiles.

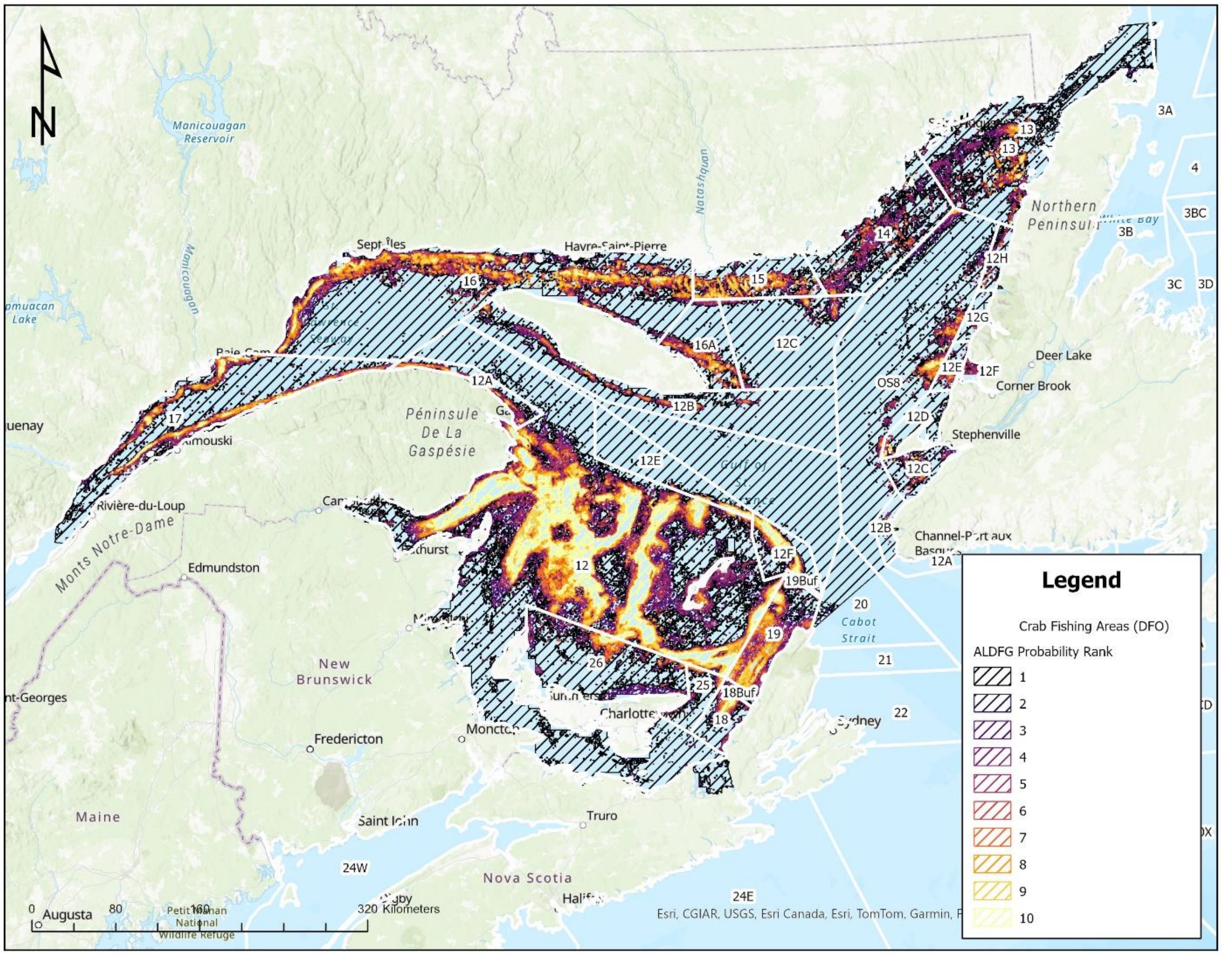

Figure 9. ALDFG predictive model result for snow crab gear in entire Gulf of St. Lawrence; areas of low to high potential for ALDFG occurrence ranked from 1 – 10 (low – high).

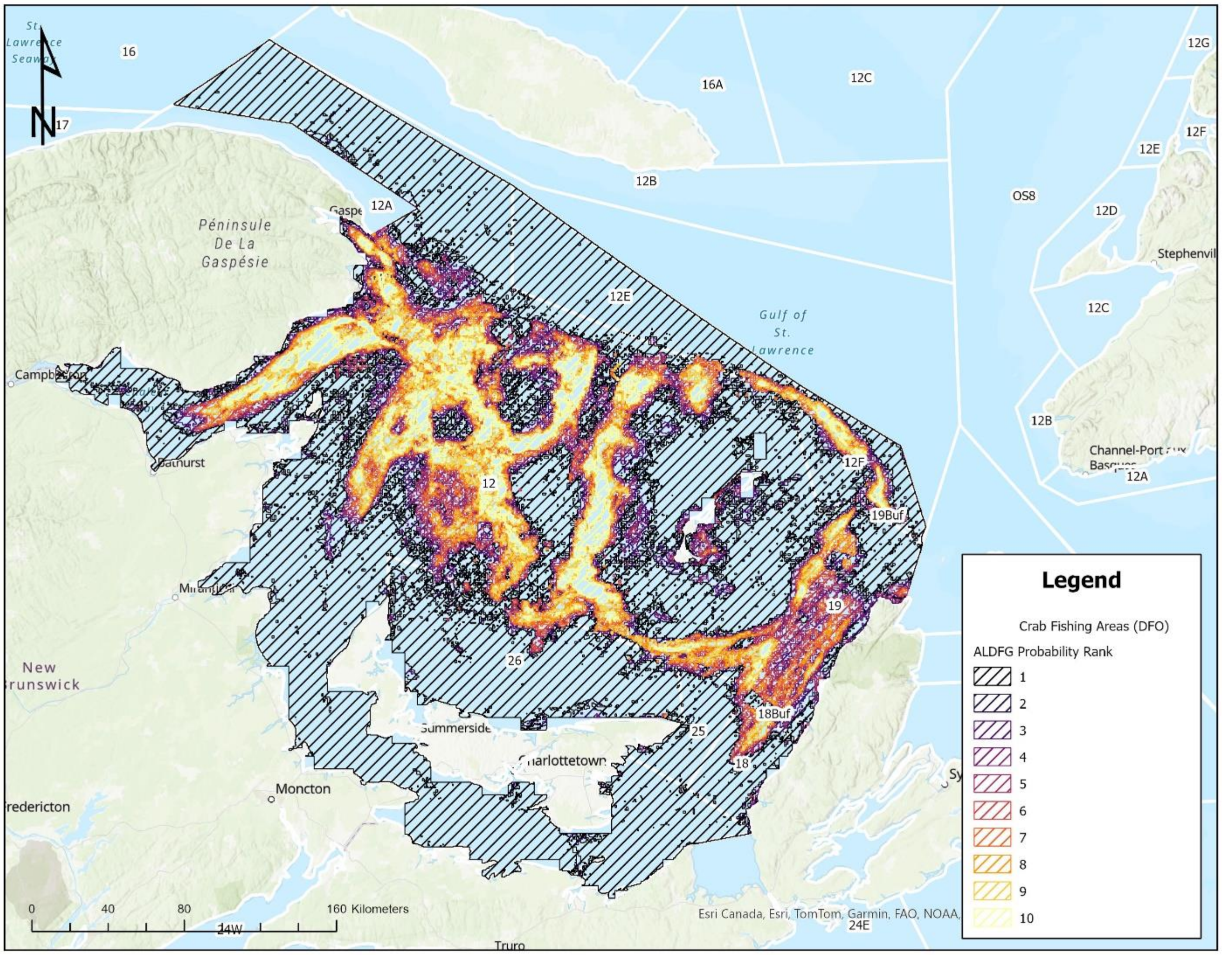


Figure 10. ALDFG predictive model result for snow crab gear in southern Gulf of St. Lawrence; areas of low to high potential for ALDFG occurrence ranked from 1 – 10 (low – high).

The ALDFG predictive model for snow crab gear in the entire Gulf of St. Lawrence covers 230,165 km$^2$, with the lower half of the probability rankings (1 – 5) covering 88% of the total study area, with the remaining 12% of the study area in the upper half of the rankings (6 – 10) (Table 6; Figure 9). Similarly, lower probability values for the model for the southern Gulf of St. Lawrence account for 83% of the area, with 17% in the upper rankings (Table 6; Figure 10) The final probability rankings are heavily influenced by the high concentrations of fishing effort in the southern Gulf of St. Lawrence in CFA 12 and therefore naturally the areas with the highest probability values occur where crab fishing intensity is highest. High probability areas also occur off the Quebec coast in CFA15 and 16, in small patches in CFA 16A, 17, and off the western coast of Newfoundland (Figure 9).

Table 6. Total area by model values and probability rankings for the final ALDFG predictive models developed for snow crab gear in Gulf of St. Lawrence.

| | | | **Model: All GoSL** | | **Model: southern GoSL** | |
|---|---|---|---|---|---|---|
| **Probability Value** | **Original Model Values** | **Probability Rank** | **Total Area (km$^2$)** | **% of Study Area** | **Total Area (km$^2$)** | **% of Study Area** |
| 1 | 0.0 - 0.1 | Low | 154,201 | 67% | 53,872 | 60% |
| 2 | 0.1 - 0.2 | | 25,086 | 11% | 9,849 | 11% |
| 3 | 0.2 - 0.3 | | 11,065 | 5% | 4,335 | 5% |
| 4 | 0.3 - 0.4 | | 6,902 | 3% | 3,056 | 3% |

| | | | Model: All GoSL | | Model: southern GoSL | |
|---|---|---|---|---|---|---|
| Probability Value | Original Model Values | Probability Rank | Total Area ($km^2$) | % of Study Area | Total Area ($km^2$) | % of Study Area |
| 5 | 0.4 - 0.5 | | 5,869 | 3% | 2,778 | 3% |
| 6 | 0.5 - 0.6 | | 5,123 | 2% | 2,743 | 3% |
| 7 | 0.6 - 0.7 | | 4,655 | 2% | 2,776 | 3% |
| 8 | 0.7 - 0.8 | | 4,547 | 2% | 3,190 | 4% |
| 9 | 0.8 - 0.9 | | 5,325 | 2% | 3,638 | 4% |
| 10 | 0.9 – 1.0 | High | 7,391 | 3% | 3,242 | 4% |

## Lobster Gear

Two predictive models were also developed for lobster gear specifically, one for the entire Gulf of St. Lawrence, and the other focusing on southern Gulf of St. Lawrence. Explanatory variables used in the final predictive models included lobster landings, vessel traffic density, bathymetric depth, wind speed, ocean surface temperature and current speed. Variables were chosen based on their relative importance to the predictability of ALDFG presence and response curves which all showed positive relationships through a portion of their value ranges. The AUC, COR, TSS, and Deviance values for both models show values representative of good to excellent models (Mkala et al., 2023)(Table 5).

Bathymetric depth was by far the most important variable in both lobster models, and of secondary importance were eastward current velocity, lobster effort, and surface temperature. Northward current velocity and vessel traffic density were the least important of the variables (Figure 11). Response curves for explanatory variables are highly variable, likely reflecting the inshore nature of the fishery and lack low spatial resolution for lobster fishing effort (Figure 12).

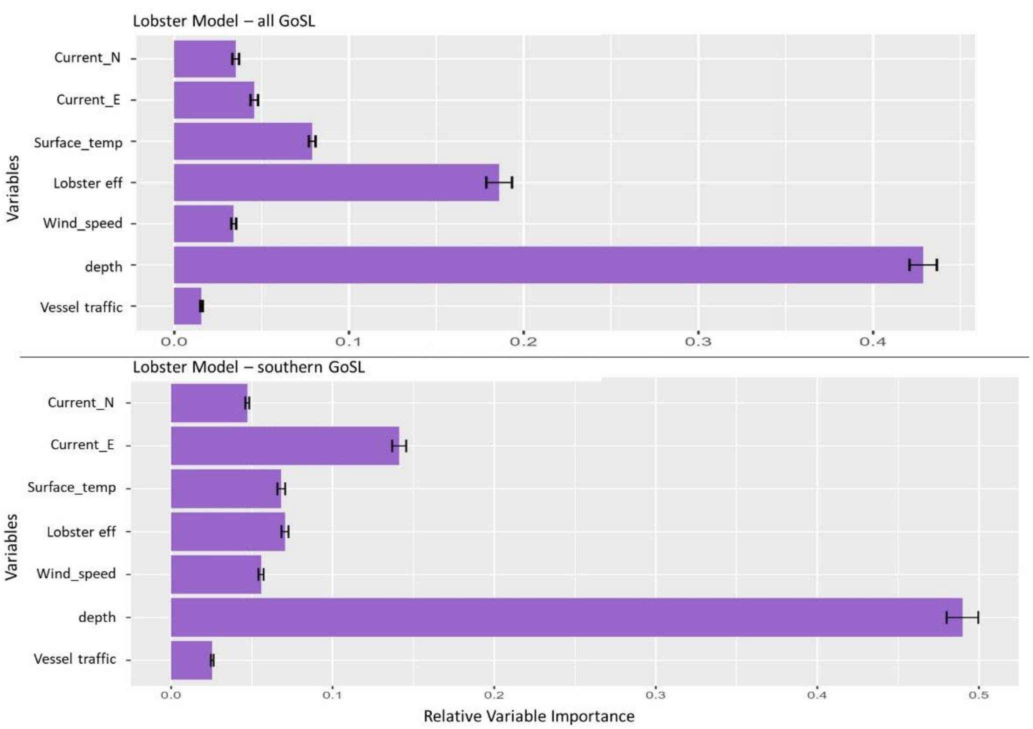


Figure 11. Relative variable importance for all explanatory variables used in the final predictive models for lobster ALDFG in all Gulf of St. Lawrence (top) and southern Gulf of St. Lawrence (bottom).

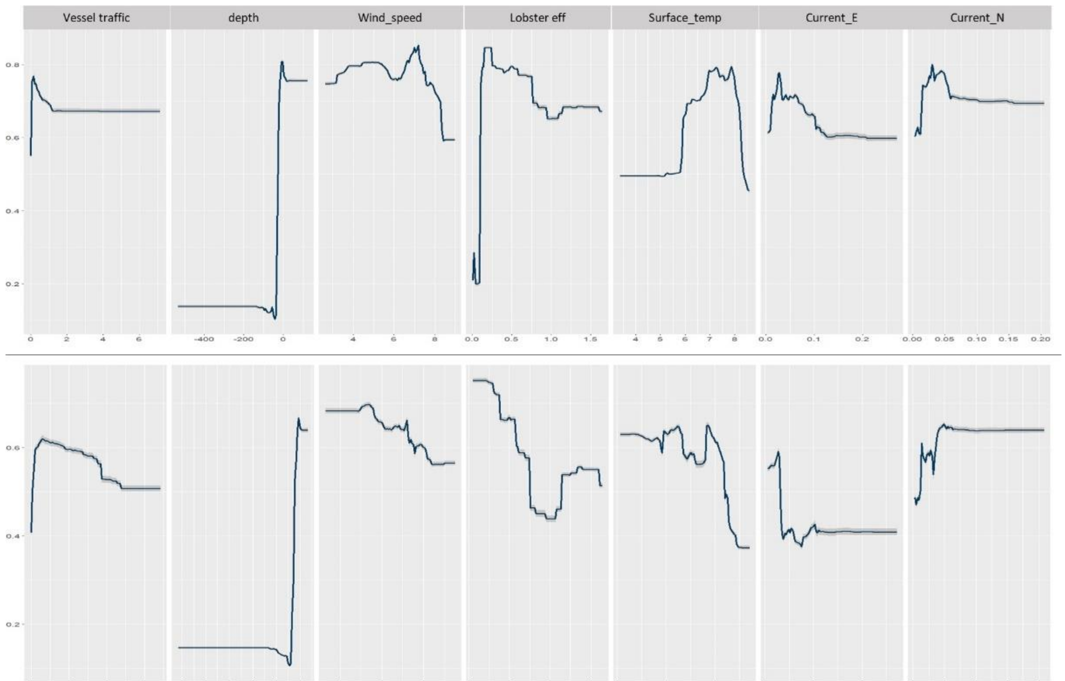

Figure 12. Response curve charts showing the effect of changing values on presence probability within each individual dataset used in the predictive model for lobster ALDFG in all of Gulf of St. Lawrence (top), and for southern Gulf of St. Lawrence (bottom).

The probability model outputs included 15 arc-second raster cells each with a value from 0.00 to 1.00, from lowest to highest probability for lobster gear presence, respectively. For interpretation, rasters were reclassed and converted to shapefiles in the same way as the snow crab models (Figures 13 & 14).

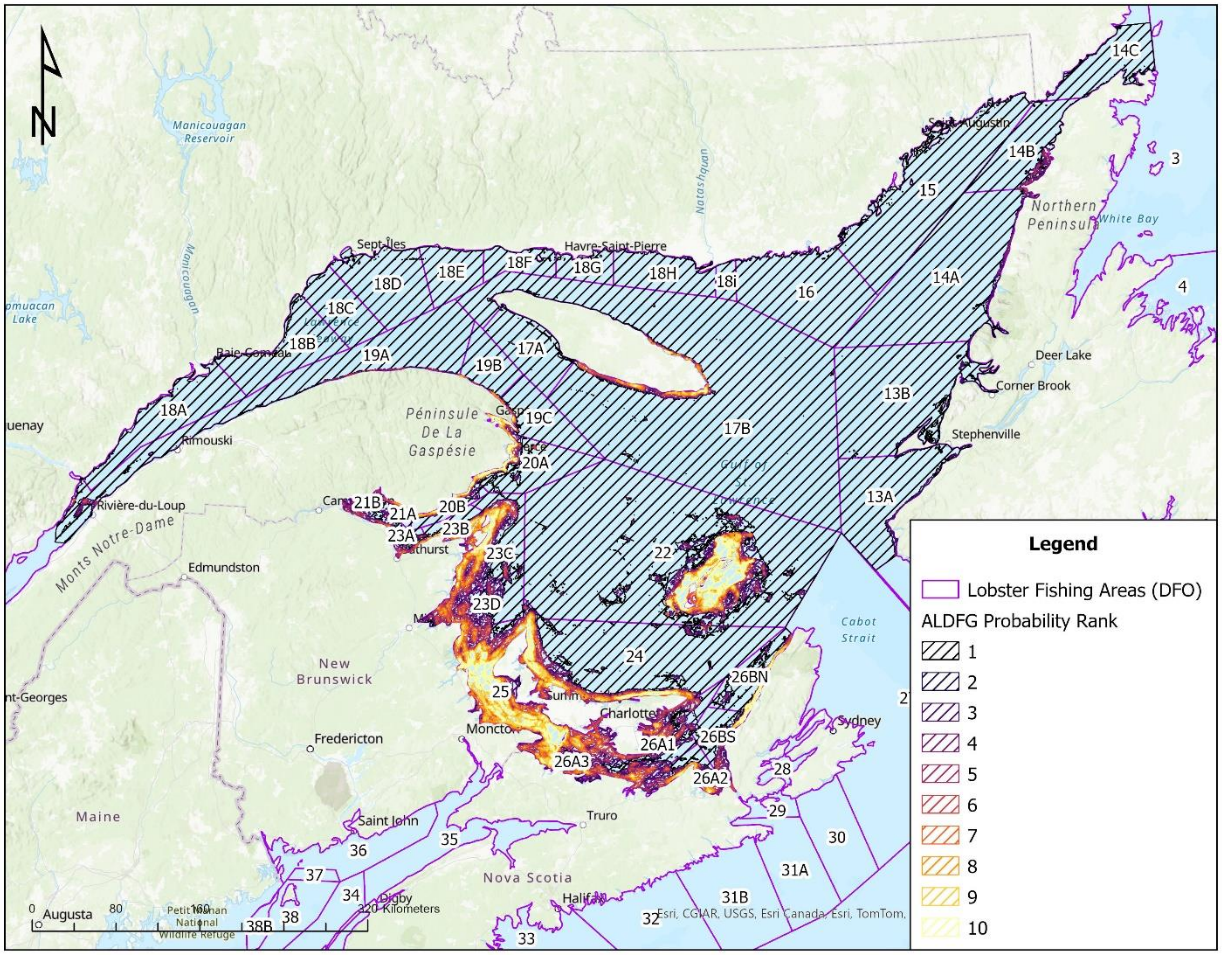

Figure 13. ALDFG predictive model result for lobster gear in entire Gulf of St. Lawrence; areas of low to high potential for ALDFG occurrence ranked from 1 – 10 (low – high).

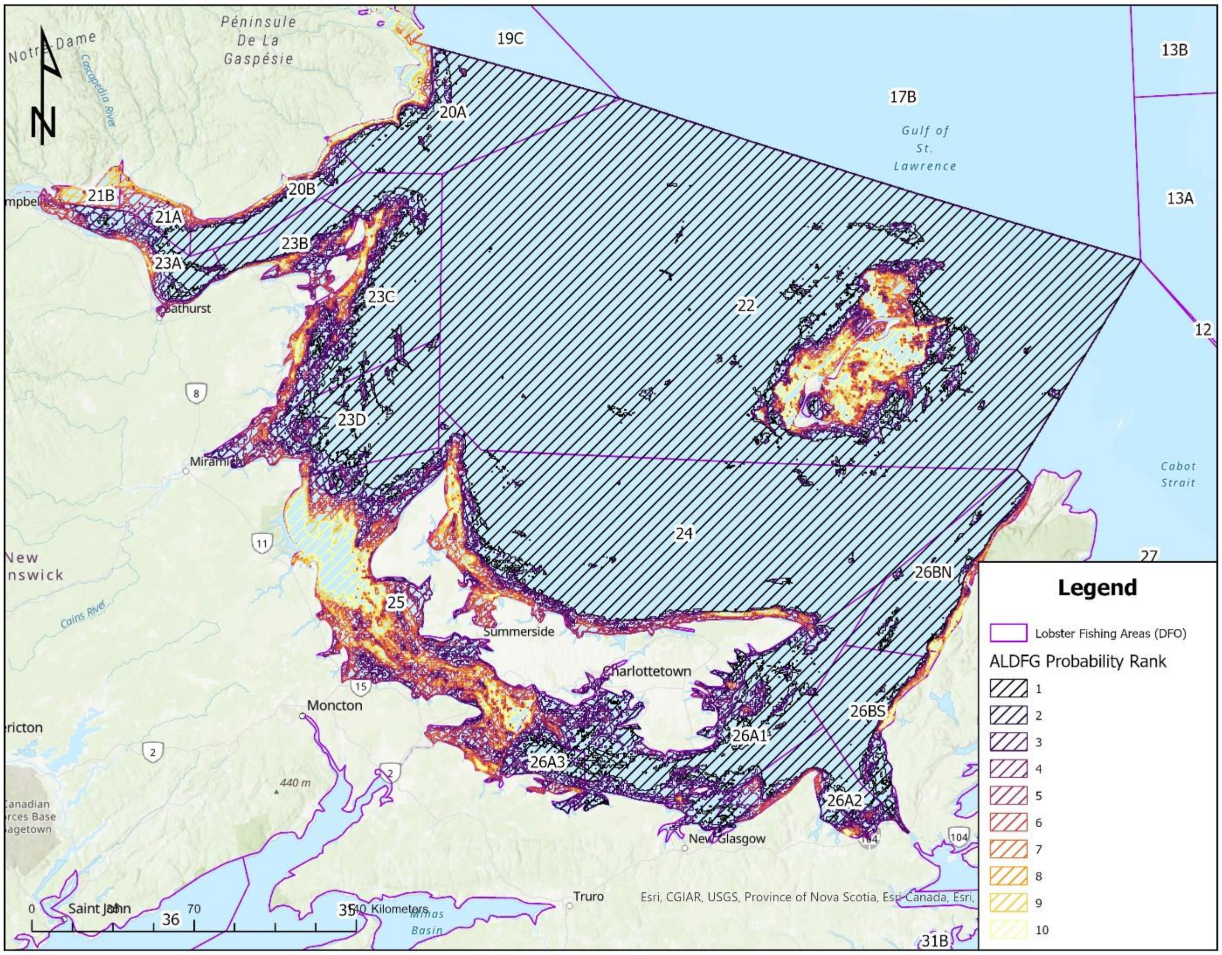


Figure 14. ALDFG predictive model result for lobster gear in southern Gulf of St. Lawrence; areas of low to high potential for ALDFG occurrence ranked from 1 – 10 (low – high).

The ALDFG predictive model for lobster gear in the entire Gulf of St. Lawrence covers 229,983 km$^2$, with the lower half of the probability rankings (1 – 5) covering 95% of the total study area, with the remaining 5% in the upper rankings (6 – 10) (Table 7; Figure 13). Similarly, lower probability values for the model for the southern Gulf of St. Lawrence account for 89% of the area, with 11% in the upper rankings (Table 7; Figure 14). The final probability rankings are heavily influenced by the high concentrations of fishing effort and reported gear loss in the southern Gulf of St. Lawrence. High probability areas surrounded by moderate-high probability areas are concentrated in the southern Gulf of St. Lawrence off New Brunswick (LFA 23B, 23C, 25), Prince Edward Island (LFA 24), and the Magdalena Islands (LFA 22), also off the Quebec coast (LFA 20A, 20B, 21A), the Nova Scotia coast (LFA 26BS, 26BN), and in small patches in the mid-Gulf of St. Lawrence along the southern portion of Anticosti Island (LFA 17B). Outside these listed areas, the highest probability areas are ranked as moderate, occurring in small patches along the northern peninsula of New Brunswick (LFA 14A, 14B), and low-moderate areas along most of the western coast of New Brunswick (LFA 13A, 13B, 14A, 14B)(Figure 13).

Table 7. Total area by model values and probability rankings for the final ALDFG predictive models developed for lobster gear in Gulf of St. Lawrence.

| | | | Model: All GoSL | | Model: southern GoSL | |
|---|---|---|---|---|---|---|
| **Probability Value** | **Original Model Values** | **Probability Rank** | **Total Area ($km^2$)** | **% of Study Area** | **Total Area ($km^2$)** | **% of Study Area** |
| 1 | 0.0 - 0.1 | Low | 197,404 | 86% | 59,685 | 73% |
| 2 | 0.1 - 0.2 | | 8,278 | 4% | 5,182 | 6% |
| 3 | 0.2 - 0.3 | | 4,870 | 2% | 3,176 | 4% |
| 4 | 0.3 - 0.4 | | 3,738 | 2% | 2,492 | 3% |
| 5 | 0.4 - 0.5 | | 3,225 | 1% | 2,214 | 3% |
| 6 | 0.5 - 0.6 | | 2,721 | 1% | 2,185 | 3% |
| 7 | 0.6 - 0.7 | | 2,089 | 1% | 1,943 | 2% |
| 8 | 0.7 - 0.8 | | 2,110 | 1% | 1,710 | 2% |
| 9 | 0.8 - 0.9 | | 2,526 | 1% | 1,491 | 2% |
| 10 | 0.9 – 1.0 | High | 3,022 | 1% | 1,840 | 2% |

## Recommendations for ALDFG Removal

### Recommended retrieval areas

Identified priority retrieval areas are those where concentrated NARW sightings correspond to areas of high probability for snow crab trap ALDFG. Primary priority areas are divided into grids and defined as Priority areas 1a, 1b, 1c, and 1d. Priority areas 1a, 1b, 1c, and 1d include 146 grids measuring 9 $km^2$ for a total of 1,314 $km^2$. Secondary priority areas are defined as Priority areas 2a, 2b, and 2c (Figure 15). Secondary priority areas include 235 grids measuring 36 $km^2$ for a total area of 8,460 $km^2$ (Table 8). Depths in the primary priority areas range from 58m to 139m. Depths in the secondary priority areas range from 0 (shoreline) to 230m (Table 8). All primary priority areas identified are located in CFA 12, as are 220 of 235 secondary priority areas. The remaining secondary priority areas occur in CFA 12F (n=3), CFA 26 (n=4), CFA 12E (n=1), CFA 12A (n=1), and CFA 16 (n=6) (Figure 15). Geospatial data delineating each priority area by cell is available in the ArcGIS shapefile labeled *NARW_SnowCrabALDFG_RemovalPriorityAreas.shp* in the supplemental material accompanying this report.

We recommend continued ALDFG retrieval activities in each area starting with primary priority areas, followed by secondary priority areas.

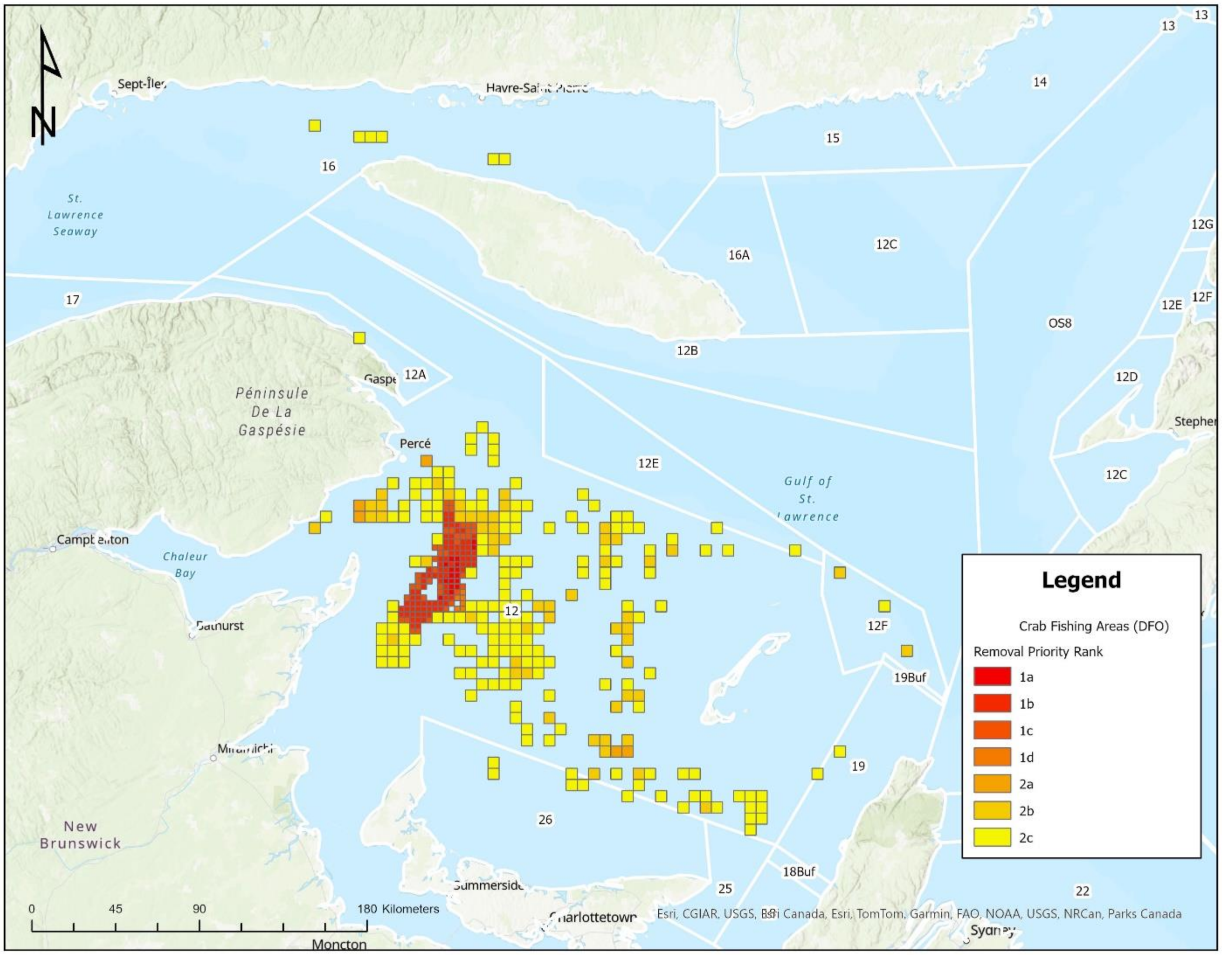


Figure 15. Priority areas for ALDFG snow crab gear removal operations based on Hot Spot Analysis results of predictive model, known gear loss locations, and NARW sightings. Rank 1a – 1d are highest priority areas, 2a – 2c area secondary priority.

Table 8. Priority ALDFG retrieval areas names, depths, and areas.

| Priority Areas | Mean Depth (m) | Min Depth (m) | Max Depth (m) | Numbers of Grids | Area per Grid (km²) | Total Area |
|---|---|---|---|---|---|---|
| 1a | -91.0 | -72 | -107 | 17 | 9 | 153 |
| 1b | -87.6 | -63 | -122 | 83 | 9 | 747 |
| 1c | -84.4 | -58 | -130 | 40 | 9 | 360 |
| 1d | -73.8 | -66 | -80 | 6 | 9 | 54 |
| 2a | -88.3 | -61 | -124 | 5 | 36 | 180 |
| 2b | -82.4 | -44 | -152 | 55 | 36 | 1,980 |
| 2c | -78.2 | 0* | -203 | 175 | 36 | 6,300 |
| **Total** | | | | **381** | | **9,774** |

*Denotes shoreline area.

### Recommended retrieval methods

Eight responses were received to the online survey from Ghost Gear fund recipients with direct experience removing ALDFG from the study area. For full results of these online surveys, see Appendix 1.

Based on these survey responses and literature review of methods to locate and retrieve ALDFG, the following recommendations were developed.

- In the priority areas, where depths generally exceed 60m, we recommend retrieval using a two-step process of locating ALDFG using sidescan sonar followed by targeted grappling for identified ALDFG targets.
- Combining the survey and retrieval activities during the same mission has yielded good results. This approach involves the survey vessel and the retrieval vessel deploying together and retrieval activities following immediately upon identification of targets.
- Alternately, retrieval operations can be conducted separately from location activities and following post-processing of sidescan survey data to ensure more accurate location data. It should be noted, however, that due to shifting sediment, tides and currents potentially moving ALDFG, retrieval activities should follow location activities within at least the same season and preferably within weeks of location operations.
- Retrieval activities should be conducted from May through October, maximizing work windows with optimal weather conditions.
- In all areas, we recommend engaging experienced ALDFG location and retrieval teams, building on the capacity established by previous funding from the DFO's Ghost Gear Fund.

## Conclusion

The results can provide guidance when determining where to apply resources to address ALDFG and can be used to identify potential ALDFG survey locations. The high probability areas shown here were developed through a predictive model based on input from available datasets and known characteristics of ALDFG, and a dataset of known locations of ALDFG. The purpose of this is to assist interested parties in identifying where the potential for ALDFG presence is more likely and help guide assessments in survey investigations, increase efficacy of removal operations, and reduce potential for NARW entanglements. The models presented can be updated with new caches of gear loss, ALDFG recovery, and NARW distribution data.

Accompanying this report are three datasets for use in ArcGIS. They include:

- *scpm_allgosl* – raster of original predictive model output for snow crab ALDFG in all Gulf of St. Lawrence
- *scpm_sgosl* – raster of original predictive model output for snow crab ALDFG in southern Gulf of St. Lawrence
- *GoSL_All_SnowCrab_PredMod.shp* – vector shapefile with 10 features, each representing coverage of the modeled and reclassified values (1 – 10), with attributes describing their area, and corresponding probability rankings for all Gulf of St. Lawrence.
- *GoSL_CFA12_SnowCrab_PredMod.shp* – vector shapefile with 10 features, each representing coverage of the modeled and reclassified values (1 – 10), with attributes describing their area, and corresponding probability rankings for southern Gulf of St. Lawrence.

- *lobpm_allgosl* – raster of original predictive model output for lobster ALDFG in all Gulf of St. Lawrence
- *lobpm_sgosl* – raster of original predictive model output for lobster ALDFG in southern Gulf of St. Lawrence
- *GoSL_All_Lobster_PredMod.shp* – vector shapefile with 10 features, each representing coverage of the modeled and reclassified values (1 – 10), with attributes describing their area, and corresponding probability rankings for all Gulf of St. Lawrence.
- *GoSL_South_Lobster_PredMod.shp* – vector shapefile with 10 features, each representing coverage of the modeled and reclassified values (1 – 10), with attributes describing their area, and corresponding probability rankings for southern Gulf of St. Lawrence.
- *NARW_SnowCrabALDFG_RemovalPriorityAreas.shp* – vector shapefile with prioritized recommended removal areas, including area size and mean, min, and max depth.

This report provides recommendations for location and retrieval of snow crab trap ALDFG. Retrieval of ALDFG is the only way to fully remediate harmful effects of ALDFG, such as entanglement risk for NARW. However, preventive actions that reduce the amount of ALDFG and mitigation measures, that minimize harmful effects of ALDFG are also important.

Canadian fisheries already implement key best management practices that serve to mitigate and prevent ALDFG (GGGI, 2021), such as limits on the amount of gear allowed, mandatory biodegradable escape mechanisms on each trap and mandatory reporting of lost fishing gear. Mandatory reporting increases the likelihood of retrieval and informs fisheries managers and fishers of the extent, location, and rate of loss. This data informs retrieval actions and informs regulatory measures, and spatial and temporal closures. Other current measures specifically addressing risk of NAWR entanglement include periodic fishery closures and exploration of ropeless gear technologies. Both of these measures effectively reduce the amount of vertical lines present in the water column.

However, it is clear from data received on the amount and frequency of gear loss in the Gulf of St. Lawrence, that more loss prevention actions should be explored. To develop effective prevention actions, understanding the causes of gear loss is essential. Because the DFO Lost Fishing Gear Form requests fishers to note the cause of their gear loss, collating these responses is a first step to identifying the prevalent causes of gear loss. Next, a suite of voluntary or regulatory prevention actions designed to ameliorate identified causes of loss can be identified and evaluated in collaboration with fishers, fisheries managers, and resource managers.

## References


Canada, 2018. Ocean Plastics Charter.

Canadian Council of Ministers of the Environment, 2020. Canada-Wide Action Plan on Zero Plastic Waste Phase 2. Can. Counc. Minist. Environ. 1–9.

Canadian Council of Ministers of the Environment, 2018. Strategy on Zero Plastic Waste 14.

CMEMS, 2021. Global Total Surface and 15m Current (COPERNICUS-GLOBCURRENT) from Altimetric Geostrophic Current and Modeled Ekman Current Reprocessing. E.U. Copernicus Marine Service Information.

DFO, 2021. Integrated Fisheries Management Plan: Snow crab – Estuary and Northern Gulf of St. Lawrence Inshore Areas. October 2021. https://www.dfo-mpo.gc.ca/fisheries-peches/ifmp-gmp/snow-crab-neige/2021/index-eng.html#app-1

DFO, 2023. Vessel Density Mapping of 2022 AIS Data in the Northwest Atlantic. Dataset accessed at: https://ouvert.canada.ca/data/dataset/248e2e14-456c-414e-b093-14022d367fb0

Drinkwin, J., Antonelis, K., Calloway, M., 2022. Methods to Locate and Remove Lost Fishing Gear from Marine Waters.

ESRI 2023. ArcGIS Pro 3.2.2. Redlands, CA: Environmental Systems Research Institute.

ESRI, 2024. Modeling Spatial Relationships. ArcGIS Pro 3.3. https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-statistics/modeling-spatial-relationships.htm

Fu, G., Dai, X., & Liang, Y. (2021). Functional random forests for curve response. *Scientific reports*, *11*(1), 24159.

GEBCO Compilation Group (2022) GEBCO 2022 Grid (doi:10.5285/c6612cbe-50b3-0cff-e053-6c86abc09f8f)

GESAMP, 2021a. Sea-based sources of marine litter, (Gilardi, K., ed.) (IMO/FAO/UNESCO-IOC/UNIDO/ WMO/IAEA/UN/UNEP/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 108, 109 p.

GGGI (Global Ghost Gear Initiative), 2021. Best Practice Framework for the Management of Fishing Gear: June 2021 Update. Prepared by Huntington, T. of Poseidon Aquatic Resources Management Ltd.

Global Wind Atlas, 2023. Global Wind Atlas 3.0. Technical University of Denmark & World Bank Group. URL https://globalwindatlas.info

GOSAF (Gulf of St-Lawrence Allied Fisheries), 2024. A pathway to innovation for the Gulf of St-Lawrence Snow Crab fishing fleet. Presentation accessed at: https://fisheryprogress.org/sites/default/files/documents_actions/A%20pathway%20to%20an%20innovative%20snow%20crab%20fishery%20PC.pdf

Hijmans R (2024). terra: Spatial Data Analysis. R package version 1.7-71, https://CRAN.R-project.org/package=terra.

Koen-Alonso, M., Favaro, C., Ollerhead, N., Benoit, H., Bourdages, H., Sainte-Marie, B., Treble, M., Hedges, K., Kenchington, E., Lirette, C., King, M., Coffen-Smout, S., and Murillo, J. (2018). Analysis of the overlap between fishing effort and Significant Benthic Areas in Canada's Atlantic and Eastern Arctic marine waters. Canadian Science Advisory Secretariat (CSAS).

Martens, J., Huntington, B.E., 2012. Creating a GIS-based model of marine debris “hot spots” to improve efficiency of a lobster trap debris removal program. Mar. Pollut. Bull. 64, 949–955. https://doi.org/10.1016/j.marpolbul.2012.02.017

Mkala, E. M., Mwanzia, V., Nzei, J., Oluoch, W. A., Ngarega, B. K., Wanga, V. O., ... & Victoire, I. (2023). Predicting the potential impacts of climate change on the endangered endemic annonaceae species in east Africa. *Heliyon*, *9*(6).

Naimi B, Hamm Na, Groen TA, Skidmore AK, Toxopeus AG (2014). Where is positional uncertainty a problem for species distribution modelling. *Ecography*, **37**, 191-203. doi:10.1111/j.1600-0587.2013.00205.x

Naimi B, Araujo MB (2016). sdm: a reproducible and extensible R platform for species distribution modelling. *Ecography*, **39**, 368-375. doi:10.1111/ecog.01881.

NOAA, 2015. Impact of "Ghost Fishing" via Derelict Fishing Gear.

NOAA MDP (Marine Debris Program), 2016. 2016 MARINE DEBRIS HABITAT REPORT Habitat Marine Debris Impacts on Coastal and Benthic Habitats 2016 NOAA Marine Debris Program Report 26.

Posit team (2023). RStudio: Integrated Development Environment for R. Posit Software, PBC, Boston, MA. http://www.posit.co/.

R Core Team (2024). R: A Language and Environment Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/. R version 4.3.3.

## Appendix: Results of online survey of Ghost Gear fund recipients

To inform the recommendations on locations and retrieval techniques of lost fishing gear in marine waters of the Gulf of St. Lawrence, an online survey was developed and distributed to organizations that had received DFO Ghost Gear funding to locate or retrieve lost fishing gear from the Gulf of St. Lawrence. The survey solicited information about locations where the individuals worked, what types of gear they retrieved, what methods they used to retrieve gear, obstacles they encountered, and recommendations to increase success in derelict gear recovery in those areas. The survey questions were primarily short answer format to allow for individual details about retrieval work from each respondent, though some questions were multiple-choice format.

The survey was distributed in both English and French to 33 individuals on April 5, 2024 with a one-week response deadline. We received 8 responses, 6 in English and 2 in French from individuals with direct experience removing derelict fishing gear from the study area.

The most common zone for respondents to retrieve derelict fishing gear was CFA 12, with many respondents working out of Crab Fishing Area (CFA) Zone 12 exclusively. There were a few respondents who worked out of both CFA 12 and other zones including 12F, 16, 19, and 20-23, with only one respondent who reported working exclusively in a zone that was not CFA 12 (CFA 16) (Figure 1).

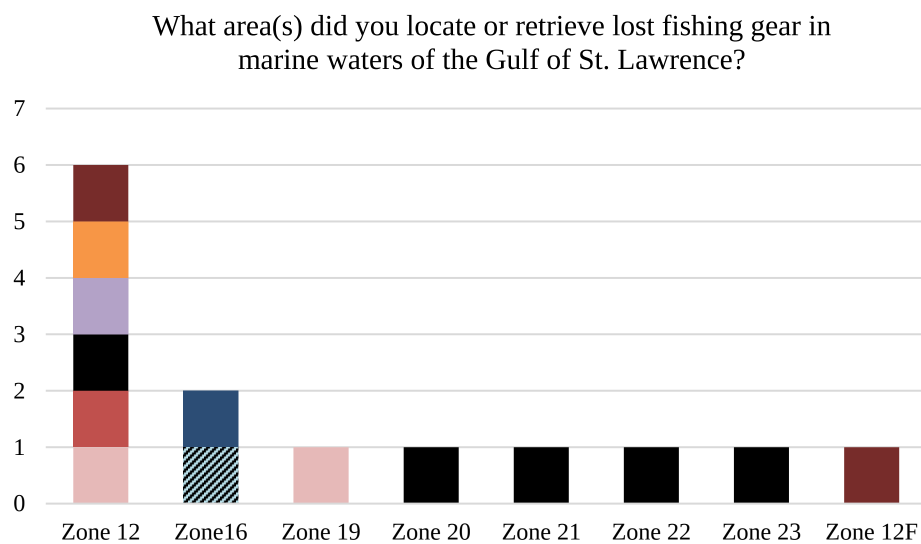


Figure 1. Number of responses for each reported Snow Crab Fishing Zone (i.e., CFA). Each color represents a respondent.

When asked how respondents selected where they would work, most respondents reported multiple factors. The most common factor in selecting their working area was knowledge from harvesters/fishers, with two respondents specifying they would receive coordinates of locations of known losses. The next most common factors in selecting working locations were DFO data or recommendations, and information gained from the prioritization algorithm developed by Merinov. Less commonly reported reasons mentioned in addition to the above include presence or absence of North Atlantic right whales, availability of a ship captain, and season convenience (Figure 2).

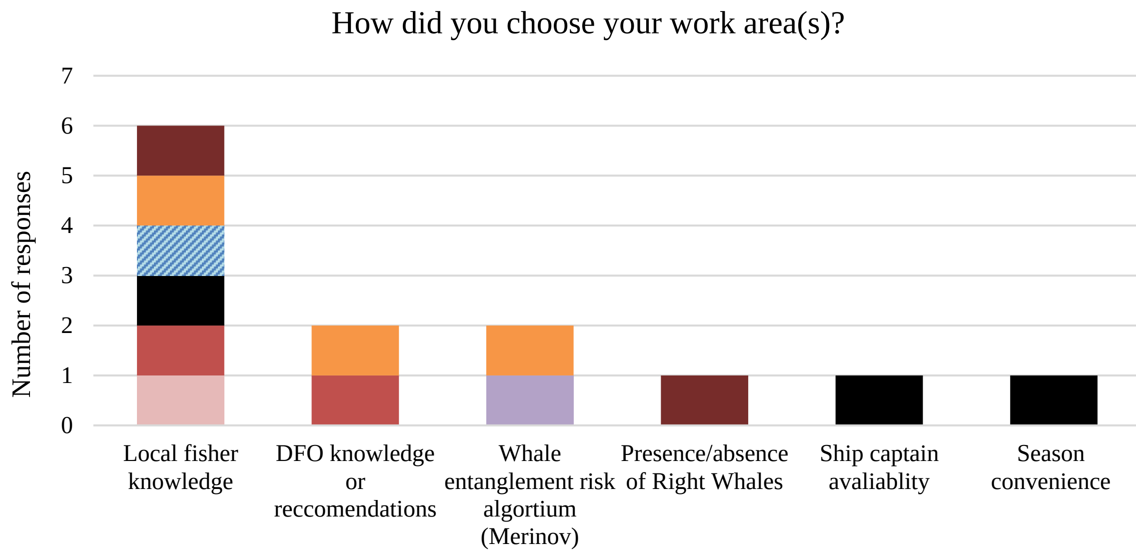


Figure 2. The reasons respondents selected their working zones. Each color represents a respondent

When asked if whale entanglement risk was a consideration in their decisions of methodology, area, or timing, six out of eight survey respondents answered yes. Even those that answered no indicated that whales are still a factor in their work. Survey responses are listed below in Table 1.

Table 1. Responses to: Was whale entanglement risk a consideration in your decisions of methodology, area, or timing?

| Yes/No | Additional Comments |
|---|---|
| Yes | We made sure there were no whale closures in the area before dragging |
| Yes | We began conducting ghost gear survey and retrieval operations in CFA 12 immediately following the closure of the crab fishing season to retrieve any buoyed gear prior to the right whales arriving in the Gulf for the summer. We were vigilant in monitoring for the presence of whales while conducting ghost gear operations through visual monitoring and the use of a hydrophone. |
| Yes | We had a safety protocol to cease all operations if whales were spotted in our working areas |
| Yes | We tried to retrieve lost gear located within areas closed to fishing because of whale presence |
| Yes | We are less affected by this risk in our area (North Shore of the Gulf; north of Zone 16). Although there are mentions of their presence, there are fewer North Atlantic right whales in our sector than in the southern Gulf. |
| Yes | |
| No | Though we were always on the lookout for them just in case |
| No | No entanglement risks with retrieval work type |

The next part of the survey solicited information about methods, and types of gear retrieved. The respondents were also asked to specify if the methods changed with area, or timing. Survey respondents most reported use of sidescan sonar, remotely operated vehicles (ROVs), and the information gained from lost gear reports and fisher knowledge (Figure 3). No respondents specified that different methods are used with different timing. One respondent specified that the ROV is used in deeper waters, while the side-scan sonar is used in lagoons. Another respondent specified that while they used DFO lost gear reports, they were not helpful.

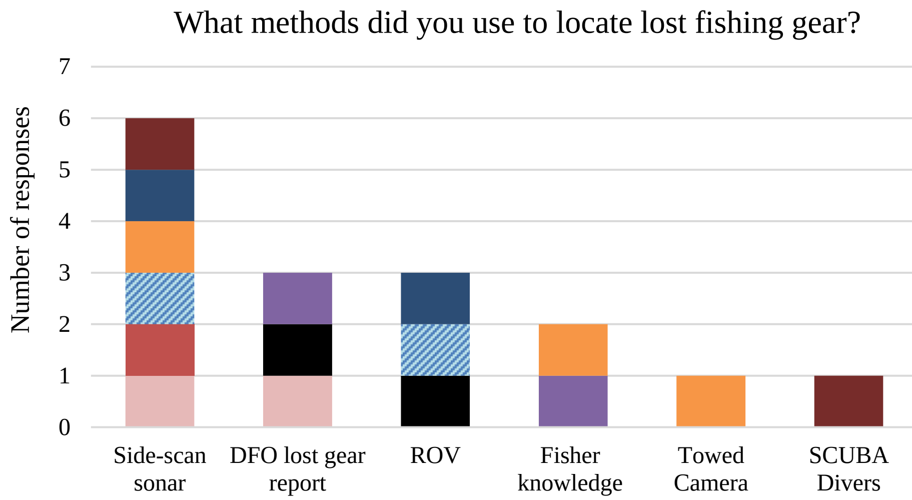


Figure 3. What methods respondents used to locate lost fishing gear. Each color represents a respondent.

Respondents specified that for most retrieval operations, they utilize a grapple towed behind a vessel. One respondent mentioned they use an a-frame trawl in addition to a grapple and ROV (Figure 4). One respondent specified that the ROV is used at shallower depths, while the grapple is used in deeper waters.

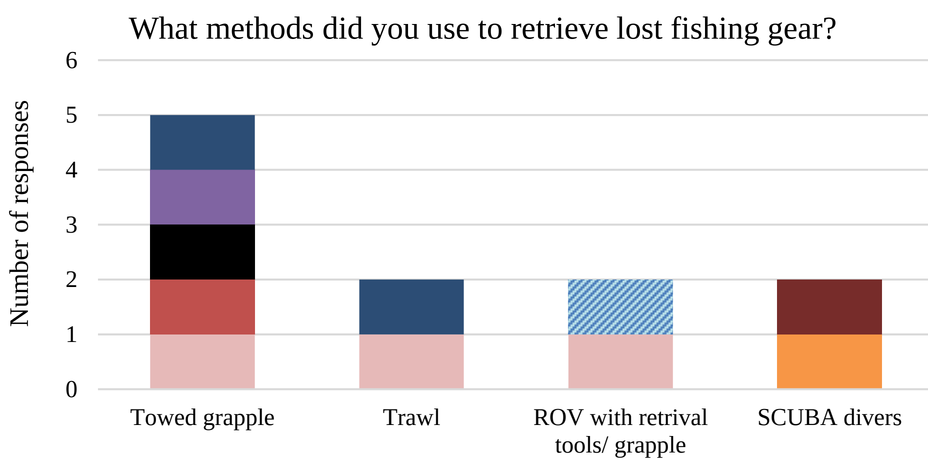


Figure 4. What methods respondents used to retrieve lost fishing gear. Each color represents a respondent.

Most survey respondents worked within a particular depth range, though there was one survey respondent who responded that they work in shallow depths (0-50 feet) in LFA, and in CFA they work at depths of 200-500 feet (Figure 5). Some respondents worked on in depths from 0-100 feet, while on respondent reported that they work within all depths from 0-500 feet (Figure 5).

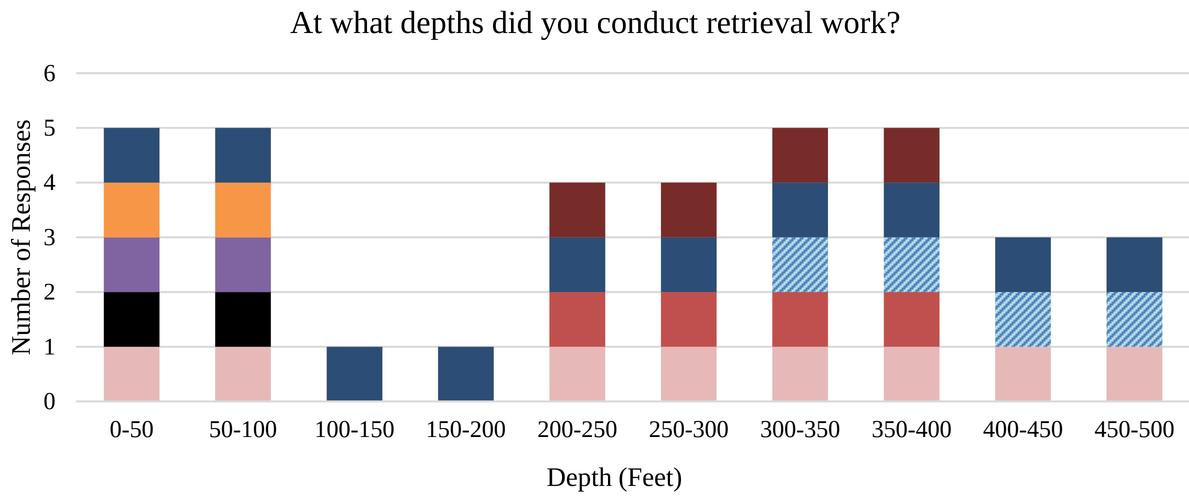


Figure 5. Responses for at what depths in feet respondents conducted retrieval work. Each color represents a respondent.

Two of eight survey respondents mentioned that their methods depended on depth, while six mentioned that they used the same methods regardless of depth (Table 2).

Table 2. Responses to: Did you use different retrieval methods at different depths?

| Yes/No | Additional Comments |
|---|---|
| Yes | Deeper water was usually just a grapple. Dragging with an A frame was used for most retrieval. Shallower waters we used an ROV with a manipulator arm. |
| Yes | Different grapple systems to accommodate the type of boat used. |
| No | We used the towed grapple for ghost gear retrievals all depths. |
| No | Particularly circular or trailing machines; once a grapple. |
| No | Only the ROV technique, which leaves no trace on the seabed and is proving to be the most effective. |
| No | |
| No | |
| No | |

Survey respondents reported a variety of obstacles they encountered when retrieving derelict gear from the marine waters of Gulf of St. Lawrence. These obstacles are listed below, grouped into categories of informational, technique, or environmental obstacles (Table 3).

Table 3. Responses to: What obstacles to success did you encounter in your location and retrieval work?

| Nature of Obstacle | Detailed response |
|---|---|
| Informational | We were not given many coordinates to go off of. There is a lot of area to cover, and it seemed like more time would have been beneficial. |
| | Erroneous positions declared by fishers. Not ill intentioned, just because they had not recorded the position of lost gear correctly the day it was lost. This led us to search areas where there was no ghost gear, thus losing time and resources. |
| Technique | The main obstacle was that we had to develop the technique from scratch, as there were no references in the field due to the singular nature of the operation* |
| | Concentrating on known or identified hotspot areas. Understanding substrate type for future retrieval and its correlation with retrieval methods |
| Equipment | Available technologies and the expertise to operate them are scarce and expensive (fortunately, we've built a good partnership with a company based in the Maritimes). |
| Environmental | The deeper waters (400 feet +) in the northern part of Chaleur Bay made it difficult to retrieve the snow crab pots. |
| | Sandy bottom is easy to grapple but it moves around with every storm and tide, burying gear. Gear was hard to locate unlike our other retrieval areas |
| | Deep water and strong tides. |

*Our success rate improved exponentially from time investment in trial-and-error for side-scan and ROV recovery, as we were able to eliminate what we knew to be a rock and locate traps that were very subtle on sidescan images but which we knew from our ROV dive history (we recognize ropes, overturned traps, ropes, recent traps filled with crabs, square traps), as the images of these elements undergo distortion, it's a real expertise that develops over time to be effective. That's why it's so important for DFO to continue with these projects, to maintain the expertise developed and the experts in place, since there is still an immense quantity of traps and rope in the water column of Zone 12.

Survey respondents mostly retrieved either lobster or snow crab traps as their primary gear type, but generally not both. There was only one survey respondent who reported retrieving both lobster and snow crab traps, as well as other crab traps, gillnets, longlines, and other types of gear as their primary gear type (Figure 6). Respondents who primarily focused on lobster traps reported their secondary gear type as snow crab traps, while those who primarily work on snow crab straps reported they focus secondary on gillnets and other types of fishing gear (Figure 7).

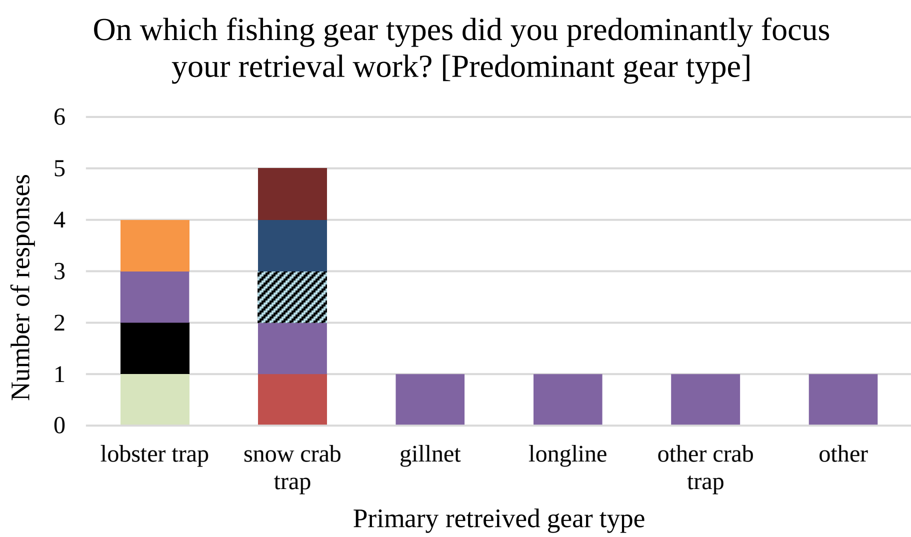


Figure 6. The primary type of derelict fishing gear that survey respondents on which respondents focus their retrieval efforts. Each color represents a respondent.

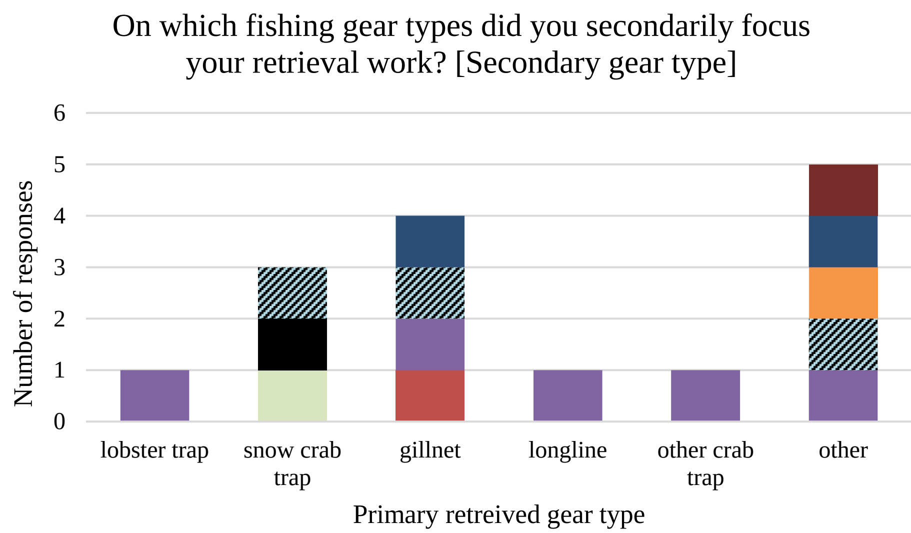


Figure 7. The secondary type of derelict fishing gear that survey respondents on which respondents focus their retrieval efforts. Each color represents a respondent.

The final segment of the survey asked the respondents for their detailed recommendations on best methods for retrieval of derelict gear, and their recommendations for strategies/actions to improve their ability to locate and retrieve lost fishing gear from the marine waters of St. Lawrence. The responses are edited in minor fashion for clarity and grouped by related themes, but otherwise presented in their original form. When asked what method they would recommend to successfully retrieve lost gear, responses varied, reflecting the different methods respondents reported using from Figure 4 above (Table 4). The final question asked respondents for their recommendations on improving both their ability to locate (Table 5) and retrieve (Table 6) gear. Responses to these questions are grouped by whether the recommendation involves access to information, funding and organizational support, or adjustments to timing and technique.

Table 4. What would you recommend as the optimum method to retrieve lost fishing gear from marine waters of the Gulf of St. Lawrence? Feel free to provide different recommendations depending on depth or timing.

| Method | Detailed response |
|---|---|
| Grapple | A boat equipped with an A frame and drag with 3 to 6 grapples. |
| | Towed grapple system |
| | Shorter grapple tows, target areas of high fishing effort, follow local fisher's lead to best grounds |
| Both ROV and Grapple | ROV with grab arm and towed grapple depending on visibility, substrate, and depths. |
| ROV and SCUBA | Best method for very deep water is the use of an ROV, it allows for a targeted approach, that minimize the environmental impact of ghost gear retrieval. In shallower water, scuba diving is the best method, for the same reason. |
| Timing and Technique | May to end of November. Better collaboration between recovery teams and fisheries officers is needed to ensure that the quadrangles targeted for recovery are completely cleared of all buoys that have remained in the area to avoid equipment breakage when sidescan equipment snags on buoy bodices. Quadrangles closed due to right whales could be targeted as the first location for location / recovery in May. |

Table 5. What would you recommend to improve your ability to successfully **locate** lost fishing gear in marine waters of the Gulf of St. Lawrence? Feel free to provide different recommendations depending on depth or timing.

| Recommendation | Detailed response |
|---|---|
| Informational | Ask harvesters. Make it clear that they will not be penalized for losing their gear. |
| | Continuing to receive information from local fishers on where lost gear may be located, as well as receiving lost gear information from DFO. |
| | Fishers' collaboration. If retrieval projects benefit from actual position of lost gear retrieval efforts will be more efficient, and therefore less expensive for an equivalent effort. |
| | More collaborative efforts to map the seafloor for understanding habitats, more efforts with ROV and Side scan sonar to identify GG. Better access to reports of lost gear and more reporting of GG when found by local fishers. |
| Funding and Support | More available time and funding to complete larger survey areas using side scan sonar. |
| Timing and Technique | ROV surveys with retrieval immediately after (can't wait and let the sands shift). |
| | Continue the work in 2024 and over several years to preserve the expertise developed in locating ghost devices, since this expertise is truly unique and stems from several hundred hours at sea locating ghost devices. What's more, we're counting on a team that, like us, also carries out recovery operations with its own team and our own equipment. This synergy optimizes resources and, as we've seen from the high number of teams not satisfied with the work carried out by external consultants with no recovery experience. As mentioned, synergy with fisheries officers is necessary to enable locating in quadrilaterals free of buoys and rope in the water column. Also, increasing the time window for locating allows the necessary time to repair equipment efficiently, as the sidescan occasionally becomes entangled in phantom rope in the water column. |

Table 6. What would you recommend to improve your ability to successfully **retrieve** lost fishing gear from marine waters of the Gulf of St. Lawrence?

| Recommendation | Detailed response |
|---|---|
| Informational | More collaborative knowledge and approaches to understand substrate types and retrieval methods with highest success rates depending on conditions and specifics to the area. |
| | If traps were equipped with underwater location beacons like PinMe would greatly increase chances of locating lost fishing gear. |
| | The retrieval is never the issue, it is either the localization of the recycling of the gear retrieved. |
| Funding and Support | More time and funding |
| Timing and Technique | Beginning retrieval work early (by June) to allow for longer periods of good weather to conduct ghost gear retrieval operations. |
| | Hire boats with the right equipment. An A frame with drag. This should be done each year, since we noticed a lot of wooden traps (which the majority of fishers use in our area) were too fragile to be retrieved after a year or two. They were breaking up, forming piles of debris on the bottom. |