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Predictive model identifying locations of fishing gear loss or accumulation in Trinidad and Tobago

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Introduction

The negative impacts of abandoned, lost, and discarded fishing gear (ALDFG) are a growing concern in the Caribbean region. 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 also damages marine and nearshore habitats, poses navigation risks, and is expensive and hazardous for fishermen and marine communities to deal with.[1,2,3] Of the fishing gears used in Trinidad and Tobago, gillnets and traps are identified as the most harmful types of ALDFG due to their risk of loss and the negative impacts they cause after loss.[4,5]

Solving this problem on a global scale has gained momentum with the efforts of the Food and Agriculture Organization (FAO), the United Nations Environmental Program, and the International Maritime Organization; the creation of the Global Ghost Gear Initiative (GGGI); and the establishment of the Joint Group of Experts on the Scientific Aspects of Marine Environmental Pollution (GESAMP) Working Group 43. FAO recently published Voluntary Guidelines for the Marking of Fishing Gear to help prevent negative impacts from ALDFG in the world's fisheries.[6] The GGGI is a multi-stakeholder alliance of over 100 organizations, business and governments that brings seafood stakeholders together to address ALDFG at all points along the seafood supply chain. GGGI has recently updated its Best Practices Framework for the Management of Fishing Gear (BPF). This document provides management strategies to prevent harm from ALDFG directed at 12 different seafood supply stakeholders, including fisheries managers.[5] The GESAMP Working Group 43 was established to develop a report of sea-based sources of marine litter identifying extent, causes, impacts, and recommended solutions to the global problem of marine litter from sea-based sources, including ALDFG. Its final report was published in late 2021.[7]

This report provides a detailed summary of responses from fisher surveys in Trinidad and Tobago about how and why fishing gear is lost, and what fishers do to prevent gear loss. Additionally, information from these fisher surveys on reasons for gear loss were used to develop a predictive model that identifies, at varying levels of probability, where fishing gear is likely to be lost, and where abandoned, lost, or discarded fishing gear (ALDFG) is

[1] Macfadyen, G., Huntington, T., Cappell, R., 2009. Abandoned, lost or otherwise discarded fishing gear. UNEP Regional Seas Reports and Studies 185. FAO Fisheries and Aquaculture Technical Paper 523., Aquaculture.

[2] National Oceanic and Atmospheric Administration 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

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

[4] Gilman, E., Musyl, M., Suuronen, P., Chaloupka, M., Gorgin, S., Wilson, J., Kuczenski, B., 2021. Highest risk abandoned, lost and discarded fishing gear. Sci. Rep. 11. https://doi.org/10.1038/s41598-021-86123-3

[5] 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.

[6] FAO, 2019. Voluntary Guidelines on the Marking of Fishing Gear. Rome. 88 pp. License: CC BY-NC-SA 3.0 IGO

[7] GESAMP, 2021. 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.

likely to accumulate in the marine waters of Trinidad and Tobago. This report will assist in evaluating the scope of the problem and potential preventive action, including planning for ground-truthing surveys and recommended specialized education programs for fishing industry stakeholders. Predictive models may also improve efficiency of future ALDFG removal activities. The focus of the research was on artisanal fisheries of Trinidad and Tobago, with an emphasis on gillnets, hooks and lines, and traps, which are the dominant gear types in those fisheries.

General Description of Fisheries and Gear

Fisheries in Trinidad and Tobago utilize multiple gear types in both the artisanal and non-artisanal (semi-industrial and industrial) sectors. The majority of fishing vessels in Trinidad and Tobago are artisanal vessels, on average, 96% of all fishing vessels from 2018/2019 to 2022. There are more fishing vessels operating in Trinidad (73%) than Tobago (22%). Over the four years/seasons, the proportion of artisanal and non-artisanal vessels in Trinidad and Tobago remained consistent. In 2021, there were approximately 2,892 fishing vessels in Trinidad and Tobago. Of those, 2145 (74%) were artisanal fishing vessels in Trinidad and 648 (22%) were artisanal fishing vessels in Tobago. There were 90 (3%) non-artisanal vessels in Trinidad, including 36 trawlers, 39 longliners (operating outside of the EEZ), and 15 multi-gear vessels; in Tobago there were only 9 (0.3%) non-artisanal vessels.[8]

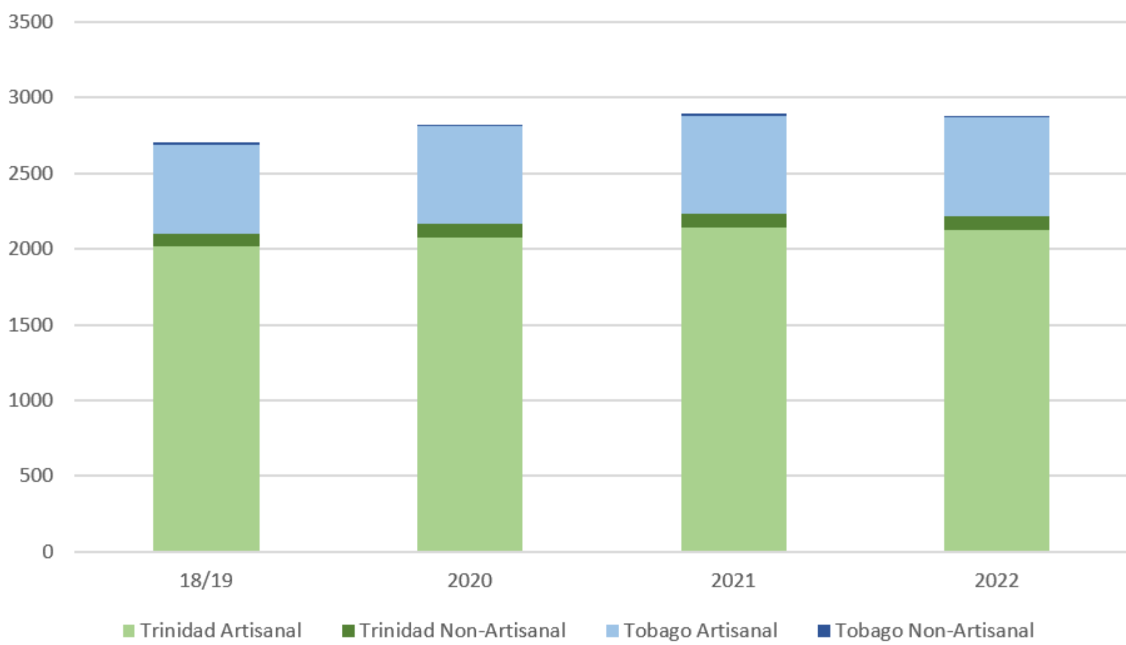

Figure 1. Number of artisanal and non-artisanal fishing vessels in Trinidad and Tobago from 2018/19 through 2022 (source: Fisheries Division, 2023).

[8] Fisheries Division, 2023 – Spreadsheet with vessels and fishers by site for Trinidad and Tobago, Fisheries Division, Ministry of Agriculture, Land and Fisheries

Most artisanal fishing vessels use gillnets and entangling nets and/or hooks and lines, followed by traps (fish pots), especially in Tobago, with a small number of vessels in Trinidad utilizing seine nets and trawls.[9]

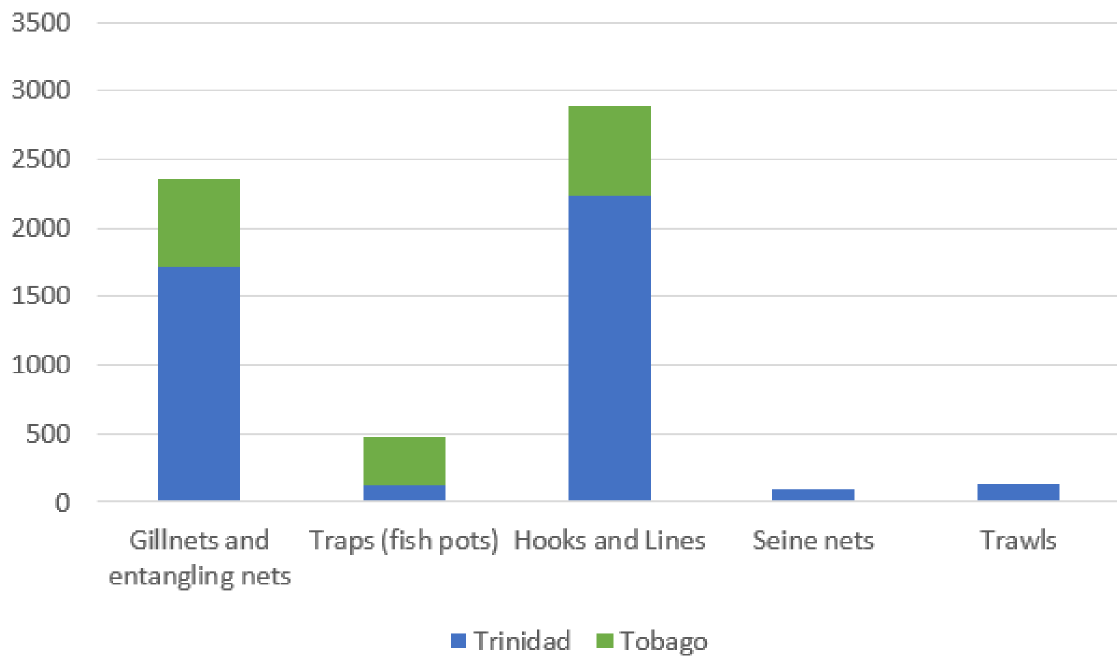

Figure 2. Number of artisanal vessels utilizing different gear types in Trinidad and Tobago (source: Kanhi, 2023).

Gillnet fishing may be found on all sides of Trinidad and Tobago (Fisheries Division, 2011[10]). They are a wall of net made of nylon monofilament or multifilament mesh suspended vertically at the surface, in the water column, or at the bottom by differently weighted, buoyed, or anchored lines along the top and bottom of the net.[11] In Trinidad and Tobago, gillnets are commonly 450 to 1,200 meters long, with mesh sizes from 9.5 to 12.7 cm. Monofilament gillnets tend to target demersal and pelagic species and are set below the surface during the day or at night. Multifilament gillnets are more commonly set at the surface during the night. Gillnets are deployed year-round, although gillnet fishers may fish in different areas different times of year.[12,13] There are approximately 1,715 vessels in the gillnet fishery. Gillnet types include set gillnets (fillette, trans bottom, transpie, green twine), drift gillnets (fillette, green, transpie, flying fish net), encircling gillnets (saine), trammel nets, and combined gillnets-trammel nets (primarily set and drift). The reported target species are demersal and pelagic, with a few fishers

[9] Kanhai, 2023 - Abandoned, Lost and Otherwise Discarded (ALDFG) Fishing Gear in Trinidad and Tobago Final Fieldwork Report, prepared by Dr. La Daana Kanhai
[10] Fisheries Division, 2011 – Map of Trinidad and Tobago showing some popular fishing areas by gear type. By Fisheries Division, Ministry of Food Production, Land and Marine Affairs
[11] NOAA, 2022, 2022 - https://www.fisheries.NOAA, 2022.gov/national/bycatch/fishing-gear-and-risks-protected-species
[12] Ferreira & Soomai, 2013 – Ecosystem Approach to Fisheries (EAF) Baseline Report for the Shrimp & Groundfish Fisheries of Trinidad and Tobago, Fisheries Division, Ministry of Food Production
[13] BP. n.d – Fisheries of South East Trinidad

targeting crustaceans, cephalopods, and benthic species.[14] Demersal species in the study area include red snapper, weakfish, grunt, catfish, Spanish mackerel, cavalli, and jacks; pelagic species include mackerel, tuna, kingfish, carite, shark, cavalli, jacks, and barracuda.[13] Artisanal gillnet fishers fished primarily from vessels smaller than 12 m in length, and in water depths from 0 to 200 meters, although some fished from 200-1,000 meters. Fishing trips are typically one day in length, with vessels taking 20 to 365 trips per year. Gillnet fishing occurs year-round, with more reported trips in the summer (around May through October). Soak time for gillnets are commonly within the 1 to 8 hour range, or for an entire day. Fishers commonly single gillnets, rather than sets of multiple nets.[14]

Trap and pot fishing may be found on all sides of Trinidad and Tobago.[10] They are baited plastic or metal cages used to capture fish and shellfish. Individual traps or the ends of each line of traps may be marked at the surface.[11] Trap fisheries target demersal and pelagic fish species, as well as crustaceans.[14] Specifically, target species include red snapper, grunt, grouper, and lobster.[13] Artisanal trap fishers fished primarily from vessels smaller than 12 m (89 vessels), in depths from 0 to 200 meters. Fishing trips were almost always 1 day in length, with different vessels conducting 40 to 365 trips per year. Year-round trap fishing occurred. The soak time was almost always 1 day. Fishers deployed both singles and sets of traps.[14]

Hook and line fishing may be found on all sides of Trinidad and Tobago.[10] This category encompasses multiple configurations of hooks and lines, from a single line with one or more hooks directly attached, to longlines -- one mainline with multiple lines (gangions) hanging off the mainline, each with multiple hooks; these longline sets can have thousands of hooks.[11] Trinidad and Tobago hook and line gear types include: handlines and hand-operated pole-and-lines (a la vive/a la vie, banking, trolling, caster, live bait, palangue), mechanized lines and pole-and-lines (banking), set longlines, drifting longlines (palangue), vertical lines, and trolling lines. Demersal and pelagic are targeted, with a few fishers targeting crustaceans, and cephalopods.[14] Demersal species include red snapper, weakfish, grunt, catfish, Spanish mackerel, cavalli, and jacks; pelagic species include mackerel, tuna, kingfish, carite, shark, cavalli, jacks, and barracuda.[13] Artisanal hook and line fishers fished from primarily vessels smaller than 12 m (130 vessels), primarily in water depths of 0 to 200 meters, and some in 200-1000 meters. Fishing trips are typically one day in length, with the number of annual trips per vessel ranging from 7 to 365 trips. Hook and line fishing occurs year-round. Soak time varies widely, typically one hour to one day. Fishers deploy both singles and sets of hooks and lines.[14]

Trawls target shrimp and groundfish, and are only allowed in Trinidad. They are present primarily in the Gulf of Paria, the Columbus Channel (Venezuela also shares these fishing grounds), and the North Coast. Trawl nets are cone shaped bag nets that are towed behind a vessel, either along the seafloor or in the water column. Cables attached to each wing of the net are attached to trawl doors that are used to spread the mouth of the net. The artisanal fleet's trawl nets are approximately 10-11 meters long (3 cm code end mesh

[14] FAO surveys, 2023 – Fisher surveys conducted in Trinidad & Tobago by UWI in 2023 as part of this project

size), while non-artisanal nets are approximately 10-15 meters long (3.5 cm – 4.45 cm cod end mesh size).[12]

Lost Fishing Gear Surveys

Fisher surveys were conducted in both Trinidad and Tobago. Fishers were asked a series of questions designed to elicit information about:

- Basic information about the fisher
- Fishing gear use and location
- Fishing operations, cost, and catches
- Gear loss and reporting
- End-of-life fishing gear and other waste management
- Fishing gear marking regulations.
- ALDFG perceptions and management insights

Four fieldwork assistants hired by the University of the West Indies interviewed fishers at landing sites in Trinidad and Tobago. Surveyed fishers were targeted by gear type (gillnets, traps, and hooks and lines) and sample size numbers targeted to reach suggested minimum samples sizes recommended by the United Nations Food and Agriculture Organization (FAO). Results of fisher surveys are reported together for Trinidad and Tobago but separated by gear type. We focus our results reporting on the sections of the surveys relating to fisher perceptions of ALDFG causes, impacts on the community from gear loss, and fisher suggestions to prevent gear loss.

In Trinidad, 282 fishers were surveyed and in Tobago 72 fishers were surveyed for a total of 354 fishers surveyed. Of those, 124 used gillnets, 95 used traps, and 145 used hooks and lines (Table 1). Vessel sizes for fishing operations did not vary by gear type, with most fishers in Trinidad and Tobago using crafts under 12 m (Table 2). The number of days fished per season ranged from 7 days to 365 days, with a median number of fishing days at 300 days for gillnets, 365 days for traps, and 95 days for hooks and lines (Table 3).

Table 1. Number of fishers across gear type for Trinidad and Tobago fishers

Gear Type	**Location**		
	Trinidad	Tobago	**total**
Gillnets	114	10	124
Traps	72	23	95
Hooks and Lines	96	39	145
Total	**282**	**72**	**354**

Table 2. Vessel size by gear type for Trinidad and Tobago fishers

Gear Type	Vessel Size		
	<12 m	12-24 m	>24 m
Gillnets	119	3	0
Traps	89	4	0
Hooks and Lines	58	1	0

Table 3. Fishing trips per year by gear type for Trinidad and Tobago fishers

Gear Type	**Number of Fishing Trips per Year**		
	minimum	maximum	**median**
Gillnets	20	365	**300**
Traps	40	365	**365**
Hooks and Lines	7	365	**95**

Fishers were asked to assess the causes of gear loss from a standard list of common causes of fishing gear loss. They were asked to identify their use of gear loss prevention strategies from a standard list of prevention strategies. And they were asked their opinion about the importance of factors relevant to gear loss and prevention of gear loss, again using a standard list of options. Varying slightly by gear type, fishers were asked how frequently gear was lost to the list of common causes of loss and how frequently they employed corresponding loss prevention measures. They were asked to rank frequency from "never" to "always". Fishers were also asked to rank the importance of other factors that could be used to reduce gear loss from "not important" to "very important". Fisher answers as a percentage of all fisher survey responses are used to assess how fishing gear is most often lost, how fishers are protecting against future loss of gear, and what factors are important in a system-wide assessment of ALDFG in Trinidad and Tobago.

Gillnets

Fishers noted that most of the common causes of loss presented by the ALDFG survey were "unknown or not relevant", "sometimes", or "never" encountered by Trinidad and Tobago fishers using gillnets. Out of the listed options, the causes of gear loss most reported as "always" the cause of fishing gear loss were high traffic of other vessels, poor weather conditions, nets being snagged on obstructions, and lack of communication between fishing vessels. Least frequent reports of loss were conflicts with other gear, and failure of equipment used with gear (Figure 1).

When asked about the use of gear loss prevention strategies, all listed survey options were ranked as “sometimes” or “always” used. Only a small proportion of fishers answered that they were “never” used, with relatively even proportion across all options. The most reportedly used strategies were ensuring gear is in good condition, securing gear against poor weather conditions, and instructing crew not to dispose of gear overboard. The least commonly used strategies were avoiding areas where animals are likely to damage gear, avoiding gear drifting out of reach, and avoiding high traffic areas or shipping lanes (Figure 2).

When asked to rate the importance of other factors for loss prevention, factors most rated “very important” were payments for delivering unwanted gear for recycling, quality of fishing gear material, and fisher’s skill in handling the gear. Options most ranked as “not important” were the type of hauling equipment and vessel design (Figure 3).

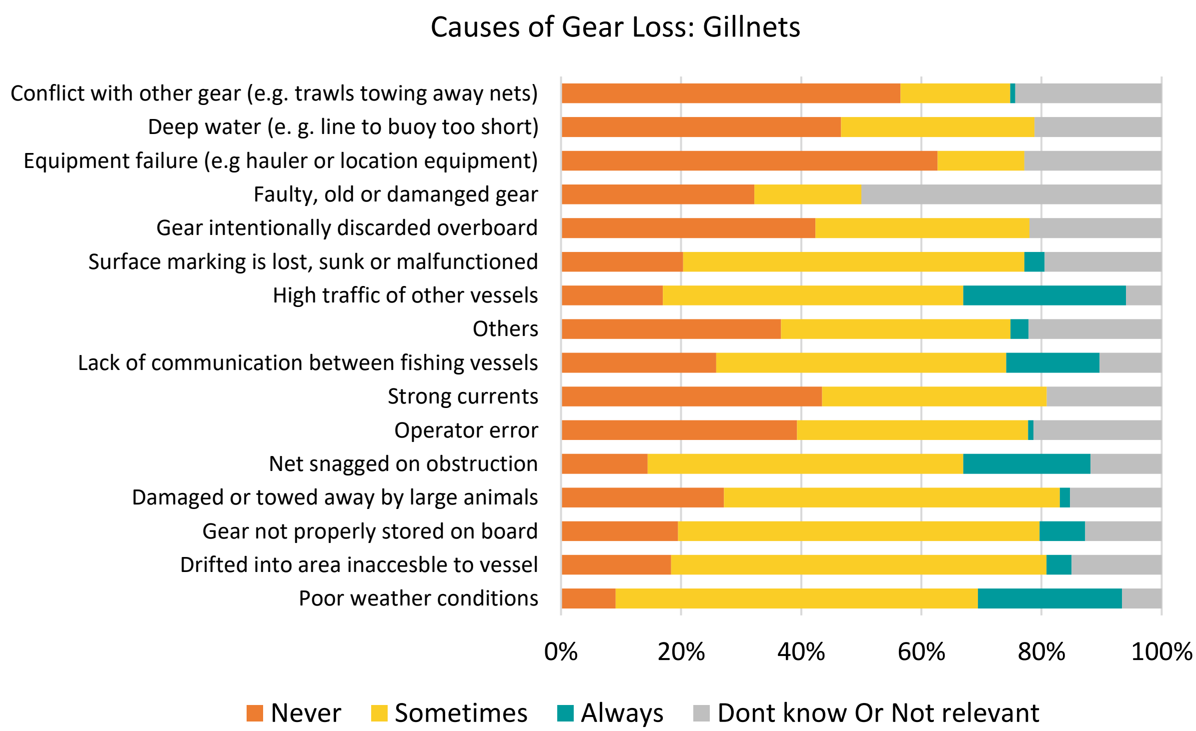

Figure 3. Stacked bar chart of the frequency of causes of gear loss for fishers using gillnets. n=118±3 for all options.

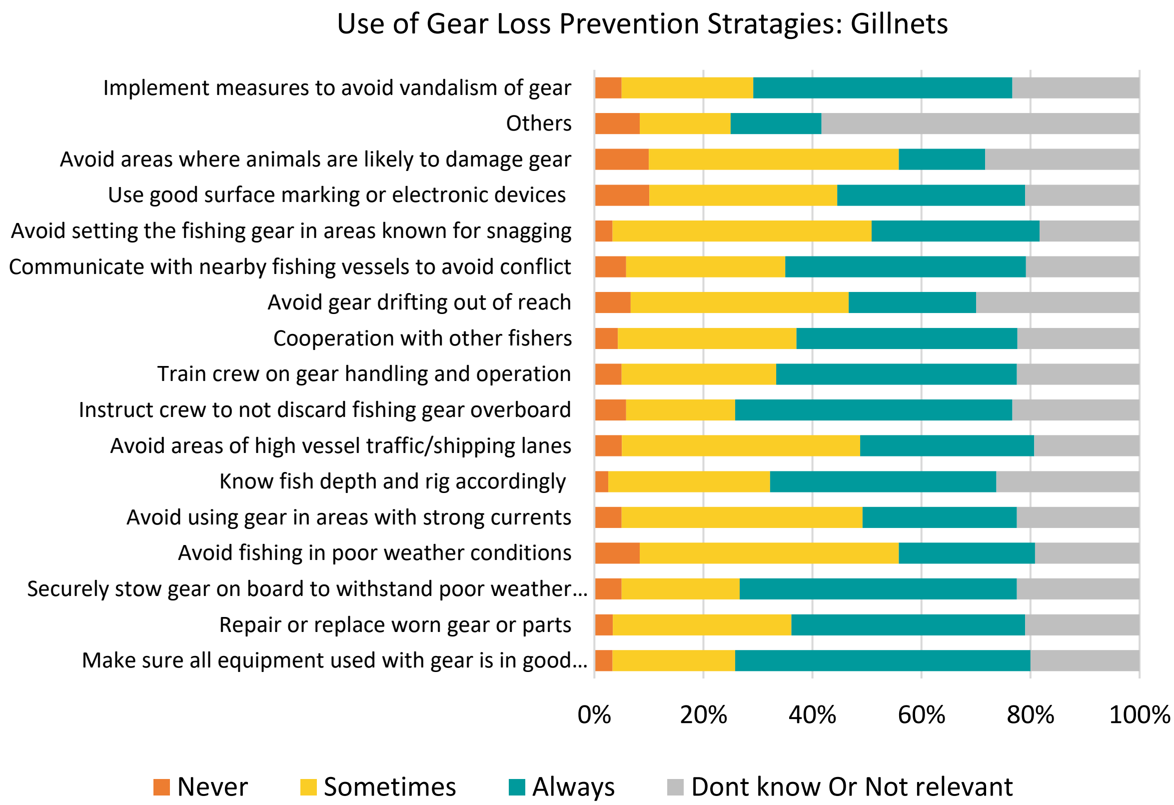

Figure 4. Stacked bar chart of the frequency of use of gear loss prevention strategies for fishers using gillnets. n=12 for "Others", n=119±1 for all other options.

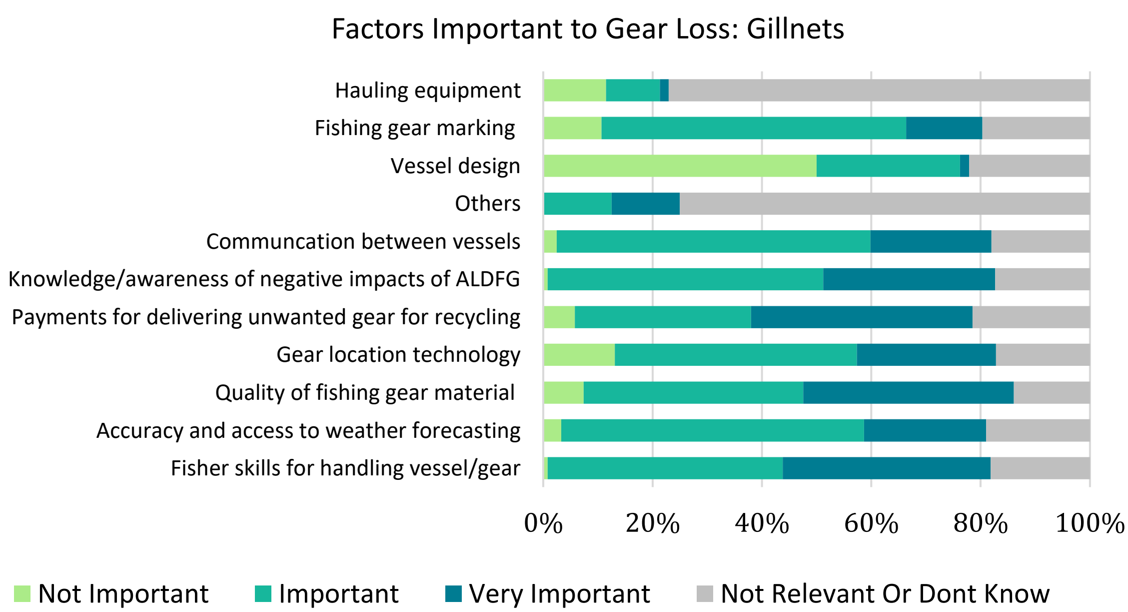

Figure 5. Stacked bar chart of the importance of factors for gear loss prevention for fishers using gillnets. n=8 for "Others", n=121±1 for all other options.

Hooks and lines

Trinidad and Tobago fishers using hooks and lines most reported causes of gear loss were gear snagging on obstructions, gear being damaged or towed by large animals, and conflict with other gear, though most listed causes were reported as "sometimes" or "never" the cause of gear loss. Notably, non-listed or "other" options were most ranked as "always" the cause of loss. The causes of loss most reported as "never" encountered were gear not properly being stored on board, and gear being intentionally discarded overboard (Figure 4).

Reporting on use of gear loss prevention strategies, hook and line fishers report using all listed prevention strategies in varying proportion as "sometimes" or "always", with proportionally few fishers stating those strategies are "never" used. Those strategies most reported as "never" used are using good surface marking, avoiding areas of high vessel traffic, and avoiding fishing in poor weather conditions (Figure 5).

When assessing the importance of factors important to ALDFG, hook and line fishers rated fisher skills for handling vessel/gear and access and accuracy of weather forecasting as "very important", while vessel design, fishing gear marking, and hauling equipment as "not important" (Figure 6).

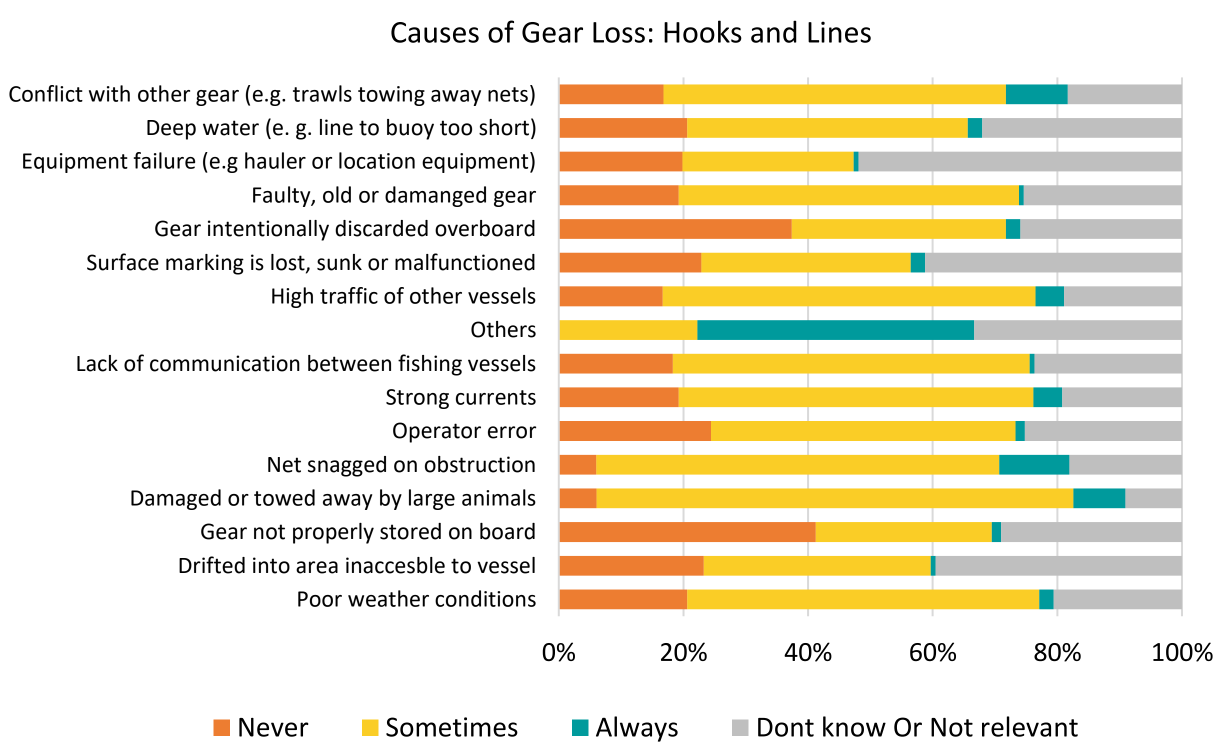

Figure 6. Stacked bar chart of the frequency of causes of gear loss for fishers using hooks and lines. n=140 for “Others”, n=131±1 for all other options.

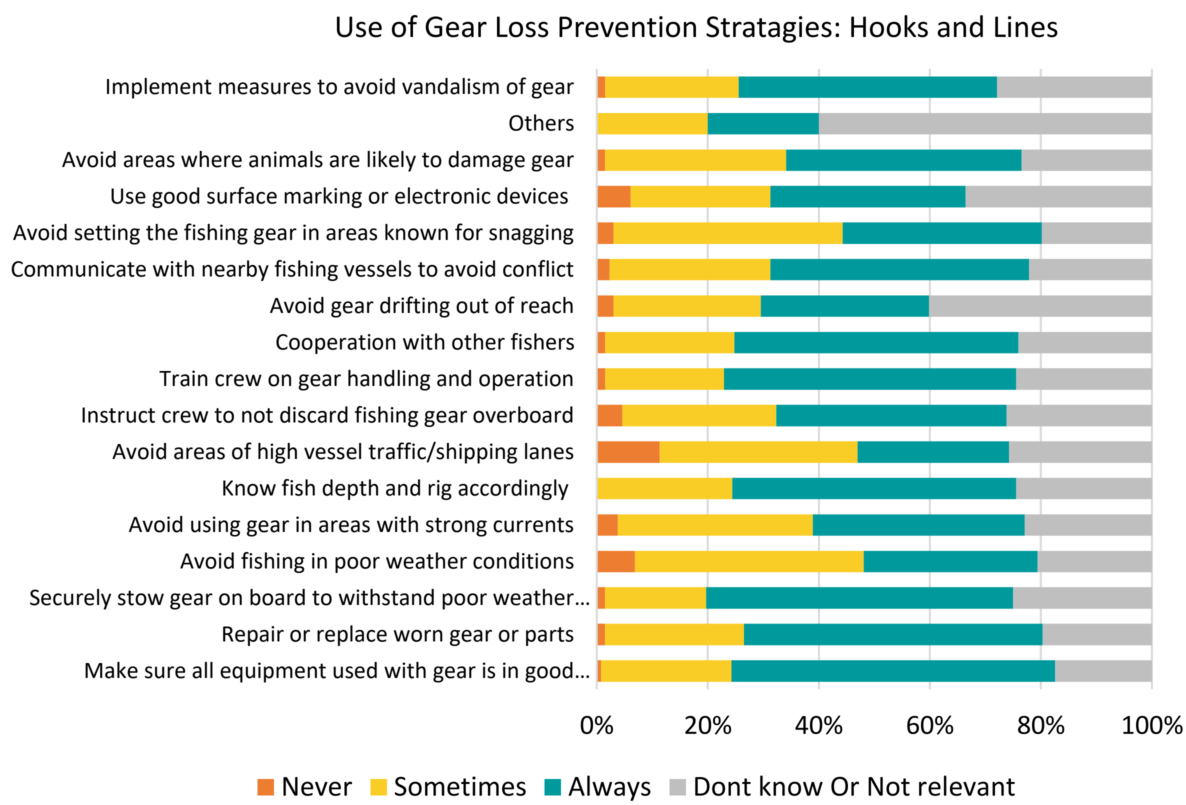

Figure 7. Stacked bar chart of the frequency of use of gear loss prevention strategies for fishers using hooks and lines. N=5 for “Others”, n=131±1 for all options.

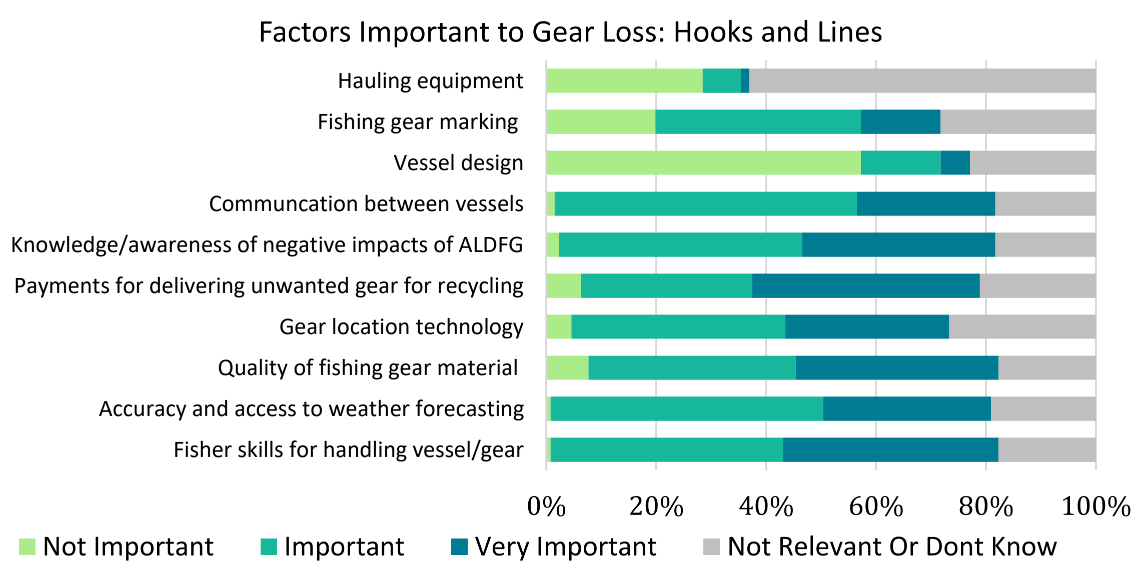

Figure 8. Stacked bar chart of the importance of factors for gear loss prevention for fishers using hooks and lines. n=130±2 for all other options.

Traps

Trinidad and Tobago trap fishers surveyed for causes of gear loss reported most frequent causes of loss were conflict with other gear, gear being snagged on obstructions, and high traffic of other vessels. Causes of loss most ranked as "never" occurring were gear being improperly stored on board, gear being intentionally discarded overboard, and operator error (Figure 7).

Fishers using traps overall evenly reported most gear loss prevention strategies as "sometimes" and "always" being used, as well as don't know or not relevant. Options which were not commonly ranked as "always" used were avoiding fishing in poor weather conditions, avoiding areas where animals are likely to damage gear, or avoiding gear drifting out of reach (Figure 8).

When ranking importance of other factors for gear loss, trap fishers reported fisher skills for handling vessels and gear, and non-listed other factors as "very important", and vessel design and hauling equipment as "not important" (Figure 9).

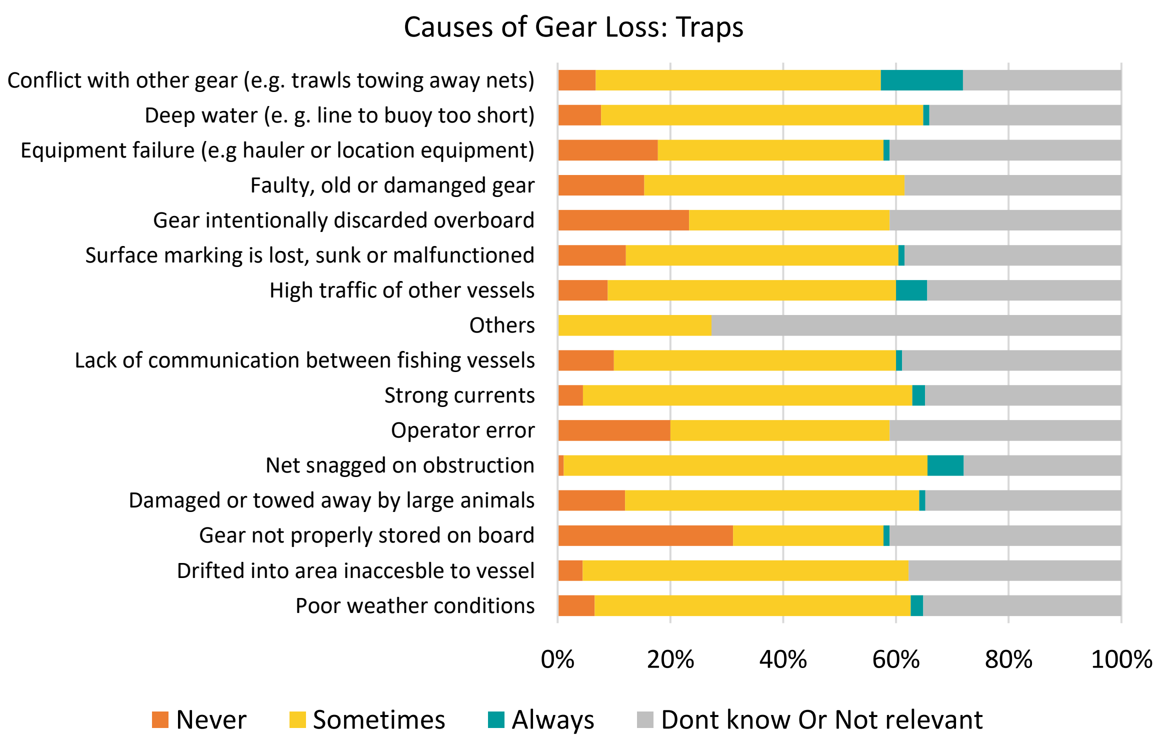

Figure 9. Stacked bar chart of the frequency of causes of gear loss for fishers using traps. n=113 for "Others", n=90±1 for all other options.

Figure 10. Stacked bar chart of the frequency of use of gear loss prevention measures for fishers using traps. n=23 for “Others”, n=89±2 for all other options.

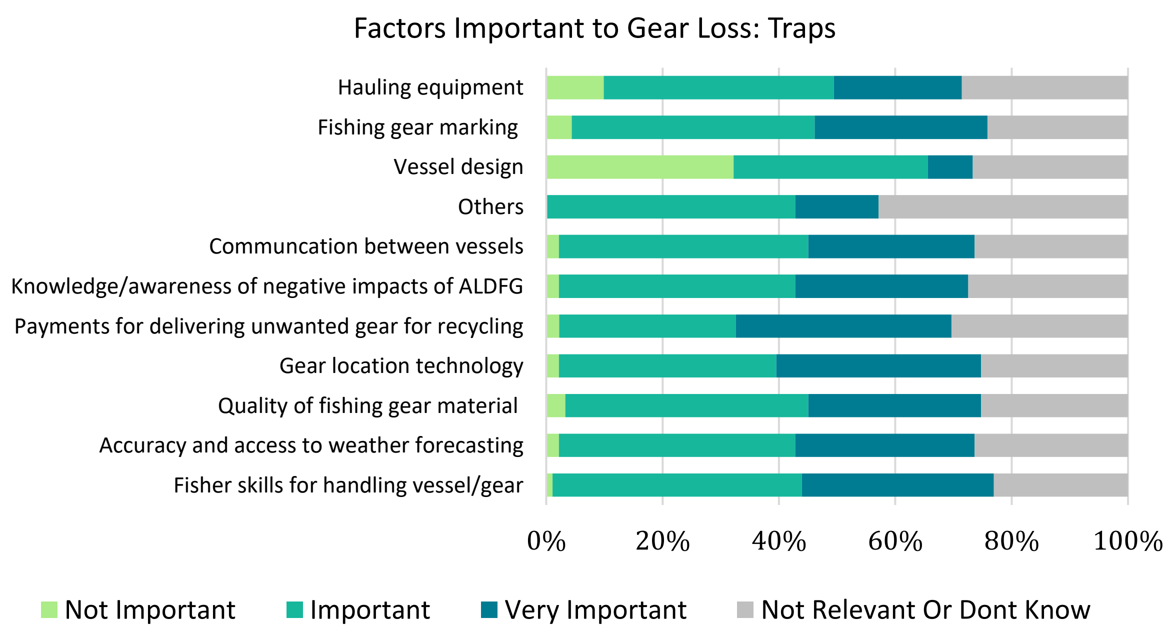

Figure 11. Stacked bar chart of the importance of factors for gear loss prevention for fishers using traps. n=30±1 for all options.

Overall, fishers in Trinidad and Tobago reported gear loss due to high traffic of other vessels, poor communication between vessels, conflict with other gear, or gear being snagged on obstructions such as shipwrecks and reefs. Compared to traps and hooks and lines, gillnet fishers reported less frequent loss due to conflict with other gear, but more frequent loss due to poor weather conditions.

The gear loss prevention strategies most reported as "always" used for fishers of all gear types were training staff to not discard gear overboard, securely stowing gear on board, and other non-listed survey options. The strategies more reported as "never" used were avoiding areas of high traffic/shipping lanes, and avoiding areas where gear was likely to be snagged.

In assessing the importance of factors related to gear loss, fishers of all surveyed gear types in Trinidad and Tobago reported that fisher skills for handling vessel/gear is very important, with gillnet fishers also considering payments for delivering gear for recycling, and hook and line fishers ranking access and accuracy of weather reporting as very important. Fishers of all gear types ranked vessel design and hauling equipment is not important.

Predictive Model Methodology

Publicly available point locations of documented ALDFG in the waters of Trinidad and Tobago were not found, and the systematic fisher surveys related to lost fishing gear locations and reasons for loss in Trinidad and Tobago were not completed in time to use the data to develop a predictive model based on known locations of ALDFG. For these reasons, the predictive model presented here should be considered *preliminary*, and can be refined when further data associated with fishing gear loss is processed.

Therefore, to develop a predictive model for ALDFG from the marine fisheries in the waters of Trinidad and Tobago, we relied on variables representing the primary reasons for gear loss that are summarized from data collected during fisher surveys, which are also well accepted common reasons for gear loss in the global ALDFG community. Those include snags on seafloor obstructions, conflict with other (mobile) gear types, inclement weather, strong ocean currents, conflicts with vessel traffic, bathymetric variance and depth profiles, and fishing intensity.[15,16,17] Environmental and fisheries data were used to represent these variables associated with gear loss. Due to the predominance

[15] Macfadyen et al. 2009

[16] Richardson, K, R Gunn, C Wilcox and BD Hardesty. 2018. Understanding causes of gear loss provides a sound basis for fishery management. *Marine Policy* 96, 278-284.

[17] Gilman, E., Musyl, M., Suuronen, P., Chaloupka, M., Gorgin, S., Wilson, J., Kuczenski, B., 2021. Highest risk abandoned, lost and discarded fishing gear. Sci. Rep. 11. https://doi.org/10.1038/s41598-021-86123-3

in size of the small-scale fleet in Trinidad and Tobago, and the often overlapping multi-gear nature of the fisheries, this model focuses on the three primary gear types used within the artisanal sector; gillnets, pots/traps, and hook and lines. Trawl gear and other gear types, primarily from the industrial fisheries, were not specifically included in this model; however, most of the environmental variables included in the model represent reasons for fishing gear loss of any type, and therefore should have some value in predicting where loss of these gears are likely to occur.

Spatial analysis using ESRI ArcGIS 10.8 with the Spatial Analyst Tools extension was conducted to design a linear additive model to predict varying levels of likelihood of ALDFG occurrence in Trinidad and Tobago waters. Analysis began with individual analysis of series of base layers, each used to represent a specific reason for gear loss (Table 2); for consistency and processing requirements across layers, datasets were set to the World Geodetic System (WGS) 1984 geographic coordinate system. Following data review and pre-modeling processing, the modeling analysis for each individual layer included clipping the layer extent to include only the waters of Trinidad and Tobago's exclusive economic zone (EEZ), then ranking values between 0 and 7 to represent low to high probability of gear loss to occur at that location based on values estimated to influence gear loss.

Table 4. List and description of spatial datasets used to represent primary causes for fishing gear loss, used to develop predictive model for ALDFG in territorial waters of Trinidad and Tobago.

Cause of Gear Loss	**Representative Dataset**	**Description & Source**
Delineation of Study Area	Trinidad and Tobago Territorial Waters	Shapefile of marine waters of Trinidad and Tobago from shoreline to 200 nm offshore, including detailed coastline (FMI 2019)[18]
Fishing Areas by Gear Type	Multiple polygon datasets	Vector polygon data delineating fishing areas by gear type as described by fishers around Trinidad and Tobago over multiple years. Data obtained from MALF Fisheries Division.
Fishing Intensity and Gear Loss Occurrence	Bathymetry	Raster data for water depth (m) at 15 arc-second grids for Trinidad and Tobago Territorial Waters, obtained from GEBCO (2022)[19]
Inclement Weather	Wind Speeds	Mean annual values (m/s) per 250 m grid cells within Trinidad and Tobago Territorial Waters (Global Wind Atlas 2021)[20]
Ocean Currents	Ocean Current Speeds	Monthly mean from March 2021 through February 2023 northward and eastward current speeds (m/s) per 0.083° grid cell in the Trinidad and Tobago Territorial Waters extracted from the Copernicus-Global current model, obtained from E.U. Copernicus Marine Service Information (CMEMS 2021)[21]
Conflict with Vessel Traffic	Vessel Traffic Density	Observed ship movement from 2015 – 2020 within 500 m grid cells inside Trinidad and Tobago Territorial Waters. Obtained from World Bank Catalog Data (Cerdeiro et al. 2020)[22]
Seafloor Obstructions	SAPA	Processed GEBCO bathymetry raster to depict terrain ruggedness, presented as surface Areas over planar area (SAPA) (GEBCO 2022; this study)
Seafloor Obstructions	Reef Areas	Vector data at locations of rocky and coral reef structures inside Trinidad and Tobago EEZ, obtained from UNEP Global Distribution of Coral Reefs (UNEP 2021)[23].
Seafloor Obstructions	Reef and Rocky Areas	Vector polygon data at locations of reef and rocky substrate delineated by fishers inside Trinidad and Tobago EEZ, obtained from Caribbean Marine Atlas (CMA, 2018)[24].
Seafloor Obstructions	Wellheads and Shipwrecks	Point locations in Gulf or Paria of wellheads and shipwrecks, digitized from figure in Baldwin (2019)[25].

[18] FMI (Flanders Marine Institute), 2019. Maritime Boundaries Geodatabase: Maritime Boundaries and Exclusive Economic Zones (200NM), version 11. Available online at http://www.marineregions.org/. https://doi.org/10.14284/386

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

[20] Global Wind Atlas, 2021. Global Wind Atlas 3.0. Technical University of Denmark & World Bank Group. URL https://globalwindatlas.info

[21] 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. URL https://resources.marine.copernicus.eu/product-detail/MULTIOBS_GLO_PHY_REP_015_004/INFORMATION

[22] Cerdeiro, Komaromi, Liu and Saeed, 2020. IMF's World Seaborne Trade monitoring system. https://datacatalog.worldbank.org/dataset/global-shipping-traffic-density

[23] UNEP-WCMC, WorldFish Centre, WRI, TNC (2021). Global distribution of warm-water coral reefs, compiled from multiple sources including the Millennium Coral Reef Mapping Project. Version 4.1. Includes contributions from IMaRS-USF and IRD (2005), IMaRS-USF (2005) and Spalding et al. (2001). Cambridge (UK): UN Environment World Conservation Monitoring Centre.

[24] CMA (Caribbean Marine Atlas). 2018. https://www.caribbeanmarineatlas.net/layers/geonode:tv_trinidad_substrait_type_off_east_coast_tri/metadata_detail

To spatially represent fishing effort and intensity by gear type, multiple datasets were reviewed, including tabulated data provided by MALF Fisheries Division. Eventually, it was determined to use the vector polygon data provided by MALF Fisheries Division, to depict fishing effort. It should be noted that these polygons delineate fishing areas by gear type, but do not depict variance in fishing intensity within each area, or compared to the other areas. Therefore, fishing effort by gear type in this model is represented as presence/absence of fishing effort, rather than fishing effort intensity. Polygon data were summarized by four different gear types; gillnet, hook and line, trap, and trawl. The fishing areas for each gear type were converted to raster format to be included in the predictive models. Trawl fishing areas were used to represent areas where conflict with other fishing gears cause loss of gillnet, hook and line, and trap gears, as explained in fisher surveys. Gillnet, hook and line, and trap fishing areas were each given numeric values of either 0 (absence) or 5 (presence) to highlight within the model where those gears may be lost, based on where fishing occurs (Table 5; Figure 12).

[25] Baldwin, K. 2019. Applying Participatory GIS (PGIS) to support an Ecosystem Approach to Fisheries (EAF) for the shrimp resources and trawl fishery in the Gulf of Paria, Trinidad. Final Report to FAO. REBYC-II LAC Project.

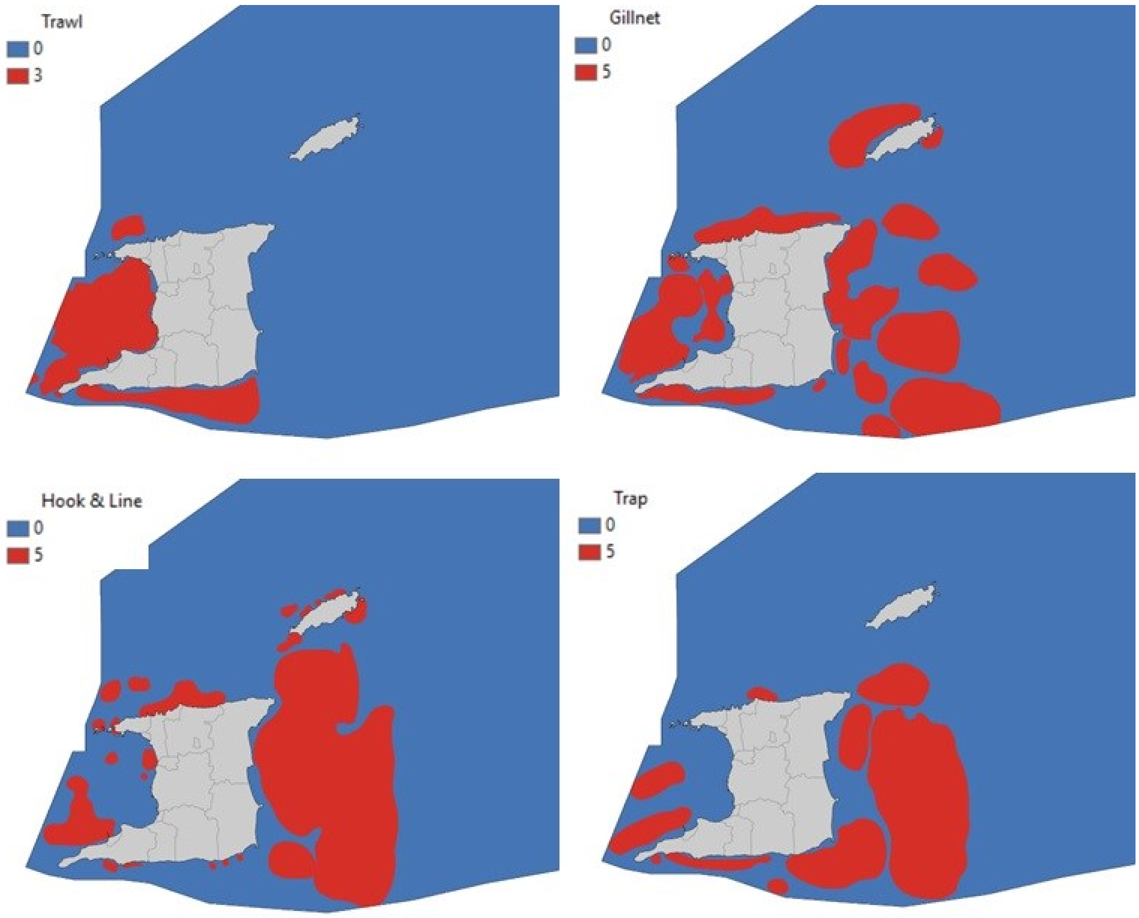

Figure 12. Four input variables representing fishing areas, re-classed to represent probability of ALDFG occurrence in waters of Trinidad and Tobago. 0 = Low Probability, 7 = High Probability.

Because the spatial representation of fishing effort relatively coarse, bathymetry data were also used to distinguish areas where fishing effort most likely occurs, and where gear is most likely to be lost. Based on the fisher surveys, most fishing effort and gear loss, within all gear types modeled, is within 0 – 50 m water depths, followed by 50 – 200 m, and significantly less activity and subsequent gear loss in the 200 – 1,000 m range, and even less in waters beyond 1,000 m. Using these and other anecdotal information, with a focus on gillnets, hook and line, and traps, the bathymetric depth variable was binned into five categories, with 7 being the highest probability for lost gear presence, and 0 being the lowest (Table 5; Figure 13). The shallow water area was given the higher, non-sequential, value of 7 to highlight the significance of this depth range in terms of fishing activity, compared to the other depths.

The Global Wind Atlas dataset provided mean annual wind speed (m/s); wind direction was not analyzed. Assuming there is a direct correlation between higher wind speeds and what would be considered *inclement weather* at sea, the mean wind speeds were split by quantile into four bins, and then classified by rank order 1 – 4, with 4 being the highest wind speeds and most likely to cause gear loss, and 1 being the lowest (Table 5; Figure 13). From the ocean currents data obtained from CMEMS, the monthly mean current speed (m/s) were summarized by month per 0.25° cell within the study area over the two year period 2021 – 2023. For a simple analysis of this parameter as a reason for gear loss, we chose to eliminate the current direction and focus only on current speed. Therefore, each cell was represented by the mean absolute value of current speeds per month over the two year period. As it pertains to contributing to lost fishing gear, we treat current speed similar to wind speed, such that the potential for gear loss increases with the increase in ocean current speed, which is supported by responses in the fisher surveys. The ranking values for ocean currents were split by quantile into three bins of values ranked 1 – 4, from low to high probability of gear loss, respectively (Table 5; Figure 13).

Vessel traffic density as a variable representing potential gear loss due to conflicts with vessel traffic was represented by the dataset showing all observed ship movement from 2015 through 2020 within 500 m cells. Values were split by quantile in to three bins, with a fourth bin representing a zero value where no vessel traffic has been recorded. The bins ranking from 0 – 3 represent low to high probability of gear loss occurring due to conflict with passing vessels (Table 5; Figure 13).

Reef structures were used to represent *underwater obstructions*, with the potential for gear loss and/or accumulation as they can snag and foul both passive and active fishing gears. Spatial distribution of reef structures and rocky substrate were collected from two datasets; that from Caribbean Marine Atlas, which includes substrate types delineated by fishers, and the UNEP global reef dataset. Additionally, point locations of wellheads and shipwrecks in the Gulf of Paria were used to identify where gear could become snagged, and lost, on underwater obstructions. Features from these three datasets were summarized by presence/absence within a 15-arc second cell raster covering the entire study area. Therefore, this does not represent specific known snag locations, rather a known presence or absence of snag locations within each grid cell relative to the entire study area. Values per cell without known obstructions were given a rank value of 0, and those with potential snag hazards were assigned a rank value of 3 (Table 5; Figure 13).

Another way to analyze seafloor features is through bathymetric variance, as abrupt changes in water depth and the ruggedness of benthic terrain can cause gear loss. To identify areas of high bathymetric variance, the bathymetry data was processed to determine the surface area to planar area (SAPA) within a 3-cell radius neighborhood, which is one of several ways to identify changes in terrain[26] (Du Preez, 2014). High values of SAPA represent greater complexity in the benthic terrain, and therefore areas we assume to have greater chances of causing fishing gear loss and/or accumulation. Values ranged from 1.00 – 1.09, and were split by quantile into three bins, 1 – 3, representing low to high probability of ALDFG presence (Table 5; Figure 13).

It should be noted that the differences in number and values of bin rankings per dataset were the result of determining the best fit for the model after analysis of each individual dataset. In some cases, a standard number of bins per variable can often cause models to be overwhelmed by vast spans of high probability areas or understated with a paucity of high probability areas. Additionally, the reliability of the data and the importance of each reason for gear loss is considered during analysis and contribute to the decision process. These considerations can be narrowed when known locations of ALDFG are available to analyze as part of the modeling process.

Table 5. Probability ranking for potential to predict ALDFG presence for datasets used to represent different causes of gear loss.

Rank	**0**	**1**	**2**	**3**	**5**	**7**
Trawl fishing	Absence			Presence		
Gillnet fishing	Absence			Presence	Presence	
Hook and Line fishing	Absence			Presence	Presence	
Trap fishing	Absence			Presence	Presence	
Bathymetry (m)	>3,000	1,000 – 3,000	200 – 1,000	50 – 200		0 - 50
Wind (m/s)		4.11 – 6.33	6.33 – 6.95	6.95 – 7.86		
Ocean currents (m/s)		0.01 – 0.40	0.40 – 0.60	0.60 – 1.42		
Vessel traffic (1million * v/cell)	0	0 – 1.80	1.80 – 10.35	10.35 – 20.00		
Reefs, rocks, wellheads, shipwrecks	Absence			Presence		
SAPA	1	1.000 – 1.003	1.003 – 1.09			

[26]Du Preez, C. 2014. A new arc-chord ratio (ACR) rugosity index for quantifying three-dimensional landscape structural complexity. Landscape Ecology. 30, 181–192.

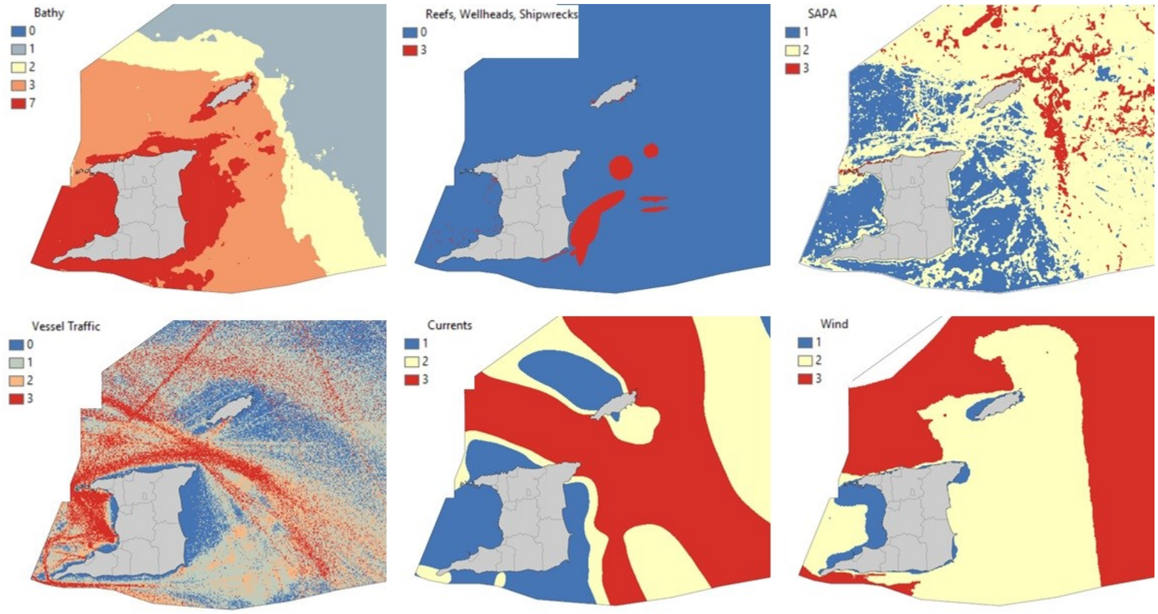

Figure 13. Six input variables re-classed to represent probability of ALDFG occurrence in waters of Trinidad and Tobago. 0 = Low Probability, 7 = High Probability.

Using ArcGIS Spatial Analyst, all datasets that were not in raster format were converted to raster, and the values of each of the six variables were reclassified by their value bins. All re-classed raster sets, except for gillnet, hook and line, and trap effort were input into the ArcGIS Cell Statistics Tool and summed. The output result was a full coverage raster with cell values ranging from 1 to 21 (low to high probability). Then for each of the three gear types, the fishing effort raster was added to the model separately, resulting in a separate model highlighting potential gear loss or accumulation for each of the gear types; gillnet, hook and line, and traps. The final models included cell values ranging from 1 to 26.

Predictive Model Results and Conclusion

Using spatial representation of variables known to influence the probability of fishing gear loss including concentration of fishing effort, bathymetric depths, wind speed, current speed, vessel traffic, and benthic terrains, the probability models reported here provides integer values from 1 to 26 representing low to high probability, respectively, of ALDFG from gillnet, hook and line, and trap fisheries in Trinidad and Tobago territorial waters.

The gillnet predictive model covers 75,793 km^2, with the low half of probability rankings (1 – 14) accounting for 88% of the total study area, with the remaining 12% in the upper probability rankings (15 - 26). Table 6 shows the breakdown of probability rankings by size and percent of total area covered within the study area. The final probability rankings are distributed throughout the study area, in a relatively expected manner, with the patches of highest values where fishing effort is known to occur in high vessel traffic areas, trawl fishing grounds, and where underwater obstructions occur. The greatest concentration of higher ranked areas occur within the trawl fishing zones along the south coast of Trinidad, and in the Gulf of Paria (Figure 14).

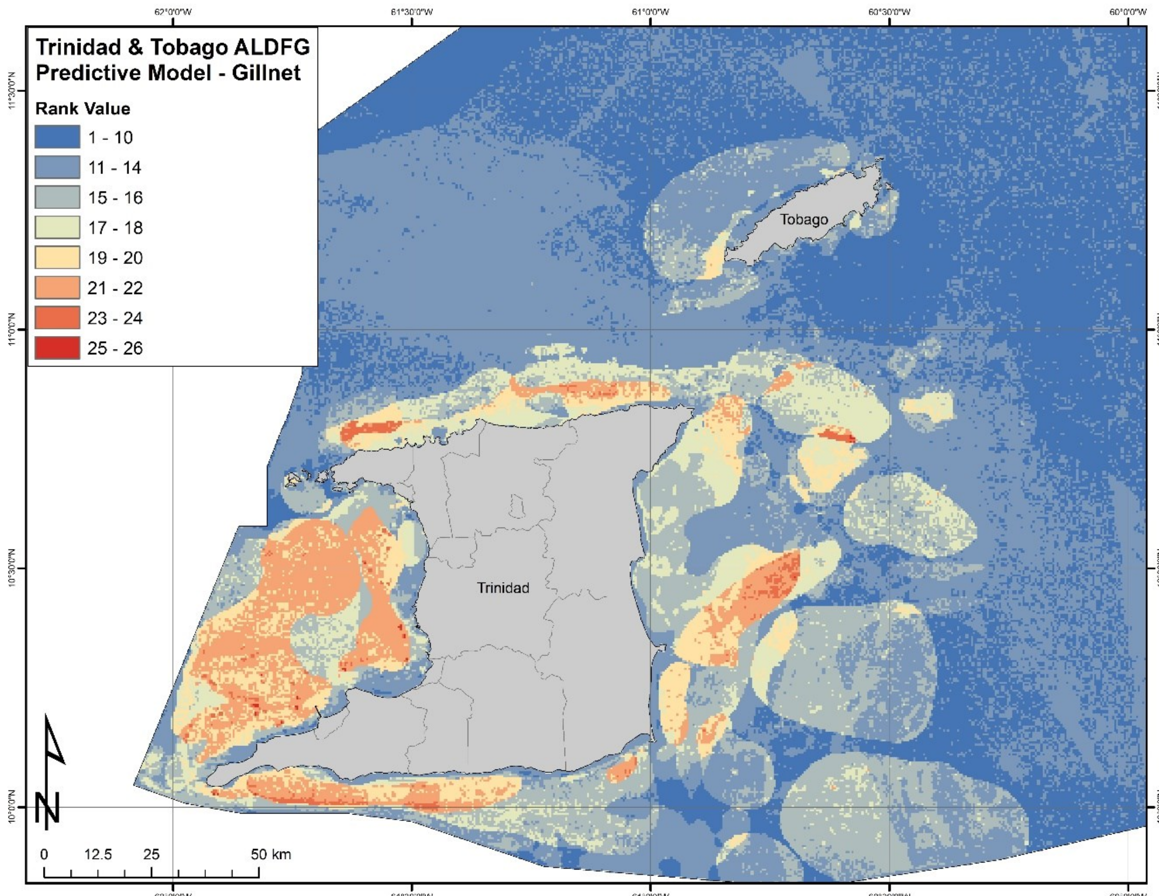

Figure 14. Predictive model results for ALDFG gillnets; areas of low to high potential for occurrence based on spatial analysis of multiple data layers in waters of Trinidad and Tobago.

The hook and line predictive model covers 75,269 km^2, with the low half of probability rankings (1 – 14) accounting for 87% of the total study area, with the remaining 13% in the upper probability rankings (15 - 26). Table 6 shows the breakdown of probability rankings by size and percent of total area covered within the study area. The final probability rankings are distributed throughout the study area, with the greatest concentration of higher ranked areas occurring within the trawl fishing zones in southwest Gulf or Paria, and in the offshore fishing grounds to the east of Trinidad, where rocky reef substrates are known to occur (Figure 15).

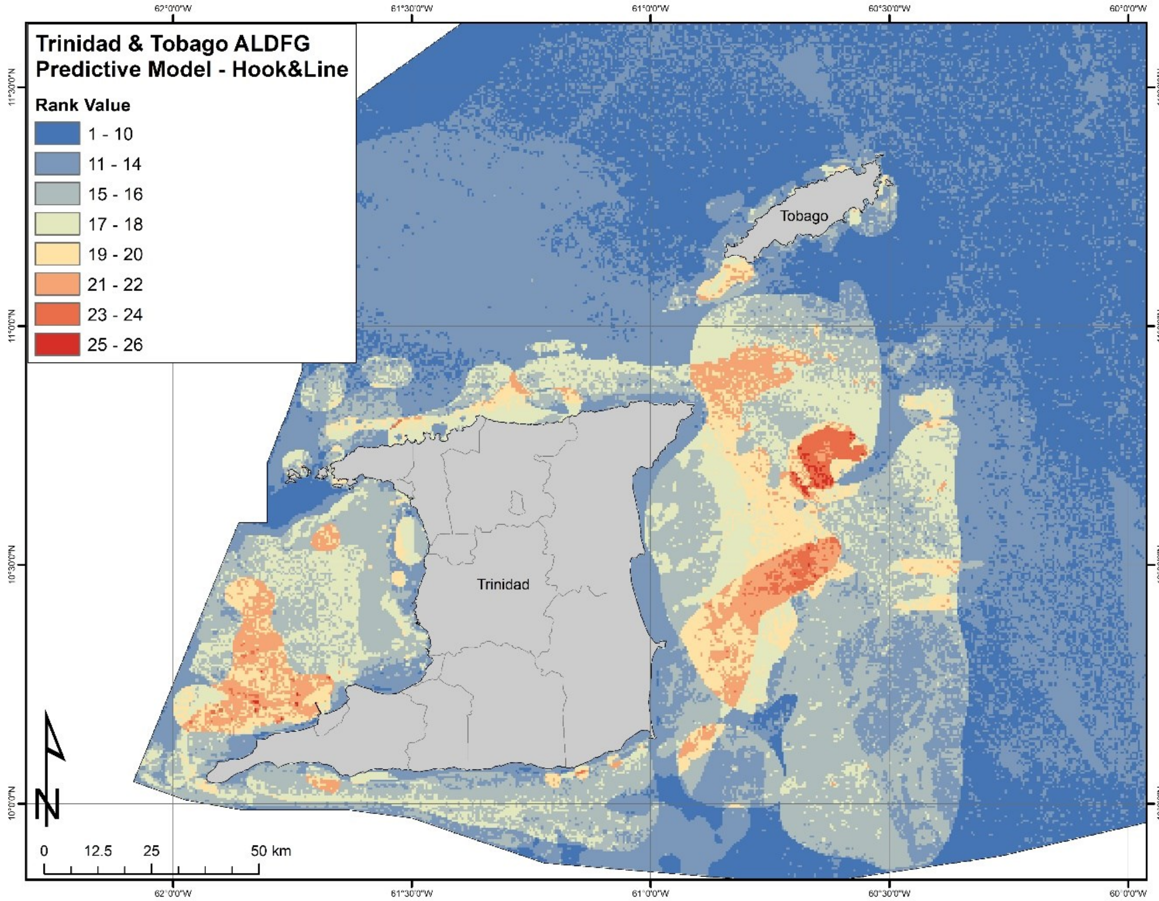

Figure 15. Predictive model results for ALDFG hook and line; areas of low to high potential for occurrence based on spatial analysis of multiple data layers in waters of Trinidad and Tobago.

The trap predictive model covers 75,695 km^2, with the low half of probability rankings (1 – 14) accounting for 88% of the total study area, with the remaining 12% in the upper probability rankings (15 - 26). Table 6 shows the breakdown of probability rankings by size and percent of total area covered within the study area. The final probability rankings are distributed throughout the study area, with the greatest concentration of higher ranked areas occurring within the trawl fishing zones in southwest Gulf or Paria, all along the southern coast of Trinidad, and in the offshore fishing grounds to the east of Trinidad, where rocky reef substrates are known to occur (Figure 16).

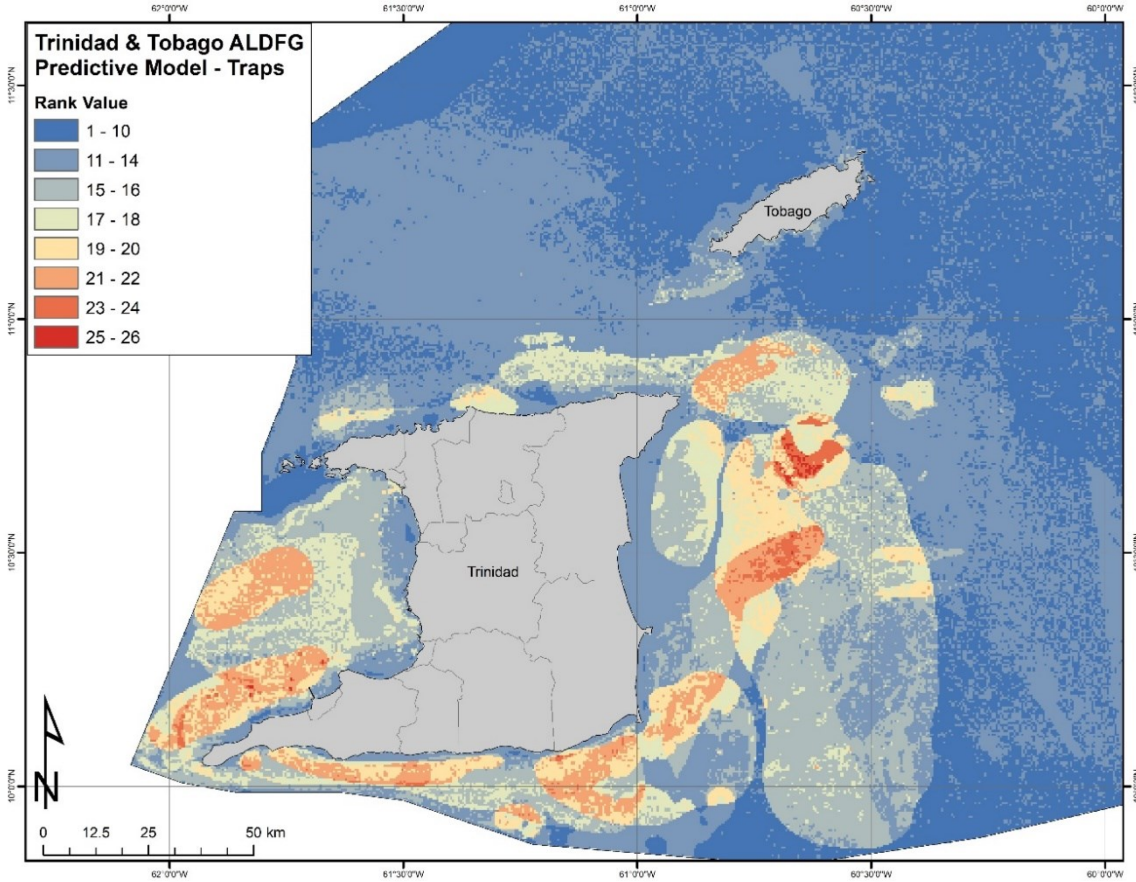

Figure 16. Predictive model results for ALDFG traps; areas of low to high potential for occurrence based on spatial analysis of multiple data layers in waters of Trinidad and Tobago.

Table 6. Total area by square kilometer and percent of total, for different probability rankings (model values) of three ALDFG predictive models developed for Trinidad and Tobago; Gillnet, Hook and Line, and Trap.

	Total Area (km^2)			% of Study Area		
Model Value	**Gillnet**	**Hook and Line**	**Trap**	**Gillnet**	**Hook and Line**	**Trap**
1 - 10	49,196	49,449	50,031	64.9%	65.7%	66.1%
11 - 14	17,471	15,915	16,904	23.1%	21.1%	22.3%
15 - 16	4,535	5,700	4,625	6.0%	7.6%	6.1%
17 - 18	1,400	1,694	1,338	1.8%	2.3%	1.8%
19 - 20	1,440	1,335	1,390	1.9%	1.8%	1.8%
21 - 22	1,592	946	1,188	2.1%	1.3%	1.6%
23 - 24	152	207	197	0.2%	0.3%	0.3%
25 - 26	7	23	23	0.0%	0.0%	0.0%
Total	75,793	75,269	75,695	100%	100%	100%

It should be emphasized that these are not “hot spot” maps; yet we believe that they 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 data from publicly available datasets and known characteristics of ALDFG. The one input feature that did not exist in these models were 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. As the first iteration of this model in Trinidad and Tobago, it is most valuable if considered a working model that is updated as more information becomes available.

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

- TT_ALDFG_PM_Gillnet.shp – vector shapefile with 26 features, each representing coverage of the modeled values 1 – 26 for ALDFG gillnet probability, with attributes describing their area and corresponding probability rankings.
- TT_ALDFG_PM_HookLine.shp – vector shapefile with 26 features, each representing coverage of the modeled values 1 – 26 for ALDFG hook and line probability, with attributes describing their area and corresponding probability rankings.
- TT_ALDFG_PM_Trap.shp – vector shapefile with 26 features, each representing coverage of the modeled values 1 – 26 for ALDFG trap probability, with attributes describing their area and corresponding probability rankings.