Report - Final results: INT2021-02 Characterisation of protected coral interactions

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Client Report for Department of Conservation

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Front cover photo: Cup coral (Courtesy of Department of Conservation).

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1. Summary

This study focused on analyzing the spatio-temporal distribution of observed coral captures in New Zealand's commercial fisheries between the 2007–08 and 2019–20 fishing years. The majority (99%) of reported coral catch was attributed to bottom trawl fisheries. The study specifically examined trends in protected coral species groups, including black corals, gorgonians, lace corals, and stony corals.

The analysis of stony coral catch weights did not reveal a clear pattern over the assessed period, although the first three years stood out with particularly high reported catch weights. However, caution is necessary when interpreting these findings due to inconsistent methods of determining catch weights. The assessment of coral bycatch data and presence-absence data suggests a low risk of coral captures in New Zealand's commercial fisheries within and outside the Exclusive Economic Zone (EEZ), except for stony corals, which are predominantly caught in bottom trawl fisheries targeting orange roughy in the North-East Chatham Rise.

The study suggests that the current grouping of protected coral species is sufficient for assessing coral-fisheries interactions. However, it recommends further differentiating stony corals into stony cup corals and stony branching corals, as the latter have higher catch rate within bottom trawl fisheries. Analysis reveals areas of higher risk for branching corals within FMA6 and FMA9, while cup-forming corals are typically caught within FMA4.

The analysis highlights the limitations of using catch weight as a measure of the impact of fishing on coral reefs. Large coral captures are often subjectively estimated, and the accuracy of reported catch weights is questionable. Therefore, catch weight is not

considered a reliable indicator of fishery impact on coral communities. We suggest assessing the risk of commercial fishing on corals based on presence-absence data of coral captures.

While the analysis of presence-absence data can help identify risk areas of coral catch in commercial fisheries, it does not provide a comprehensive measure of the actual impact on coral communities. Factors such as habitat destruction, physical damage, and post-capture mortality should be considered. The study emphasizes the need for standardized protocols for determining coral catch weights and exploring alternative indicators that capture the broader ecological implications of fishing on coral reefs.

2. Introduction

In this project, protected coral bycatch records stored in the the Centralised Observer Database (COD) for the 2007–08 to 2019–20 fishing years were collated and analysed to assess coral interactions with commercial fisheries in New Zealand (in and outside the Exclusive Economic Zone (EEZ)), and how this relates to predicted coral distributions, so as to assess the risk of coral interactions for various fishery strata (e.g., target fishery, fishing method, etc.). Further, fisher-reported data (in and outside the EEZ) were evaluated to determine its usefulness to further our understanding of the extent of coral bycatch across New Zealand fisheries. Capture locations were mapped, and captures were summarized to identify areas and/or factors with increased risk for coral-fisheries interactions. Where possible, the visual assessment of risk factors was supported via statistical analysis (limited to data within the EEZ) to quantify the relative effect of risk factors on coral taxa. An interactive dashboard allowing DOC and other potential end-users to dynamically explore the results and to restructure outputs different from those provided in the static report was developed.

Objectives

1. To improve our understanding of the historical and current extent of, and variation in, protected coral bycatch across multiple fisheries and fishing methods.
2. To improve our understanding of the risks of fishing to protected corals and how those risks vary temporally and spatially.
3. To understand which coral taxa are most vulnerable to interactions with commercial fisheries.
4. To inform focus areas / fisheries for mitigation efforts.
5. To inform development of a risk assessment.

Table 2.1: Milestones

Milestone	Due date	Status
1: Scoping meeting with DOC	10/11/2021	Completed
2: Preliminary results presentation	01/06/2022	Completed
3. Draft report	30/06/2022	Completed
4. Draft final report	01/09/ 2022	Completed
5. Dashboard development	01/11/2022	Completed
6: Final report/data submission	20/11/2022	Report submitted

3. Methods

Main changes since initial report:

- *CSP and DOC recommendations integrated*
- *Sub-fishery management areas (FMAs) merged into general FMAs (FMA6A joined to FMA6)*
- *Dashboard including instructions finalized*
- *Model fitting to captures of protected coral species*
- *Fisher-reported data assessed*

3.1 Data preparation

Observer-reported coral captures. Coral captures in commercial fisheries are not formally recorded in the Protected Species Captures Database (PSCDB) (Abraham and Berkenbusch, 2019). Therefore, the Centralised Observer Database (COD) was used to characterise the extent and variation of coral bycatch across New Zealand's commercial fisheries. The collection of coral samples by observers commenced in 2007. Therefore, coral-fisheries interactions were updated for the 2007–08 to 2019–20 fishing years.

An extract of observed captures (including attributes such as fishing locations) from the COD were supplied by the Ministry for Primary Industries (MPI). The following data preparation steps were applied:

- Observer-reported coral identifications were subsituted with expert-based coral identifications when these were available (both provided in COD extract).
- Existing and missing (start) fishing event locations (i.e., coordinates) were imputed from fishing locations from the PSCDB which has been subject to rigorous data cleansing (e.g., fixing erroneous locations) and imputation of missing locations (Abraham and Berkenbusch, 2019).
- Remaining missing (start) fishing event locations (i.e., coordinates) were imputed from other data sources in the following sequence: (1) end fishing locations from COD, (2) centroid locations for statistical areas reported in PSCDB (if available for a fishing event), (3) centroid locations for Fishery Management Areas (FMAs) reported in PSCDB (if available for a fishing event).
- Missing (start) FMAs were imputed using FMAs reported in the PSCDB (if available for a fishing event) or by intersecting recorded or updated corrdinates with a spatial layer for FMAs.
- Missing (start) statistical areas were imputed using statistical areas reported in the PSCDB (if available for a fishing event) or by intersecting recorded or updated coordinates with a spatial layer for statistical areas.
- Missing target species were imputed using target species reported in the PSCDB (if available for a fishing event).

In addition to the detailed analysis of observer reported coral bycatch, fisher-reported data were evaluated for its usefulness to further our understanding of coral bycatch. There are two prime considerations during this evaluation: 1) the accuracy of the reported species identifications; and 2) the representativeness of fisher-reported data, relative to the COD data.

Additionally, it is important to note that the coral catch weight reported by observers was not consistently measured via standardized approach across capture events. The provided excerpt of observer-recorded coral captures includes a column (method_analysis_desc) that describes the methods employed to determine the catch weight, typically used for determining the weight of fish. The methods utilized encompass direct weighing of the catch, estimation of the catch through subsamples, and visual estimates. These methods are further dscribed in the results section of this report to evaluate the overall quality of the available coral catch data for this assessment.

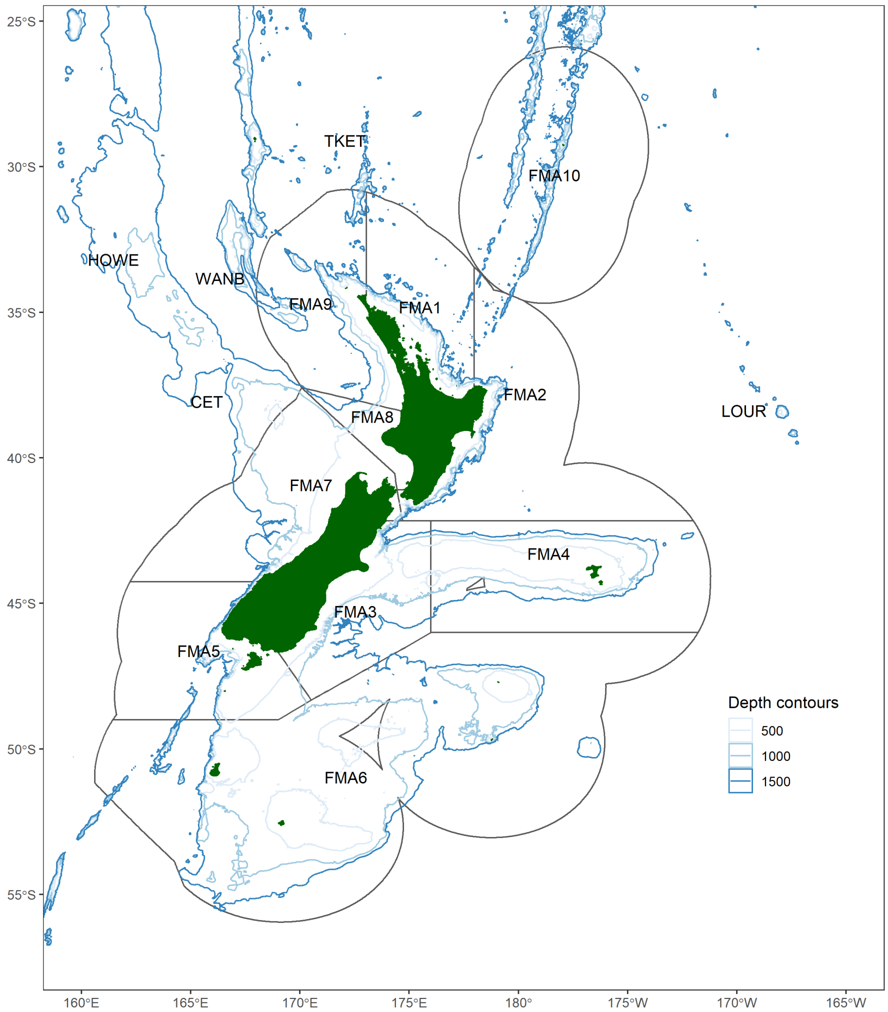

Figure 3.1: Fishery management areas (FMAs) and areas outside the 200 nautical mile EEZ; acronyms outside EEZ are: CET (outside the EEZ on the Challenger Plateau), HOWE (Lord Howe Rise), LOUR (Louisville Ridge), TKET (Three Kings Rise), and WANB (Wanganella Bank); occluded area of the EEZ near Pukaki Rise: PRET; occluded area in FMA4 and general Southern Ocean outside EEZ: SOET.

Fisher-reported coral captures. Fisher-reported species identifications are potentially less reliable, or reported at a higher taxonomic level, than observer-reported captures that have been subsequently verified by an expert. However, fisher-reported data may cover a greater breadth of fishing activities than observed effort, thereby provide a greater overview of coral-fisheries interactions. COD and fisher-reported data are each based on a different sampling process and are therefore subject to different potential biases. Although fishers are legally obliged to report protected species bycatch (i.e., fisher-reported bycatch data is self-selected), under-reporting may occur, hence not necessarily reflecting the true level of bycatch occurring across all fishing events. Whereas observers may only monitor a fraction of all fishing events, and observed fishing events do not necessarily represent a random sample of all fishing events (e.g., some FMA or target species could be over-represented). Hence, both data sets were treated separately.

For fisher-reported captures, a file was provided by MPI that included reported catch weight (in kg) of Cnidaria taxa and information such as fishing start location, target species, etc., for the fishing years 2001–02 (one capture) and 2008–09 to 2020–21. Some data checking and processing steps were applied to the dataset of fisher-reported captures. First, a visual assessement was carried out to check whether the fisher-reported FMA lines up with the actual reported fishing location of each fishing event. In some cases, when there was a mismatch between reported FMA and fishing location (i.e., there are a few events with reported FMA3 but accoring to coordinates it should be FMA5), the FMA was imputed based on the fishing location. Furthermore, some fishing events had FMAs assigned but, based on visual assessment, their actual fishing location was outside the EEZ (e.g., some occurred along Louisville Ridge). These fishing events, and all other events outside the EEZ, were removed from the assessment of fisher-reported coral captures. Finally, missing FMAs were obtained by matching the reported fishing location by intersecting recorded corrdinates with a spatial layer for FMAs.

3.2 Species grouping

The coral species identifications used in this project reflect a mixture of observer-based identifications and expert-based identifications (i.e., when a sample was kept for post-hoc expert identification). Therefore, identification might not be accurate to the lowest taxonomic level. Further, not all specimen were identified to species level. To account for the ease of species identification and some potential inaccuracy in species identification, higher taxonomic level groups were specified in an initial scoping meeting with the Conservation Services Programme (CSP). Two alternate species groupings were developed and results for each will be presented in this report:

1. Four protected coral groups (stony corals, black corals, gorgonians and lace corals) plus coral rubble (separately for live and dead coral rubble)
2. Seven groups that represent a mix of morphological and/or taxonomic division

Coral groups and assigned species are described in Table 6.1. In addtion, results were compiled for 12 individual taxa species level corresponding to those used in species distribution models by Anderson et al. (2020) and including representatives from the four protected coral groups.

3.3 Data summaries and spatial mapping

Coral bycatch was summarised for observer data by FMA, target fishery, species group (e.g., stony corals, black corals, gorgonians and lace corals), fishing method, and fishing year. For a more in-depth assessment of coral-fisheries interactions, spatial maps were compiled for all years combined per species (group) and time series plots of coral bycatch were compiled for FMAs with a high level of reported coral catch.

To contextualize the results of the statistical analysis, additional spatial data layers were compiled: FMA (source: MPI), summarised number of fishing events (number of fishing events sumarised by 0.2° latitude x 0.2° longitude cells), bathymetry (source: NZ 250m gridded bathymetric data set; NIWA; (Mitchell et al., 2012)), and sea surface temperature, chlorophyll a and turbidity (source: NASA's OceanColor Web; (NASA Goddard Space Flight Center, Ocean Ecology Laboratory, Ocean Biology Processing Group, 2018)). Maps were generated using the R-packages sf (Pebesma et al., 2018) and raster (Hijmans, 2022).

Fisher-reported catch weights of corals were summarised by protected coral species groups, fishing year, and FMA. Catch rates for fisher-reported data were not calculated, because a dataset for all commercial fishing in New Zealand was not provided to us.

3.4 Coral captures dashboard

A dashboard was developed that can be used via a web-browser to provide greater ability to investigate the capture data by dynamically creating maps and tables (Figure 3.2). The dashboard was developed using the R-package flexdashboard (Iannone et al., 2020), and includes the following features:

- A panel for mapping observed captures with the option to add other layers such as FMA, number of fishing events at capture locations, etc.
- A panel showing annual trends of captures and capture rates which can be dynamically grouped by different strata
- A panel showing tables of total observed captures which can be dynamically grouped by different strata
- Data filter options (e.g., species, fishing method, fishing year) so as to customize the set of data being tabularized and mapped
- Download option for each map, plot, and table

Instructions for the use of the dashboard and content are provided on the dashboard's landing page.

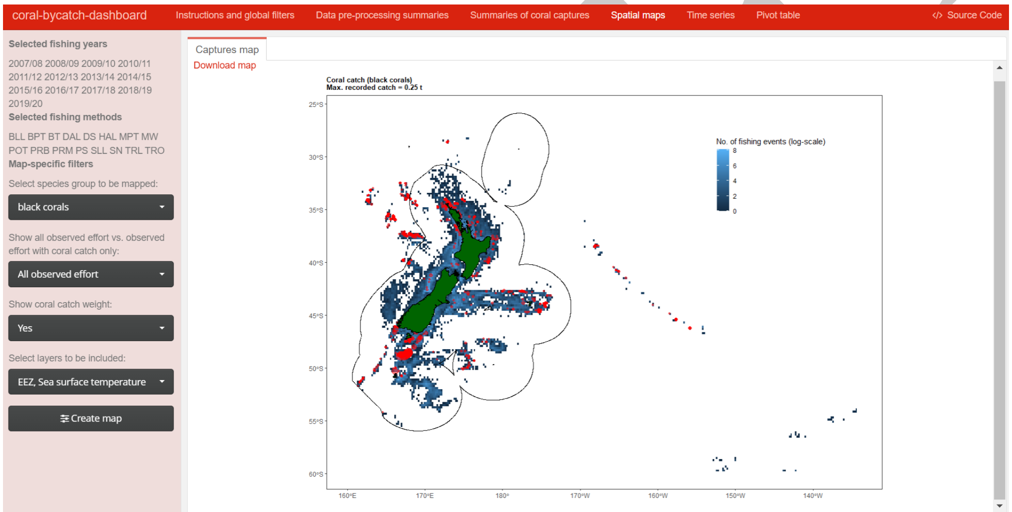

Figure 3.2: Screenshot of the coral bycatch dashboard captures mapping feature.

3.5 Statistical analysis

Generalized Additive Models (GAMs) were used to analyze coral catch data for four protected coral species groups: stony corals, lace corals, black corals, and gorgonians. Two separate models were developed for each coral group: (1) a logistic GAM model to assess the presence or absence of observed coral catch per fishing event, and (2) a GAM model using Box-Cox transformed coral catch weights for fishing events with observed coral catch. The Box-Cox transformation was neccessary to satisfy the assumption of normally distributed data.

Both models were implemented within a GAM framework, allowing for the inclusion of non-linear relationships between coral catch (presence and catch weight) and environmental covariates. The selection of covariates was done in consultation with the Department of Conservation (DOC) and aimed to incorporate factors influencing both the distribution of coral species and spatio-temporal fishing activity.

The chosen covariates included bathymetry, chlorophyll a, and sea surface temperature, as these variables have been found to correlate with coral distribution (Baird et al., 2013) and fishing activity (Wiryawan et al., 2020; Sachoemar et al., 2012; Welliken et al., 2018; Sambah et al., 2021). Thus, they play a crucial role in determining areas where coral-fishery interactions may occur. Fishing method and Fisheries Management Area (FMA) were also considered, as different fishing methods are expected to have varying degrees of interaction with corals. Fishing year and month were included to account for temporal and interannual variations in coral catch. Initially, turbidity was considered as a covariate, but it was later excluded from the model fitting process because preliminary analysis indicated that turbidity and chlorophyll a were confounded.

For bottom trawl fisheries, the fishing method was combined with the target fishery to gain a more detailed understanding of which target fisheries pose the highest risk to corals in New Zealand. The five bottom trawl target fisheries with the highest observed coral catch (across all species) were identified. A covariate called "method_group" was created, consisting of five separate bottom trawl methods for each of the top-five target fisheries, along with a bottom trawl group representing all other target species combined. No specific target species groups were created for other fishing methods. Fishing methods without any observed coral captures were excluded from the model fitting process. Table 3.1 provides an overview of the final method-target species variables used in the analysis. Additionally, it is important to note that the bottom trawl methods MPT, BPT, and BT were combined into a single bottom trawl group, and a similar approach was taken for the mid-water trawl method (refer to Table 4.3 for a description of fishing methods).

Table 3.1: Description of method-target species variable used in the statistical analysis of coral catch. Shown are also catch weight and number fo fishing events per group between the 2007–08 to 2019–20 fishing years. Acronyms for target species are: ORH (Orange roughy, *Hoplostethus atlanticus*), SSO (Smooth oreo *Pseudocyttus maculatus*), SQU (Arrow squid, *Nototodarus sloanii* & *N. gouldi*), BOE (Black oreo, *Allocyttus niger*), SWA (Silver warehou, *Seriolella punctata*).

method_group	Catch weight (t)	Number of fishing events
bottom_trawl_ORH	112.729	11855
bottom_trawl_SSO	39.896	3836
bottom_trawl_SQU	36.946	20620
bottom_trawl_other_targets	4.749	67679
bottom_trawl_BOE	3.302	2234
bottom_trawl_SWA	1.434	3120
set_netting	0.666	8347
midwater_trawl	0.556	59705
bottom_longlining	0.350	9741
pots	0.002	1088
danish_seining	0.000	249

The logistic regression model for presence and absence of observer-reported coral captures was as followed:

$$\begin{aligned} log(\frac{P}{(1-P)}) \sim s(bathymetry, k=4) + s(chlor_a, k=4) + s(sst, k=4) + \\ s(fishing\_year, method\_group, bs = \text{"re"}) + method\_group + \\ month + start\_obs\_fma \end{aligned} \quad (3.1)$$

where $log(\frac{P}{(1-P)})$ is the log-odds of coral catch occuring during a fishing event. $s(bathymetry, k=4)$, $s(chlor\_a, k=4)$, and $s(sst, k=4)$ are smooth terms (each with four knots) to allow for potential non-linear relationships between the odds-ratio of coral catch and each environmental covariate. $s(fishing\_year, method\_group, bs = \text{"re"})$ denotes a random fishing year effect interacting with the combined fishing method and target fishery variable, to allow that annual coral catch can vary independently for each fishing method and target fishery. $method\_group$ is a fixed effect for the combined fishing method and target fishery variable to account for different fishery-coral interaction per fishing method and also to account for fishing method-specific fishing effort units. The fixed effects $month$ and $start\_obs\_fma$ allow for different fishing effort (and hence fishery-coral interactions) throughout the year and fishery management areas (as a proxy for the spatial distribution of fishing activity).

The goodness of fit for the logitics regression model was assessed using the the Hosmer-Lemeshow test (Hosmer Jr et al., 2013). Data were split into 20 groups based on predicted probabilities of coral catch. Within each group the observed and expected proportions of coral catch (both presence and absence) were calculated and visually assessed.

The model for coral catch weight on fishing events with observer-reported coral captures used the same variable and was as followed:

$$(catch^{\lambda}-1)/\lambda) \sim s(bathymetry, k=4) + s(chlor_a, k=4) + s(sst, k=4) \\ +s(fishing\_year, method\_group, bs = "re") + \\ method\_group + month + start\_obs\_fma \tag{3.2}$$

where $(catch^{\lambda}-1)/\lambda)$ is the Box-Cox transformed coral catch weight for for fishing events with reported coral catch. The Box-Cox power transformation λ was numerically derived using the boxcox-function by the R-package MASS (Venables and Ripley, 2002). Standard Q-Q plots were used to assess the model fit and additionally predicted catch weights were visually compared against actual observations.

Given the wide range of observed coral captures, particularly for stony corals (see results), we also fitted both models to an alternative data set for stony corals that included only reported captures smaller than one tonne. Results for model fits to a reduced and full data set of stony corals were compared to understand the potential implications of potentially over-reported coral captures on the model results.

4. Results

4.1 Data imputation

Between the fishing years 2007–08 and 2019–20, a total of 188 967 fishing events were reported in the Catch Effort Observer Database (COD), out of which 7371 events included documented coral captures (Table 4.1). Several data imputation procedures were carried out to address missing information (Table 4.2). For one fishing event (0.001% of all events), the missing effort record was obtained from the Protected Species Capture Database (PSCDB). However, for 60 records (0.031% of all events), effort data could not be obtained from any other sources.

To fill in missing Fisheries Management Areas (FMAs), the reported start positions were intersected with spatial polygons representing FMAs, overwriting or imputing FMAs for 93.648% of all fishing events. Existing FMA records were overwritten to remove any potential instances of false reporting (assuming the start positions were more accurate). Similarly, areas outside the Exclusive Economic Zone (EEZ) were recreated by intersecting the reported start positions with spatial polygons for areas outside the EEZ, which was applied to 4.907% of all fishing events.

Manual changes were made for 0.041% of all fishing events, including changing the area code ET (representing the general outside EEZ code) to SOET (occluded area in FMA 4) based on visual assessment of actual fishing locations. Additionally, one event had the area code changed from LOUR (Louisville Ridge) to FMA2 after visual assessment of fishing locations. The FMA code remained missing for 0.021% of all fishing events.

The COD start fishing locations (latitude and longitude) were replaced or imputed (if missing) with start locations from the PSCDB for 90.158% of all fishing events. In some cases, missing start locations in COD were imputed using fishing end locations from the COD for 0.018% of all fishing events. The start fishing location remained missing for 0.055% of all fishing events.

Observed coral species codes were replaced with codes based on expert identification for 0.464% of all fishing events (note that not all fishing events included coral captures). Statistical areas were imputed by matching fishing start positions against spatial polygons for 93.714% of all fishing events, while outside EEZ area codes were used for 6.251% of all fishing events. Missing target species were imputed using target species codes reported in the PSCDB for 5.756% of all fishing events.

In the case of trawl fisheries, most records only reported the general code for trawling, while additional information on bottom- and midwater-trawling was available in a separate column (gear code). Therefore, for all trawl fishing events, the fishing method was updated using the actual gear code for 80.957% of all fishing events. For 0.015% of all fishing events, the gear code (and thus the fishing method) was obtained from the PSCDB. A detailed description of all fishing methods can be found in Table 4.3.

Table 4.1: Summary of fishing events and coral catch (all methods) per FMA and outside EEZ areas between the 2007–08 to 2019–20 fishing years; Outside EEZ acronyms are: CET (Challenger Plateau), HOWE (Lord Howe Rise), LOUR (Louisville Ridge), SOET (occluded area in FMA 4), WANB (Wanganella Bank), TKET (Three Kings Rise).

FMA	No. of observed events	No. of observed events with coral catch	Perc. of observed events with catch	Catch weight (t)	Catch rate (tonnes per 100 events)
Within EEZ					
FMA4	18800	1129	6.01	93.017	0.495
FMA9	12495	435	3.48	20.668	0.165
FMA6	30839	887	2.88	42.378	0.137
FMA5	26032	821	3.15	26.281	0.101
FMA3	25588	637	2.49	3.195	0.012
FMA2	6604	153	2.32	0.46	0.007
FMA1	13080	317	2.42	0.671	0.005
FMA7	33541	248	0.74	0.276	0.001
FMA8	11086	43	0.39	0.05	0
FMA10	11	0	0	0	0
Outside EEZ					
LOUR	2277	760	33.38	19.917	0.875
WANB	843	364	43.18	2.923	0.347
TKET	117	46	39.32	0.298	0.254
HOWE	3458	677	19.58	1.901	0.055
CET	4108	833	20.28	1.390	0.034
SOET	88	21	23.86	0.012	0.013
All areas	188967	7371	3.9	213.436	0.113

Table 4.2: Summary of data imputation applied to observed fishing events in COD between the 2007–08 to 2019–20 fishing years; shown are affected variables, imputation step (blank fields: no data imputation applied), number of affected events, and percentage of affected events.

Variable	Imputation	No. of events	Percentage of events
effort		191163	99.968
effort	unresolved	60	0.031
effort	effort from PSCDB taken	1	0.001
fma	start position matched against FMA layer	179078	93.648
fma	start position matched against outside-eez-area layer	9383	4.907
fma		2643	1.382
fma	ET changed to SOET	78	0.041
fma	FMA unresolved	41	0.021
fma	manual fix from LOUR to FMA2	1	0.001
lat	replaced with start latitude from PSCDB	172404	90.158
lat		18680	9.769
lat	start latitude unresolved	106	0.055
lat	replaced with end latitude from COD	34	0.018
long	replaced with start longitude from PSCDB	172404	90.158
long		18680	9.769
long	start longitude unresolved	106	0.055
long	replaced with end longitude from COD	34	0.018
species_obs		190336	99.536
species_obs	replaced with expert identification	888	0.464
stats_areas	start position matched against stats area layer	179203	93.714
stats_areas	outside EEZ areas used	11953	6.251
stats_areas		64	0.033
stats_areas	stats area unresolved	4	0.002
target		180218	94.244
target	target species from PSCDB used	11006	5.756
trawl_method	COD gear code used	154810	80.957
trawl_method		36385	19.027
trawl_method	replaced with gear code from PSCDB	29	0.015

Table 4.3: Description of methods and fishing effort and catch rate units.

Acronym	Description	Fishing effort unit	Catch rate unit
MPT	Midwater pair trawl	no. of tows	t per 100 tows
BPT	Bottom pair trawl	no. of tows	t per 100 tows
PRM	midwater trawls fitted with a patented Modular Harvest System	no. of tows	t per 100 tows
PRB	bottom trawls fitted with a patented Modular Harvest System	no. of tows	t per 100 tows
BT	Bottom Trawl (single)	no. of tows	t per 100 tows
MW	Midwater Trawl (single)	no. of tows	t per 100 tows
POT	Pots unspecified, includes Rock lobster pots and/or cod pots	no. of pots	t per 100 pots
DS	Danish Seine	no. of tows	t per 100 tows
PS	Purse Seine	no. of tows	t per 100 tows
TRO	Trolling lines	no. of lines	t per 100 lines
BLL	Bottom Longline	no. of hooks	t per 10,000 hooks
SLL	Surface Long Line (tunas etc.)	no. of hooks	t per 10,000 hooks
DAL	Drop or Dan Lines	no. of hooks	t per 10,000 hooks
HAL	Handlines	no. of hooks	t per 10,000 hooks
TRL	Trot Lines	no. of hooks	t per 10,000 hooks
SN	Set Net	net length in meter	t per 10,000 meter

4.2 Data quality

For 97% of all capture events in the assessed data, the method used to determine the coral catch weight was not documented. Approximately 0.7% of capture fishing events approximated the catch weight (e.g., extact count of catch times the estimated or averaged weight of a specimen). In 0.05% of assessed capture events, the reported coral catch weight was based on what is described as a vessel figure (Table 4.4). For 0.78% of assessed capture events, the catch weight was determined through a full measurement of the catch, where it was weighed in its entirety. Approximately 1.6% of assessed capture events reported coral catch weight based on eyeball estimates, which accounted for 88% of the reported coral catch weight between the 2007–08 to 2019–2 fishing years.

Figure 4.1 illustrates the observed annual catch weight for stony corals by method and the type of catch weight estimation. Generally, reported stony coral catch weight based on eyeball estimates was considerably higher compared to other methods used to determine coral catch weights. This discrepancy was particularly noticeable for bottom trawling in the 2008–09 fishing year, where the total stony coral catch weight exceeded 60 tonnes for capture events with eyeball estimates, in contrast to only 0.2 tonnes when based on fully weighed coral catch after hauling. However, higher-than-usual stony coral catch during the 2008–09 fishing year was also recorded when based on fully weighed coral catch and approximated catch weight. Similar patterns were observed for the other three protected coral groups (Figures 6.1 to 6.3).

Table 4.4: Description of methods to determine coral catch weight by observers. Column grouping: Estimation methods grouped into categories used for Figure 4.1.

Estimation method	Grouping	Catch weight (t)	Number of reported capture events
Eyeball estimate	Eyeball estimate	173.526	3067
Vessel figure	Vessel figure	5.251	102
Weighed in full	Weighed in full	5.18	1520
Calculated by deduction (the total catch weight minus the weights of all other species)	Approximated	4.648	4
Exact count of bins x estimated or average weight of a bin	Approximated	2.881	60
Inexact count of bins x estimated or average weight of a bin	Approximated	2.774	15
Eyeball estimate of greenweight x species composition (from time sampling)	Eyeball estimate	2.11	17
Exact count of fish x estimated or average weight of a fish	Approximated	1.907	871
Inexact count of fish x estimated or average weight of a fish	Approximated	0.582	364
NA	Unknown	0.554	188435
Accurate full count of bins x average weight (obtained from a random sample of bins in a previous appropriate tow in this trip)	Approximated	0.349	4
Accurate full count of bins x average weight of bins obtained from a random sample of bins in this tow.	Approximated	0.31	2
Measured dimensions of catch x average density x species composition	Approximated	0.024	1
Accurate full count of fish x average weight obtained from a random sample from this tow.	Approximated	0.006	5
Accurate full count of fish x average weight obtained from a random sample of fish in a previous appropriate tow in this trip	Approximated	0.004	5

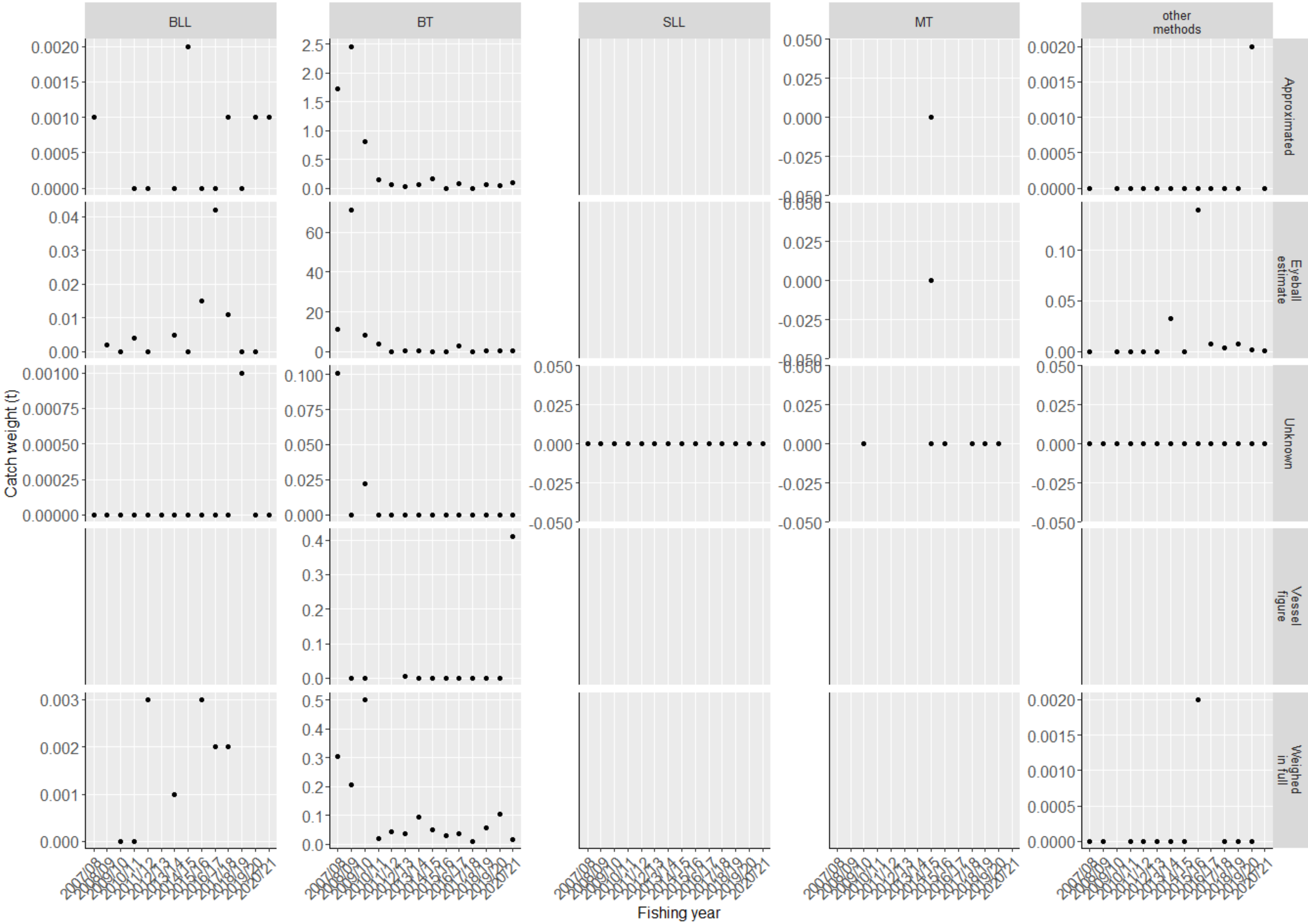

Figure 4.1: Time series of observed stony coral catch weight by fishing method and methodology to determine catch weight as recorded by observers.

4.3 Overall coral captures

In what follows is an overview of observed fishing effort and captures of all coral taxa combined to assess the general distribution of coral-fishery interactions across management areas within and outside the EEZ (Fig. 3.1) and across fishing methods. A summary of coral captures per species group is provided in the subsequent section.

Between the 2007–08 to 2019–20 fishing years, single bottom trawling (BT) was the fishing method with the highest number of observed fishing events (103 819 events) , followed by mid-water trawling, (56 544 events), bottom-longlining (BLL; 9434 events), set-netting (SN; 4202 events), single bottom trawl fitted with a Modular Harvest System (PRB; 4202 events), surface-longlining (SLL; 3979 events), and purse seining (PS; 1473 events). For all other methods, the number of observed fishing events was smaller than 1000 events (range: 1 to 859 events) (Table 4.5). Withing the EEZ, the top-five areas with the highest number of observed fishing events (predominantly BT) were: FMA7, FMA6, FMA5, FMA3, and FMA4. Outside the EEZ, observed fishing effort occurred predominantly (i.e., with more than 1000 observed fishing events) in the areas Challenger Plateu (CET), Lord Howe Rise (HOWE), and Wanganella Bank (WANB) (Table 4.5).

Table 4.5: Number of observed fishing events between 2007–08 to 2019–20 fishing years by FMA (and outside EEZ areas) and fishing method; outside EEZ acronyms are: CET (Challenger Plateau), HOWE (Lord Howe Rise), LOUR (Louisville Ridge), SOET (occluded area in FMA 4), WANB (Wanganella Bank), TKET (Three Kings Rise); see Table 4.3 for method descriptions.

	BT	MW	BLL	SN	PRB	SLL	PS	POT	PRM	DS	TRO	DAL	BPT	HAL	TRL	MPT	Totals
FMA7	11188	19843	470	190	200	1378	131	5	66		68		1			1	33541
FMA6	19439	9873	1438		44				15				30				30839
FMA5	15270	8321	359	1424	49	518		17				33	41				26032
FMA3	15019	4736	897	3373	760	19	13	738	12		1	12	8				25588
FMA4	15161	1430	1985		190			27	1				6				18800
FMA1	6096	96	2458	8	1979	1166	1008	16		249		3			1		13080
FMA9	8630	2171	280	119	802	230	219	2			17	24		1			12495
FMA8	483	7376	647	2340	1	6	84	48			101						11086
FMA2	2821	2122	461	6	173	650	18	6	333		5	1	1		7		6604
FMA10						11											11
Outside EEZ																	
CET	3792	22	136		4	1						85		68			4108
HOWE	2902	554												2			3458
LOUR	2261		13								3						2277
WANB	680		162											1			843
TKET	75		42														117
SOET	2		86														88
Totals	103819	56544	9434	7460	4202	3979	1473	859	427	249	195	158	87	72	8	1	188967

Overall, fisheries targeting orange roughy have the highest interaction with corals. For these fisheries, 3579 out of 7371 observed fishing events had reported coral captures with most of them occuring along the Challenger plateu (CET), Louisville ridge (LOUR), Lord Howe Rise (HOWE), FMA4, Wanganella Bank (WANB), and FMA9 (Table 4.6).

Within the EEZ, the top-four FMAs with highest total catch and catch rates per 100 observed events were FMA4, FMA9, FMA6, and FMA5, with a catch rate of 0.495, 0.165, 0.137, and 0.101 tonnes of coral catch per 100 observed events, respectively (Table 4.1). The top-two targeted species (based on catch weight) in each of these FMAs were typical deepwater species (Table 4.6): orange roughy (*Hoplostethus atlanticus*) and scampi (*Metanephrops challengeri*) (FMA4), orange roughy and tarakihi (*Nemadactylus macropterus* & *N. rex*) (FMA9), smooth oreo (*Pseudocyttus maculatus*) and black oreo (*Allocyttus niger*) (FMA6), and arrow squid (*Nototodarus sloanii* & *N. gouldi*) and school shark (*Galeorhinus galeus*) (FMA5).

Outside the EEZ, Louisville Ridge (LOUR) stand out with the highest coral catch rate (0.875 tonnes per 100 observed events compared to 0.347 tonnes per 100 observed events for the outside-EEZ area with the second highest coral catch rate (WANB: Wanganella Bank); Table 4.1) and fisheries in all areas outside the EEZ targeted predominantly orange roughy (Table 4.6).

Table 4.6: The number of observed fishing events (all methods) with reported coral catch, by area and target species between the 2007–08 to 2019–20 fishing years; refer to 4.1 for outside EEZ acronym descriptions.

Target	FMA1	FMA2	FMA3	FMA4	FMA5	FMA6	FMA7	FMA8	FMA9	CET	HOWE	LOUR	SOET	TKET	WANB	Totals
ORH	124	59	3	518	7	73	98	1	316	812	488	747			333	3579
SQU			75	15	511	80										681
HOK	7	16	304	144	25	31	32									559
SSO			51	55	17	237										360
SCI	2	16		278		5										301
HAK			4		15	107	82									208
BOE			7	4	3	176						2				192
BYX	1	27	1	16					21	1	78					145
LIN	1	5	27	31	25	34	6		2							131
BYS	9	3		8					3	4	102	1				130
SWA			60	16	51											127
SCH			24	13	88		1		1							127
S	101						1		6							108
TAR	34	6	9				2		37							88
OEO			2	4		77										83
WWA			2		55	5										62
JMA			6		2		17	30	4							59
PTO						52										52
CDL	9	18								7	8				4	46
YBO														45		45
BAR			15	9	13		5									42
SPO			39		2											41
TRE	10							4	24							38
HPB							1			1		6			13	21
ATO													21			21
BNS	4		1							8					7	20
SPE				13												13
BAS	1								4						7	12
HAP	1		2	5								4				12
RSN	2								10							12
NOS					6	2										8
RBY	5	3														8
SBW						8										8
GUR	1						1		5							7
WAR								7								7
JDO	5															5
RBT			1		1											2
RCO			2													2
SBO														1		1
FLA							1									1
CRA								1								1
SOR											1					1
SKI							1									1
UNI									1							1
MDO									1							1
MIX			1													1
TRU			1													1
Totals	317	153	637	1129	821	887	248	43	435	833	677	760	21	46	364	7371

The methods for which coral captures were reported between the 2007–08 to 2019–20 fishing years were: single bottom-trawling (BT), bottom-longlining (BLL), mid-water trawling (MW), set-netting (SN), bottom trawl fitted with a Modular Harvest System (PRB), midwater trawling fitted with a Modular Harvest System (PRM), and paired bottom trawling (BPT) (Table 4.7). For all other methods, there existed no reports of coral captures on observed fishing events. The fishing method with the hightest number of observed fishing events (6615 events) was bottom-trawling, with 211.58 tonnes of corals being observed caught between the 2007–08 to 2019–20 fishing years, resulting in an observed captures rate of 0.204 tonnes per 100 trawls. For all other methods with reported coral catch, the number of fishing events with reported coral catch ranged from 11 (out of 87 observed BPT events) to 271 (out of 9435 BLL events) events. Some bottom-trawlers used alternative gear configuratons: (1) paired bottom-trawling (BPT) and (2) bottom trawl fitted with a Modular Harvest System (PRB) and the coral catch rates were 0.007 and 0.006 tonnes per 100 trawls, respectively (but note the small number of observed fishing events relative to the usually applied single bottom trawling (BT). Note that the catch rates are note compareable across all fishing methods because of different units for fishing effort.

Within the EEZ, the top-four management areas with highest reported coral catch were: FMA4, FMA6, FMA5, and FMA9 (range: 20.668 to 93.017 tonnes of reported coral catch), and 99% of reported coral catch in these area was for single bottom trawl fisheries (Table 4.8). Outside the EEZ, the majority of coral catch was reported for the Louisville Ridge (19.981 tonnes compared to 26.452 tonnes for all outside-EEZ areas combined).

Table 4.7: Summary of fishing effort and total coral catch in tonnes per method between the 2007–08 to 2019–20 fishing years. Method acronyms and associated units for effort and catch rate are described in Table 4.3. Rows are ordered by number of events with catch.

Fishing method	Total observed effort	Catch weight (t)	Catch rate	No. of observed events	No. of observed events with coral catch	Perc. of events with catch
BT	103828	211.58	0.204	103828	6615	6.37
BLL	40146737	0.37	0	9435	271	2.87
MW	56545	0.49	0.001	56545	178	0.32
SN	7035965	0.65	0.001	7460	159	2.13
PRB	4202	0.26	0.006	4202	114	2.71
PRM	427	0.09	0.02	427	11	2.58
BPT	87	0.01	0.007	87	11	12.64
POT	884	0	0	884	11	1.24
DS	249	0	0	249	1	0.4
DAL	10089	0	0	158	0	0
HAL	1165	0	0	72	0	0
MPT	1	0	0	1	0	0
PS	1473	0	0	1473	0	0
SLL	6037979	0	0	3979	0	0
TRL	10625	0	0	8	0	0
TRO	200	0	0	200	0	0

Table 4.8: Observer-reported coral catch weight in tonnes between 2007–08 to 2019–20 fishing years by FMA (and outside EEZ areas) and fishing method; outside EEZ acronyms are: CET (Challenger Plateau), HOWE (Lord Howe Rise), LOUR (Louisville Ridge), SOET (occluded area in FMA 4), WANB (Wanganella Bank), TKET (Three Kings Rise).

	BT	MW	BLL	SN	PRB	SLL	PS	POT	PRM	DS	TRO	DAL	BPT	HAL	TRL	MPT	Totals
Within EEZ																	
FMA4	92.864	0.032	0.116		0.005			0	0				0				93.017
FMA6	42.249	0.015	0.113		0				0				0.001				42.378
FMA5	25.47	0.351	0.011	0.445	0	0		0				0	0.004				26.281
FMA9	20.618	0.001	0.012	0	0.037	0	0	0			0	0		0			20.668
FMA3	2.925	0.038	0.035	0.194	0.001	0	0	0.002	0		0	0	0.001				3.196
FMA1	0.422	0	0.032	0	0.216	0	0	0		0		0			0		0.67
FMA2	0.43	0.006	0.014	0	0	0	0	0	0.01		0	0	0		0		0.46
FMA7	0.179	0.01	0.009	0.002	0	0	0	0	0.075		0		0			0	0.275
FMA8	0.026	0.017	0	0.007	0	0	0	0			0						0.05
FMA10						0											0
Outside EEZ																	
LOUR	19.917		0.001								0						19.918
WANB	2.906		0.017											0			2.923
HOWE	1.884	0.017												0			1.901
CET	1.389	0.001	0.001		0	0						0		0			1.391
TKET	0.298		0														0.298
SOET	0		0.012														0.012
Totals	211.577	0.488	0.373	0.648	0.259	0	0	0.002	0.085	0	0	0	0.006	0	0	0	213.438

Figures 4.2 and 4.3 show the spatial distribution of fishing activity for all fishing methods combined and for trawling only, respectively. Observed fishing effort occurred along the NZ coastline and areas such as the Auckland Islands shelf, Campbell plateu and outside EEZ areas such as Louisville ridge (Fig. 4.2). Most of that observed fishing activity was bottom trawling (Fig. 4.3 and Table 4.7) and reflected the general distribution of total bottom trawl fishing activity (not shown here). Fishing events with observed coral catch typically occurred around seamount features, slope margins and on flat tops of slopes or rises (Figs. 4.4 and 4.5).

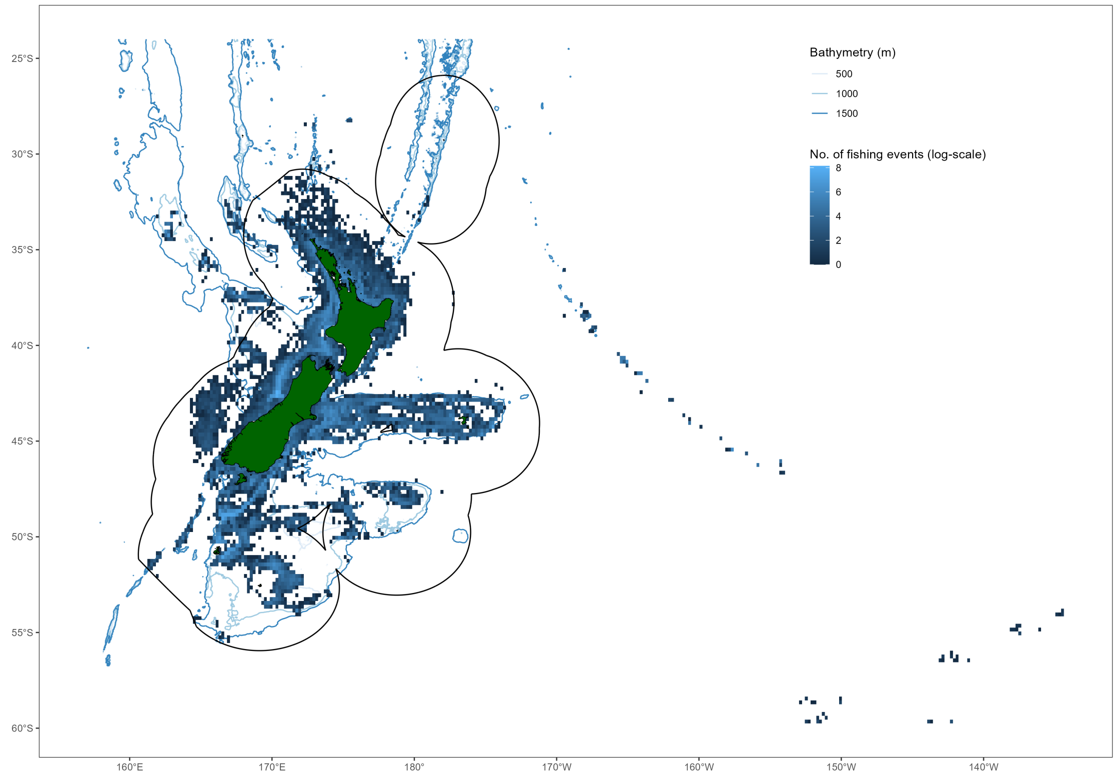

Figure 4.2: Distribution of observed fishing events for all methods (0.2° latitude x 0.2° longitude cells) between the 2007–08 and 2019–20 fishing years.

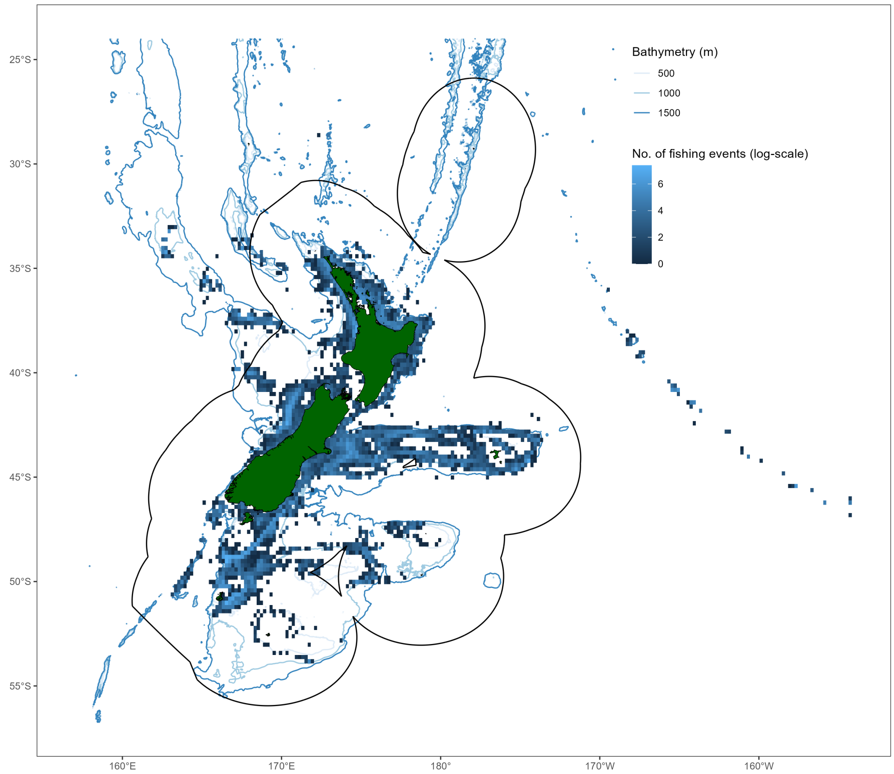

Figure 4.3: Distribution of observed fishing events (i.e., number of tows) for bottom-trawl fisheries ($0.2°$ latitude x $0.2°$ longitude cells) between the 2007–08 and 2019–20 fishing years.

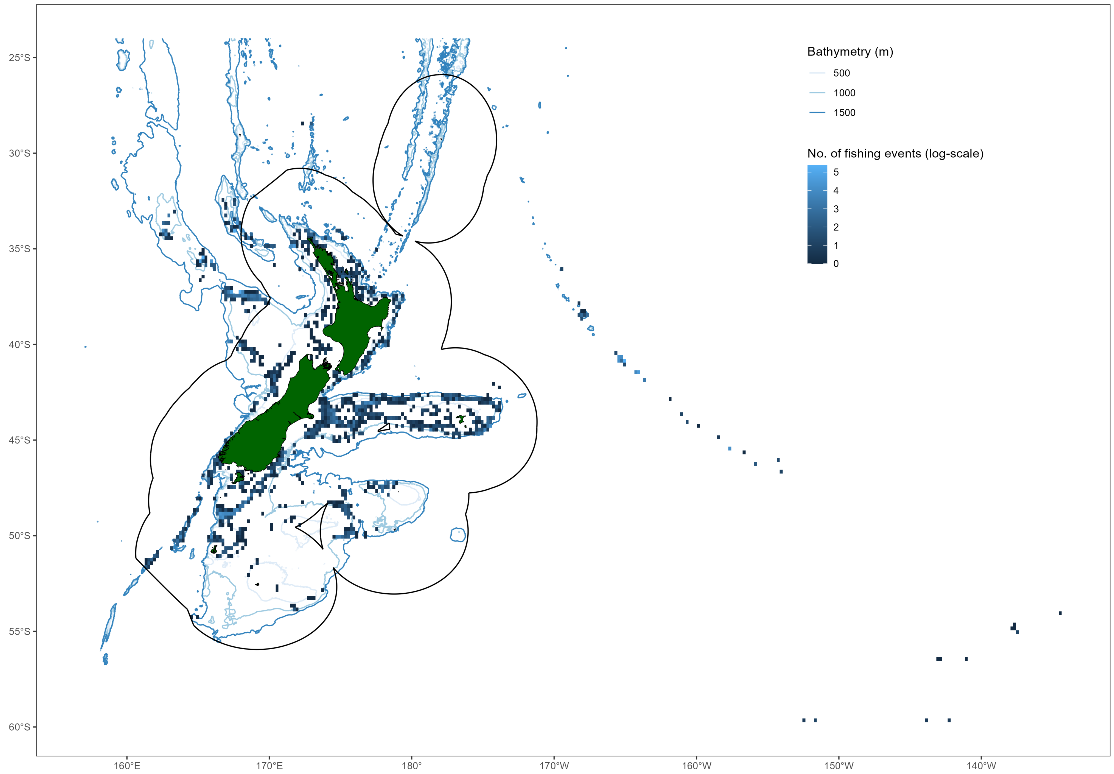

Figure 4.4: Distribution of observed fishing events with reported coral catch for all methods ($0.2°$ latitude x $0.2°$ longitude cells) between the 2007–08 and 2019–20 fishing years.

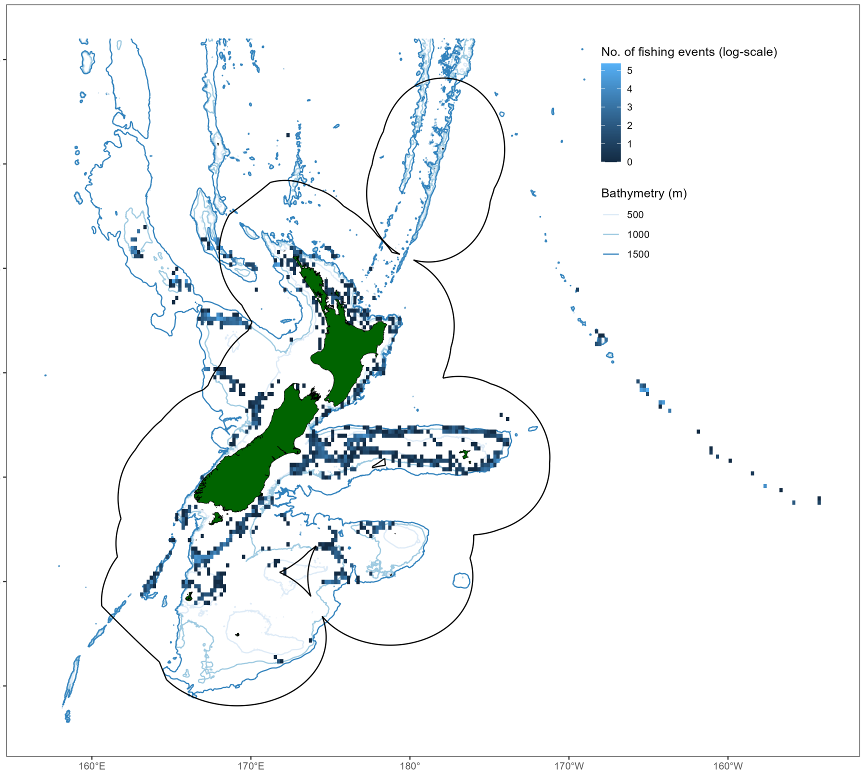

Figure 4.5: Distribution of observed fishing events (i.e., number of tows) with reported coral catch for bottom-trawl fisheries ($0.2°$ latitude x $0.2°$ longitude cells) between the 2007–08 and 2019–20 fishing years.

4.4 Species group-specific coral catch

99% of coral catch was observed in bottom trawl fisheries (Tables 4.94.10). Based on observed catch weights, stony corals were the predominant coral group (131.078 tonnes or approx. 76% across all protected coral species groups) caught on observed fishing events between the 2007–08 and 2019–20 fishing years (Table 4.9), and stony coral captures were mainly comprised of branching stony corals (Table 4.10). All other coral groups were caught in a smaller order of magnitude (range: 3.633 to 13.250 tonnes; Table 4.9). Except for stony corals, alternative species grouping by morphology and/or taxonimic division does not indicate substantial changes in results when, for example, splitting gorgonians into three separate groups (Table 4.10). Note that in some cases, zero tonnes of returned coral catch were recorded for danish seining (DS), but was listed as a method with reported coral catch. For the species with known species distribution, stony branching corals accounted for most of observed coral catch, ranging from 10.051 to 33.008 tonnes (for all fishing methods combined) compared to 0.013 to 2.433 tonnes for all other species assessed here (Table 4.11).

Table 4.9: Coral catch weight (in tonnes) for each protected species groups between the 2007–08 and 2019–20 fishing years. Unspecified coral catch: based on MPI taxa code used for unspecified coral catch (COU); Unidentified: no code provided in COD.

Coral group	BT	BPT	PRB	MW	PRM	BLL	SN	DS	POT	Total
Stony corals	130.705	0.005	0.064	0.042		0.098	0.162	0.000	0.002	131.078
Unspecified coral catch	12.923	0.001	0.033	0.039		0.080	0.174			13.250
Gorgonians	11.685		0.003	0.073	0.085	0.072	0.008			11.926
Unidentified	5.769	0.000	0.000	0.002		0.001	0.002			5.774
Lace corals	5.671		0.135	0.000		0.036	0.044			5.886
Black corals	3.102		0.025	0.282		0.033	0.191			3.633
Total	169.855	0.006	0.260	0.438	0.085	0.320	0.581	0.000	0.002	171.547

Table 4.10: Coral catch weight (in tonnes) for each species group based on morphotype and/or taxonomic division between the 2007–08 and 2019–20 fishing years. Unidenitfied species and coral rubble not included!!!

Coral group	BT	SN	BLL	MW	PRB	PRM	BPT	POT	DS	Total
Stony corals - branching	82.224	0.146	0.076	0.034	0.023					82.503
Stony corals - cup	9.974	0.001	0.011	0.002	0.039		0.005	0.002	0	10.034
Gorgonians - calcaxonia	8.59	0.005	0.041	0.014	0.001	0				8.651
Lace corals	5.671	0.044	0.036	0	0.135					5.886
Black corals	3.102	0.191	0.033	0.282	0.025					3.633
Gorgonians - scleraxonians	2.505	0.002	0.008	0.017						2.532
Gorgonians - others	0.044		0.007	0.022	0	0.085				0.158
Total	112.11	0.389	0.212	0.371	0.223	0.085	0.005	0.002	0	113.397

Table 4.11: Coral catch weight (in tonnes) for seven species used in species distribution modelling by REF between the 2007–08 and 2019–20 fishing years.

Species	Protected species group	Morphotype group	BT	BPT	PRB	MW	PRM	BLL	SN	DS	POT	Total
Solenosmilia variabilis	stony corals	stony corals - branching	33.004			0.002		0.001				33.007
Goniocorella dumosa	stony corals	stony corals - branching	22.482		0.002			0.071	0.006			22.561
Enallopsammia rostrata	stony corals	stony corals - branching	16.464		0.02	0		0.001				16.485
Madrepora oculata	stony corals	stony corals - branching	9.948					0.001	0.102			10.051
Paragorgia arborea	gorgonians	gorgonians - scleraxonians	2.411			0.017		0.003	0.002			2.433
Keratoisis spp.	gorgonians	gorgonians - calcaxonia	2.012		0.001	0		0.015				2.028
Primnoa	gorgonians	gorgonians - calcaxonia	0.231			0.003		0.017				0.251
Lepidisis spp.	gorgonians	gorgonians - calcaxonia	0.169									0.169
Leiopathes	black corals	black corals	0.147			0.001		0.015				0.163
Corallium	gorgonians	gorgonians - scleraxonians	0.094					0.005				0.099
Bathypathes	black corals	black corals	0.078					0				0.078
Errina spp	lace corals	lace corals	0.044			0			0.001			0.045
Stylaster spp	lace corals	lace corals	0.013					0				0.013
Total	-	-	87.097	0	0.023	0.023	0	0.129	0.111	0	0	87.383

Within bottom trawl fisheries, stony corals had the highest capture rate (0.126 tonnes per 100 tows, respectively) whereas for all other species groups the capture rate ranged between 0.003 and 0.012 tonnes per 100 tows (Table 4.12). Overall, coral captures were observed around seamounts or sloping areas (Figs. 6.4–6.31). Catch rates and distribution maps of observed coral captures in trawl fisheries suggest that trawl fishing predominatly overlaps with distribution hotspots for stony corals and to some extent lace corals (mainly concentrated in small areas within FMA1 and FMA4). For example, the species *Madrepora oculata*, *Solenosmilia variabilis*, *Goniocorella dumosa*, *Enallopsammia rostrata* and *Oculina virgosa* are described as the dominant habitat-forming cold-water Scleractinia (i.e., stony corals) within the New Zealand (Cairns, 1995; Tracey et al., 2011). These species are described as occuring at seamount features, slope margins and on flat tops of slopes or rises (Squires, 1965; Dawson, 1984), which are areas that overlap with the NZ trawl fisheries (see Figs. 6.46.31 for observed fraction of trawl fisheries). In fact, all these stony coral species, except for *Oculina virgosa*, were among the top-four stony coral species caught in trawl fisheries between the 2007–08 and 2019–20 fishing years. In contrast, black corals are known to inhabit deeper-water environments, hence the lower catch rates within trawl fisheries.

Table 4.12: Coral catch rate (tonnes per 100 events) for each protected species group between the 2007–08 and 2019–20 fishing years.

Coral group	BT	PRM	BPT	PRB	MW	SN	BLL	DS	POT
Stony corals	0.126		0.006	0.002	0	0	0	0	0
Unspecified coral catch	0.012		0.001	0.001	0	0	0		
Gorgonians	0.011	0.02		0	0	0	0		
Unidentified	0.006		0	0	0	0	0		
Lace corals	0.005			0.003	0	0	0		
Black corals	0.003			0.001	0.001	0	0		
Mean	0.027	0.02	0.002	0.001	0	0	0	0	0

Table 4.13: Coral catch rate (tonnes per 100 events) for each species group based on morphotype and/or taxonomic division between the 2007–08 and 2019–20 fishing years. Note that unidentified corals and coral rubble are not included in this summary.

Coral group	BT	BPT	PRB	PRM	BLL	DS	MW	SN	POT
Stony corals - branching	0.079		0.001		0		0	0	
Stony corals - cup	0.01	0.006	0.001		0	0	0	0	0
Gorgonians - calcaxonia	0.008		0	0	0		0	0	
Lace corals	0.005		0.003		0		0	0	
Black corals	0.003		0.001		0		0.001	0	
Gorgonians - scleraxonians	0.002				0		0	0	
Gorgonians - others	0		0	0.02	0		0		
Mean	0.015285714	0.006	0.001	0.01	0	0	0.000142857	0	0

Coral rubble. In addition to coral species catch, coral rubble accounted for a considerable amount of recorded coral catch in the COD. For bottom trawl fisheries, 48.304 tonnes of coral catch was recorded between the 2007–08 and 2019–20 fishing years. The data can further be disaggregated into live coral rubble or dead coral rubble, resulting in 6.342 tonnes and 35.381 tonnes, respectively.

4.5 Temporal distribution of coral catch (bottom trawl fisheries)

To analyze the temporal trend in coral bycatch, only data from bottom trawl fisheries (BT, BPT, PRB) were used, as they accounted for 99% of all reported coral catch during the assessed period. The trend analysis focused solely on the protected coral species groups: black corals, gorgonians, lace corals, and stony corals. Table 4.15 shows the time series of catch weight for stony corals, which had the highest overall catch weight, across all bottom trawl fisheries in each FMA. No clear trend in stony coral catch was evident between

Table 4.14: Coral catch rate (tonnes per 100 events) for seven species used in species distribution modelling by REF between the 2007–08 and 2019–20 fishing years.

Species	Protected species group	Morphotype group	BT	BPT	PRB	MW	PRM	BLL	SN	DS	POT
Solenosmilia variabilis	stony corals	stony corals - branching	0.032			0		0			
Goniocorella dumosa	stony corals	stony corals - branching	0.022		0			0	0		
Enallopsammia rostrata	stony corals	stony corals - branching	0.016		0	0		0			
Madrepora oculata	stony corals	stony corals - branching	0.01					0	0		
Paragorgia arborea	gorgonians	gorgonians - scleraxonians	0.002			0		0	0		
Keratoisis spp.	gorgonians	gorgonians - calcaxonia	0.002		0	0		0			
Primnoa	gorgonians	gorgonians - calcaxonia	0			0		0			
Lepidisis spp.	gorgonians	gorgonians - calcaxonia	0								
Leiopathes	black corals	black corals	0			0		0			
Corallium	gorgonians	gorgonians - scleraxonians	0					0			
Bathypathes	black corals	black corals	0					0			
Errina spp	lace corals	lace corals	0			0			0		
Stylaster spp	lace corals	lace corals	0					0			
Mean			0.006								

the 2007–08 and 2019–20 fishing years. However, the first three fishing years stood out with particularly high reported catch weights, especially the 2008–09 fishing year, which recorded 75.186 tonnes of stony coral catch for all areas combined, accounting for 57% of all stony coral catch (130.772 tonnes) reported during the entire assessed period. This high catch weight was predominantly reported in FMA4 (45.383 tonnes), although higher than usual stony coral catch was also observed in FMA6 and FMA9. Excluding the 2008–09 fishing year, the total stony coral catch (within and outside the EEZ) ranged from 0.53 to 13.848 tonnes. Within the EEZ, the FMAs with the highest reported coral catch weight were FMA4, FMA6, and FMA9, accounting for 96% of all coral catch within the EEZ. Louisville Ridge accounted for 86% of reported coral catch weight outside the EEZ. When excluding the unusual catch weight during the 2008–09 fishing year, all areas would rank similarly, but FMA6 would have the highest reported catch weight for stony corals within the EEZ.

Table 4.15: Time series of observed coral catch weight (bottom trawl fisheries only) in tonnes for stony corals in each FMA between the 2007–08 and 2019–20 fishing years. Total catch weight per FMA is shown for all fishing years and for time period with the 2008/09 fishing year excluded.

Fishing year	FMA4	FMA6	FMA9	FMA5	FMA3	FMA2	FMA1	FMA7	FMA8	LOUR	WANB	CET	HOWE	Totals
2007/08	4.448	8.7		0.004	0.231		0.006	0.014			0.07	0.002	0.019	13.494
2008/09	45.383	15.147	13.316	0.016	0.126	0.001	0.012	0.001			0.857	0.263	0.064	75.186
2009/10	2.952	2.843	3.739	0.01	0.06	0.153	0			3.673	0.024	0.262	0.132	13.848
2010/11	0.07	0.866	2.585	0.029	0.255	0.11	0.012	0.002		1.852	0.128	0.061	0.016	5.986
2011/12	0.005	0.105		0.011	0.044	0.017		0.002		0.166	0.075	0.095	0.005	0.525
2012/13	0.401	0.115	0.001	0.03	0.132	0.002		0.007		0.407	1.074	0.042	0.241	2.452
2013/14	0.053	0.147	0.063	0.092	0.067	0	0.002	0.003	0.02	0.203				0.65
2014/15	0.11	0.029	0.003	0.071	0.153	0.011	0.003	0.015		0.552	0.056	0.035	0.343	1.381
2015/16	0.143	0.009	0.005	0.002	0.037		0.02	0.002		8.01		0.127	0.001	8.356
2016/17	0.357	0.407	0.02	2.004	0.006	0.004	0.036	0.027		3.867	0.04	0.116	0.022	6.906
2017/18	0.016	0.04	0	0	0.016			0.002		0.835	0.042	0.046	0.016	1.013
2018/19	0.185	0.086	0.012	0.078	0.043	0.001	0	0.002		0.005		0.025	0.008	0.445
2019/20	0.115	0.158	0.01	0.002	0.022	0.021	0.11	0.001		0.069	0.011	0.01	0.001	0.53
Totals	54.238	28.652	19.754	2.349	1.192	0.32	0.201	0.078	0.02	19.639	2.377	1.084	0.868	130.772
Totals (without 2008/09)	8.855	13.505	6.438	2.333	1.066	0.319	0.189	0.077	0.02	19.639	1.52	0.821	0.804	55.586

For the other three protected coral groups (black corals, gorgonians, and lace corals), the total observed catch weights were considerably smaller compared to stony corals, and no clear trends in observed coral catch weights were evident (see Tables 4.16 to 4.18). However, the 2008–09 fishing year stood out for gorgonians and lace corals, with unusually high reported catch weights approximately 15 and 76 times higher, respectively, than the average reported catch weight for all other fishing years (Tables 4.16 and 4.17). The reported catch weights for gorgonians and lace corals between the 2007–08 and 2019–20 fishing years ranged from 0.137 to 6.587 tonnes and 0.001 to 5.016 tonnes, respectively. For black corals, the observed catch weight ranged from 0.019 to 1.416 tonnes, with the highest catch weight observed in the 2019–20 fishing year.

Table 4.16: Time series of observed coral catch weight (bottom trawl fisheries only) in tonnes for gorgonians in each FMA between the 2007–08 and 2019–20 fishing years. Total catch weight per FMA is shown for all fishing years and for time period with the 2008/09 fishing year excluded.

Fishing year	FMA4	FMA6	FMA9	FMA5	FMA3	FMA1	FMA2	FMA7	HOWE	WANB	CET	LOUR	TKET	Totals
2007/08	0.008	0.107		0.005	0.032	0.032	0		0.002	0.01	0			0.196
2008/09	5.216	0.606	0.028	0.008	0.007	0.014	0	0.001	0.345	0.356	0.006			6.587
2009/10	0.482	0.618	0.143	0.146	0.031	0.006	0.002	0	0.062	0.004	0.002	0.017		1.513
2010/11	0.12	0.056	0.007	0.005	0.008	0.03	0.005	0.001	0.146	0.035	0.004	0.009		0.426
2011/12	0	0.129	0.122	0.01	0.001	0.006	0	0.002	0.005	0.067	0.001	0.004		0.347
2012/13	0.003	0.011	0.007	0.012	0.008	0		0.001	0.028	0.005	0.002	0.001		0.078
2013/14	0.004	0.005	0.003	0.005	0.095	0.002		0	0.004		0	0		0.118
2014/15	0.127	0.89	0.047	0.002	0.005	0.001	0.003	0.007	0.043	0	0.083	0.004		1.212
2015/16	0.009	0.006	0.04	0.083	0.004	0.001		0	0.055		0.011	0.009		0.218
2016/17	0.151	0.044	0.002	0.001	0.001	0.006	0.016	0.009	0.015	0.006	0.005	0.046		0.302
2017/18	0.001	0.087	0.008	0.003	0.005	0.001	0	0.006	0.017	0.003	0.004	0.002		0.137
2018/19	0.002	0.154	0.079	0.026	0.057	0.003	0		0.012		0.005	0	0.04	0.378
2019/20	0.074	0.009	0.054	0.003	0.023	0	0.004	0.001	0.001		0.001	0		0.17
Totals	6.197	2.722	0.54	0.309	0.277	0.102	0.03	0.028	0.735	0.486	0.124	0.092	0.04	11.682

Table 4.17: Time series of observed coral catch weight (bottom trawl fisheries only) in tonnes for lace corals in each FMA between the 2007–08 and 2019–20 fishing years. Total catch weight per FMA is shown for all fishing years and for time period with the 2008/09 fishing year excluded.

Fishing year	FMA4	FMA1	FMA6	FMA5	FMA8	FMA9	FMA2	FMA3	WANB	CET	HOWE	LOUR	Totals
2007/08	0		0.009										0.009
2008/09	5.005		0			0			0.008	0.001	0.002		5.016
2009/10	0.006		0.002	0.002					0	0			0.01
2010/11	0.001	0	0.05									0	0.051
2011/12	0.001		0	0.001					0	0		0	0.002
2012/13	0		0.013	0.001				0	0			0.001	0.015
2013/14		0.004	0	0			0				0.003		0.007
2014/15	0		0	0.001		0.001			0.002				0.004
2015/16	0.5		0	0.001									0.501
2016/17	0		0	0.025						0.002		0.002	0.029
2017/18	0		0	0	0.006	0.001				0.002			0.009
2018/19		0.145		0				0					0.145
2019/20	0.001		0					0		0			0.001
Totals	5.514	0.149	0.074	0.031	0.006	0.002	0	0	0.01	0.005	0.005	0.003	5.799

Table 4.18: Time series of observed coral catch weight (bottom trawl fisheries only) in tonnes for black coral in each FMA between the 2007–08 and 2019–20 fishing years. Total catch weight per FMA is shown for all fishing years and for time period with the 2008/09 fishing year excluded.

Fishing year	FMA5	FMA4	FMA6	FMA9	FMA3	FMA1	FMA7	FMA2	HOWE	CET	LOUR	WANB	TKET	Totals
2007/08		0.018	0.002			0.007	0.01		0.006	0.001		0.002		0.046
2008/09		0.053	0.004	0.002		0.006		0	0.047	0.004		0.016		0.132
2009/10	0	0.029	0.011	0.006		0.003			0.022	0.009	0.004	0		0.084
2010/11			0.004	0	0	0.007		0.007	0.033	0.018	0.011	0.005		0.085
2011/12	0.001	0.007	0.001	0.012	0	0.011	0.001	0.004	0.006	0.01	0.006	0		0.059
2012/13	0.002	0.001	0		0.002	0	0		0.071	0.02	0.003	0.001		0.1
2013/14		0.001	0.002			0.006			0.007	0.001	0.002			0.019
2014/15	0	0.001	0	0.016		0.001	0.006	0.001	0.028	0.004	0.003	0.004		0.064
2015/16	0.411	0.005	0.002		0.004	0	0.006		0.011	0.041	0.004			0.484
2016/17	0.001	0.013	0.002	0.023		0.007	0		0.006	0.015	0.024			0.091
2017/18	0.103	0.006	0.101	0.016	0	0.008	0		0.017	0.017	0.002	0		0.27
2018/19	0.176	0.004	0	0.003	0.05	0.003		0.005	0.006	0.016	0.001		0.008	0.272
2019/20	1.371	0.011		0.008	0.01	0.004	0.002	0.008	0.001	0.001	0			1.416
Totals	2.065	0.149	0.129	0.086	0.066	0.063	0.025	0.025	0.261	0.157	0.06	0.028	0.008	3.122

Figure 4.6 displays the time series of observed coral capture rates in bottom trawl fisheries for the top five areas (within and outside the EEZ) with the highest average catch rates across all coral groups and fishing years. These areas were FMA4, FMA6, FMA9, Louisville Ridge (LOUR), and Wanganella Bank (WANB). The same time series with square-root transformed catch rates is shown in Figure 4.7. Overall, no clear trends in observed coral catch rates were apparent. For all coral groups within FMA4, the 2008–09 fishing year exhibited the highest catch rates across all study years. For instance, the observed catch rate for stony corals in the 2007–08 fishing year was about four tonnes per 100 tows but remained close to zero in all other years (Figure 4.6).

Observed stony coral capture rates were generally low in other areas, except for the 2008–09 to 2010–11 fishing years in FMA9 with close to five tonnes per 100 tows, more than 20 tonnes per 100 tows in Wanganella Bank during the 2012–13 fishing year, and a high capture rate close to 5 tonnes per 100 tows in Louisville Ridge (LOUR) during the 2015–16 fishing year 4.6. Similarly, peak capture rates were found for the other three coral groups in the same years and some other years, but at a much lower order of magnitude.

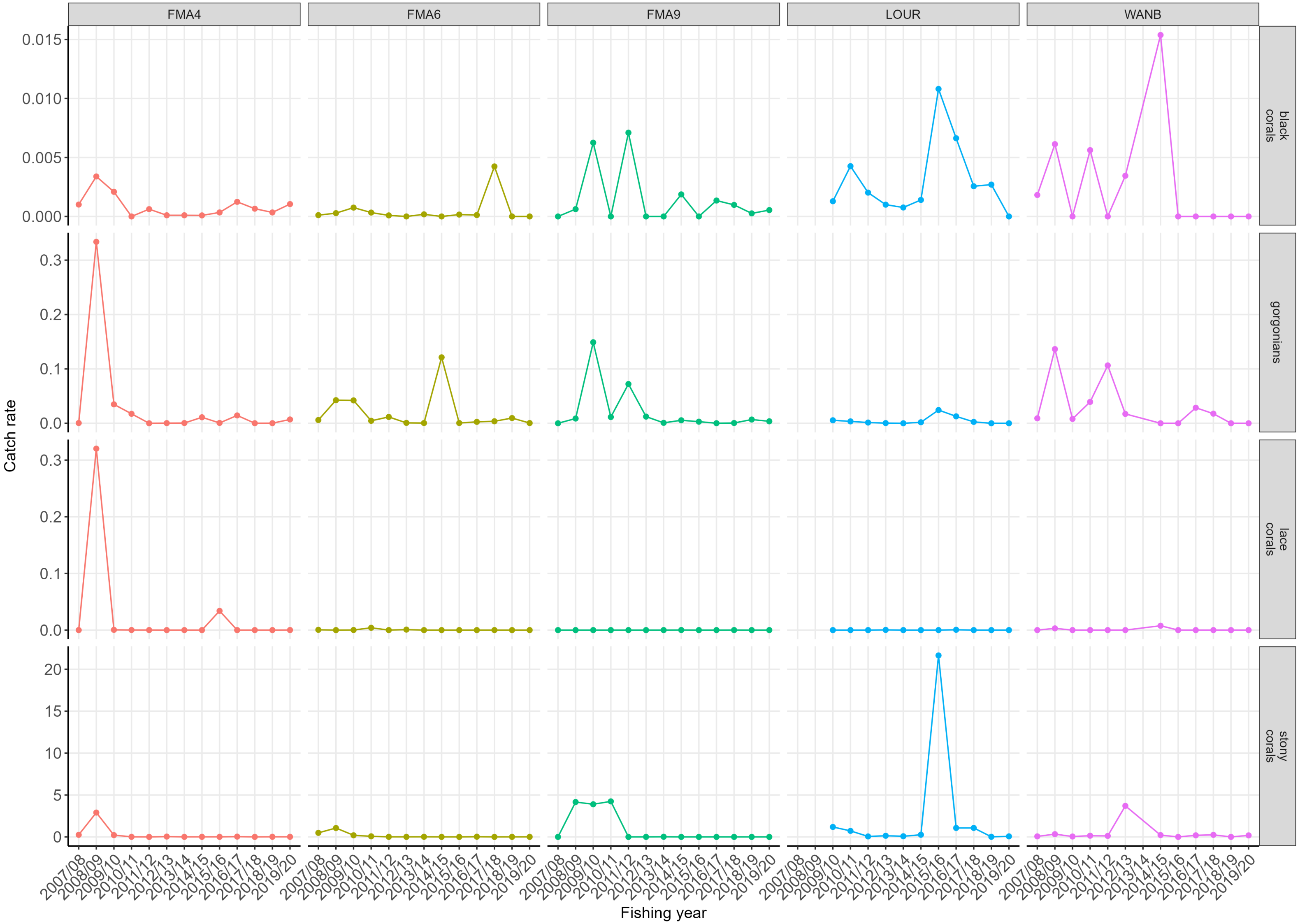

Figure 4.6: Time series of observed coral catch rate (bottom trawl fisheries only) for all protected species coral groups combined (i.e., black corals, gorgonians, lace corals, and stony corals) reported in top-five FMAs with highest mean total coral catch rate across all protected coral species groups between the 2007–08 and 2019–21 fishing years. Note the different y-axis scale for each coral group.

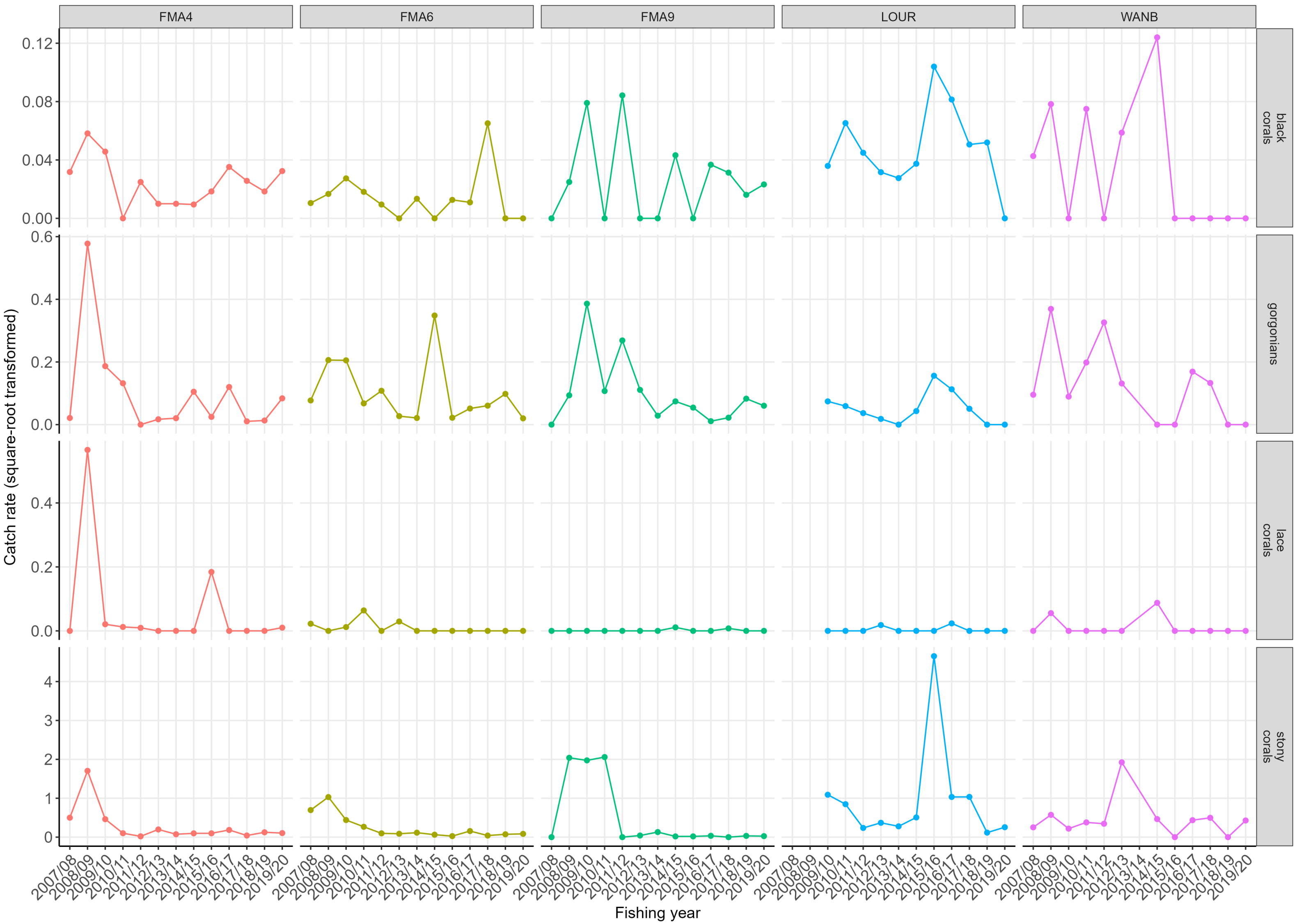

Figure 4.7: Time series of square-root transformed observed coral catch rate (bottom trawl fisheries only) for all protected species coral groups combined (i.e., black corals, gorgonians, lace corals, and stony corals) reported in top-five FMAs with highest mean total coral catch rate across all protected coral species groups between the 2007–08 and 2019–21 fishing years. Note the different y-axis scale for each coral group.

4.6 Model fitting

For each of the four protected coral groups, two Generalized Additive Models (GAMs) were fitted. The first GAM was fitted to presence-absence data of coral catch on fishing events, while the second GAM was fitted to Box-Cox transformed catch weights on fishing events with coral catch (i.e., events without coral catch were omitted). The logistic GAM fitted to the presence-absence data performed well for all four coral groups, accurately predicting both the presence and absence of coral catch on fishing events (see Appendix 6.6). However, the GAM fitted to Box-Cox transformed catch weights was unable to produce estimates that allowed for the prediction of actual observed catch weight possibly due to the wide range of observed catch weights, likely caused by inconsistencies in how catch weights were determined, despite the transformation to ensure normally-distributed data. Therefore, only the results for the logistic GAM will be discussed here, but model estimates for the GAMs fitted to Box-Cox transformed catch weights are provided in Appendix 6.6.

For stony corals, the logistic GAM suggested a mean probability of coral catch on a fishing event of 0.012 (95% confidence interval (CI): 0.006–0.021) based on back-transformed log-odds (Table 6.2) to the probability scale. The assessment of the smooth term for bathymetry (Figure 4.8) suggested a high chance of stony coral captures from approximately 800 meters and deeper, which seemed unusual. Given that branching and cup-forming stony corals have different depth profiles, the same model was refitted to presence-absence data separately for branching and cup-forming stony corals. Figure 4.9 suggests an increasing probability of branching stony coral captures at depth between approximately 600 to 1500 meters after which it gradually declines (though notice the wide uncertainty for the smooth term beyond 2000 m depth). Cup-forming stony coral captures, appear to occur more likely at depth below 1000 m but peak again beyond 2000 meter though the observation at that depth were scarce (Figure 4.10). Also note that bathymetry reflects ocean depth at the start of each fishing event and does not neccessarily reflect the actual depth during coral capture.

The smooth terms for SST and chlorophyll a, imply that stony coral captures are more likely to occurr at less productive areas relative to inshore areas and increase towards warmer ocean temperatures (e.g., from and beyong the Chatham Rise). Partial effects plot for all other remaining coral groups implied similar effects, but due to the low number of observations, were subject to considerable uncertainty (see Appendix 6.6). However, the partial effects plots for bathymetry for these coral groups suggests that most captures occur at depth between 1000 and 1500 meters. Similar results were obtained when fitting the same model to presence-absence data of stony coral captures for catch weights smaller than 1000 tonnes (Table 6.3).

Based on the logistic GAM fitted separately to data for branching stony corals and cup-forming stony corals, the average probability for stony coral catch was 0.002 (95% confidence interval (CI): 0.001–0.005) and 0.006 (95% CI: 0.003–0.011), respectively, for bottom trawl fisheries targeting orange roughy in FMA4 during July, at ocean depth close to zero meters, SST close to eight degrees celsius and chlorophyll a around 0.160 $mgm^{-}3$ (i.e., at predictor values for the estimated intercapt term for the model). However, the actual range of probability can vary depending on location and by fishing year. For example, the probability of cup-forming stony coral catch for bottom trawl fisheries targeting orange roughy in FMA4 during July ranged from 0.002 (95% confidence interval (CI): 0.001–0.006) (depth: 1425.017 meter, SST: 15.19 degress celsius, chlorophyll a: 0.419 $mgm^{-}3$, fishing year: 2020–21) to 0.080 (95% confidence interval (CI): 0.052–0.112) (depth: 783.313 meter, SST: 14.919 degress celsius, chlorophyll a:0.413 $mgm^{-}3$, fishing year: 2009–10).

Figure 4.11 presents the predicted probabilities of coral catch per 0.2ř grid cells averaged across the 2007–08 and 2019–20 fishing years. The predicted probabilities of coral captures were representative of actual observations (Figure 4.12). As suggested by the model estimates, for stony corals, the highest chance of observed coral catch occurred within FMA4, specifically between 1000 and 1500 meters of ocean depth (Figure 4.11). These areas are frequently fished by bottom trawl fisheries targeting orange roughy. There was no significant difference in the chance of stony coral catch across other bottom trawl target species (Table 6.2). As expected, there was a significantly lower probability of coral catch in mid-water trawl fisheries (the probability reduced to less than 0.001). Other fishing methods showed no significant differences, but the direction of the effects indicated generally fewer coral captures in all other fishing methods compared to bottom trawling. Across FMAs, there were certain areas with particularly high probabilities of coral catch, often found around seamounts at depths between 1000 and 1500 meters. For all other coral groups, the chance of being caught in observed fishing events was generally low compared to stony corals (see Appendix 6.6 and Figure 4.11), although areas around seamounts tended to have higher levels of coral bycatch. Splitting stony corals into branching and cup-forming stony corals suggests some areas of high branching stony corals within FMA6 and FMA9 (Figure 4.13).

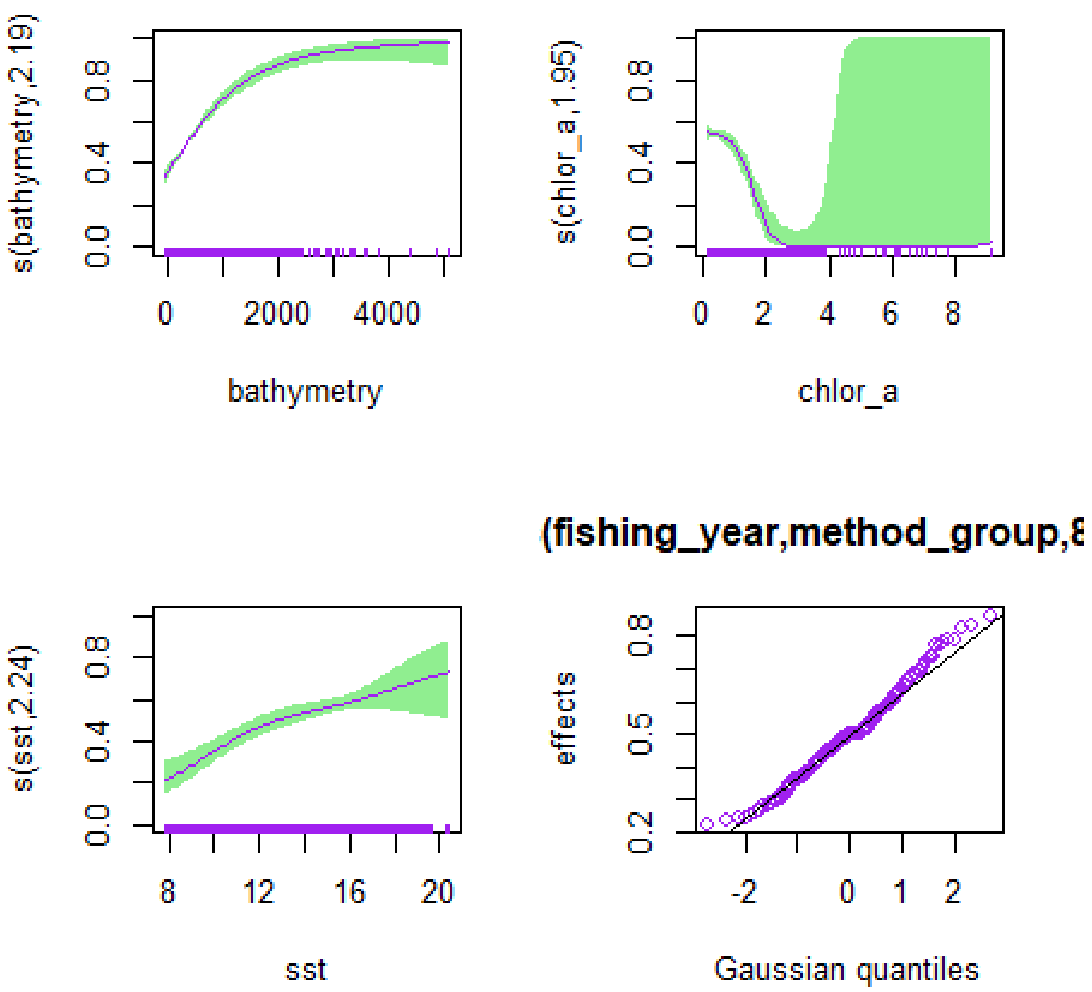

Figure 4.8: Partial effects from logistic GAM fitted to presence-absence data of stony coral captures in all fishing methods.

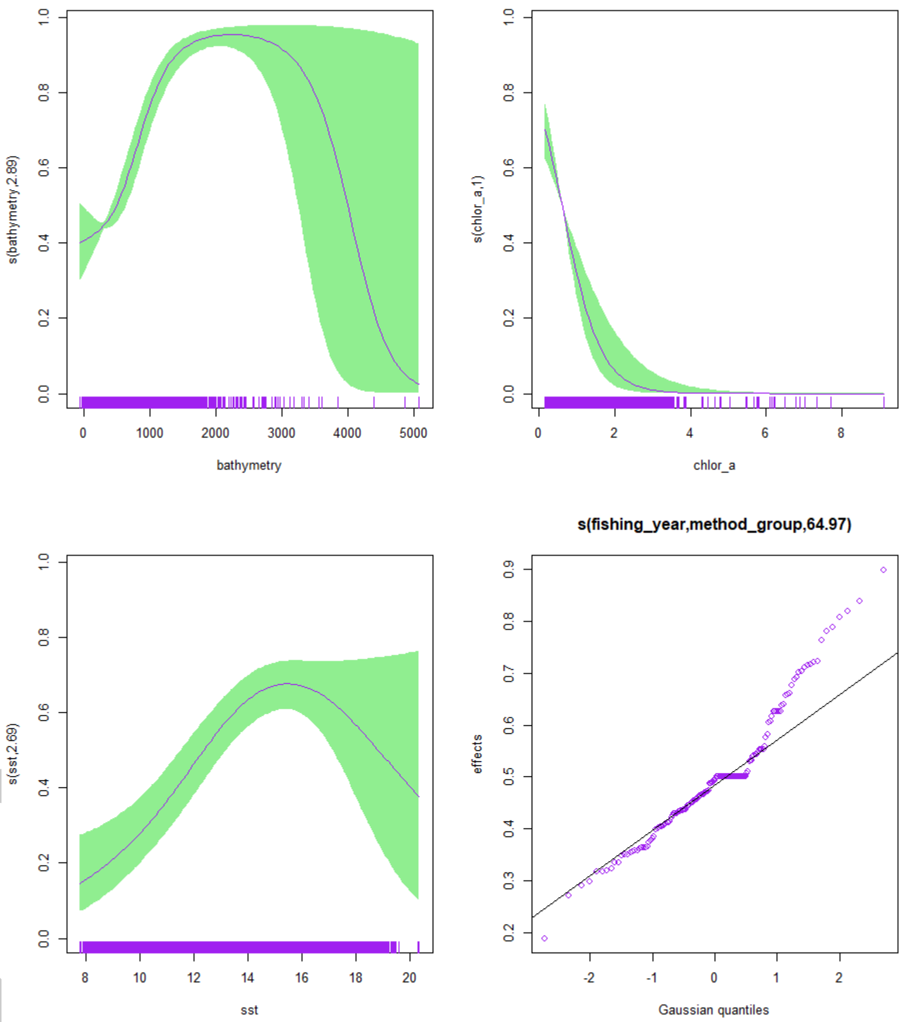

Figure 4.9: Partial effects from logistic GAM fitted to presence-absence data of branching stony coral captures in all fishing methods.

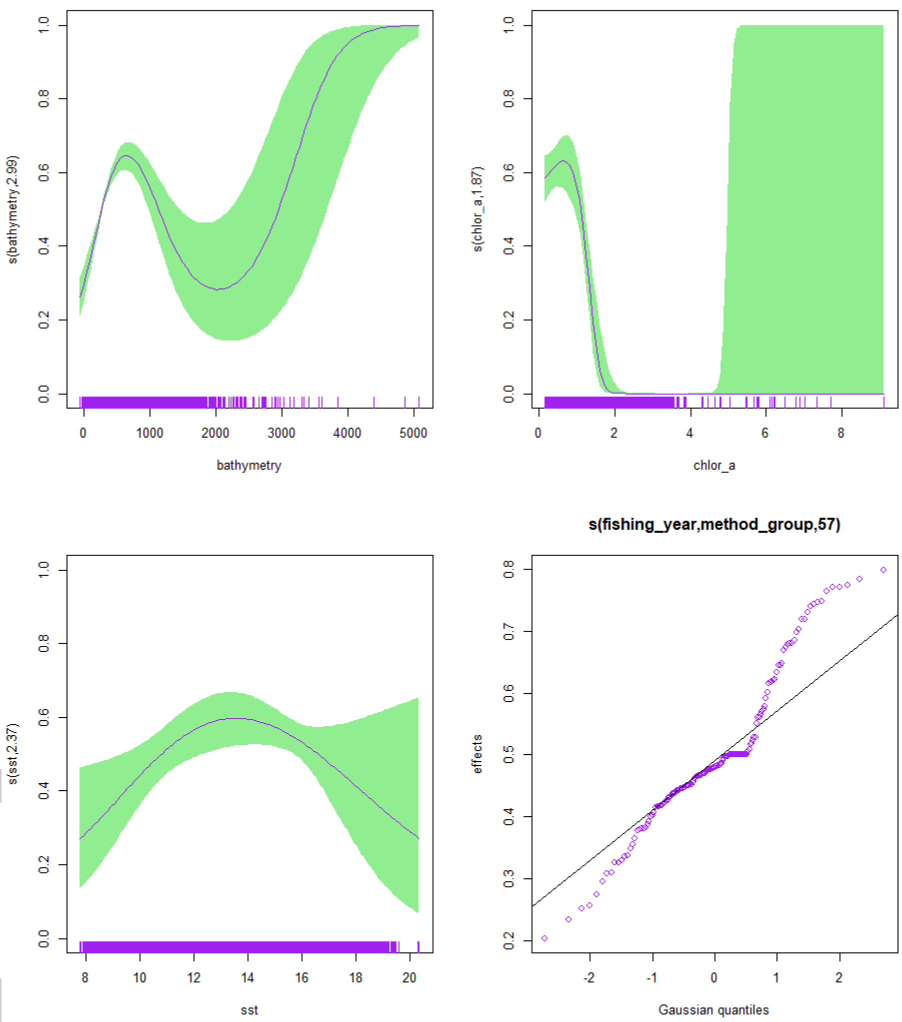

Figure 4.10: Partial effects from logistic GAM fitted to presence-absence data of cup-forming stony coral captures in all fishing methods.

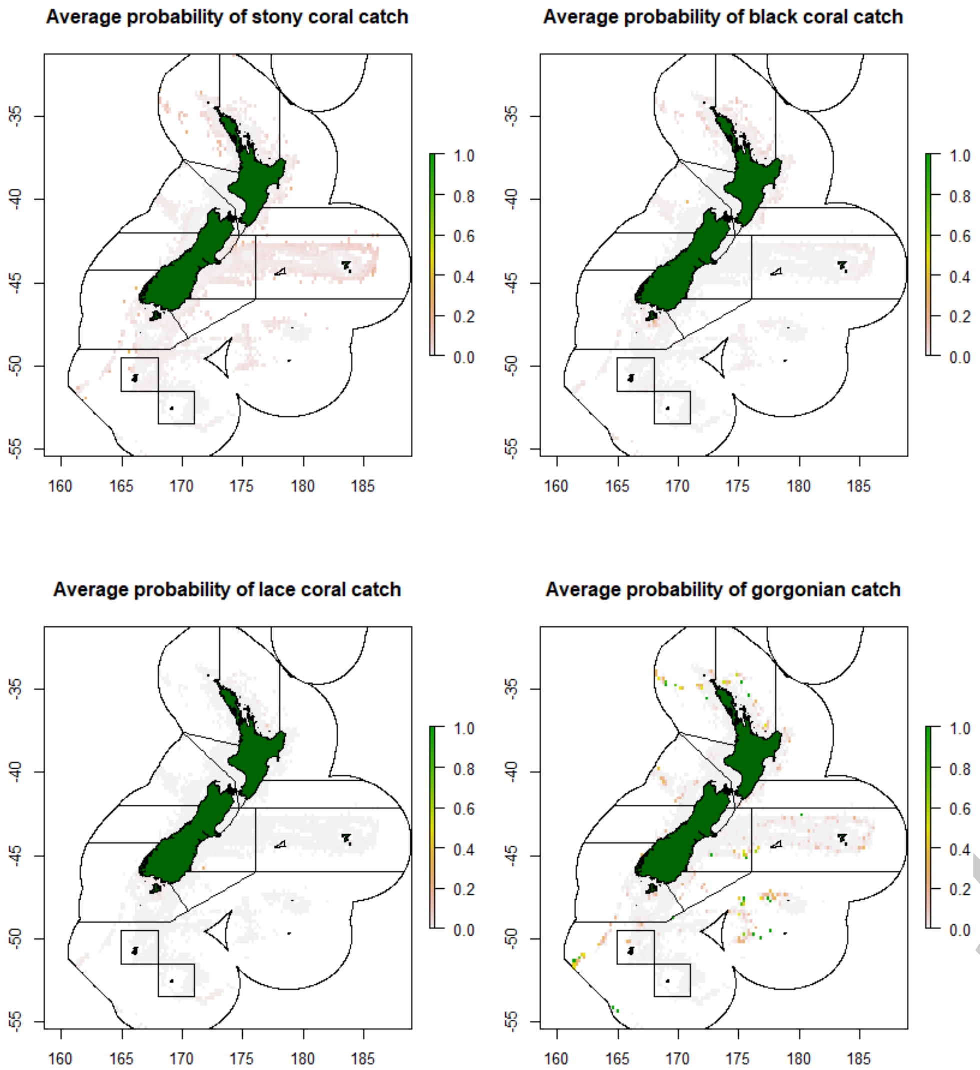

Figure 4.11: Average probability of coral catch on observed fishing events per grid cell (0.2° latitude x 0.2° longitude cells) for the four protected coral species groups: stony corals, black corals, lace corals, gorgonians, between the 2007–08 and 2019–20 fishing years.

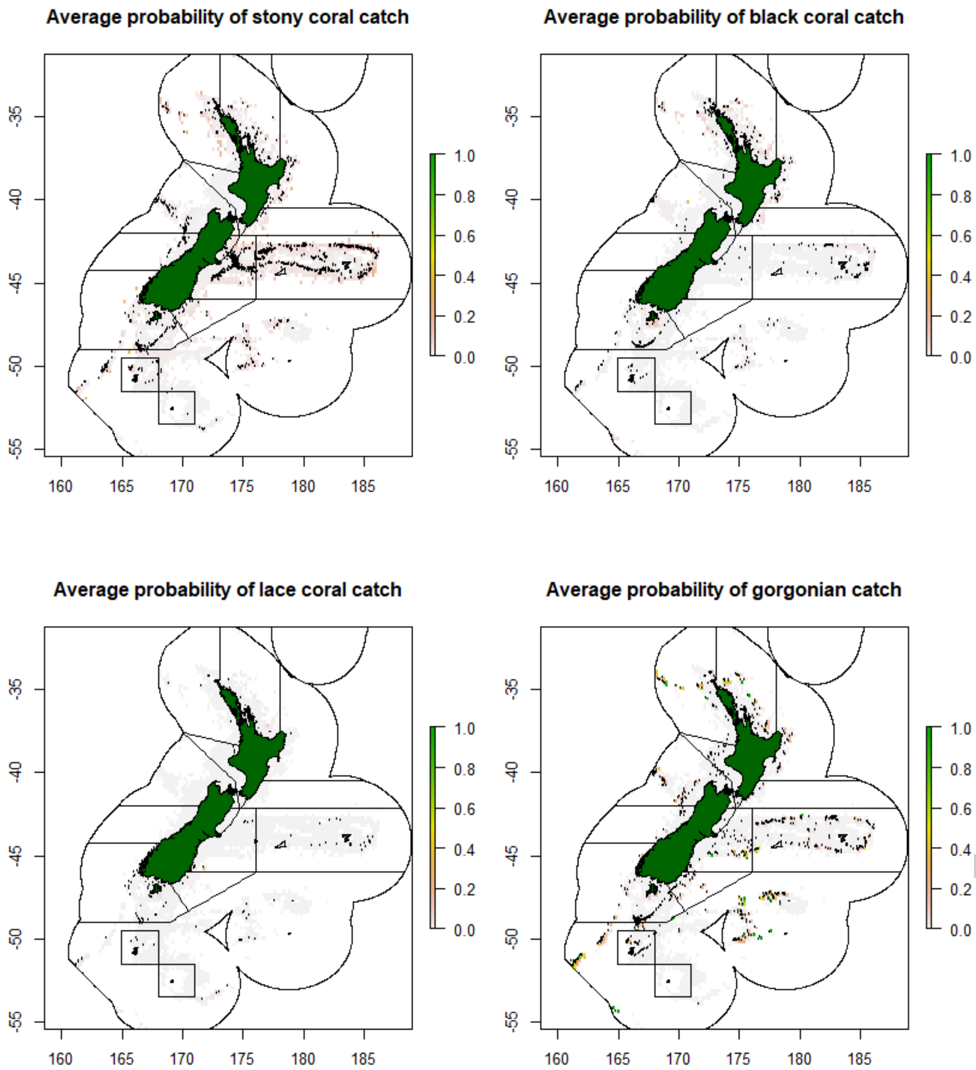

Figure 4.12: Average probability of coral catch on observed fishing events per grid cell (0.2° latitude x 0.2° longitude cells) plus actual observed captures (black dots) for the four protected coral species groups: stony corals, black corals, lace corals, gorgonians, between the 2007–08 and 2019–20 fishing years.

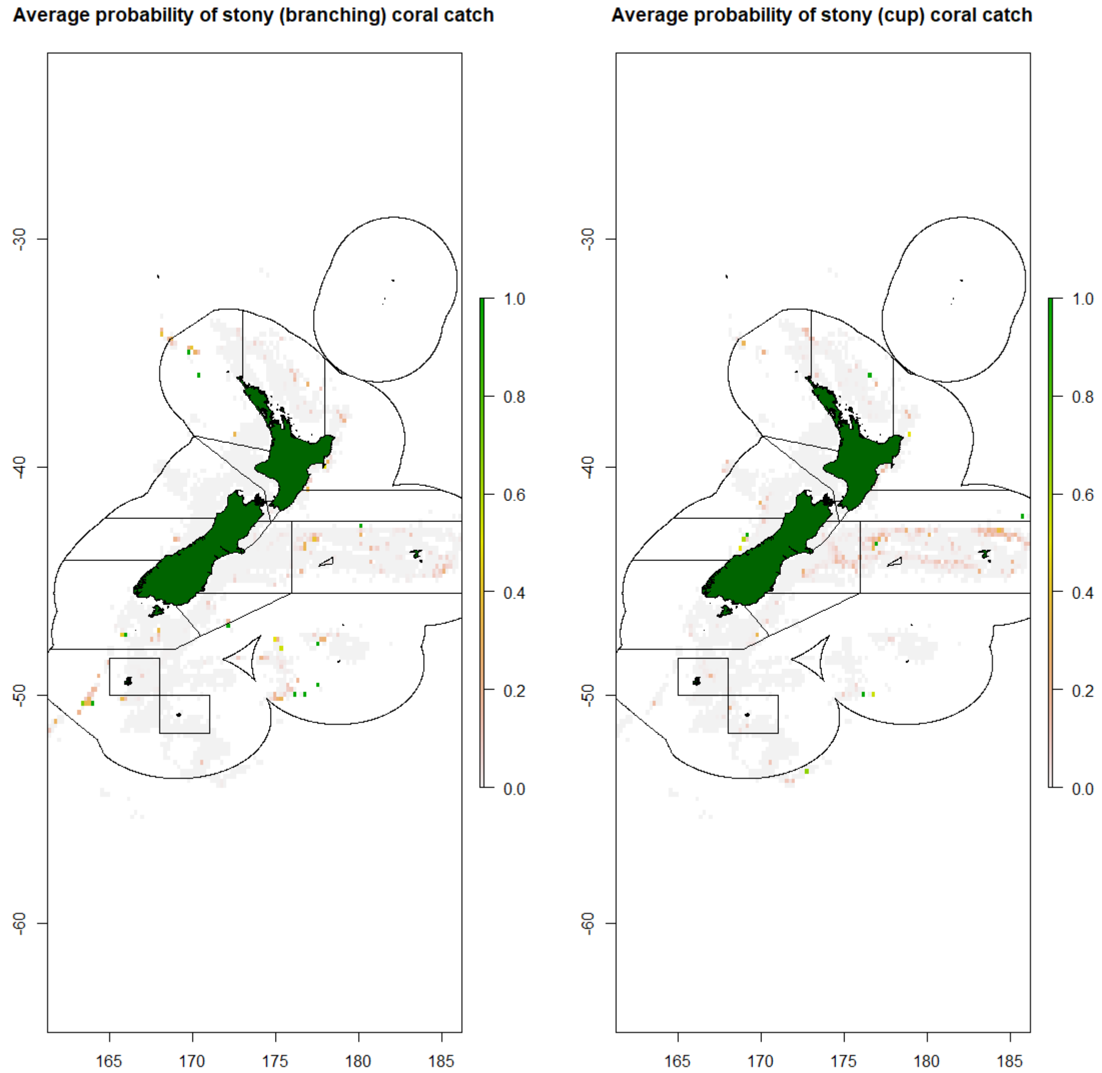

Figure 4.13: Average probability of coral catch on observed fishing events per grid cell ($0.2°$ latitude x $0.2°$ longitude cells) separately for braching stony corals and cup-forming stony corals between the 2007–08 and 2019–20 fishing years.

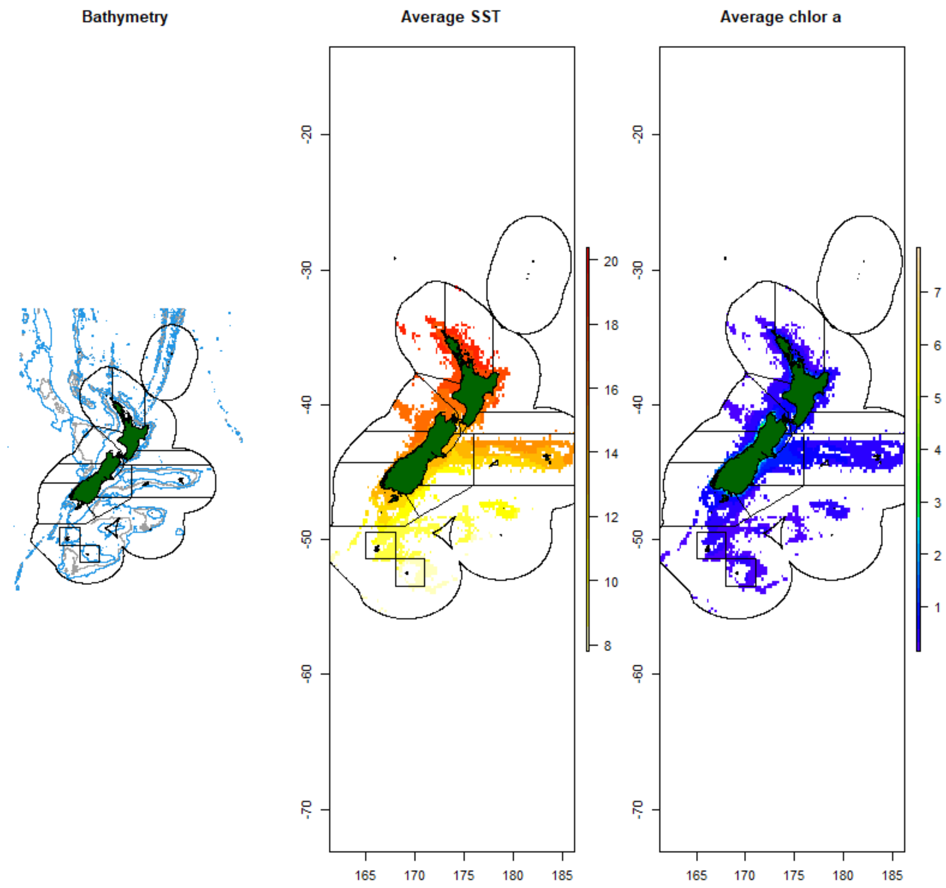

Figure 4.14: Environmental covariates used for model fitting. For SST and chlor a, the average value per grid cell ($0.2°$ latitude x $0.2°$ longitude cells) between the 2007–08 and 2019–20 fishing years is shown.

4.7 Fisher-reported coral captures

The reported coral captures provided by fishers included data from the fishing years 2008–09 to 2020–21, and the corresponding catch weights per protected coral species group are presented in Table 4.19. A comprehensive list of all reported species can be found in Table 6.14. It is important to note that a direct comparison between fisher-reported and observer-reported catch is only possible through catch rates. However, we were not provided with a complete record of all commercial fishing events, which means that catch rates for fisher-reported coral catch could not be calculated. Nevertheless, it is expected that fisher-reported coral catch would be higher because it encompasses the entirety of fishing activities, whereas observer monitoring covers only a fraction of total fishing activity.

The majority of reported coral captures did not specify the taxa. Among those with species identification, stony corals accounted for the majority of fisher-reported coral captures (82.265 tonnes). The total fisher-reported coral catch, including unspecified coral catch, amounted to 108.741 tonnes. This is lower than the total coral catch reported by observers during the same time period (137.367 tonnes) as shown in Table 4.20. The annual fisher-reported coral captures were generally within the same order of magnitude as the observer-reported coral captures. One exception was the 2008–09 fishing year, where observer-reported coral captures amounted to 95.034 tonnes, compared to 17.828 tonnes reported by fishers. During the 2015–2016 and 2016–2017 fishing years, fishers reported coral captures that were an order of magnitude higher than the observer-reported coral captures. Similarly, the fisher-reported captures by FMA were generally comparable to those reported by observers, except for FMA4, where observers reported approximately twice the amount of coral catch compared to fishers. Overall, the expectation that higher amount of coral captures would occur in the dataset of fisher-reported captures compared to observer-reported captures was not met.

Table 4.19: Fisher-reported coral captures grouped by protected coral groups between the 2008–09 and 2020–21 fishing years.

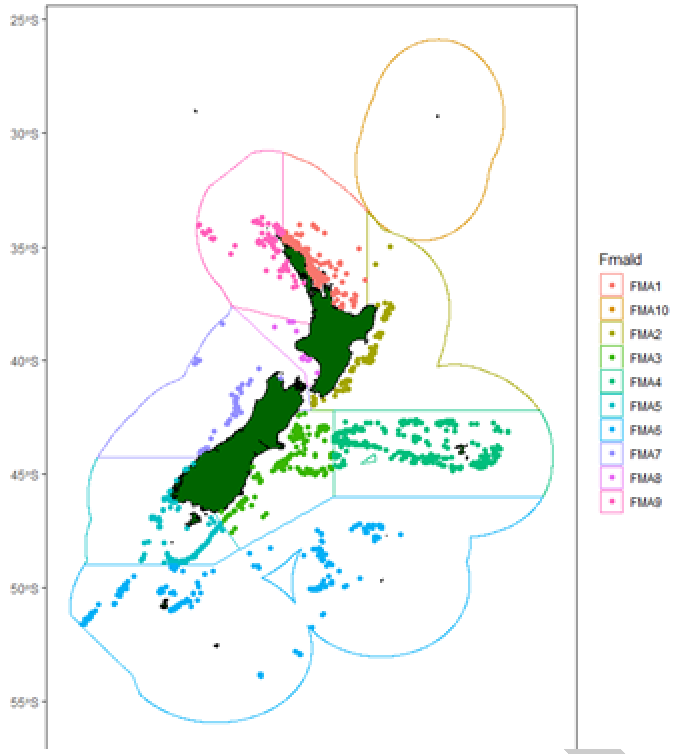

Figure 4.15: Spatial distribution of fisher-reported coral captures within the EEZ. Capture events are color-coded by start FMA of the fishing event.

Coral group	Catch weight (t)
Unspecified coral catch	82.265
stony corals	23.736
lace corals	1.667
black corals	0.688
gorgonians	0.384
Total	108.741

Table 4.20: Fisher-reported coral captures grouped by protected coral groups.

Fishing year	Fisher-reported catch weight (t)	Observer-reoprted catch weight (t)
2008–2009	17.828	95.034
2009–2010	10.578	11.328
2010–2011	8.560	4.343
2011–2012	2.153	0.877
2012–2013	4.165	1.405
2013–2014	3.741	0.635
2014–2015	2.958	1.601
2015–2016	21.972	2.119
2016–2017	26.649	3.254
2017–2018	2.068	0.52
2018–2019	3.190	1.201
2019–2020	1.812	2.188
2020–2021	3.068	12.862
Total	108.741	137.367

Table 4.21: Fisher-reported coral captures grouped by fishery management area (FMA) between the 2008–09 and 2020–21 fishing years.

FMA	Fisher-reported catch weight (t)	Observer-reoprted catch weight (t)
FMA4	37.625	73.537
FMA9	22.670	20.551
FMA6	20.430	23.121
FMA5	3.859	17.595
FMA3	3.691	1.454
FMA2	1.127	0.417
FMA1	1.027	0.553
FMA7	0.171	0.113
FMA8	0.023	0.026
Unknown	18.11646	
Total	108.741	137.367

5. Discussion

This study examined the spatio-temporal distribution of observed coral captures between the 2007–08 and 2019–20 fishing years, with bottom trawl fisheries responsible for the majority (99%) of reported coral catch during this period. The analysis focused on trends in protected coral species groups, including black corals, gorgonians, lace corals, and stony corals. The temporal trend analysis of stony coral catch weights did not reveal a clear pattern between the fishing years 2007-08 and 2019-20, although the first three years stood out due to particularly high reported catch weights. However, caution is needed in interpreting these findings due to inconsistent methods of determining catch weights.

The assessment of coral bycatch data recorded in the COD, along with the analysis of presence-absence data of coral bycatch, suggests a low risk of coral captures in New Zealand's commercial fisheries within and outside the Exclusive Economic Zone (EEZ), except for stony corals, which are predominantly caught in bottom trawl fisheries targeting orange roughy in the North-East Chatham Rise.

Overall, the protected coral species grouping appears sufficient to assess coral-fisheries interactions. However, it would be beneficial to further differentiate stony corals into stony cup corals and stony branching corals, as the latter are caught at a rate almost ten times higher within bottom trawl fisheries. This distinction is supported by fitting logistic GAMs separately to data for branching and cup-forming stony corals, where depth profiles for captures for each species align with the actual depth profile for each taxonomic group. This suggests the existence of higher risk areas for branching corals within FMA6 and FMA9, while cup-forming corals are typically caught within FMA4.

It should be noted that the data used in this study is sparse, and there may be potential bias in estimating coral catch weights, as large coral captures are often based on subjective estimates ("eyeball estimtes"'). Nontheless, extremly high captures of corals have been previously reported. For example, Anderson and Clark (2003) analysed data collected by fisheries observers in New Zealand fisheries between October 1997 and August 2000 in the South Tasman Rise orange roughy fishery, and in some trawls coral captures ranged between 1 tonne and 15 tonnes. However, the authors also note that it was generale practice that very large coral captures were release by opening the cod-end on the stern-ramp, hence these high numbers of reported catch are likely to be subject to subjective guessing of the actual catch weight. The largest captures of corals were reported based on eyeball estimates of catch weights. The majority of reported coral catch weights in this study lack specific information on the method used to determine the weight, making it difficult to remove potentially biased catch weights based on data quality. Therefore, catch weight is currently not a reliable measure of fishery impact on coral communities.

Despite the findings that align with previous studies, caution is warranted given the sparseness of the data and particularly the potential bias in estimated coral catch weights given that particuarly large coral catch is usually based on eyeball estimates. Nontheless, extremly high captures of corals have been previously reported. For example, Anderson and Clark (2003) analysed data collected by fisheries observers in New Zealand fisheries between October 1997 and August 2000 in the South Tasman Rise orange roughy fishery, and in some trawls coral captures ranged between 1 tonne and 15 tonnes. However, the authors also note that it was generale practice that very large coral captures were release by opening the cod-end on the stern-ramp, hence these high numbers of reported catch are likely to be subject to subjective guessing of the actual catch weight. The largest captures of corals were reported based on eyeball estimates of catch weights. For the majority of reported coral catch weights the actual method to determine catch weight was not specified, rendering the ability to remove potentially biased catch weights based on the quality of data recording. We therefore suggest that catch weight is currently not a good measure of fishery impact on coral communities.

Instead, we recommend assessing the risk of commercial fishing on corals based on presence-absence data of coral captures. The logistic GAM performed well and suggested that specfcially organe roughy is a high risk fisheries for stony corals captures and particualrly within FMA4. Other variables that could have been included in the model were, for example, fishing duration and actual tow depth (for trawl fisheries). However, these variables are not always availabe for all fishing events (e.g., end time of fishing is often not recorded) resulting in the loss of valuable data for the model fitting. If used for predicting coral captures on unobserved fishing events (not done in this study), we suggest to included a random effect for vessel key to account for gear configurations and general fishing behaviour that has nnot been accounted for in the models fitted here.

While the analysis of presence-absence data of coral captures can help identify risk areas

of coral catch in commercial fisheries, it does not provide a comprehensive measure of the actual impact of fishing on coral communities. Bottom trawling, for example, is known to cause damage to sessile invertebrate fauna (Koslow et al., 2001; Rise, 2002). However, the presence of coral bycatch alone does not indicate the extent of damage or mortality to coral reefs. To assess the impacts of fishing on coral reefs, an evaluation of affected coral reefs, such as transect studies in areas of low and high risk of coral catch, would be required (e.g., (Van Dolah et al., 1987)). Additionally, catch weight alone does not provide a comprehensive understanding of the ecological consequences and potential harm inflicted on coral communities. Other factors, including habitat destruction, physical damage, and post-capture mortality, should be considered when assessing the impacts of fishing on coral reefs.
Fisher-reported coral captures were lower but in the same order of magnitude than observer-reported captures. A direct comparison via catch rates was not possible due to the lack of data. However, the general assumption was that more coral catch should be contain in fisher-reported catch data because observer-reoprted data only contain a fraction of all fishing activity. Observer coverage could not be calculated in this project due to lack of required data but observer coverage in, for example, trawl fisheries targeting oragne roughy within New Zealand's EEZ ranged between 11.5% and 43.9% between the 2007–08 and 2019–20 (retrieved from https://protectedspeciescaptures.nz/PSCv6/released/birds/orange-roughy-trawl/all-vessels/eez/2002-03-2019-20/). Hence, it appears that fishery-reported coral captures are generally under-reported.

The dashboard developed in this project provides the ability to update the results of this project quicky, which allows the identification of changes in the overall pattern of coral captures in New Zealand's commercial fisheries. Further, alternative summaries than those created in this report can be created for further data exploration. However, the lack of standardized protocols for determining coral catch weights introduces uncertainty and potential bias in the results of this analysis. It is crucial to address this issue by developing clear data collection protocols for coral catch in fisheries to ensure consistency and improve the reliability of future studies, and to look at solutions to determine the amount of large amount of bycatch that cannot be easily measured (e.g., through photo documentation). To overcome the limitations of catch weight as a sole measure, future research should explore alternative indicators that capture the broader ecological implications of fishing on coral reefs. For example, metrics such as the extent of habitat damage, species composition changes, and abundance of target and non-target species can provide valuable insights into the ecological effects of fishing activities on coral reef ecosystems (Hixon et al., 2014; Thurstan et al., 2017).

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6. Appendix

6.1 Description of coral groups

Table 6.1: Description of coral groups summarized in this study.

Name	Scientific name	MPI code	Protected coral groups	Morphotypes	SDM groups
Acanthogorgiid coral	Acanthogorgia spp.	ACC	gorgonians	gorgonians - others	
Acanthogorgiid coral	Acanthogorgiidae	ACD	gorgonians	gorgonians - others	
Bushy bamboo coral	Acanella spp.	ACN	gorgonians	gorgonians - calcaxonia	
Black coral	Antipathella spp.	AHL	black corals	black corals	
Acanthogorgiid coral	Anthogorgia spp.	ANA	gorgonians	gorgonians - others	
Anthothelid coral	Anthothela spp.	ANB	gorgonians	gorgonians - others	
Anthothelid coral	Anthothelidae	AND	gorgonians	gorgonians - others	
Plexaurid sea fan	Astrogorgia spp.	ASD	gorgonians	gorgonians - others	
Black coral	Antipathes spp.	ATP	black corals	black corals	
Bamboo coral	Keratoisis spp.	BOO	gorgonians	gorgonians - calcaxonia	Keratoisis spp.
Black coral	Bathypathes spp.	BTP	black corals	black corals	Bathypathes
Caryophyllia spp.	Caryophyllia spp.	CAY	stony corals	stony corals - cup	
Coral rubble	N/A	CBB	coral rubble		
Coral rubble - dead	N/A	CBD	coral rubble - dead		
Stony branching corals	Families Dendrophylliidae & Oculinidae & some spp. in family Caryophylliidae	CBR	stony corals	stony corals - branching	
Golden corals	Chrysogorgia spp.	CHR	gorgonians	gorgonians - calcaxonia	
Whip corals	Cirrhipathes spp.	CIR	black corals	black corals	
Clumping cup coral	Cladopsammia spp.	CLA	stony corals	stony corals - cup	
Callogorgia spp.	Callogorgia spp.	CLG	gorgonians	gorgonians - calcaxonia	
Precious corals	Corallium spp.	CLL	gorgonians	gorgonians - scleraxonians	Corallium
Ambrosia cup coral	Caryophyllia (Caryophyllia) ambrosia	CMB	stony corals	stony corals - cup	
Black corals	Antipatharia (Order)	COB	black corals	black corals	
Flabellum cup corals	Flabellum spp.	COF	stony corals	stony corals - cup	
Conopora spp.	Conopora spp.	COO	lace corals	lace corals	
Stylasterids (hydrocorals)	Stylasteridae (Family)	COR	lace corals	lace corals	
White hydrocoral	Calyptopora reticulata	CRE	lace corals	lace corals	
Cryptelia spp.	Cryptelia spp.	CRY	lace corals	lace corals	
Calyptrophora spp.	Calyptrophora spp.	CTP	gorgonians	gorgonians - calcaxonia	
Stony cup corals	Families Flabellidae & Fungiacyathidae & some spp. in family Caryophyllidae	CUP	stony corals	stony corals - cup	
Stony branching coral	Dendrophyllia spp.	DDB	stony corals	stony corals - branching	
Crested cup coral	Desmophyllum dianthus	DDI	stony corals	stony corals - cup	
Black coral	Dendropathes spp.	DDP	black corals	black corals	
Black coral	Dendrobathypathes spp.	DEN	black corals	black corals	
Bottlebrush coral	Dasystenella spp.	DSY	gorgonians	gorgonians - calcaxonia	
Stony branching coral	Eguchipsammia japonica	EJA	stony corals	stony corals - branching	
Deepwater branching coral	Enallopsammia rostrata	ERO	stony corals	stony corals - branching	Enallopsammia rostrata
Red hydrocorals	Errina spp.	ERR	lace corals	lace corals	Errina spp
Apertum cup coral	Flabellum (Ulocyathus) apertum	FAP	stony corals	stony corals - cup	
Fungiacyathus spp.	Fungiacyathus spp.	FUG	stony corals	stony corals - cup	
Bushy hard coral	Goniocorella dumosa	GDU	stony corals	stony corals - branching	Goniocorella dumosa
Gorgonian octocoral coral	Gorgonian (order) in Order Alcyonacea	GOC	gorgonians		
Anthothelid coral	Iciligorgia spp.	ICI	gorgonians	gorgonians - others	
Iridescent coral	Iridogorgia spp.	IRI	gorgonians	gorgonians - calcaxonia	
Bamboo corals	Isididae (Family)	ISI	gorgonians	gorgonians - calcaxonia	
Bamboo coral	Isidella spp.	ISP	gorgonians	gorgonians - calcaxonia	
Javania spp.	Javania spp.	JAA	stony corals	stony corals - cup	
Jasonisis	Jasonisis	JAS	gorgonians	gorgonians - calcaxonia	
Black coral	Leiopathes spp.	LEI	black corals	black corals	Leiopathes
Black coral	Lillipathes spp.	LIL	black corals	black corals	
Bamboo coral	Lepidisis spp.	LLE	gorgonians	gorgonians - calcaxonia	Lepidisis spp.
Bushy lace coral	Lepidopora spp.	LPP	lace corals	lace corals	
Spiny white hydrocorals	Lepidotheca spp.	LPT	lace corals	lace corals	
Leiopathes black coral	Leiopathes secunda	LSE	black corals	black corals	Leiopathes
Branching sea fan coral	Metafannyella spp.	MEF	gorgonians	gorgonians - calcaxonia	
Worm-commensal bamboo coral	Minuisis spp.	MIN	gorgonians	gorgonians - calcaxonia	
Madrepora coral	Madrepora oculata	MOC	stony corals	stony corals - branching	Madrepora oculata
Plexaurid sea fan	Muriceides spp.	MRI	gorgonians	gorgonians - others	
Metallic coral	Metallogorgia spp.	MTL	gorgonians	gorgonians - calcaxonia	
Rasta coral	Narella spp.	NAR	gorgonians	gorgonians - calcaxonia	
Deepwater branching coral	Oculina virgosa	OVI	stony corals	stony corals - branching	
Bubblegum coral	Paragorgia arborea	PAB	gorgonians	gorgonians - scleraxonians	Paragorgia arborea
Bamboo bottlebrush coral	Primnoisis antarctica	PAN	gorgonians	gorgonians - calcaxonia	
Primnoid sea fan	Parastenella spp.	PLD	gorgonians	gorgonians - calcaxonia	
Sea fans	Plexauridae (Family)	PLE	gorgonians	gorgonians - others	
Sea feather	Plumigorgia spp.	PLG	gorgonians	gorgonians - calcaxonia	
Plumarella spp.	Plumarella spp.	PLL	gorgonians	gorgonians - calcaxonia	
Plexaurid sea fan	Placogorgia spp.	PLO	gorgonians	gorgonians - others	
Primnoella spp.	Primnoella spp.	PML	gorgonians	gorgonians - calcaxonia	
Primnoa spp.	Primnoa spp.	PMN	gorgonians	gorgonians - calcaxonia	Primnoa
Plexaurid sea fan	Paracis spp.	PRF	gorgonians	gorgonians - others	
Plexaurid sea fan	Paramuricea spp.	PRG	gorgonians	gorgonians - others	
Whip-like primnoid	Primnoella	PRH	gorgonians	gorgonians - calcaxonia	
Primnoidae (Family)	Primnoidae (Family)	PRI	gorgonians	gorgonians - calcaxonia	
Black coral	Parantipathes spp.	PTP	black corals	black corals	
WHIP-LIKE GOLDEN CORAL	RADICIPES SPP.	RAD	gorgonians	gorgonians - calcaxonia	
Red encrusting polyps	Rhodelinda gardineri	RGA	gorgonians	gorgonians - others	
Stony corals	Scleractinia (Order)	SIA	stony corals		
Black coral	Stylopathes spp.	SLP	black corals	black corals	
Black coral	Saropathes spp.	SRO	black corals	black corals	
Black coral	Stichopathes spp.	STI	black corals	black corals	
Rose lace corals	Stylaster spp.	STL	lace corals	lace corals	Stylaster spp
Solitary bowl coral	Stephanocyathus platypus	STP	stony corals	stony corals - cup	
Stephanocyathus spiniger	Stephanocyathus spiniger	STS	stony corals	stony corals - cup	
Deepwater branching coral	Solenosmilia variabilis	SVA	stony corals	stony corals - branching	Solenosmilia variabilis
Plexaurid sea fan	Swiftia spp.	SWI	gorgonians	gorgonians - others	
Black coral	Triadopathes spp.	TDP	black corals	black corals	
Bottlebrush coral	Thouarella spp.	THO	gorgonians	gorgonians - calcaxonia	
Encrusting polyps	Telestula spp.	TLA	gorgonians	gorgonians - others	
Long polyp soft corals	Telesto spp.	TLO	gorgonians	gorgonians - others	
Branching bushy coral	Tokoprymno spp.	TOK	gorgonians	gorgonians - calcaxonia	
Trissopathes spp.	Trissopathes spp.	TPT	black corals	black corals	
Gorgonian coral	Trachymuricea spp.	TRH	gorgonians	gorgonians - others	
Black coral	Tylopathes spp.	TYL	black corals	black corals	
Deep-sea purple gorgonian	Victorgorgia spp.	VCT	gorgonians	gorgonians - others	
Deep-sea purple gorgonian	Victorgorgiidae	VIC	gorgonians	gorgonians - others	
Plexaurid sea fan	Villogorgia spp.	VIL	gorgonians	gorgonians - others	

6.2 Time series of coral captures by method and capture weight estimation method for black corals, lace corals, and gorgonians

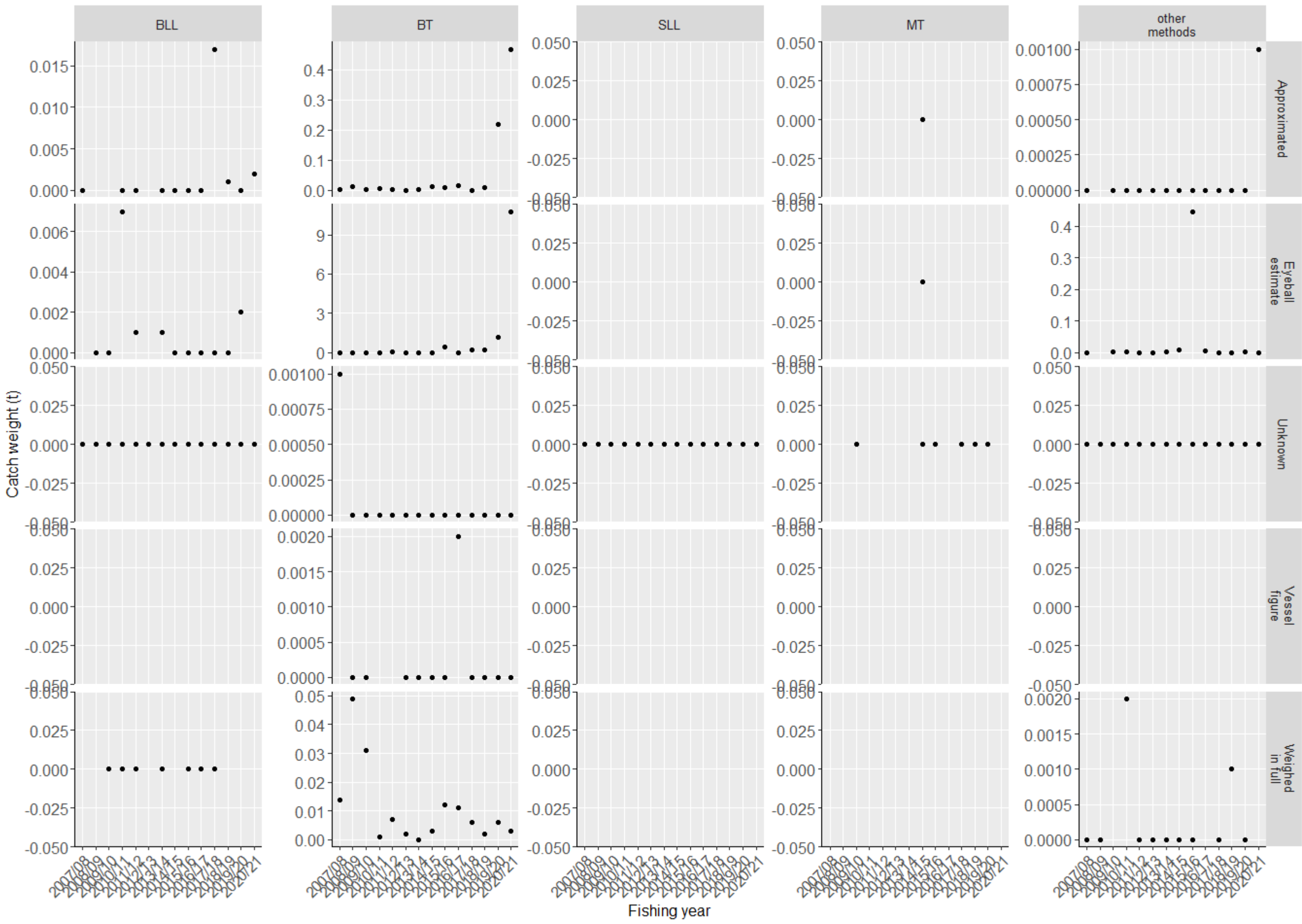

Figure 6.1: Time series of observed black coral catch weight by fishing method and methodology to determine catch weight as reocrded by observers.

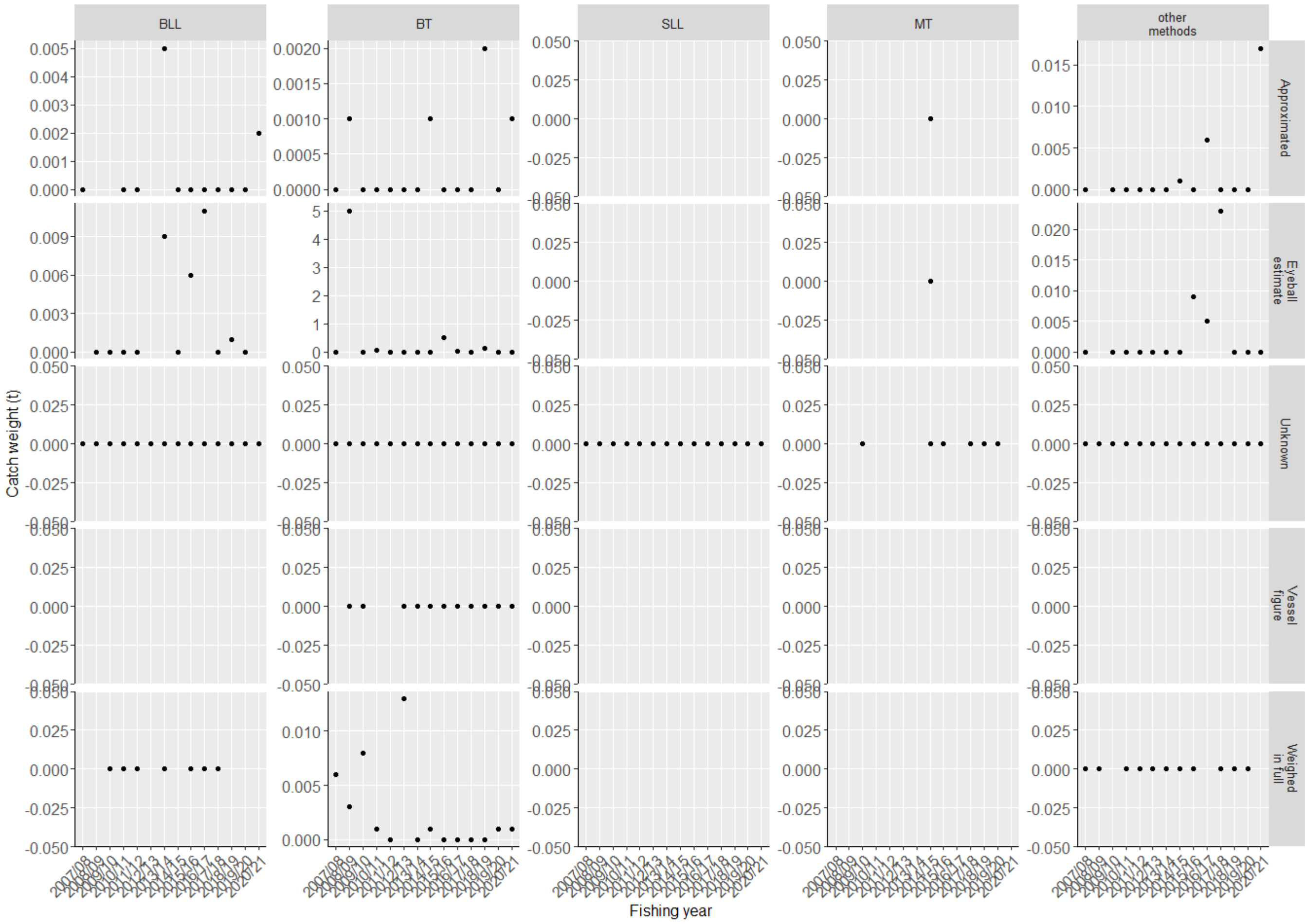

Figure 6.2: Time series of observed lace coral catch weight by fishing method and methodology to determine catch weight as reocrded by observers.

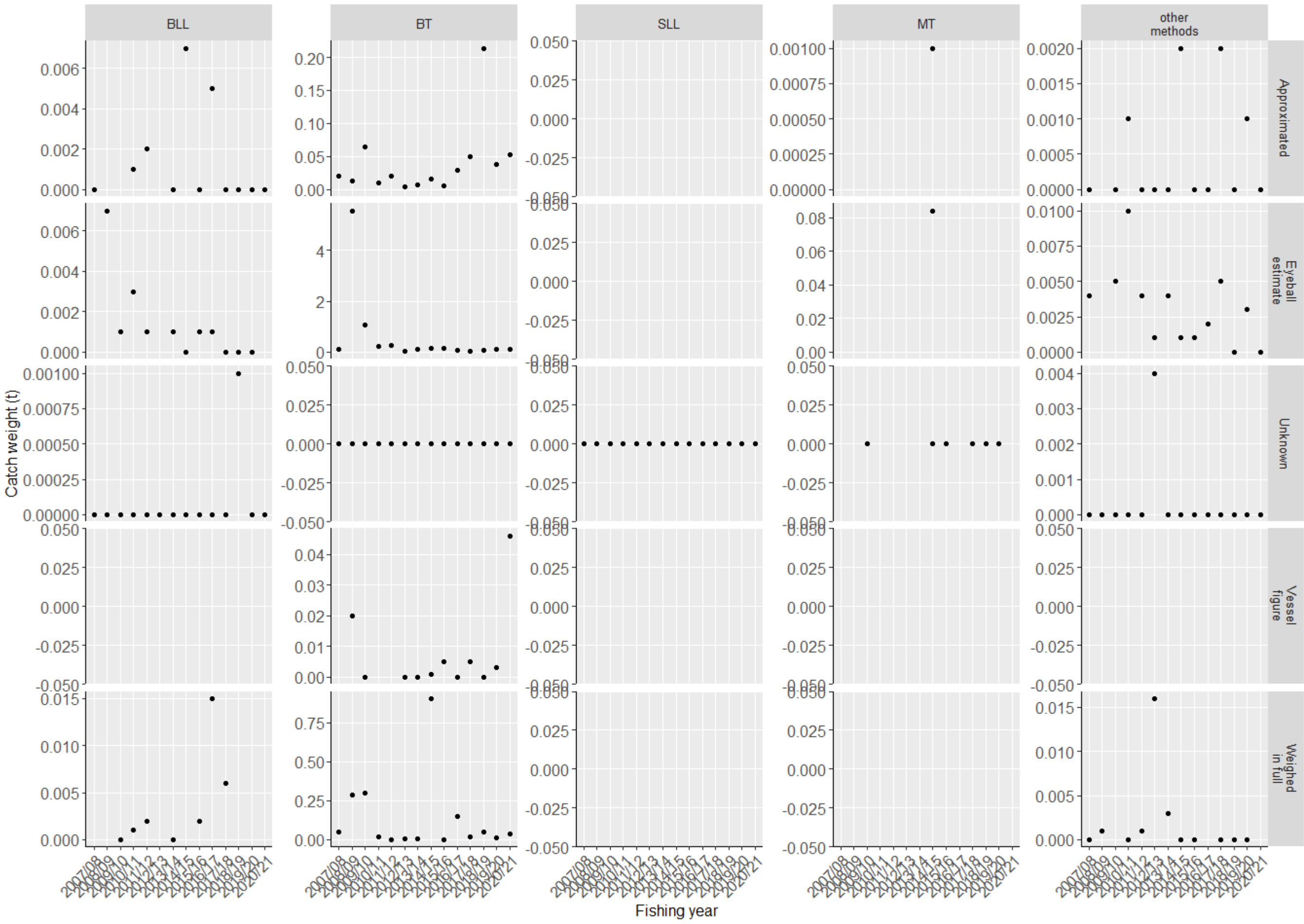

Figure 6.3: Time series of observed gorgonian catch weight by fishing method and methodology to determine catch weight as reocrded by observers.

6.3 Spatial distribution of protected coral species group captures in bottom-trawl fisheries

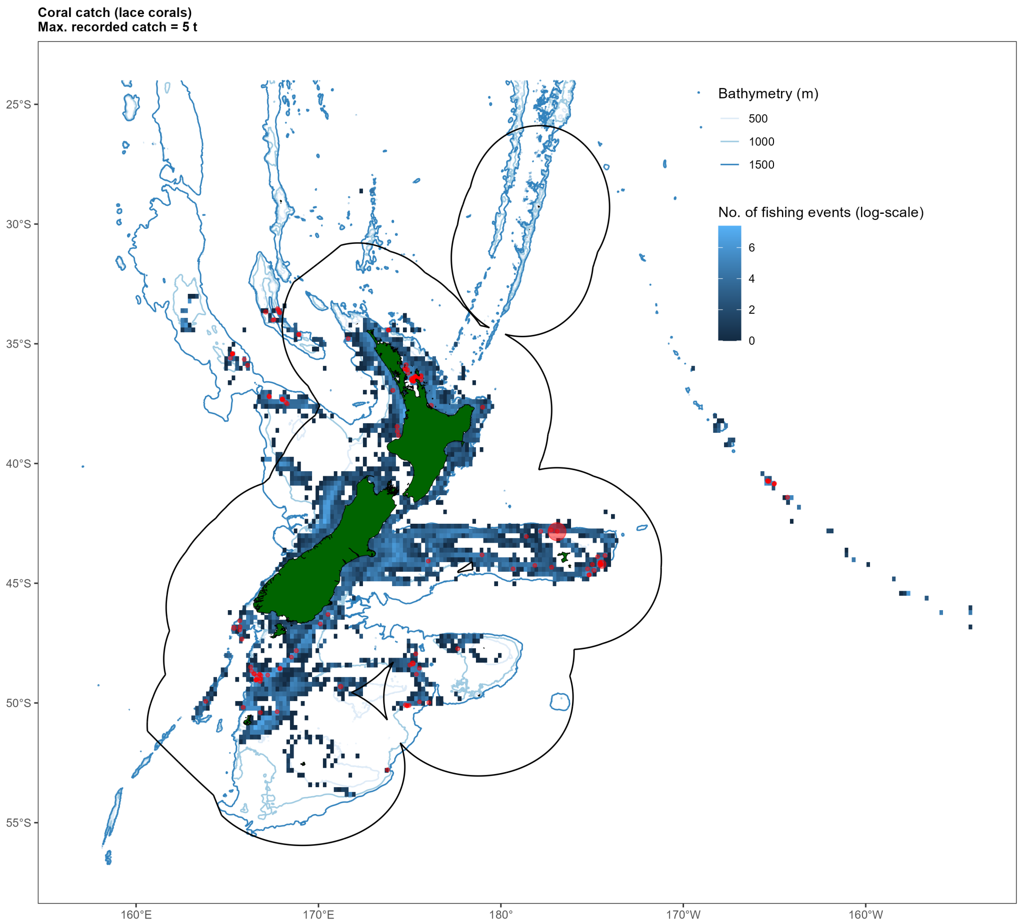

Figure 6.4: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries (0.2° latitude x 0.2° longitude cells) and the lace corals tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 to 2019–20 fishing years.

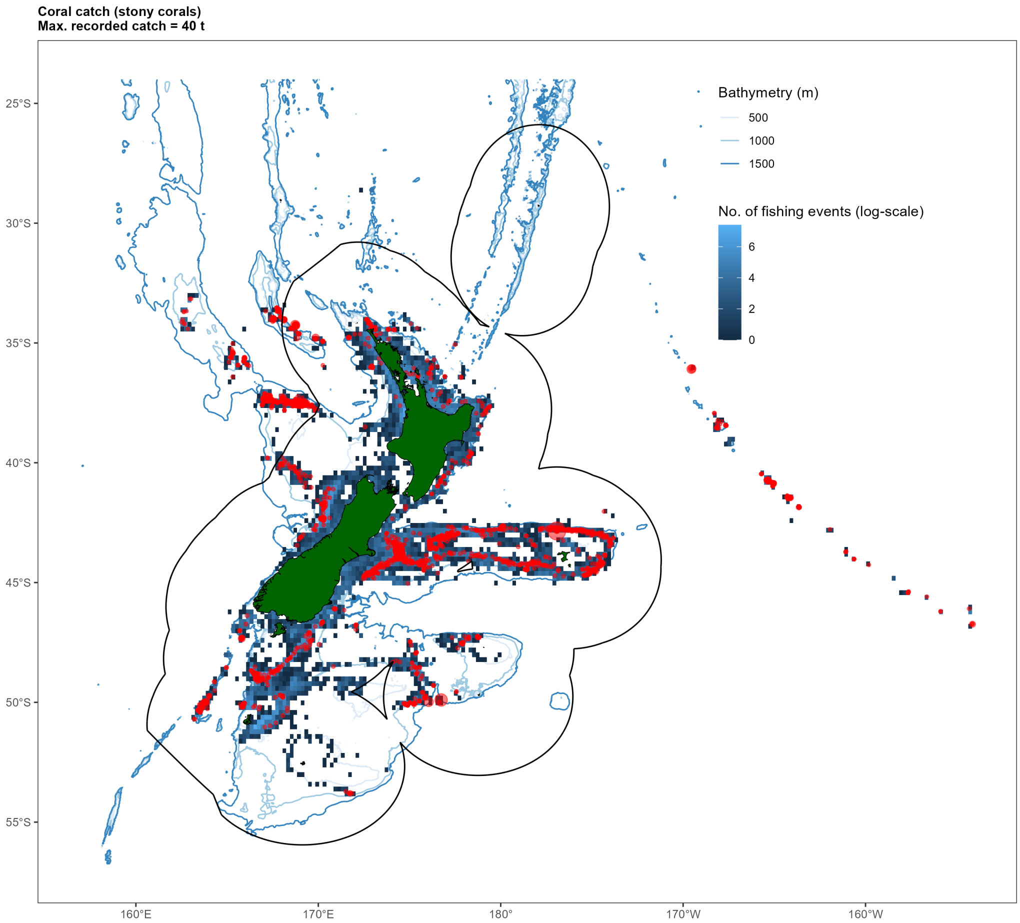

Figure 6.5: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries (0.2° latitude x 0.2° longitude cells) and the stony corals tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

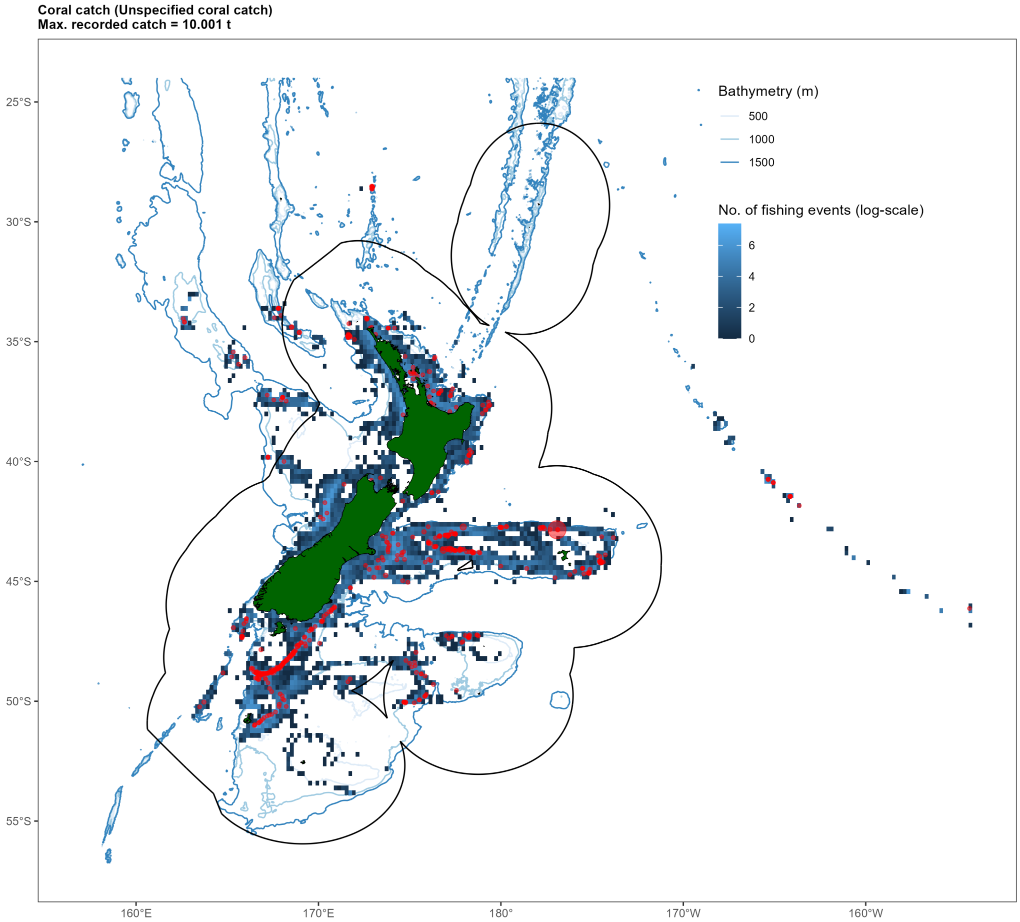

Figure 6.6: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries ($0.2°$ latitude x $0.2°$ longitude cells) and the tow catch weights (t) for unidentified true corals (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

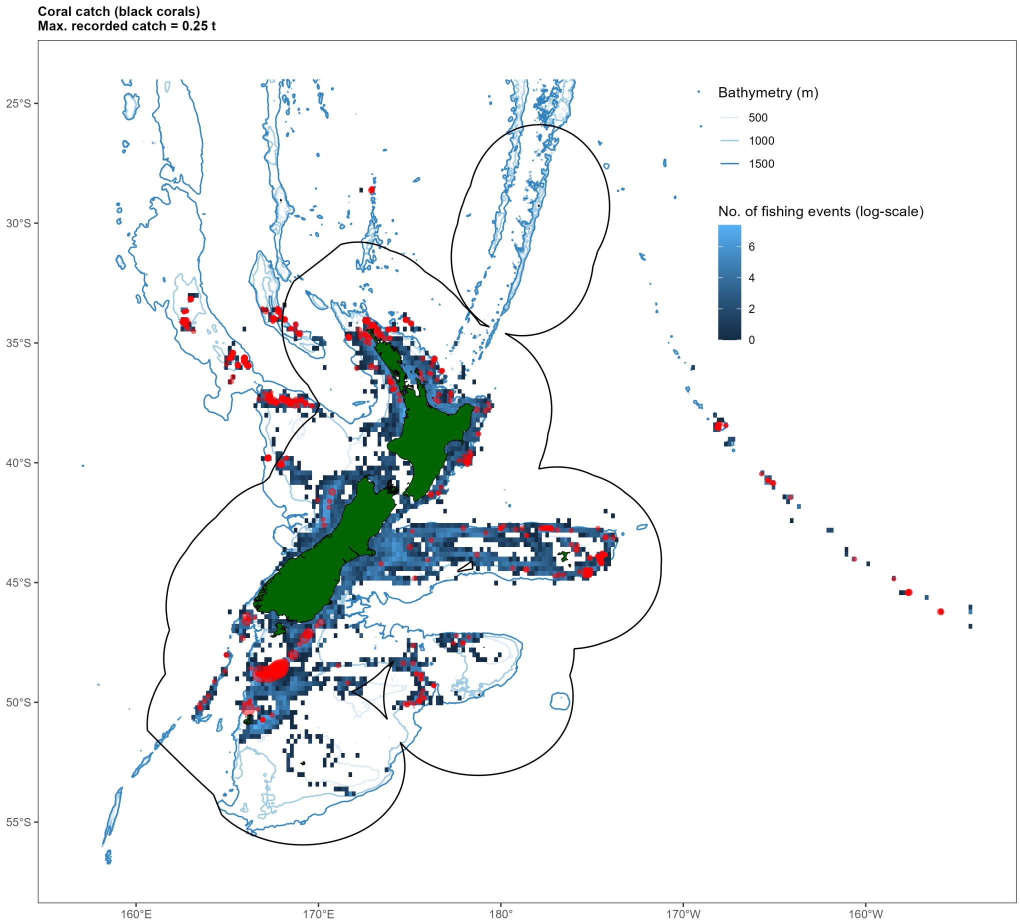

Figure 6.7: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries ($0.2°$ latitude x $0.2°$ longitude cells) and the black coral tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

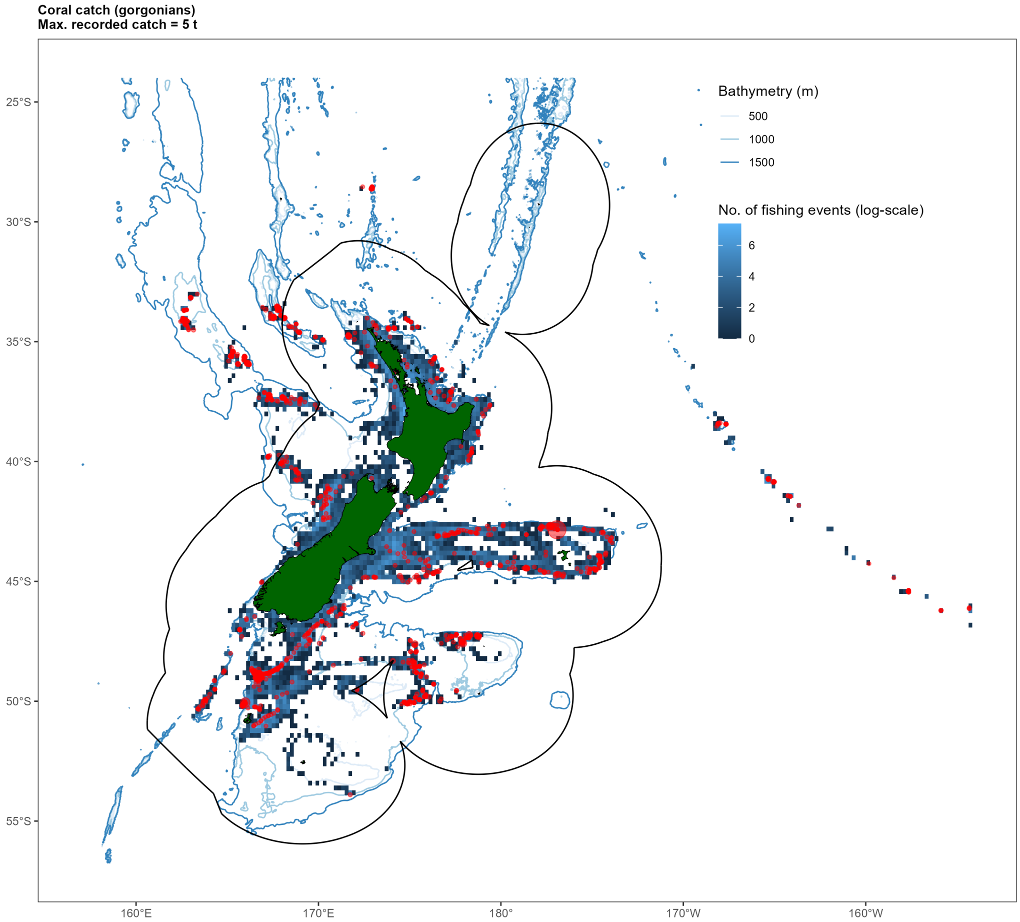

Figure 6.8: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries (0.2° latitude x 0.2° longitude cells) and the gorgonian tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

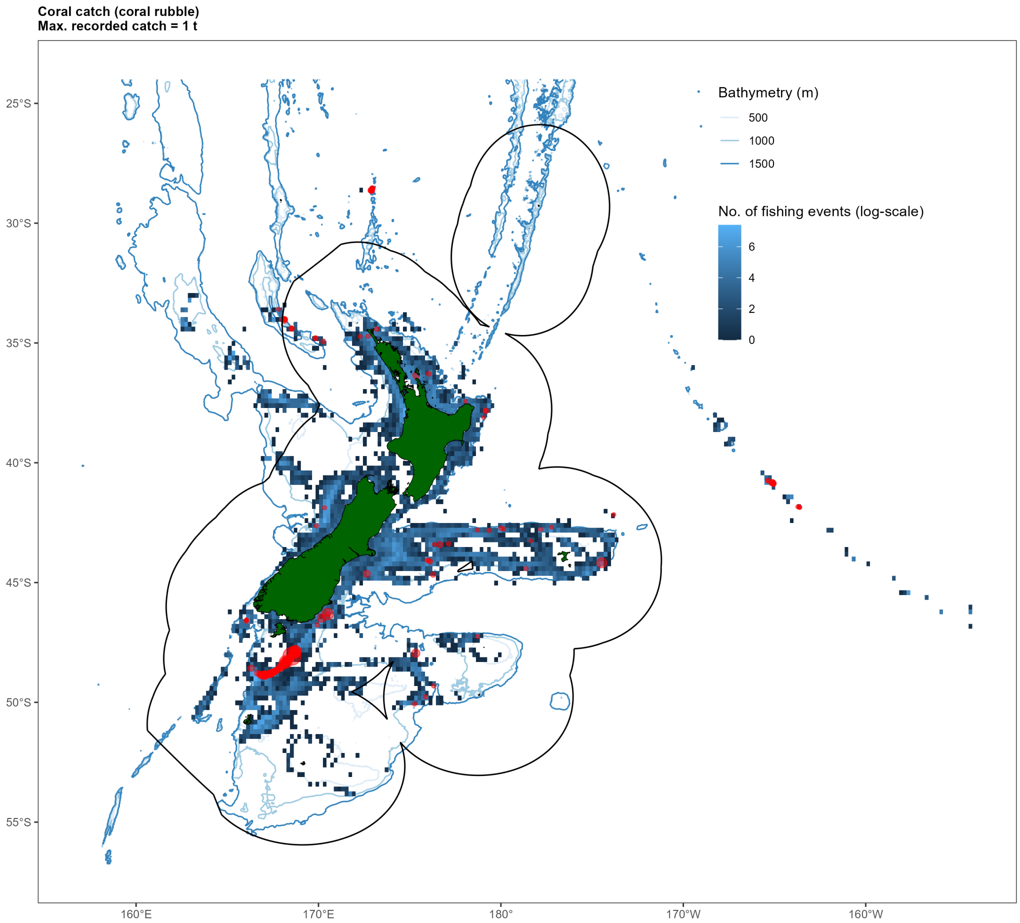

Figure 6.9: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries (0.2° latitude x 0.2° longitude cells) and the tow catch weights (t) for coral rubble (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

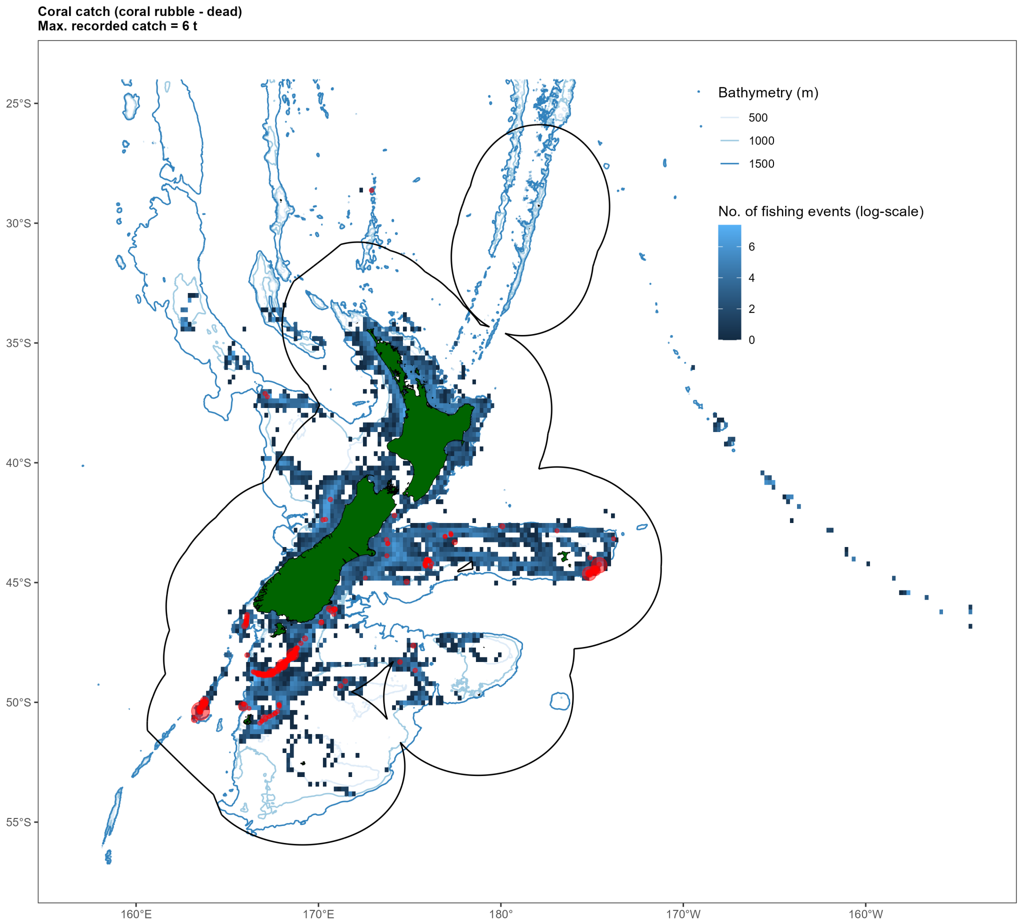

Figure 6.10: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries ($0.2°$ latitude x $0.2°$ longitude cells) and the tow catch weights (t) for dead coral rubble (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

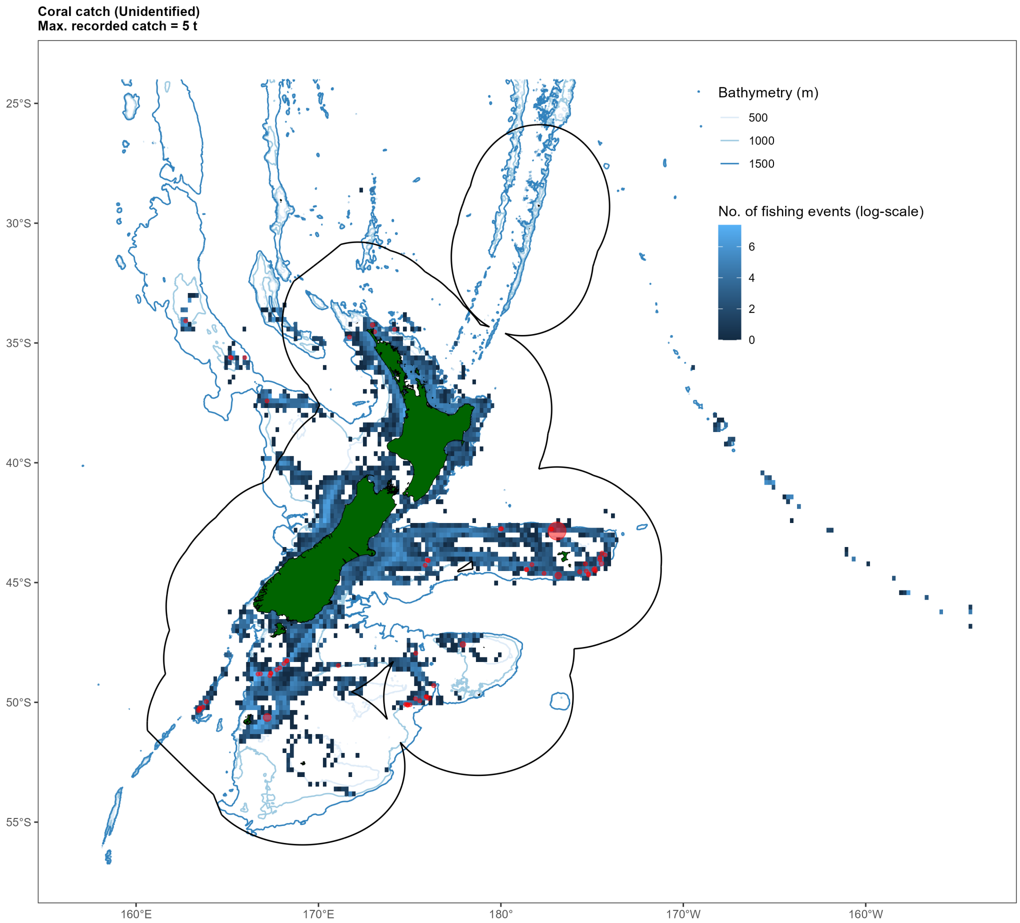

Figure 6.11: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries (0.2° latitude x 0.2° longitude cells) and the tow catch weights (t) for unidenitfied catch (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

6.4 Spatial distribution of coral captures for seven groups representing mix of morphological and/or taxonomic division in bottom-trawl fisheries

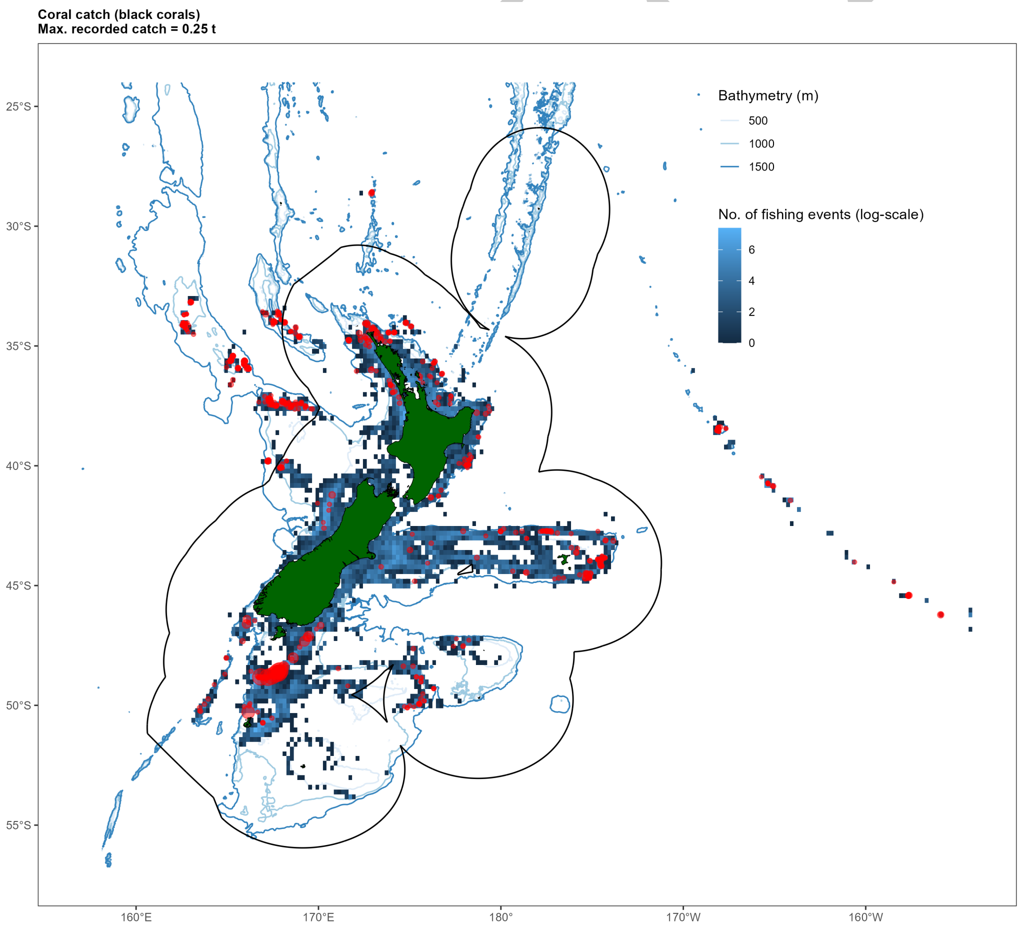

Figure 6.12: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries (0.2° latitude x 0.2° longitude cells) and the black coral tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

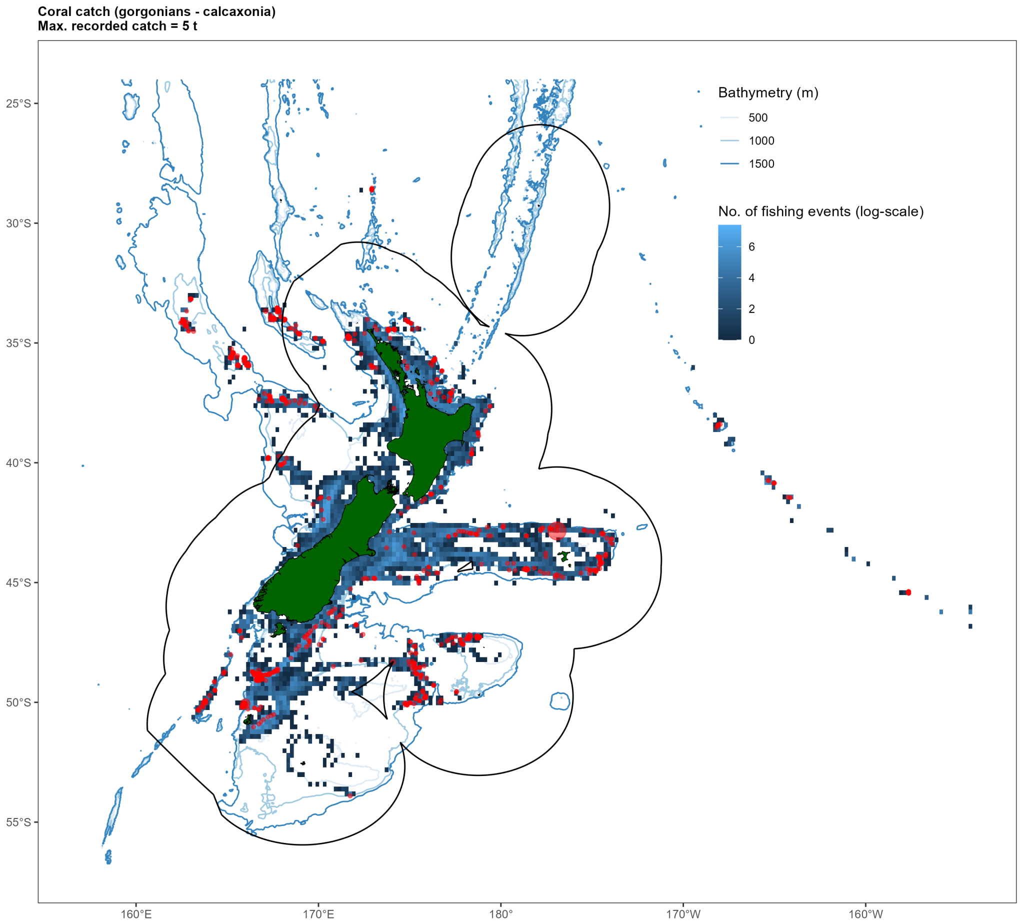

Figure 6.13: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries ($0.2°$ latitude x $0.2°$ longitude cells) and the gorgonians (clcaxonia branching) tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

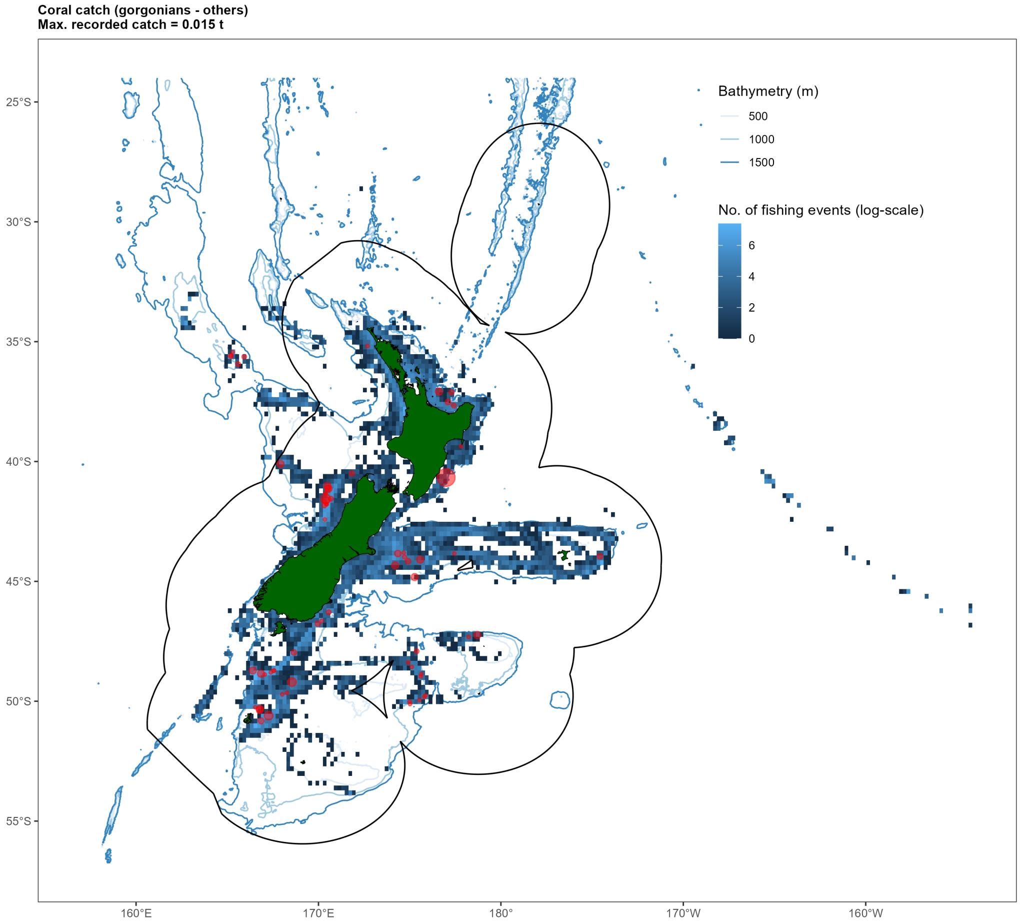

Figure 6.14: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries (0.2° latitude x 0.2° longitude cells) and the gorgonians (other branching) tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

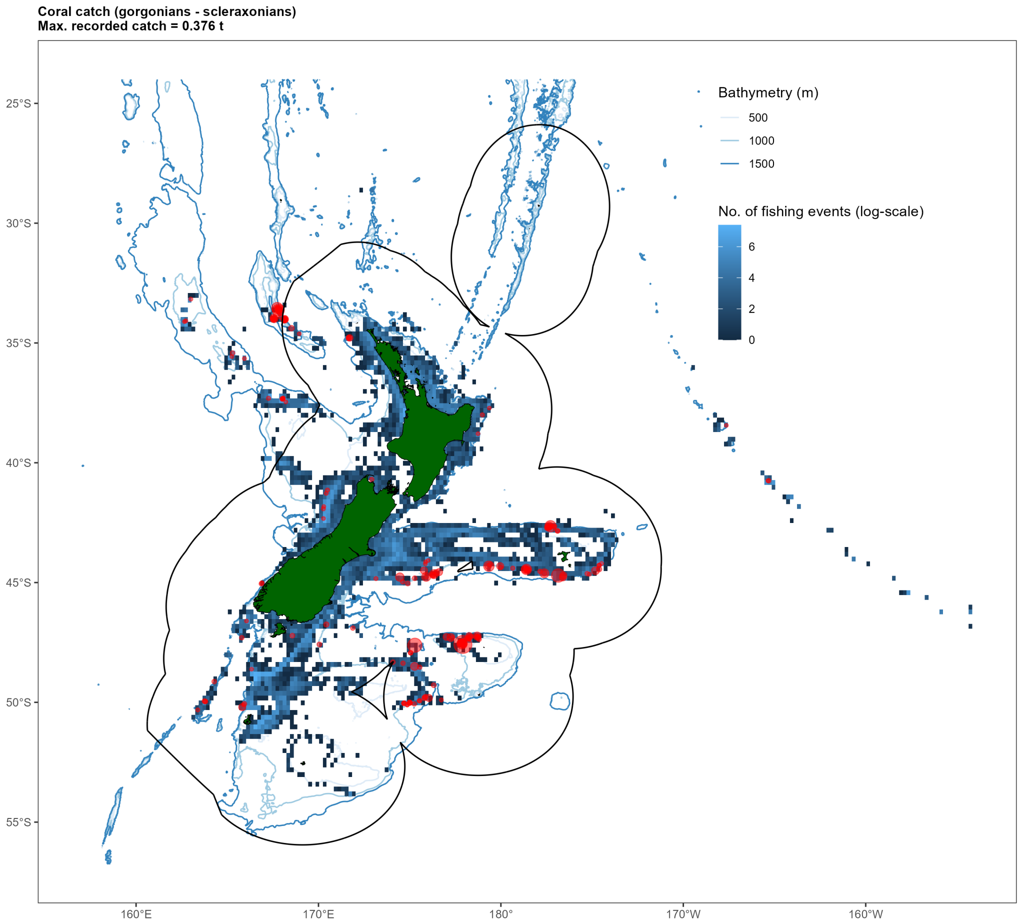

Figure 6.15: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries ($0.2°$ latitude x $0.2°$ longitude cells) and the gorgonians (scleraxonians-branching) tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

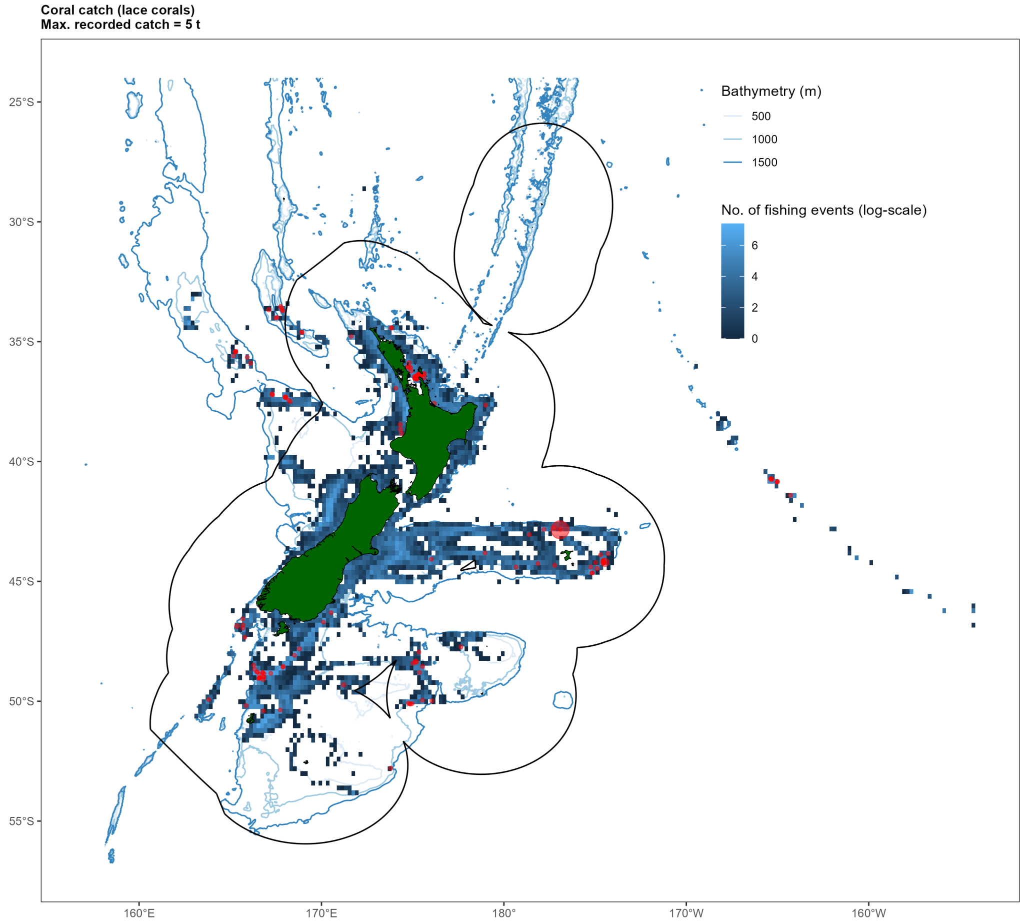

Figure 6.16: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries ($0.2°$ latitude x $0.2°$ longitude cells) and the lace coral tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

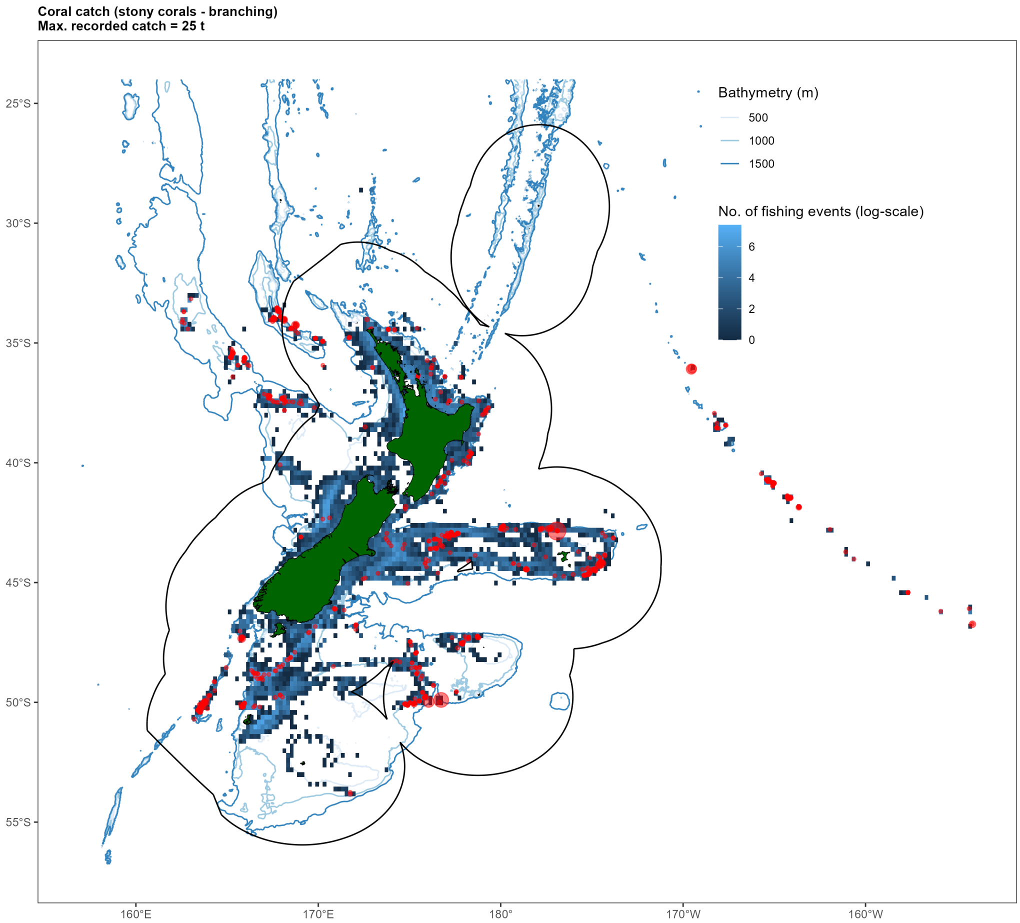

Figure 6.17: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries ($0.2°$ latitude x $0.2°$ longitude cells) and the stony coral (branching) tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

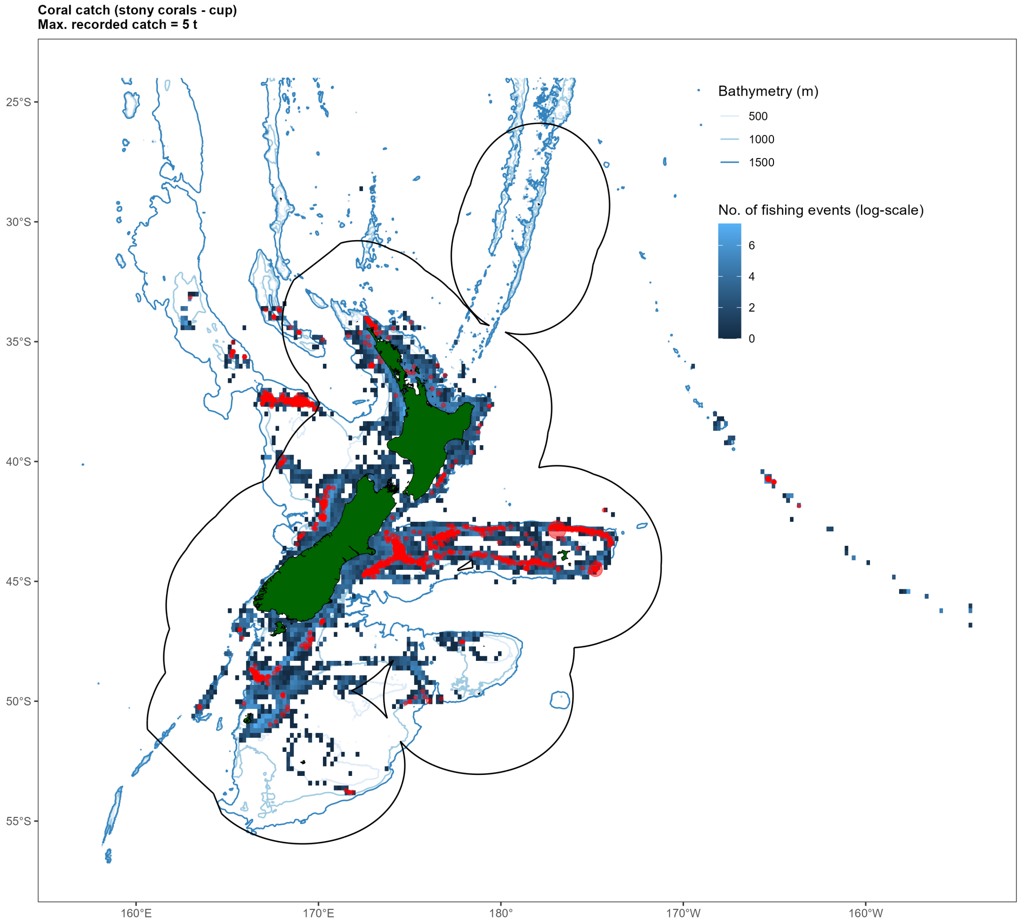

Figure 6.18: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries ($0.2°$ latitude x $0.2°$ longitude cells) and the stony coral (cup) tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

6.5 Spatial distribution of 12 individual taxa with known species distribution in bottom-trawl fisheries

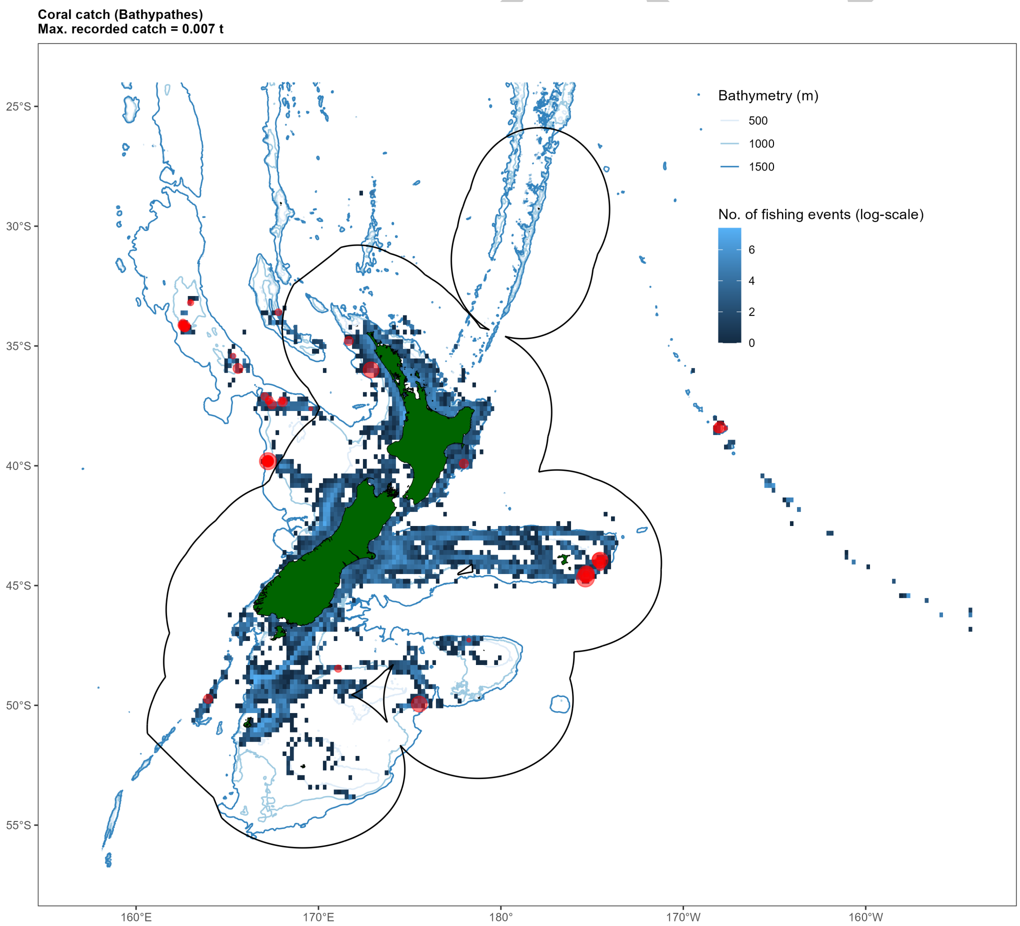

Figure 6.19: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries ($0.2°$ latitude x $0.2°$ longitude cells) and the *Bathypathes* tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

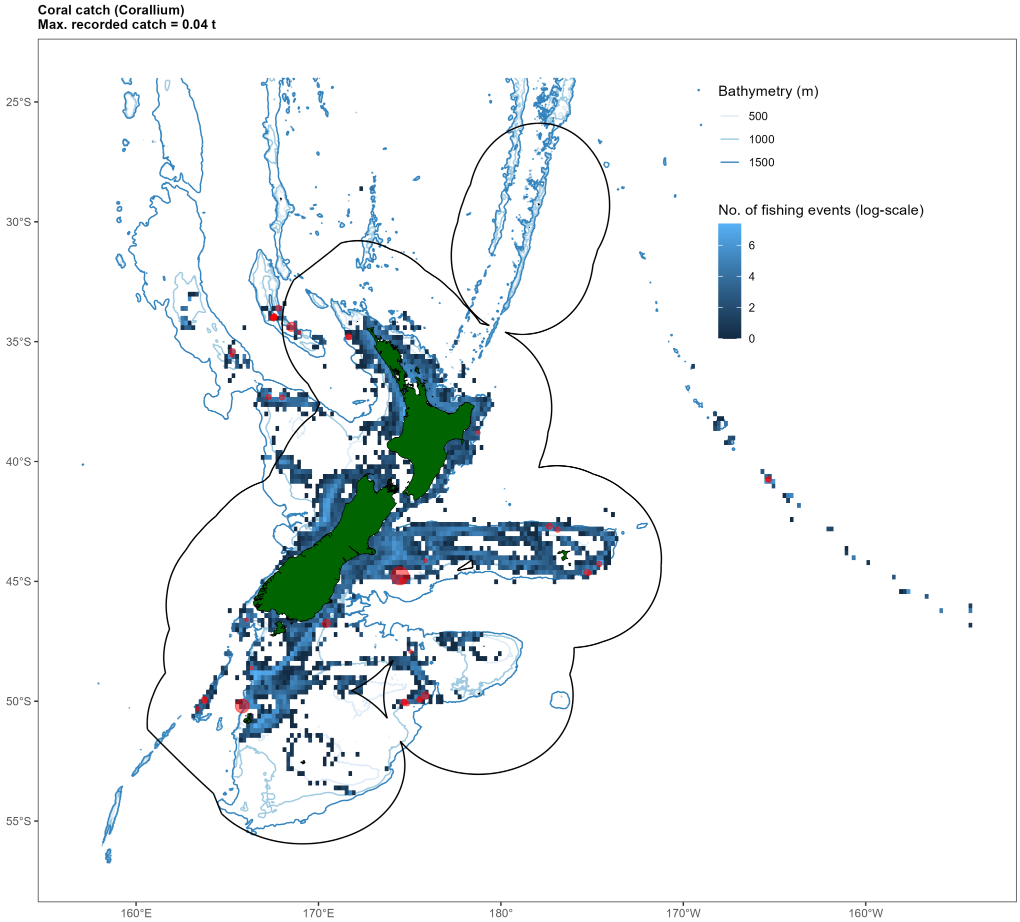

Figure 6.20: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries ($0.2°$ latitude x $0.2°$ longitude cells) and the *Corallium* tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

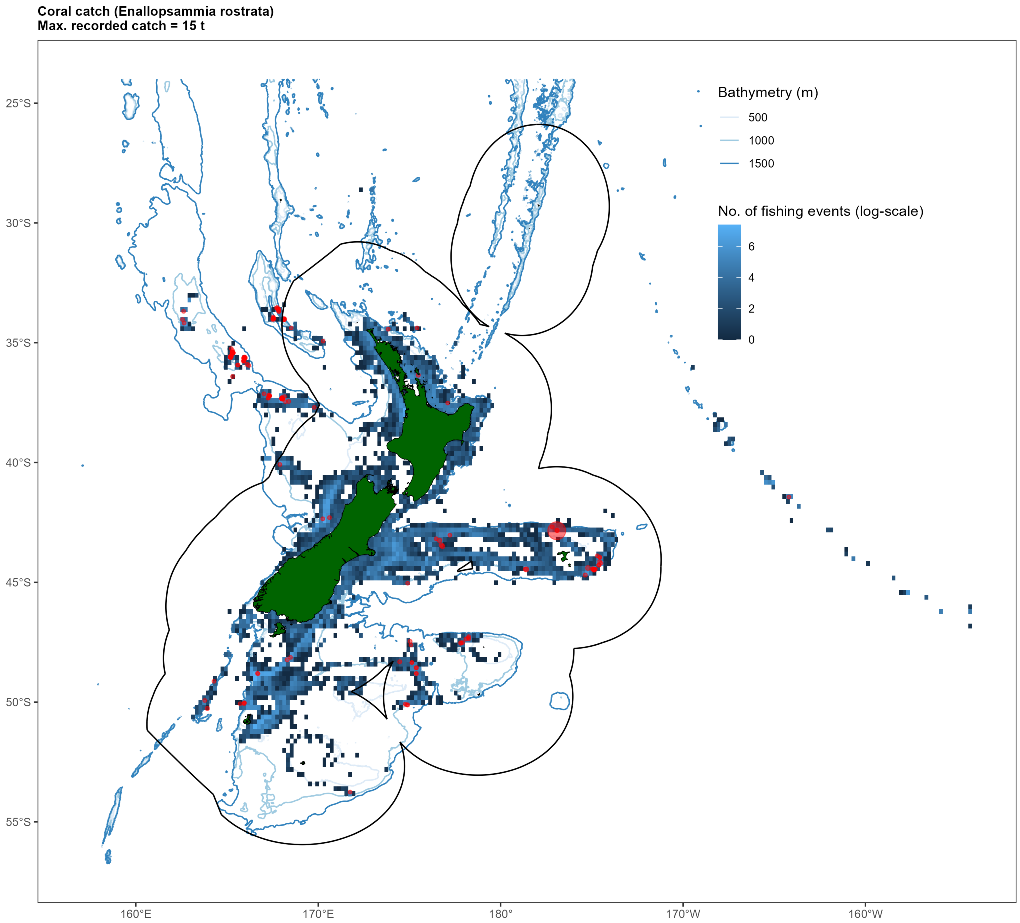

Figure 6.21: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries ($0.2°$ latitude x $0.2°$ longitude cells) and the *Enallopsammia rostrata* tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

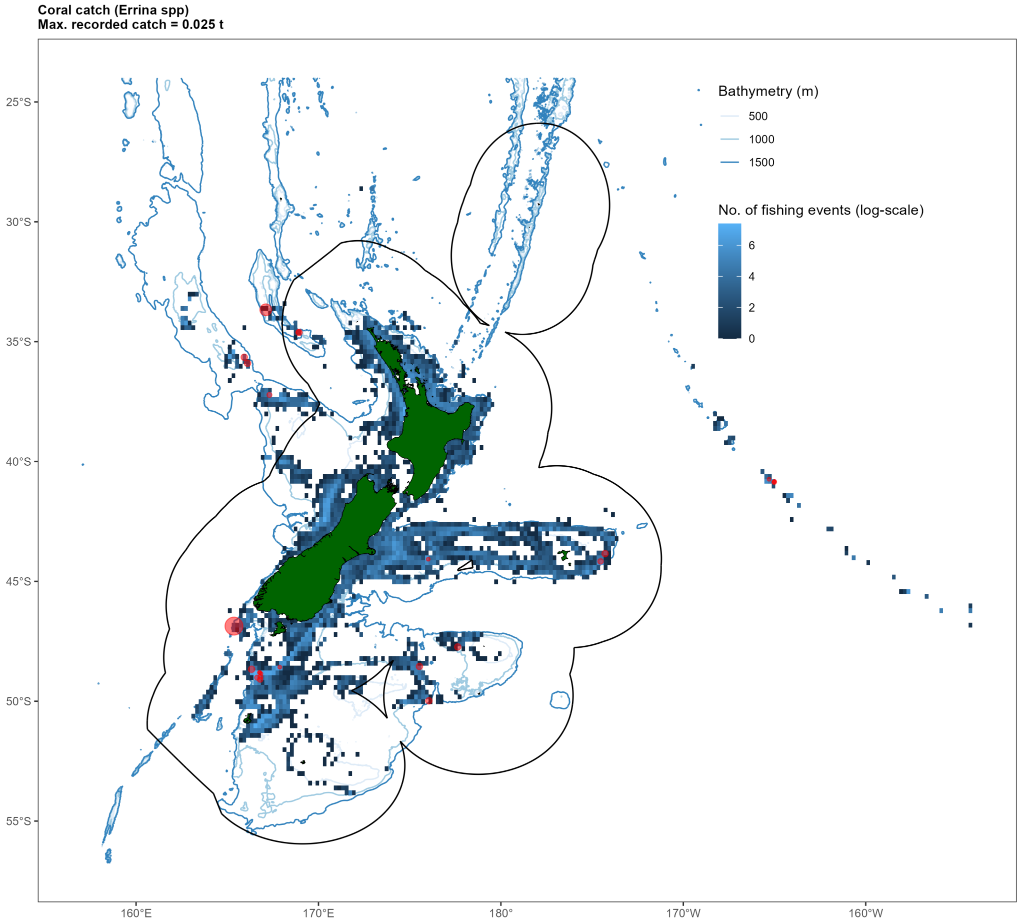

Figure 6.22: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries (0.2° latitude x 0.2° longitude cells) and the *Errina* tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

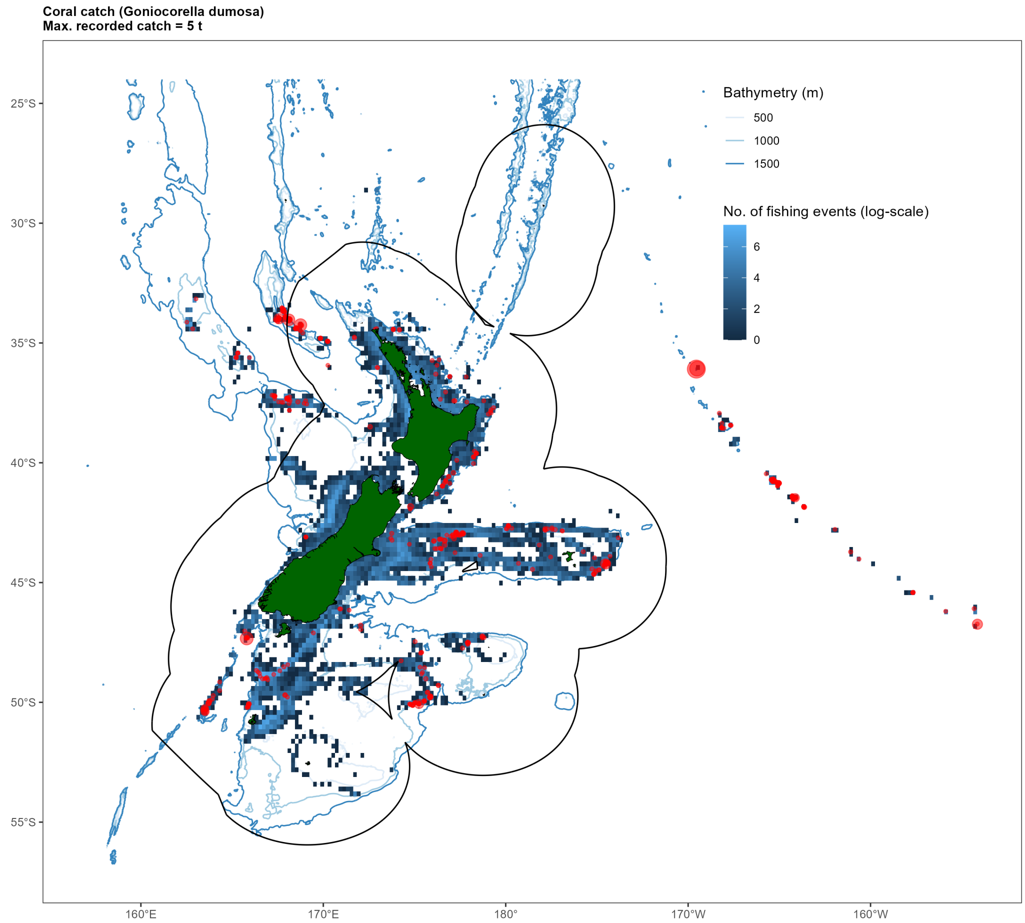

Figure 6.23: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries ($0.2°$ latitude x $0.2°$ longitude cells) and the *Goniocorella dumosa* tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

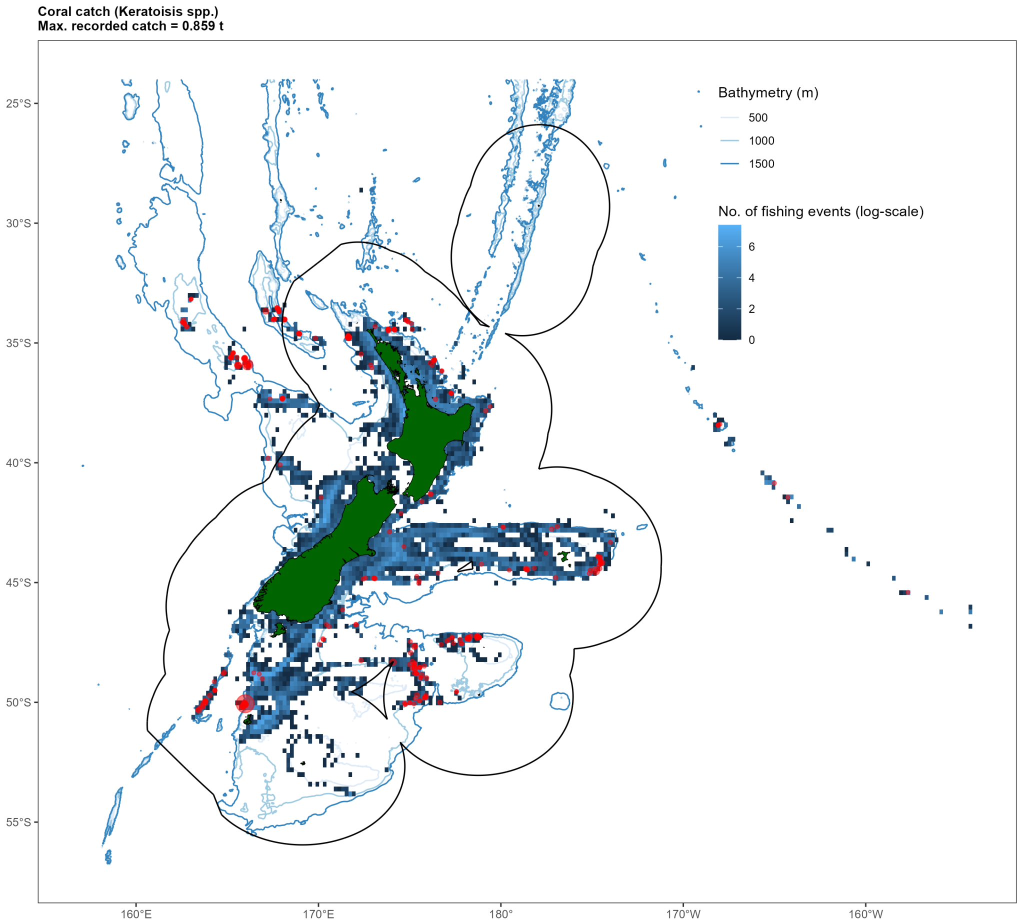

Figure 6.24: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries ($0.2°$ latitude x $0.2°$ longitude cells) and the *Keratoisis* tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

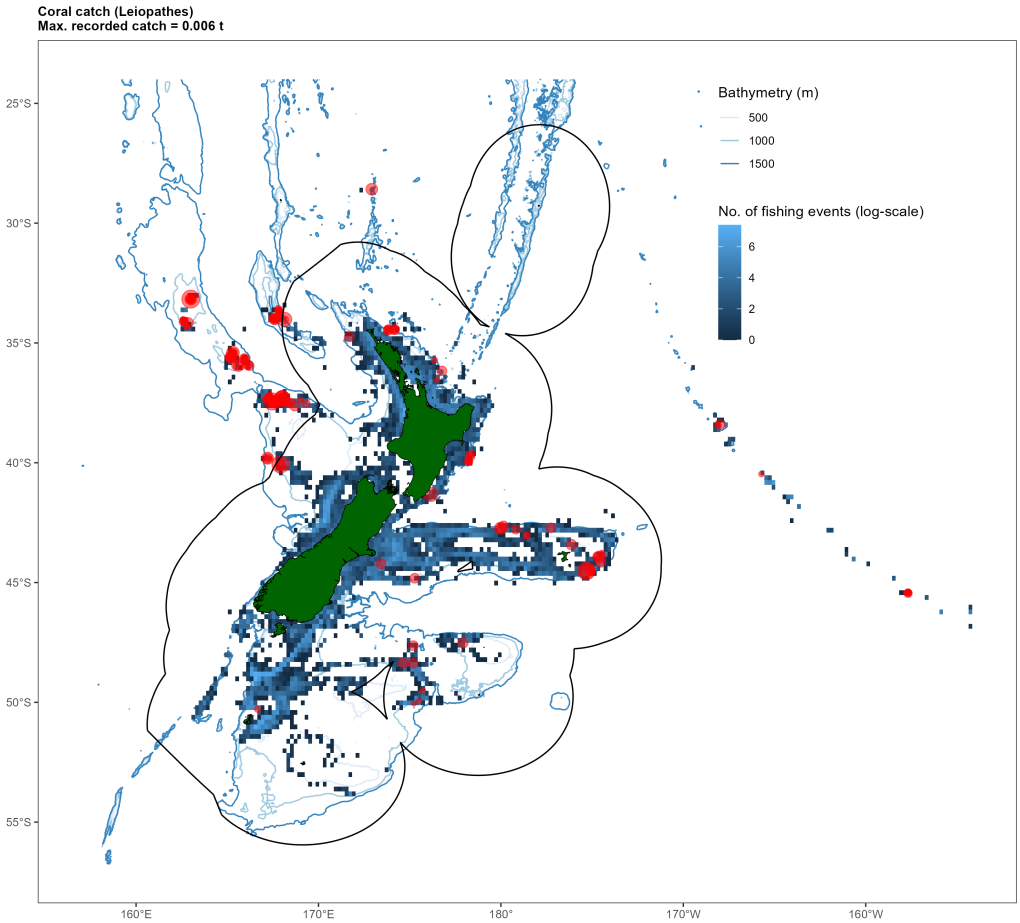

Figure 6.25: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries ($0.2°$ latitude x $0.2°$ longitude cells) and the *Leiopathes* tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

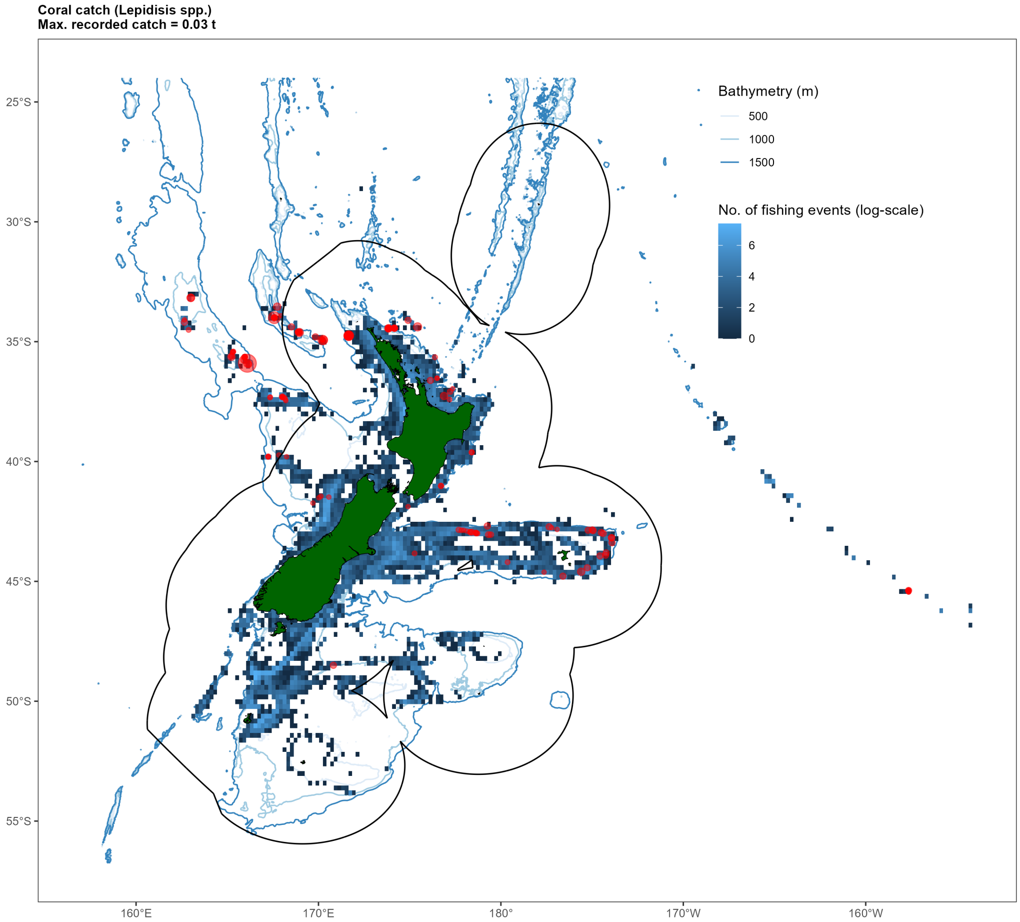

Figure 6.26: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries (0.2° latitude x 0.2° longitude cells) and the *Lepidisis* tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

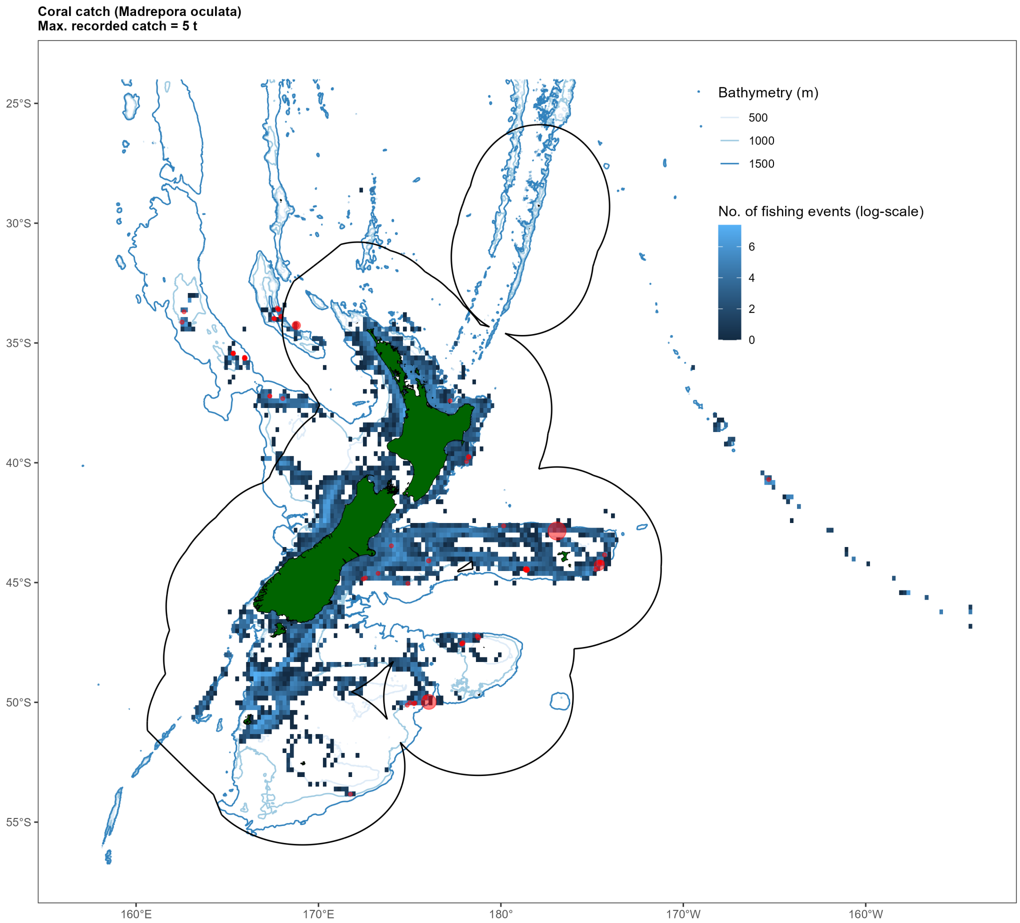

Figure 6.27: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries ($0.2°$ latitude x $0.2°$ longitude cells) and the *Madrepora oculata* tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

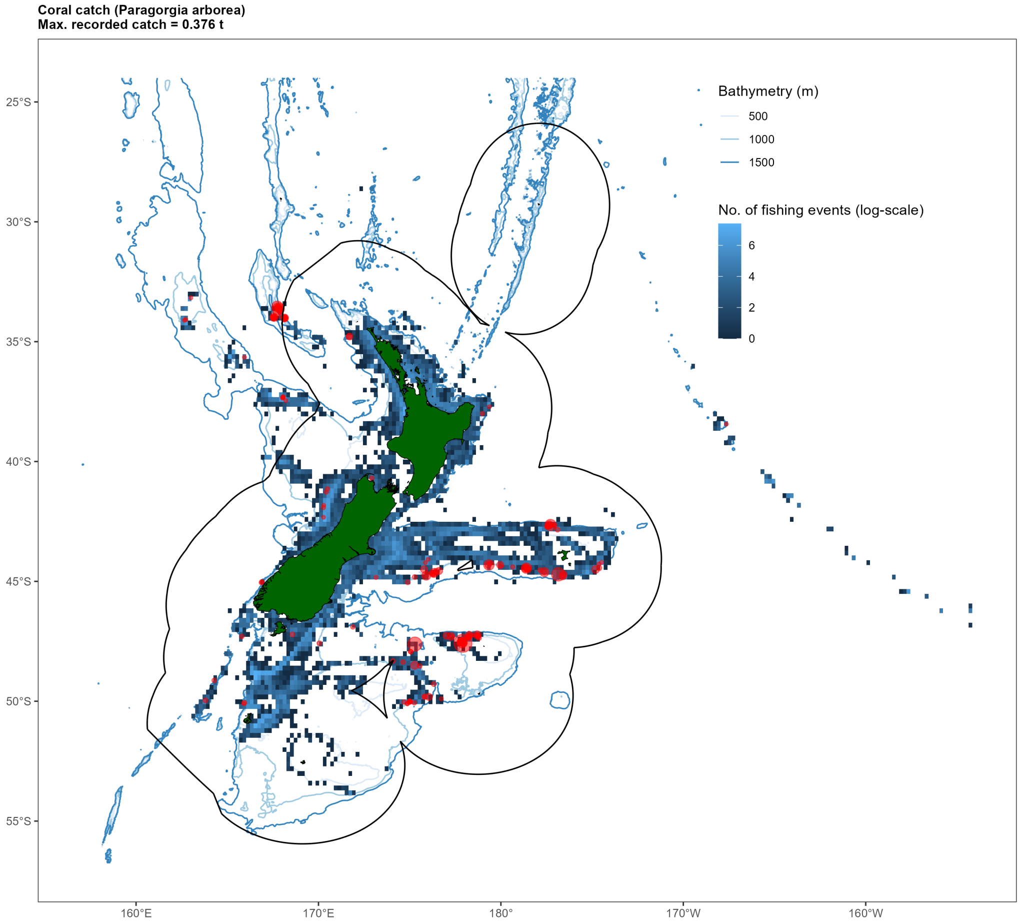

Figure 6.28: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries ($0.2°$ latitude x $0.2°$ longitude cells) and the *Paragorgia arborea* tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

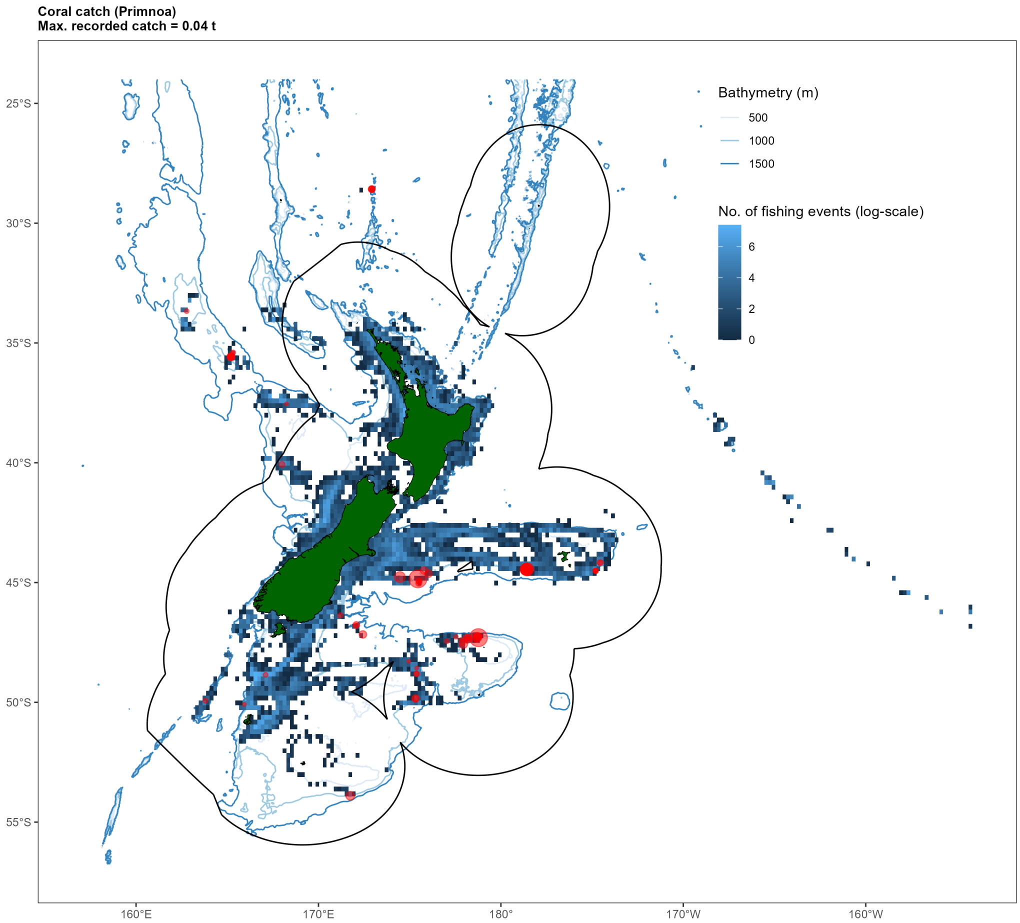

Figure 6.29: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries (0.2° latitude x 0.2° longitude cells) and the *Primnoa* tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

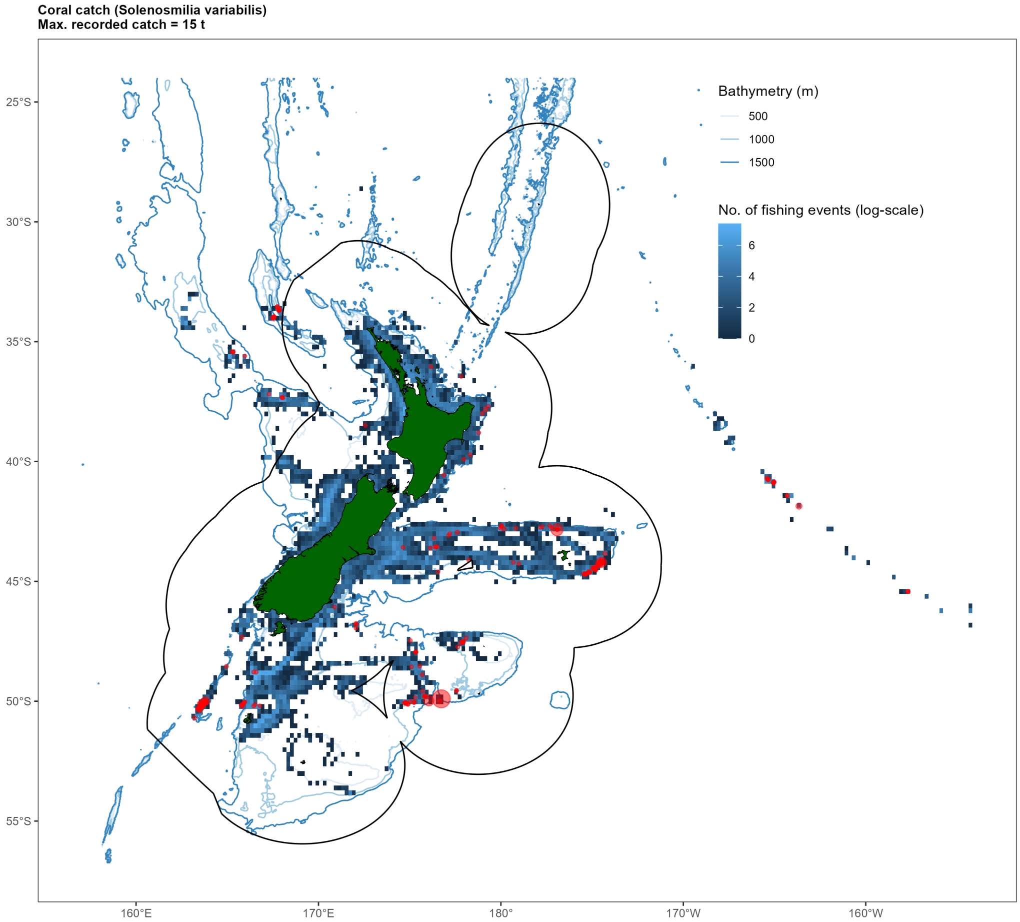

Figure 6.30: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries ($0.2°$ latitude x $0.2°$ longitude cells) and the *Solenosmilia variabilis* tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

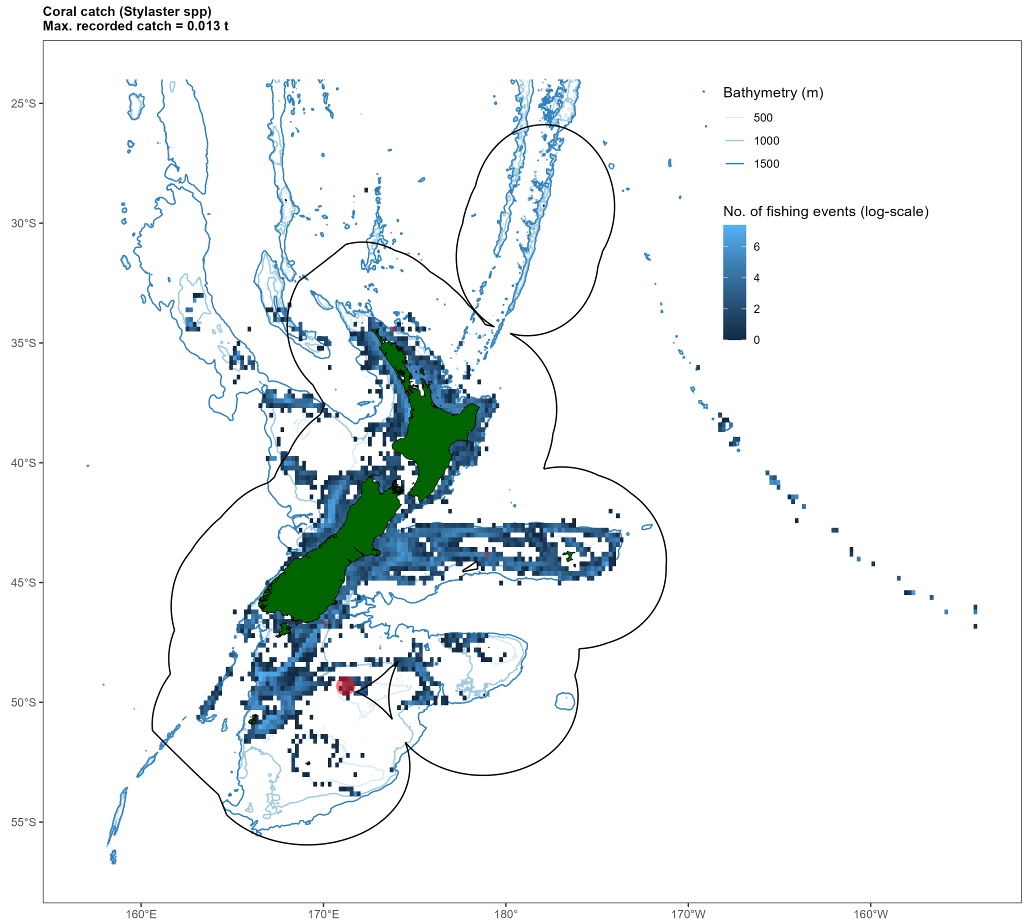

Figure 6.31: Distribution of observed fishing events (i.e., number of trawls) for bottom-trawl fisheries ($0.2°$ latitude x $0.2°$ longitude cells) and the *Stylaster* tow catch weights (t) (red circles: size is proportional to the maximum recorded catch), between the 2007–08 and 2019–20 fishing years.

6.6 Model fitting: Diagnostics and estimates

6.6.1 Logistic GAM

Stony corals

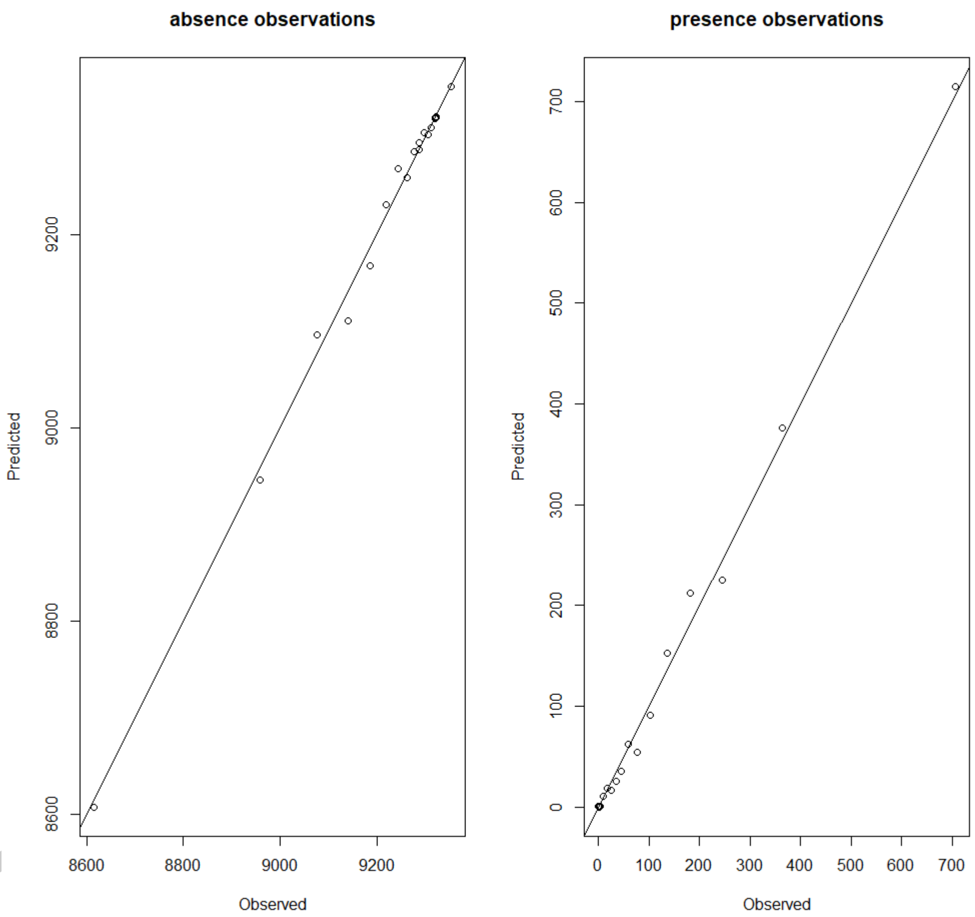

Figure 6.32: Predictive checking of logistic GAM fitted to presence-absence stony coral catch in all fishing methods. Shown are predicted vs. observed proportion of absences, i.e. no captures (left panel) and predicted vs. observed proportion of presences, i.e. captures (right panel).

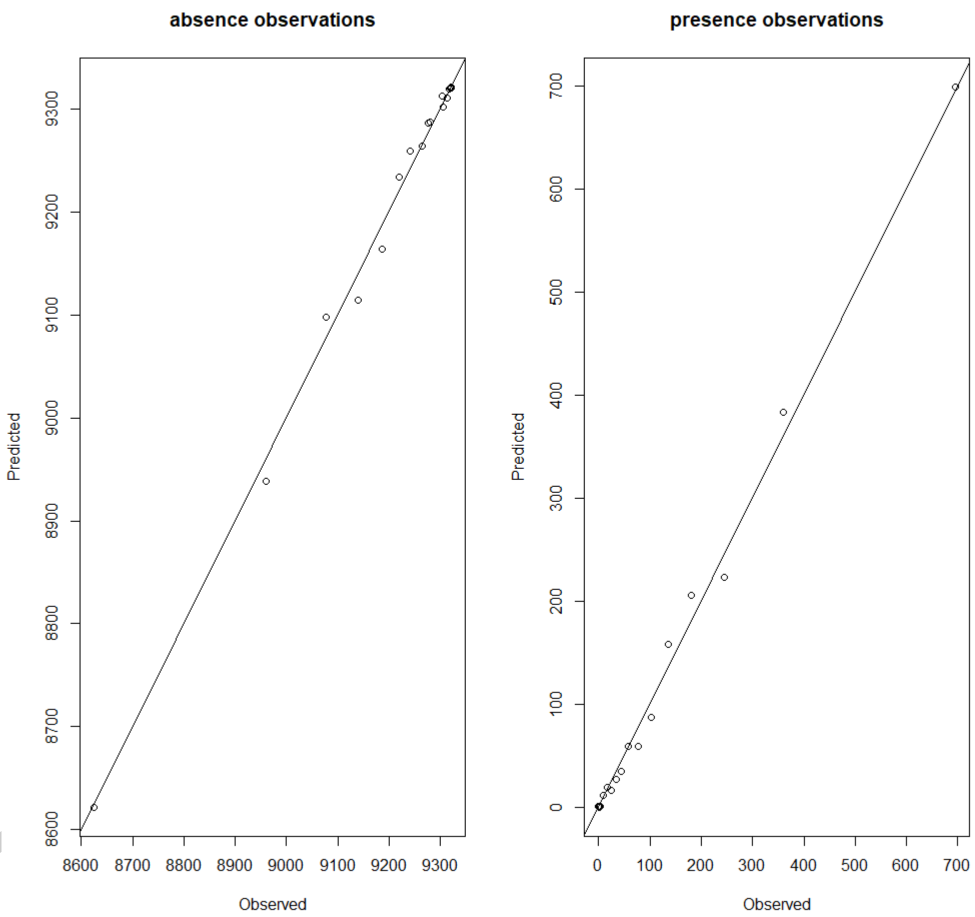

Figure 6.33: Predictive checking of logistic GAM fitted to presence-absence black coral catch in all fishing methods (for model fitted to data with catch weights smaller than 1 tonne). Shown are predicted vs. observed proportion of absences, i.e. no captures (left panel) and predicted vs. observed proportion of presences, i.e. captures (right panel).

Table 6.2: Model estimates for logistic GAM fitted to presence-absence data of stony coral catch. Base cases for fixed effect were: bottom_trawl_ORH (method_group), 7 (month), and FMA4 (start_obs_fma)

Variable	Mean	Standard Error	z-value	p-value
(Intercept)	-4.441	0.309	-14.369	< 2e-16***
method_groupbottom_longlining	-0.573	0.419	-1.366	0.172
method_groupbottom_longlining	-0.573	0.419	-1.366	0.172
method_groupbottom_trawl_BOE	0.028	0.446	0.062	0.95
method_groupbottom_trawl_other_targets	0.223	0.389	0.574	0.566
method_groupbottom_trawl_SQU	-0.519	0.426	-1.217	0.224
method_groupbottom_trawl_SSO	0.029	0.401	0.072	0.942
method_groupbottom_trawl_SWA	0.578	0.426	1.358	0.174
method_groupdanish_seining	0.175	1.256	0.14	0.889
method_groupmidwater_trawl	-4.268	0.594	-7.188	0***
method_grouppots	-0.51	0.797	-0.64	0.522
method_groupset_netting	-0.217	0.479	-0.453	0.65
month1	0.257	0.121	2.127	0.033*
month2	-0.481	0.141	-3.413	0.001***
month3	-0.123	0.137	-0.901	0.368
month4	0.046	0.136	0.34	0.733
month5	0.175	0.118	1.485	0.138
month6	0.257	0.114	2.262	0.024*
month8	-0.407	0.158	-2.571	0.01*
month9	0.36	0.128	2.813	0.005**
month10	-0.055	0.121	-0.453	0.651
month11	-0.056	0.12	-0.467	0.64
month12	0.078	0.12	0.647	0.518
start_obs_fmaFMA1	-1.607	0.37	-4.347	0***
start_obs_fmaFMA2	-0.932	0.223	-4.177	0***
start_obs_fmaFMA3	0.185	0.103	1.804	0.071
start_obs_fmaFMA5	-0.428	0.127	-3.379	0.001***
start_obs_fmaFMA6	0.069	0.161	0.432	0.665
start_obs_fmaFMA7	-1.36	0.164	-8.285	< 2e-16***
start_obs_fmaFMA8	-3.852	1.043	-3.691	0***
start_obs_fmaFMA9	-0.475	0.324	-1.466	0.143

Table 6.3: Model estimates for logistic GAM fitted to presence-absence data of stony coral catch with only including captures smaller than 1 tonne. Base cases for fixed effect were: bottom_trawl_ORH (method_group), 10 (month), and FMA4 (start_obs_fma).

Variable	Mean	Standard Error	z-value	p-value
(Intercept)	-4.496	0.309	-14.554	< 2e-16***
method_groupbottom_longlining	-0.578	0.418	-1.382	0.167
method_groupbottom_trawl_BOE	0.04	0.445	0.089	0.929
method_groupbottom_trawl_other_targets	0.218	0.388	0.561	0.575
method_groupbottom_trawl_SQU	-0.528	0.425	-1.242	0.214
method_groupbottom_trawl_SSO	0.001	0.4	0.002	0.998
method_groupbottom_trawl_SWA	0.566	0.425	1.333	0.183
method_groupdanish_seining	0.159	1.255	0.127	0.899
method_groupmidwater_trawl	-4.273	0.593	-7.206	0***
method_grouppots	-0.527	0.795	-0.663	0.508
method_groupset_netting	-0.229	0.478	-0.479	0.632
month1	0.322	0.106	3.048	0.002**
month2	-0.413	0.128	-3.221	0.001**
month3	-0.071	0.124	-0.571	0.568
month4	0.113	0.122	0.926	0.354
month5	0.234	0.102	2.29	0.022*
month6	0.321	0.104	3.085	0.002**
month7	0.06	0.122	0.497	0.619
month8	-0.36	0.157	-2.294	0.022*
month9	0.415	0.119	3.483	0***
month11	0.011	0.104	0.106	0.916
month12	0.132	0.105	1.265	0.206
start_obs_fmaFMA1	-1.577	0.372	-4.243	0***
start_obs_fmaFMA2	-0.913	0.224	-4.085	0***
start_obs_fmaFMA3	0.185	0.103	1.794	0.073.
start_obs_fmaFMA5	-0.447	0.127	-3.513	0***
start_obs_fmaFMA6	0.063	0.161	0.392	0.695
start_obs_fmaFMA7	-1.348	0.165	-8.195	0***
start_obs_fmaFMA8	-3.831	1.044	-3.672	0***
start_obs_fmaFMA9	-0.473	0.326	-1.452	0.146

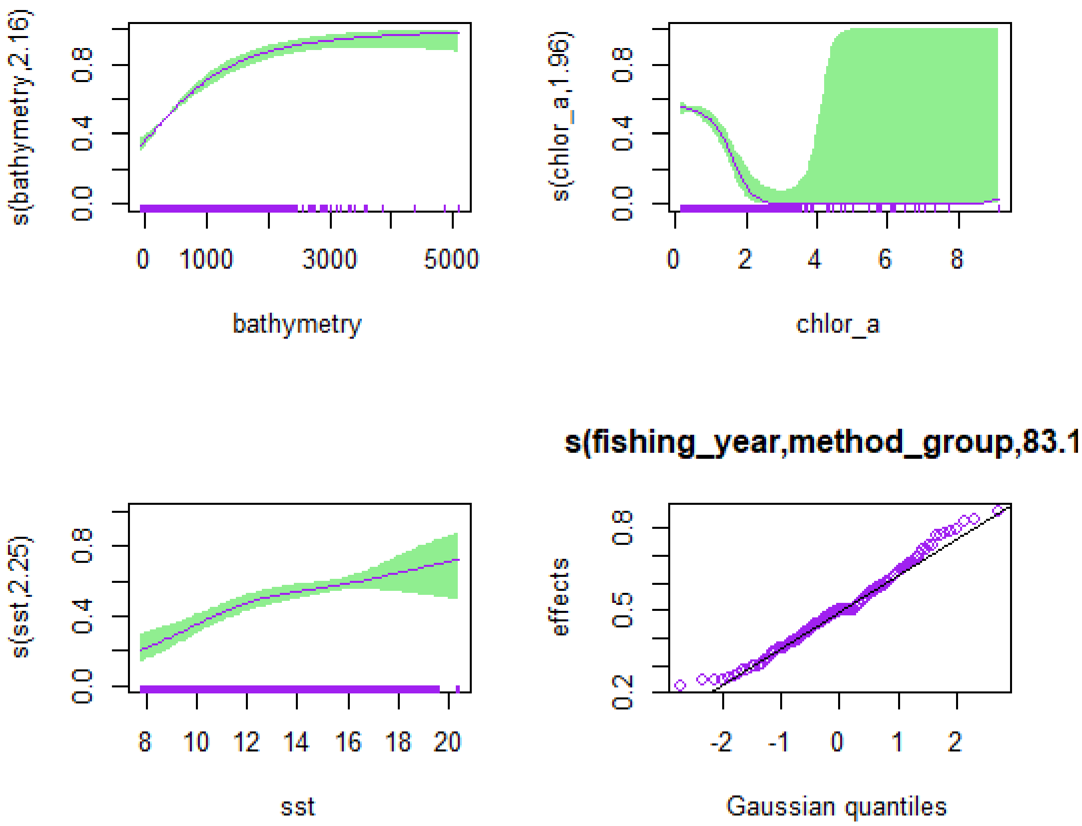

Figure 6.34: Partial effects from logistic GAM fitted to presence-absence data (only for catch weight smaller than 1 tonne) of stony coral captures in all fishing methods.

Branching stony corals

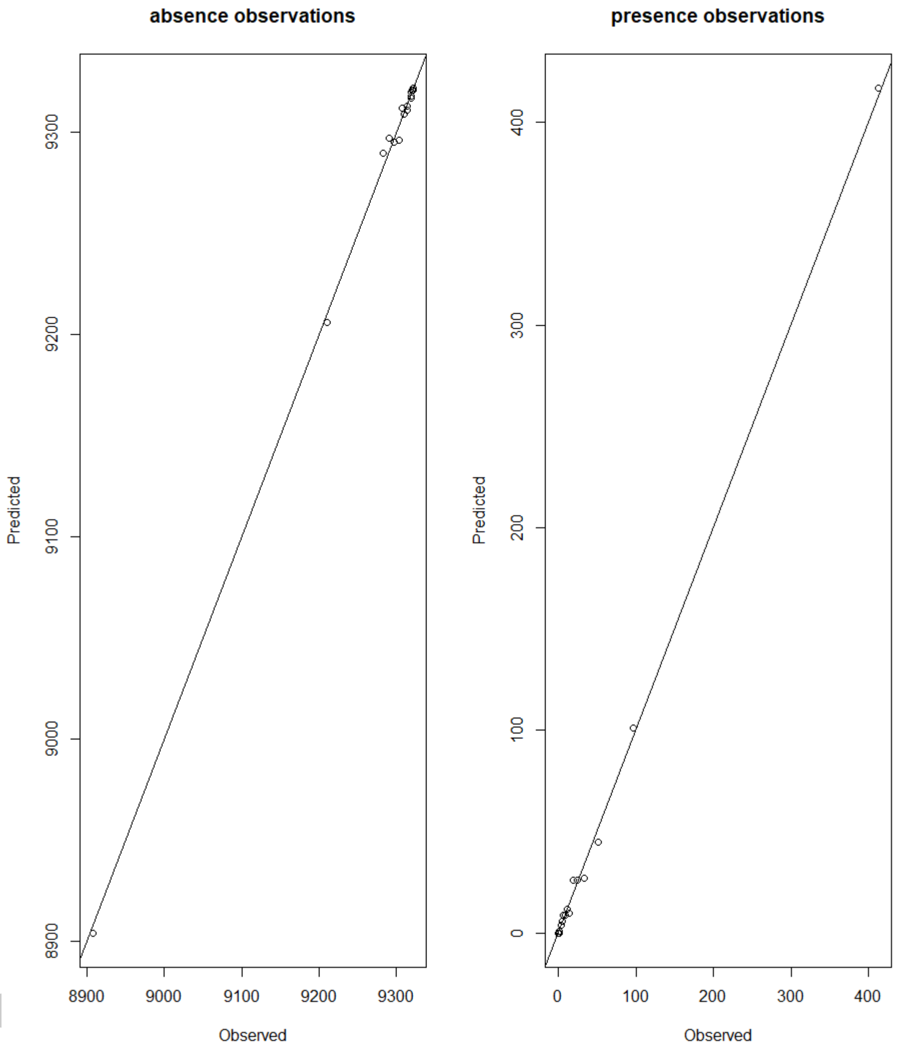

Figure 6.35: Predictive checking of logistic GAM fitted to presence-absence branching stony coral catch in all fishing methods. Shown are predicted vs. observed proportion of absences, i.e. no captures (left panel) and predicted vs. observed proportion of presences, i.e. captures (right panel).

Table 6.4: Model estimates for logistic GAM fitted to presence-absence data of branching stony coral catch. Base cases for fixed effect were: bottom_trawl_ORH (method_group), 7 (month), and FMA4 (start_obs_fma)

Variable	Mean	Standard Error	z-value	p-value
(Intercept)	-6.15E+00	3.93E-01	-15.643	< 2e-16***
method_groupbottom_longlining	-7.34E-02	4.72E-01	-0.155	0.877
method_groupbottom_trawl_BOE	9.52E-01	4.69E-01	2.03	0.042*
method_groupbottom_trawl_other_targets	1.34E-01	4.17E-01	0.321	0.748
method_groupbottom_trawl_SQU	3.88E-02	5.12E-01	0.076	0.94
method_groupbottom_trawl_SSO	9.85E-01	4.18E-01	2.359	0.018*
method_groupbottom_trawl_SWA	8.84E-01	5.74E-01	1.541	0.123
method_groupdanish_seining	-4.80E+01	4.48E+06	0	1
method_groupmidwater_trawl	-3.06E+00	6.94E-01	-4.415	0***
method_grouppots	-4.70E+01	2.04E+06	0	1
method_groupset_netting	9.98E-01	6.15E-01	1.621	0.105
month1	-1.88E-01	1.97E-01	-0.953	0.34
month2	-8.20E-01	2.24E-01	-3.663	0***
month3	-2.21E-01	2.06E-01	-1.072	0.284
month4	-3.50E-01	2.15E-01	-1.631	0.103
month5	-5.23E-01	2.00E-01	-2.61	0.009**
month6	-5.20E-02	1.85E-01	-0.281	0.778
month8	-5.01E-01	2.76E-01	-1.817	0.069.
month9	-1.55E-01	2.40E-01	-0.645	0.519
month10	-2.12E-01	1.85E-01	-1.145	0.252
month11	-7.77E-01	2.08E-01	-3.742	0***
month12	-4.78E-01	2.05E-01	-2.332	0.02*
start_obs_fmaFMA1	-3.51E-01	6.49E-01	-0.54	0.589
start_obs_fmaFMA2	3.96E-01	3.45E-01	1.148	0.251
start_obs_fmaFMA3	-1.90E-01	2.47E-01	-0.768	0.442
start_obs_fmaFMA5	2.26E-01	2.46E-01	0.918	0.359
start_obs_fmaFMA6	1.23E+00	2.82E-01	4.372	0***
start_obs_fmaFMA7	-2.84E+00	4.52E-01	-6.282	0***
start_obs_fmaFMA8	-2.68E+00	1.12E+00	-2.393	0.017*
start_obs_fmaFMA9	4.54E-01	5.75E-01	0.79	0.43

Cup-forming stony corals

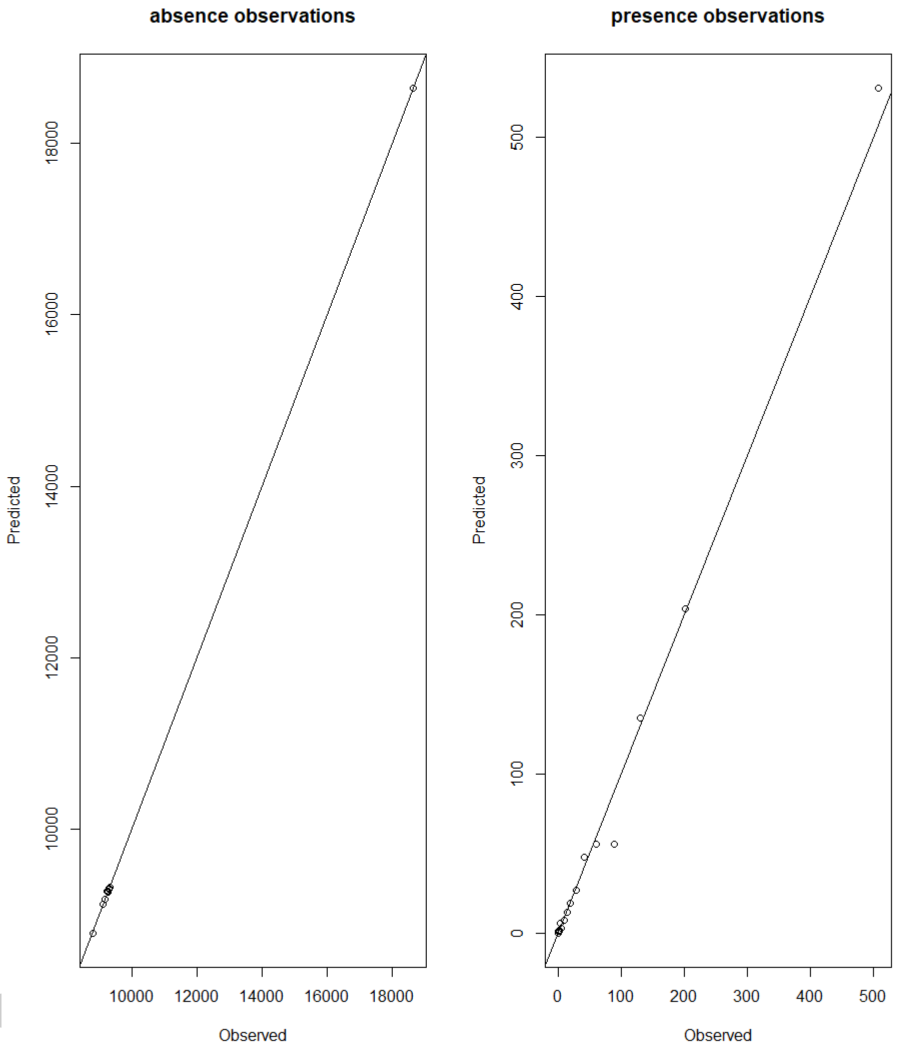

Figure 6.36: Predictive checking of logistic GAM fitted to presence-absence cup-forming stony coral catch in all fishing methods. Shown are predicted vs. observed proportion of absences, i.e. no captures (left panel) and predicted vs. observed proportion of presences, i.e. captures (right panel).

Table 6.5: Model estimates for logistic GAM fitted to presence-absence data of cup-forming stony coral catch. Base cases for fixed effect were: bottom_trawl_ORH (method_group), 7 (month), and FMA4 (start_obs_fma)

Variable	Mean	Standard Error	z-value	p-value
(Intercept)	-5.18E+00	3.66E-01	-14.161	< 2e-16***
method_groupbottom_longlining	-1.68E+00	4.90E-01	-3.42	0.001***
method_groupbottom_trawl_BOE	-9.83E-01	6.12E-01	-1.606	0.108
method_groupbottom_trawl_other_targets	-4.07E-02	4.05E-01	-0.101	0.92
method_groupbottom_trawl_SQU	-1.21E+00	4.88E-01	-2.467	0.014*
method_groupbottom_trawl_SSO	-1.48E+00	5.09E-01	-2.916	0.004**
method_groupbottom_trawl_SWA	3.21E-01	4.46E-01	0.719	0.472
method_groupdanish_seining	5.73E-01	1.25E+00	0.457	0.648
method_groupmidwater_trawl	-4.61E+00	7.22E-01	-6.389	0***
method_grouppots	-4.99E-01	8.02E-01	-0.621	0.534
method_groupset_netting	-1.68E+00	7.51E-01	-2.232	0.026*
month1	3.98E-01	1.65E-01	2.415	0.016*
month2	-5.51E-01	2.03E-01	-2.714	0.007**
month3	-3.40E-01	2.08E-01	-1.636	0.102
month4	3.63E-02	1.95E-01	0.186	0.852
month5	5.32E-01	1.58E-01	3.374	0.001***
month6	2.83E-01	1.59E-01	1.78	0.075.
month8	-5.63E-01	2.20E-01	-2.564	0.01*
month9	3.62E-01	1.71E-01	2.124	0.034*
month10	-2.30E-02	1.73E-01	-0.133	0.894
month11	2.30E-02	1.68E-01	0.137	0.891
month12	3.13E-01	1.61E-01	1.943	0.052.
start_obs_fmaFMA1	-5.05E-01	5.77E-01	-0.875	0.382
start_obs_fmaFMA2	-6.93E-01	3.24E-01	-2.14	0.032*
start_obs_fmaFMA3	2.27E-01	1.23E-01	1.847	0.065.
start_obs_fmaFMA5	-9.95E-01	1.73E-01	-5.76	0***
start_obs_fmaFMA6	-1.06E+00	2.54E-01	-4.182	0***
start_obs_fmaFMA7	-8.93E-01	2.23E-01	-4.008	0***
start_obs_fmaFMA8	-5.40E+01	6.30E+05	0	1
start_obs_fmaFMA9	1.66E-01	5.18E-01	0.32	0.749

Black corals

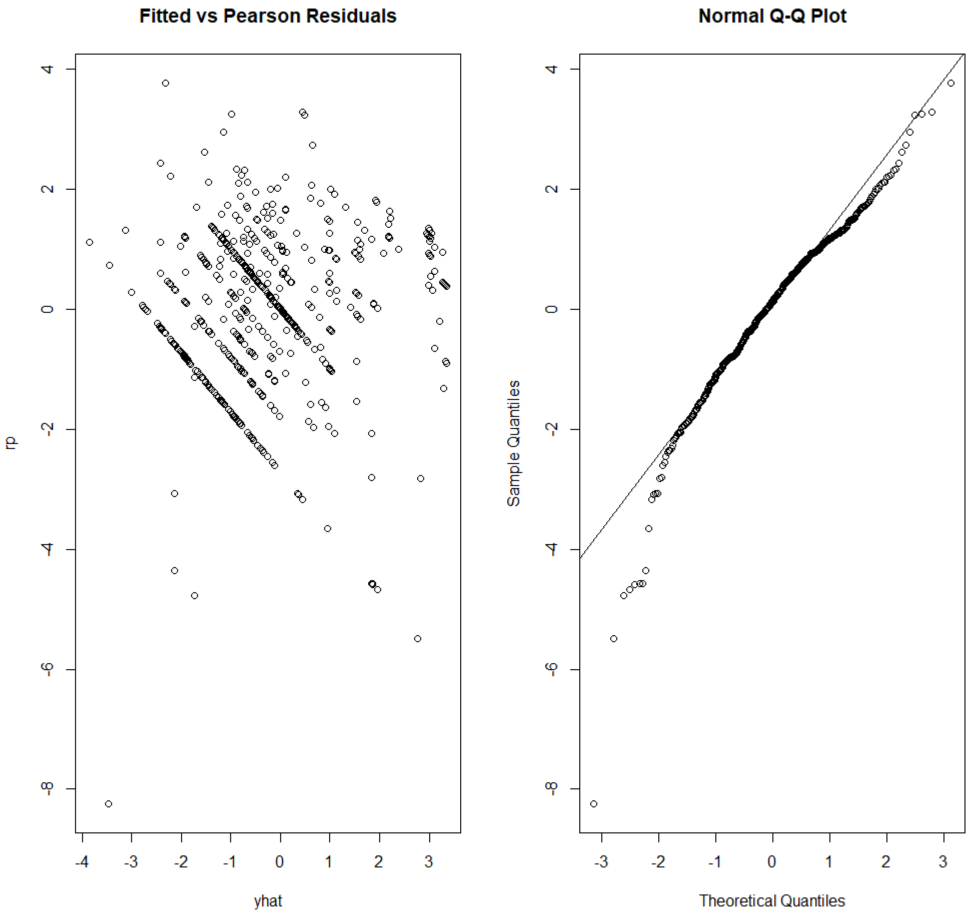

Figure 6.37: Predictive checking of logistic GAM fitted to presence-absence black coral catch in all fishing methods. Shown are predicted vs. observed proportion of absences, i.e. no captures (left panel) and predicted vs. observed proportion of presences, i.e. captures (right panel).

Table 6.6: Model estimates for logistic GAM fitted to presence-absence data of black coral catch. Base cases for fixed effect were:

Variable	Mean	Standard Error	z-value	p-value
(Intercept)	-5.249	0.551	-9.534	< 2e-16***
method_groupbottom_longlining	0.686	0.693	0.991	0.322
method_groupbottom_trawl_BOE	1.384	0.790	1.751	0.08.
method_groupbottom_trawl_ORH	1.130	0.707	1.597	0.11
method_groupbottom_trawl_other_targets	0.175	0.654	0.268	0.788
method_groupbottom_trawl_SSO	1.166	0.752	1.550	0.121
method_groupbottom_trawl_SWA	0.314	0.803	0.391	0.696
method_groupdanish_seining	-74.640	4484000.000	0.000	1
method_groupmidwater_trawl	-1.282	0.681	-1.881	0.06.
method_grouppots	-71.490	2039000.000	0.000	1
method_groupset_netting	0.864	0.781	1.106	0.269
month1	0.533	0.177	3.009	0.003**
month3	0.273	0.182	1.502	0.133
month4	-0.132	0.212	-0.624	0.533
month5	-0.373	0.212	-1.762	0.078.
month6	-0.751	0.223	-3.368	0.001***
month7	-0.926	0.259	-3.578	0***
month8	-0.501	0.304	-1.648	0.099.
month9	-0.193	0.283	-0.684	0.494
month10	-0.029	0.194	-0.151	0.88
month11	-0.374	0.216	-1.733	0.083.
month12	-0.298	0.225	-1.328	0.184
start_obs_fmaFMA1	-1.514	0.787	-1.922	0.055.
start_obs_fmaFMA2	-1.688	0.565	-2.985	0.003**
start_obs_fmaFMA3	-1.924	0.316	-6.094	0***
start_obs_fmaFMA4	-2.209	0.354	-6.245	0***
start_obs_fmaFMA6	-1.225	0.353	-3.473	0.001***
start_obs_fmaFMA7	-3.314	0.532	-6.227	0***
start_obs_fmaFMA8	-4.891	0.770	-6.355	0***
start_obs_fmaFMA9	-2.350	0.731	-3.214	0.001**

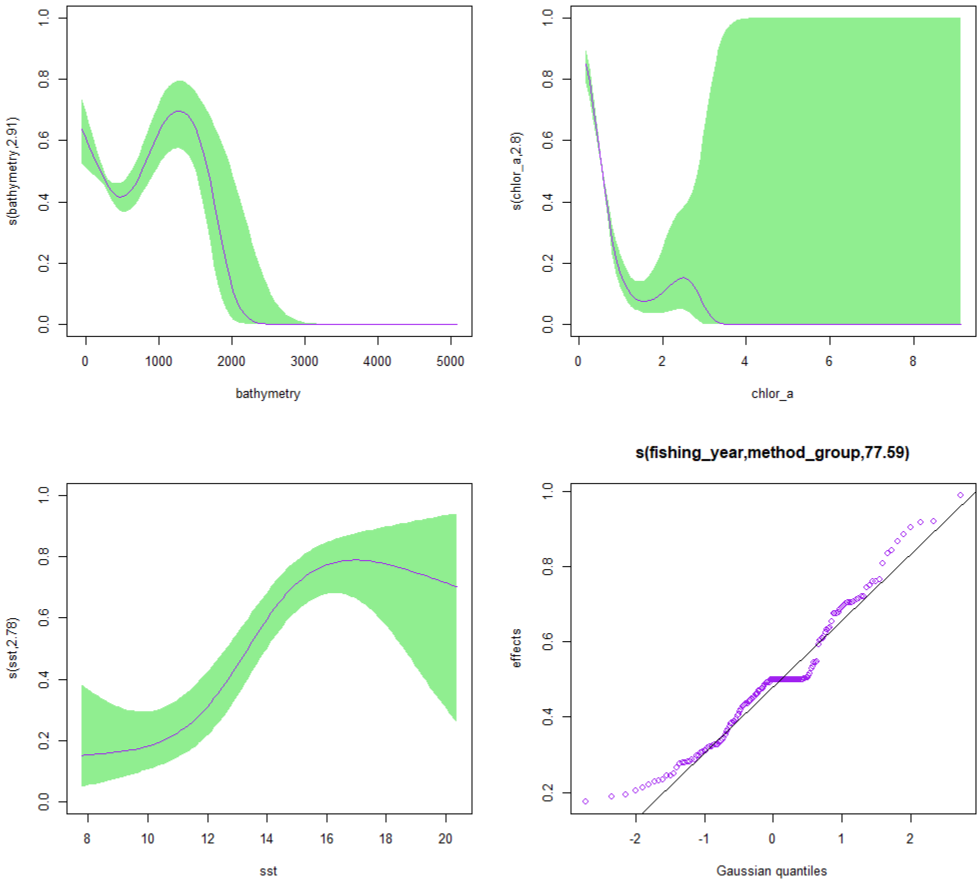

Figure 6.38: Partial effects from logistic GAM fitted to presence-absence data of black coral captures in all fishing methods.

Lace corals

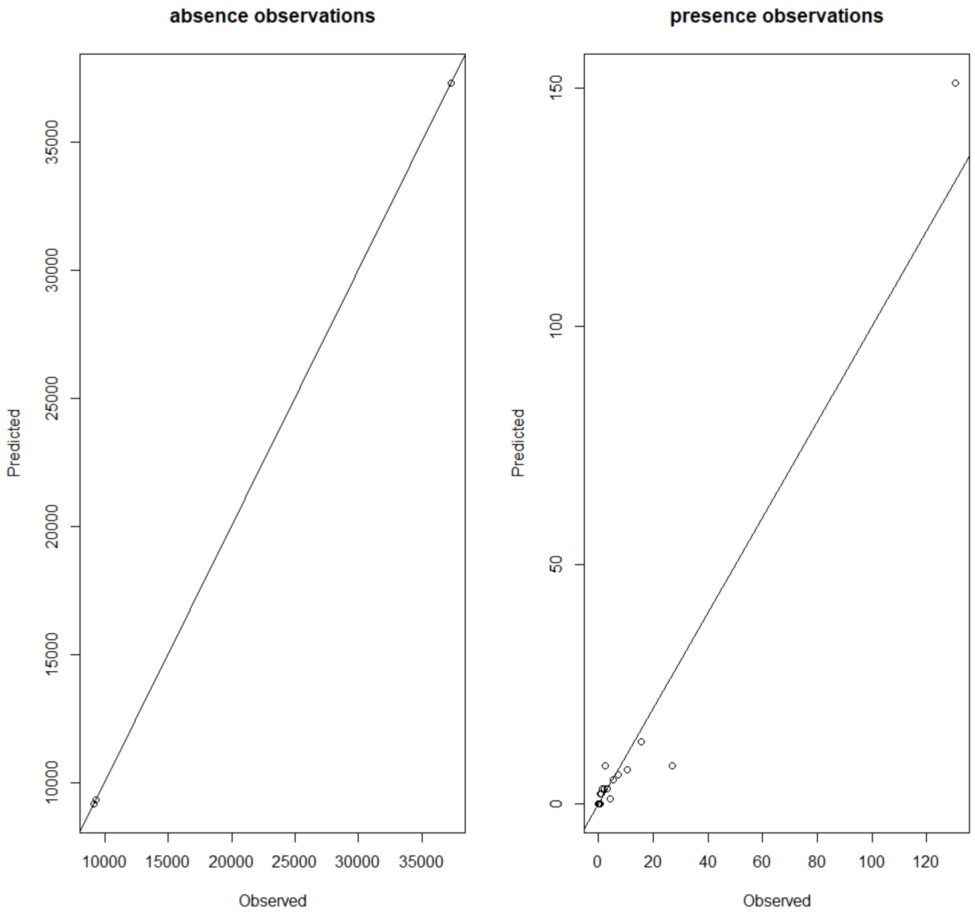

Figure 6.39: Predictive checking of logistic GAM fitted to presence-absence lace coral catch in all fishing methods. Shown are predicted vs. observed proportion of absences, i.e. no captures (left panel) and predicted vs. observed proportion of presences, i.e. captures (right panel).

Table 6.7: Model estimates for logistic GAM fitted to presence-absence data of lace coral catch. Base cases for fixed effect were:

Variable	Mean	Standard Error	z-value	p-value
(Intercept)	-8.35E+00	6.97E-01	-11.982	< 2e-16***
method_groupbottom_longlining	1.48E+00	7.36E-01	2.009	0.044*
method_groupbottom_trawl_BOE	-9.31E-02	8.63E-01	-0.108	0.914
method_groupbottom_trawl_other_targets	3.36E-01	7.10E-01	0.473	0.636
method_groupbottom_trawl_SQU	-3.30E-02	8.12E-01	-0.041	0.968
method_groupbottom_trawl_SSO	-1.33E+00	8.98E-01	-1.477	0.14
method_groupbottom_trawl_SWA	8.41E-01	9.45E-01	0.89	0.374
method_groupdanish_seining	-4.06E+01	4.48E+06	0	1
method_groupmidwater_trawl	-1.48E+00	9.03E-01	-1.639	0.101
method_grouppots	-3.90E+01	2.04E+06	0	1
method_groupset_netting	2.07E+00	7.95E-01	2.598	0.009**
month1	2.61E-01	4.81E-01	0.542	0.588
month2	-9.55E-01	5.50E-01	-1.735	0.083.
month3	3.87E-01	4.78E-01	0.81	0.418
month4	3.42E-01	4.89E-01	0.699	0.485
month5	7.20E-01	4.67E-01	1.543	0.123
month6	-8.59E-01	6.12E-01	-1.403	0.161
month8	2.75E-01	5.74E-01	0.479	0.632
month9	8.03E-02	5.40E-01	0.149	0.882
month10	4.70E-01	4.77E-01	0.985	0.325
month11	6.28E-01	4.63E-01	1.357	0.175
month12	6.23E-01	4.70E-01	1.326	0.185
start_obs_fmaFMA1	1.35E+00	6.22E-01	2.162	0.031*
start_obs_fmaFMA2	-1.58E+00	1.08E+00	-1.462	0.144
start_obs_fmaFMA3	-1.91E-01	4.02E-01	-0.475	0.635
start_obs_fmaFMA5	9.58E-01	3.82E-01	2.51	0.012*
start_obs_fmaFMA6	5.14E-01	5.60E-01	0.918	0.359
start_obs_fmaFMA7	-3.80E+01	3.64E+05	0	1
start_obs_fmaFMA8	-1.85E+00	7.64E-01	-2.419	0.016*
start_obs_fmaFMA9	-1.31E+00	7.52E-01	-1.74	0.082.

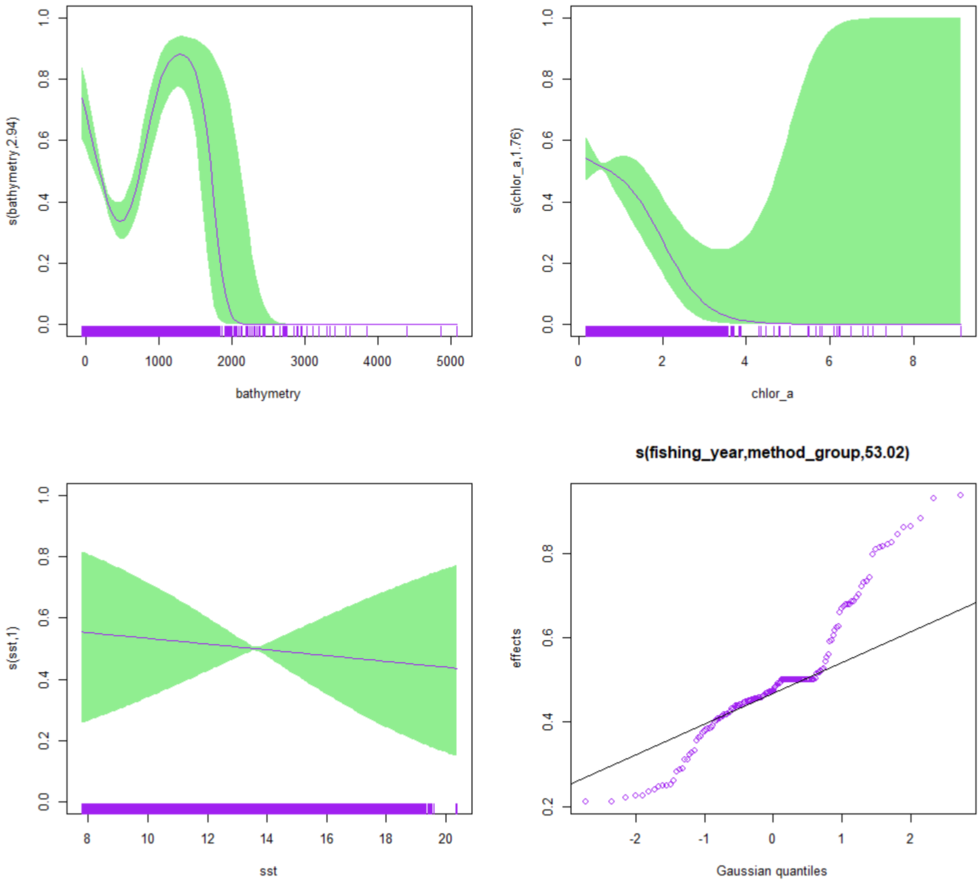

Figure 6.40: Partial effects from logistic GAM fitted to presence-absence data of lace coral captures in all fishing methods.

Gorgonians

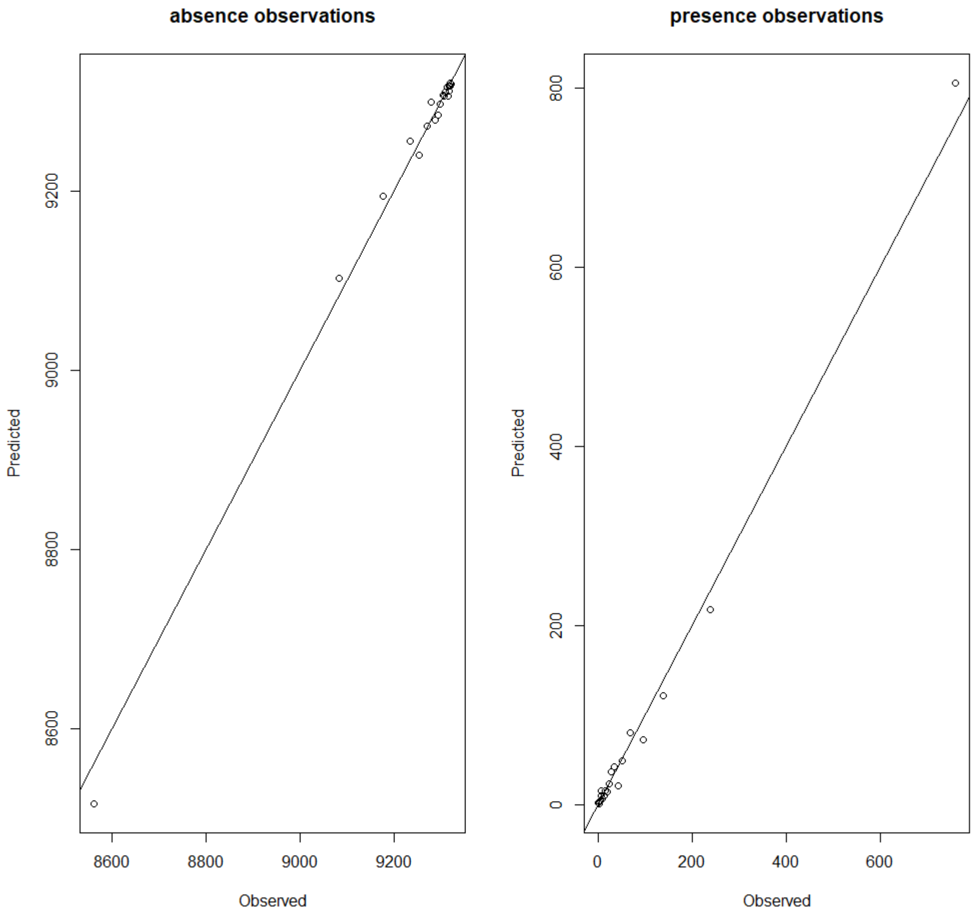

Figure 6.41: Predictive checking of logistic GAM fitted to presence-absence gorgonian catch in all fishing methods. Shown are predicted vs. observed proportion of absences, i.e. no captures (left panel) and predicted vs. observed proportion of presences, i.e. captures (right panel).

Table 6.8: Model estimates for logistic GAM fitted to presence-absence data of gorgonian catch. Base cases for fixed effect were:

Variable	Mean	Standard Error	z-value	p-value
(Intercept)	-5.49E+00	4.29E-01	-12.802	< 2e-16***
method_groupbottom_longlining	-7.67E-01	5.70E-01	-1.346	0.178
method_groupbottom_trawl_BOE	-4.98E-01	5.85E-01	-0.851	0.395
method_groupbottom_trawl_other_targets	-1.23E+00	5.45E-01	-2.255	0.024*
method_groupbottom_trawl_SQU	-8.93E-01	5.71E-01	-1.565	0.118
method_groupbottom_trawl_SSO	-1.01E-01	5.46E-01	-0.184	0.854
method_groupbottom_trawl_SWA	-5.32E-01	6.05E-01	-0.879	0.379
method_groupdanish_seining	-5.33E+01	4.48E+06	0	1
method_groupmidwater_trawl	-2.21E+00	5.68E-01	-3.891	0***
method_grouppots	-5.26E+01	2.04E+06	0	1
method_groupset_netting	-1.74E+00	7.68E-01	-2.265	0.024*
month1	4.09E-01	1.37E-01	2.987	0.003**
month2	-2.10E-01	1.46E-01	-1.434	0.152
month3	-5.12E-03	1.43E-01	-0.036	0.972
month4	-2.19E-01	1.56E-01	-1.4	0.161
month5	-2.95E-01	1.47E-01	-2.005	0.045*
month6	1.47E-02	1.29E-01	0.113	0.91
month8	-3.49E-02	1.62E-01	-0.216	0.829
month9	-3.56E-01	1.78E-01	-2.001	0.045*
month10	4.53E-02	1.27E-01	0.358	0.721
month11	6.51E-02	1.31E-01	0.496	0.62
month12	1.96E-01	1.36E-01	1.442	0.149
start_obs_fmaFMA1	1.20E+00	4.64E-01	2.597	0.009**
start_obs_fmaFMA2	1.26E+00	2.64E-01	4.751	0***
start_obs_fmaFMA3	1.90E-01	1.71E-01	1.113	0.266
start_obs_fmaFMA5	7.52E-01	1.64E-01	4.597	0***
start_obs_fmaFMA6	1.50E+00	1.88E-01	8.008	0***
start_obs_fmaFMA7	4.56E-01	2.19E-01	2.083	0.037*
start_obs_fmaFMA8	1.35E+00	3.61E-01	3.746	0***
start_obs_fmaFMA9	1.42E+00	4.15E-01	3.433	0.001***

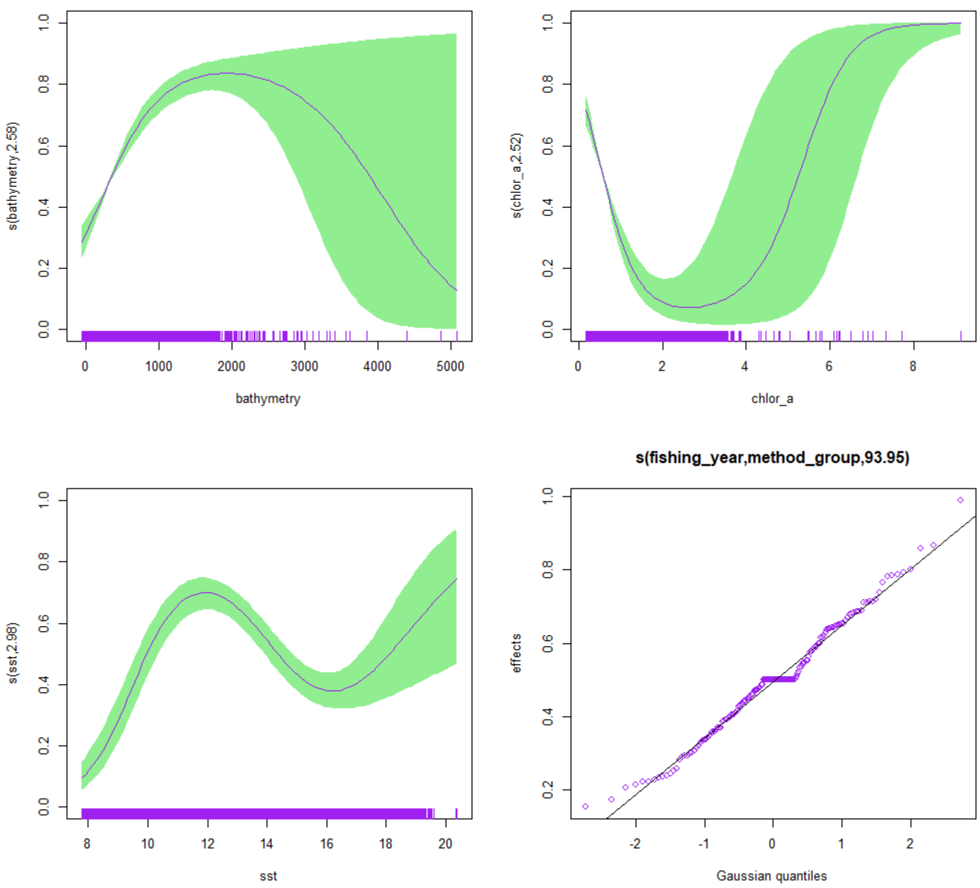

Figure 6.42: Partial effects from logistic GAM fitted to presence-absence data of gorgonian captures in all fishing methods.

6.6.2 GAM fitted to Box-Cox transformed coral catch weight data

Stony corals

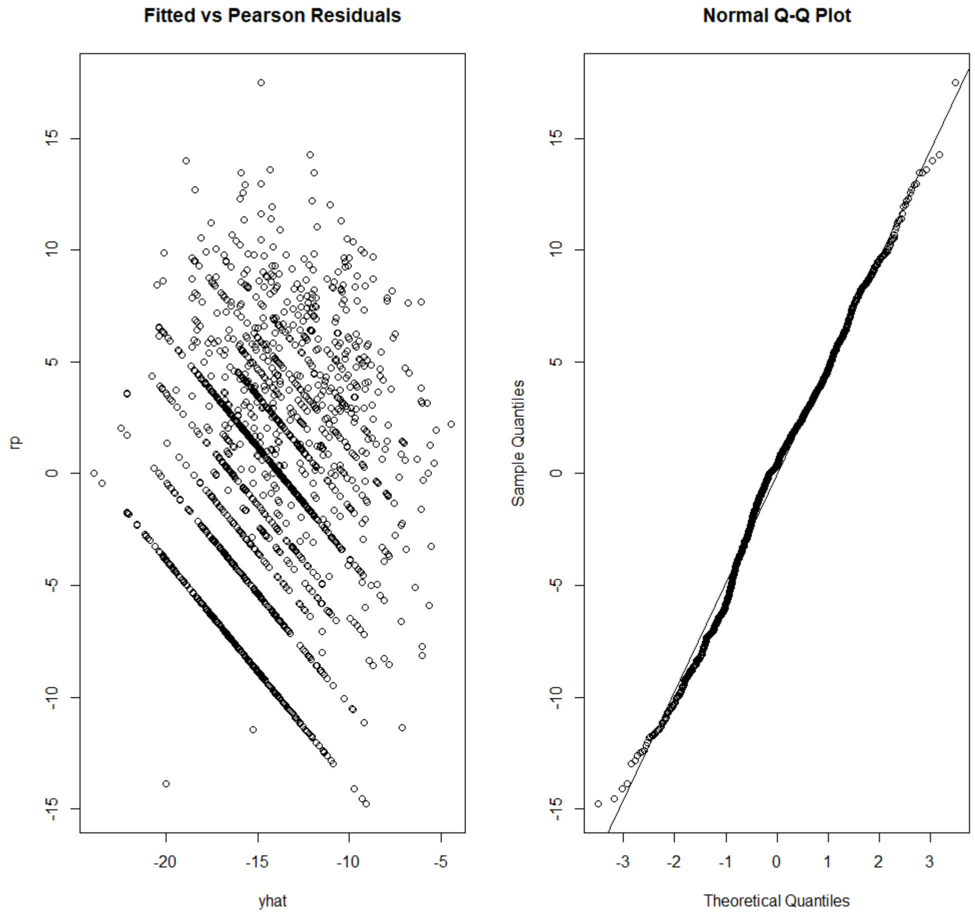

Figure 6.43: Model diagnostics for GAM fitted to stony coral catch weights.

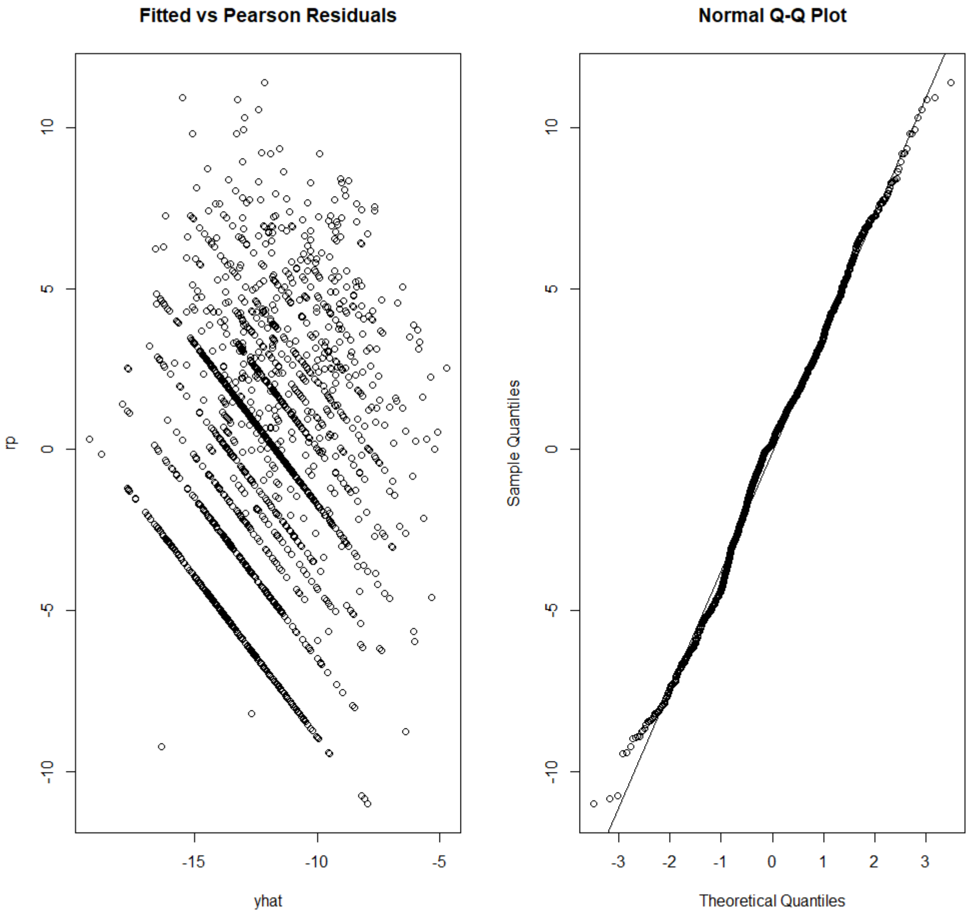

Figure 6.44: Model diagnostics for GAM fitted to stony coral catch weights (only data with catch weights smaller than 1 tonne).

Table 6.9: Model estimates for GAM fitted to stony coral catch weights on events with observed catch. Base cases for fixed effect were: bottom_trawl_ORH (method_group), 7 (month), and FMA4 (start_obs_fma)

Variable	Mean	Standard Error	z-value	p-value
(Intercept)	-16.6347	1.1466		< 2e-16***
method_groupbottom_longlining	-0.3305	1.5916		0.836
method_groupbottom_trawl_BOE	2.374	1.7705		0.18
method_groupbottom_trawl_other_targets	1.2841	1.3396		0.338
method_groupbottom_trawl_SQU	0.8524	1.7073		0.618
method_groupbottom_trawl_SSO	3.3182	1.4117		0.019*
method_groupbottom_trawl_SWA	2.4596	1.6416		0.134
method_groupdanish_seining	-3.8349	6.153		0.533
method_groupmidwater_trawl	-0.51	2.9316		0.862
method_grouppots	-5.4744	3.6571		0.135
method_groupset_netting	1.3388	2.0835		0.521
month1	0.3842	0.637		0.547
month2	0.4001	0.7414		0.589
month3	1.6524	0.7401		0.026*
month4	-0.1466	0.7253		0.84
month5	-0.3996	0.6321		0.527
month6	1.2977	0.6016		0.031*
month8	-1.3079	0.8448		0.122
month9	-0.8185	0.6938		0.238
month10	3.1222	0.6447		0***
month11	0.4475	0.648		0.49
month12	0.3976	0.6456		0.538
start_obs_fmaFMA1	2.6501	2.1733		0.223
start_obs_fmaFMA2	1.1461	1.1806		0.332
start_obs_fmaFMA3	-0.2135	0.6522		0.743
start_obs_fmaFMA5	-1.2822	0.7761		0.099.
start_obs_fmaFMA6	0.4124	0.9909		0.677
start_obs_fmaFMA7	-1.6117	0.8791		0.067.
start_obs_fmaFMA8	14.3288	5.5072		0.009**
start_obs_fmaFMA9	4.7468	1.9828		0.017*

Table 6.10: odel estimates for GAM fitted to stony coral catch weights on events with observed catch; for coral catch with only including captures smaller than 1 tonne. Base cases for fixed effect were: bottom_trawl_ORH (method_group), 10 (month), and FMA4 (start_obs_fma).

Variable	Mean	Standard Error	z-value	p-value
(Intercept)	-11.59527	0.84949		< 2e-16***
method_groupbottom_longlining	-0.11677	1.18463		0.921
method_groupbottom_trawl_BOE	2.05255	1.31803		0.12
method_groupbottom_trawl_other_targets	1.03971	0.99696		0.297
method_groupbottom_trawl_SQU	0.73979	1.27141		0.561
method_groupbottom_trawl_SSO	2.40808	1.05292		0.022*
method_groupbottom_trawl_SWA	2.02204	1.22207		0.098.
method_groupdanish_seining	-2.90663	4.57801		0.526
method_groupmidwater_trawl	-0.15656	2.18148		0.943
method_grouppots	-4.02281	2.72124		0.139
method_groupset_netting	1.15492	1.55116		0.457
month1	-1.90182	0.41966		0***
month2	-1.81051	0.51628		0***
month3	-0.99051	0.50911		0.052.
month4	-2.36262	0.48943		0***
month5	-2.64327	0.41311		0***
month6	-1.22859	0.43074		0.004**
month7	-2.27295	0.4835		0***
month8	-3.25242	0.61162		0***
month9	-2.94969	0.49615		0***
month11	-1.89214	0.41765		0***
month12	-2.03878	0.41705		0***
start_obs_fmaFMA1	2.23301	1.65411		0.177
start_obs_fmaFMA2	1.00774	0.88842		0.257
start_obs_fmaFMA3	-0.06993	0.48665		0.886
start_obs_fmaFMA5	-1.01128	0.58087		0.082.
start_obs_fmaFMA6	0.54568	0.74281		0.463
start_obs_fmaFMA7	-1.13012	0.65837		0.086.
start_obs_fmaFMA8	11.17088	4.10142		0.007**
start_obs_fmaFMA9	3.64827	1.51057		0.016*

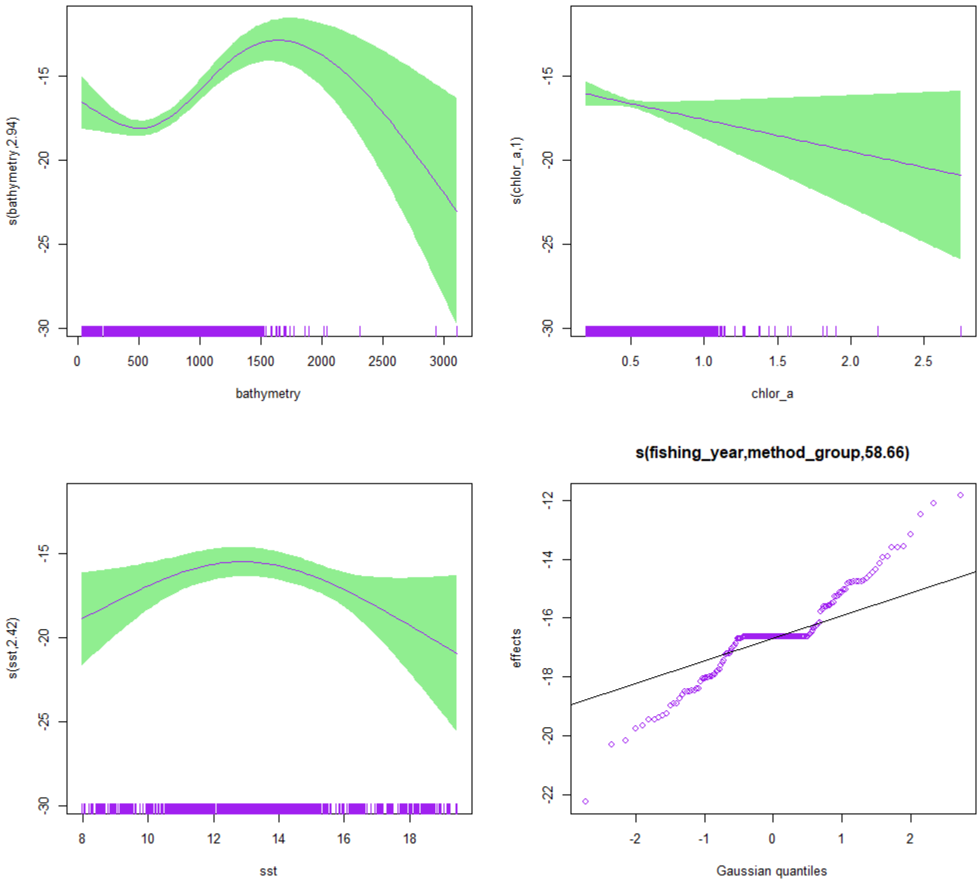

Figure 6.45: Partial effects from GAM fitted to stony coral catch weigth data in all fishing methods.

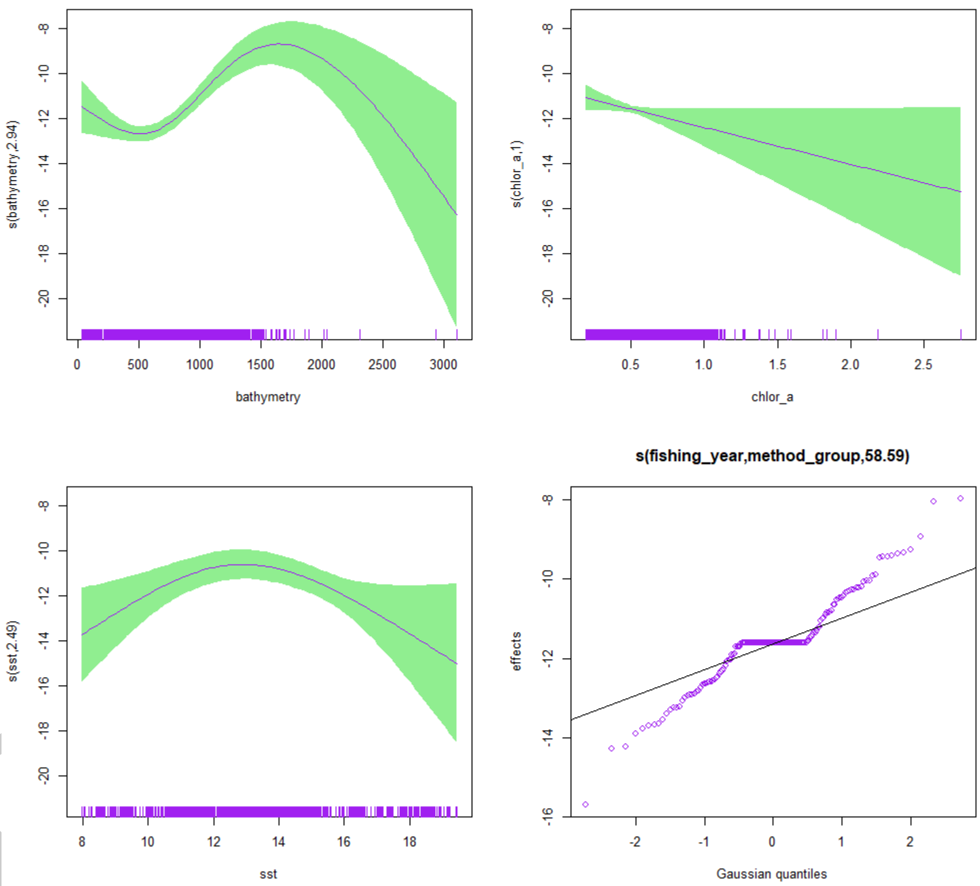

Figure 6.46: Partial effects from GAM fitted to stony coral catch weigth data (only catch weights smaller thahan 1 tonne were used) in all fishing methods.

Black corals

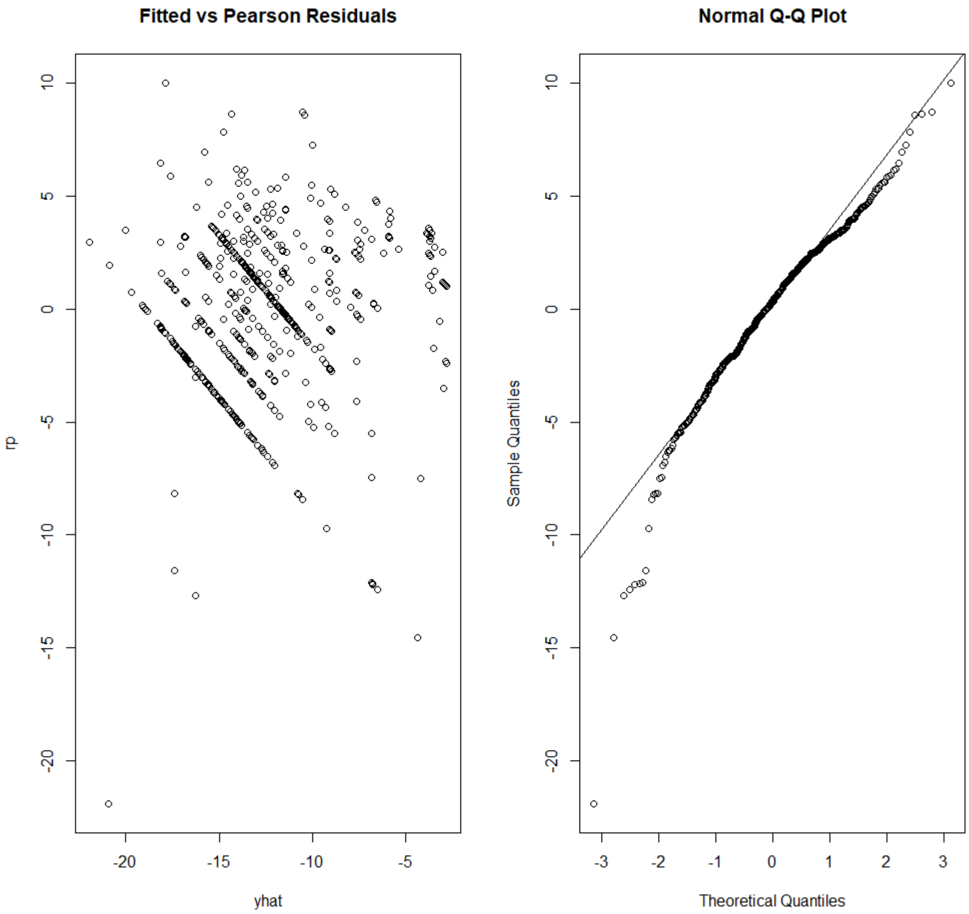

Figure 6.47: Model diagnostics for GAM fitted to black coral catch weights.

Table 6.11: Model estimates for GAM fitted to black coral catch weights on events with observed catch. Base cases for fixed effect were: bottom_trawl_ORH (method_group), 7 (month), and FMA4 (start_obs_fma)

Variable	Mean	Standard Error	z-value	p-value
(Intercept)	-9.39712	1.7094		0***
method_groupbottom_longlining	-4.34803	1.88619		0.02*
method_groupbottom_trawl_BOE	-0.88473	2.16916		0.68
method_groupbottom_trawl_ORH	-3.47381	2.05937		0.09.
method_groupbottom_trawl_other_targets	-2.48597	1.74052		0.15
method_groupbottom_trawl_SSO	-2.89454	2.05169		0.16
method_groupbottom_trawl_SWA	-5.94269	2.56613		0.02*
method_groupmidwater_trawl	-3.461	1.73041		0.05*
method_groupset_netting	-0.05446	2.27874		0.98
month1	-0.63943	0.79323		0.42
month3	0.63074	0.76632		0.41
month4	-1.76495	0.98227		0.07.
month5	-1.59367	0.93157		0.09.
month6	-1.22122	1.03463		0.24
month7	-1.77454	1.13963		0.12
month8	-1.10056	1.29083		0.39
month9	-1.99002	1.22511		0.1
month10	-1.06174	0.84661		0.21
month11	-0.13096	0.94981		0.89
month12	-2.77578	0.97009		0**
start_obs_fmaFMA1	-2.98865	3.12796		0.34
start_obs_fmaFMA2	-0.26085	2.18757		0.91
start_obs_fmaFMA3	1.71571	1.4713		0.24
start_obs_fmaFMA4	3.60291	1.50137		0.02*
start_obs_fmaFMA6	-1.97059	1.7371		0.26
start_obs_fmaFMA7	-0.64593	2.1669		0.77
start_obs_fmaFMA8	-3.3235	2.97552		0.26
start_obs_fmaFMA9	-1.23216	2.88082		0.67

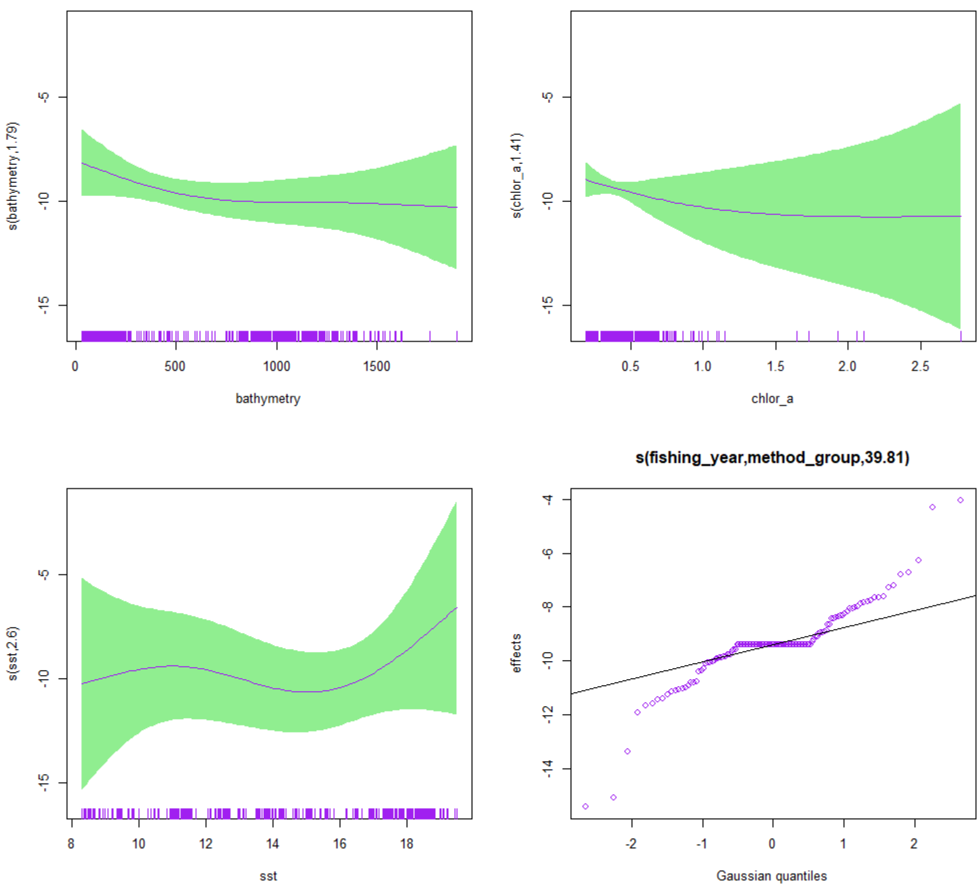

Figure 6.48: Partial effects from GAM fitted to black coral catch weigth data in all fishing methods.

Lace corals

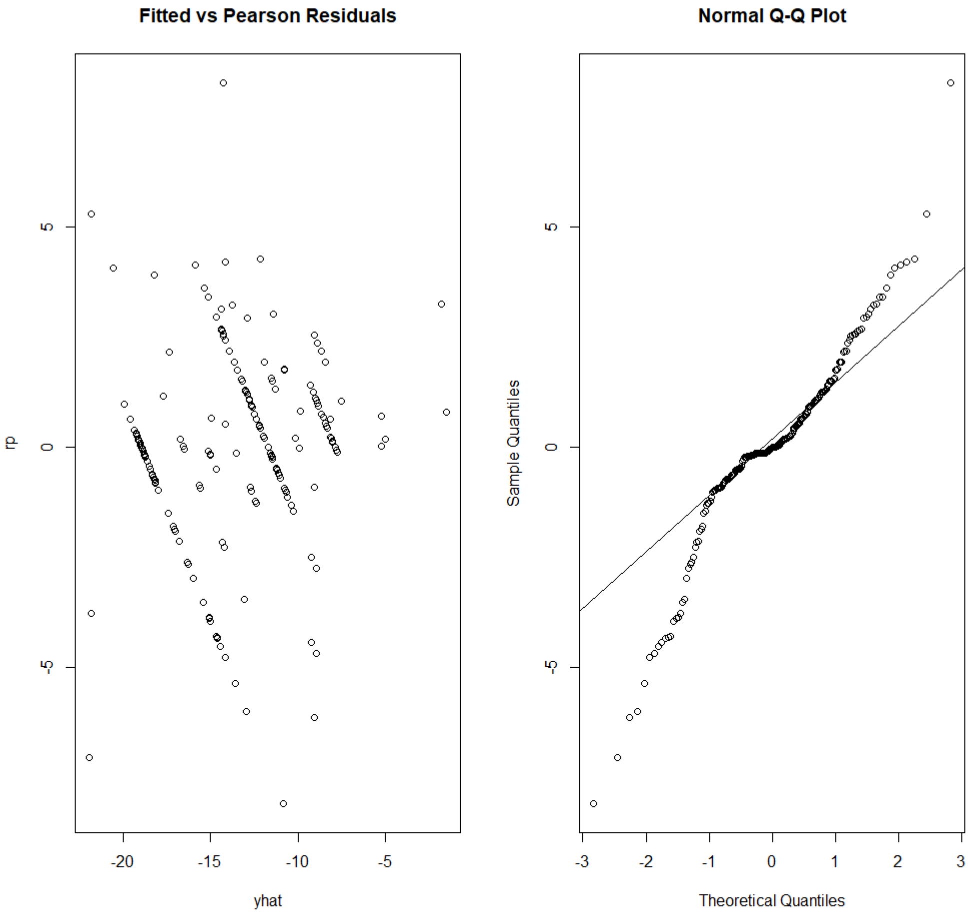

Figure 6.49: Model diagnostics for GAM fitted to lace coral catch weights.

Table 6.12: Model estimates for GAM fitted to lace coral catch weights on events with observed catch. Base cases for fixed effect were: bottom_trawl_ORH (method_group), 7 (month), and FMA4 (start_obs_fma)

Variable	Mean	Standard Error	z-value	p-value
(Intercept)	-3.93592	4.18219		0.348
method_groupbottom_longlining	-0.78743	5.51506		0.887
method_groupbottom_trawl_BOE	4.7622	6.79059		0.484
method_groupbottom_trawl_other_targets	-0.35656	4.71128		0.94
method_groupbottom_trawl_SQU	-1.11739	5.08072		0.826
method_groupbottom_trawl_SSO	8.96553	7.92615		0.26
method_groupbottom_trawl_SWA	-7.4633	6.50842		0.253
method_groupmidwater_trawl	-0.68295	6.22481		0.913
method_groupset_netting	-0.2572	5.66809		0.964
month1	-7.90366	2.78978		0.005**
month2	-12.72415	3.15275		0***
month3	-13.80417	2.8078		0***
month4	-12.09224	2.72626		0***
month5	-11.36306	2.59399		0***
month6	-12.01711	2.89125		0***
month8	-11.98042	3.56582		0.001**
month9	-5.52324	3.36777		0.103
month10	-12.59876	2.4998		0***
month11	-10.66432	2.68102		0***
month12	-8.91942	2.77003		0.002**
start_obs_fmaFMA1	1.34422	2.75001		0.626
start_obs_fmaFMA2	-9.15062	3.91573		0.021*
start_obs_fmaFMA3	6.08646	2.31408		0.009**
start_obs_fmaFMA5	1.5754	2.01372		0.435
start_obs_fmaFMA6	0.07971	2.65277		0.976
start_obs_fmaFMA8	1.32106	3.66373		0.719
start_obs_fmaFMA9	-1.72937	3.12127		0.58

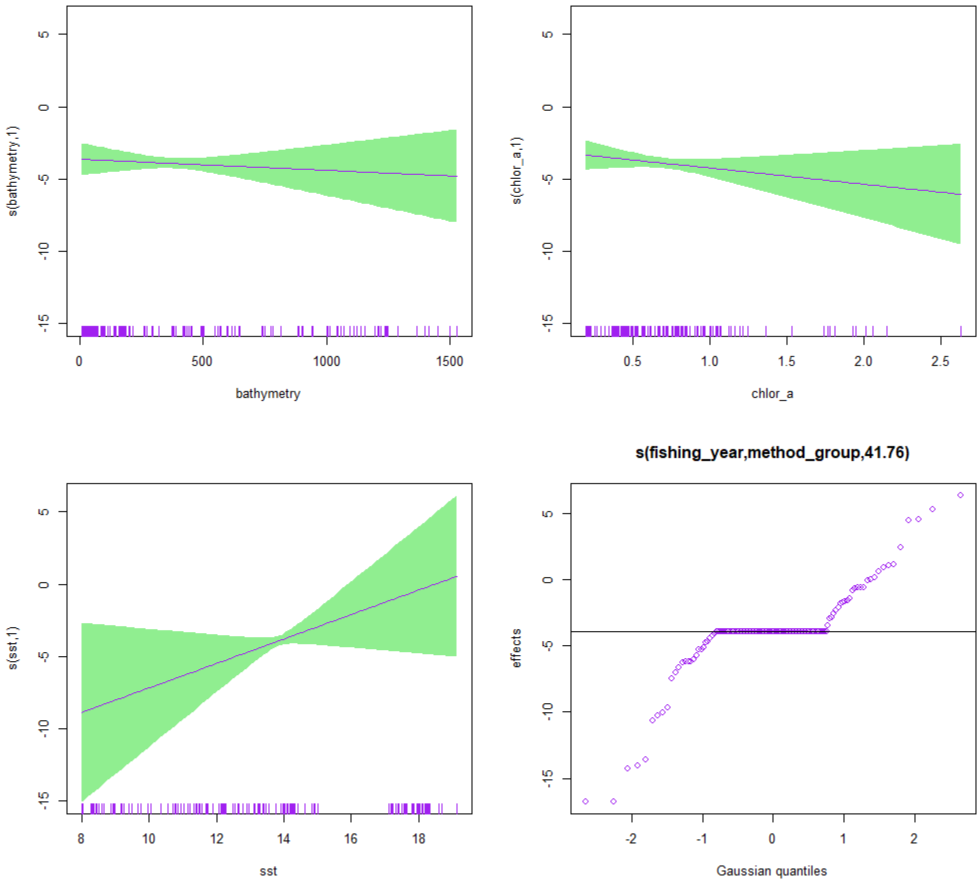

Figure 6.50: Partial effects from GAM fitted to lace coral catch weigth data in all fishing methods.

Gorgonians

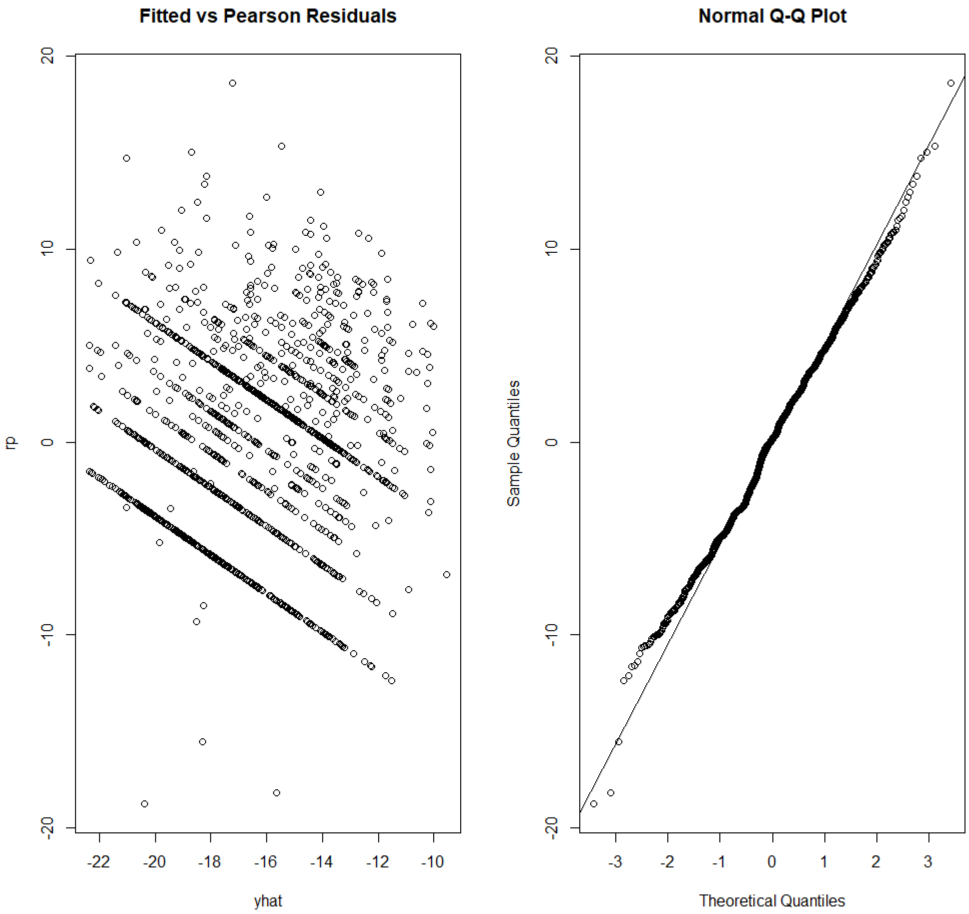

Figure 6.51: Model diagnostics for GAM fitted to gorgonian catch weights.

Table 6.13: Model estimates for GAM fitted to gorgonian catch weights on events with observed catch. Base cases for fixed effect were: bottom_trawl_ORH (method_group), 7 (month), and FMA4 (start_obs_fma)

Variable	Mean	Standard Error	z-value	p-value
(Intercept)	-17.3171	1.0398		< 2e-16***
method_groupbottom_longlining	-1.9686	1.2739		0.122
method_groupbottom_trawl_BOE	1.1283	1.3566		0.406
method_groupbottom_trawl_other_targets	-1.4986	1.0584		0.157
method_groupbottom_trawl_SQU	-0.2215	1.321		0.867
method_groupbottom_trawl_SSO	2.8669	1.0786		0.008**
method_groupbottom_trawl_SWA	-1.423	1.5714		0.365
method_groupmidwater_trawl	-0.8831	1.3485		0.513
method_groupset_netting	-3.1759	2.5197		0.208
month1	1.738	0.6888		0.012*
month2	1.4035	0.7513		0.062.
month3	2.3947	0.7165		0.001***
month4	0.8378	0.8063		0.299
month5	2.5048	0.7414		0.001***
month6	1.4027	0.6563		0.033*
month8	1.3399	0.8437		0.112
month9	1.6168	0.932		0.083.
month10	2.0401	0.6457		0.002**
month11	1.7042	0.6645		0.01*
month12	0.2676	0.7048		0.704
start_obs_fmaFMA1	0.6486	1.9611		0.741
start_obs_fmaFMA2	-1.8055	1.1891		0.129
start_obs_fmaFMA3	-1.6963	0.8411		0.044*
start_obs_fmaFMA5	-1.365	0.8093		0.092.
start_obs_fmaFMA6	-1.3199	0.9139		0.149
start_obs_fmaFMA7	-1.1355	0.9558		0.235
start_obs_fmaFMA8	1.5425	1.7693		0.383
start_obs_fmaFMA9	3.2445	1.7388		0.062.

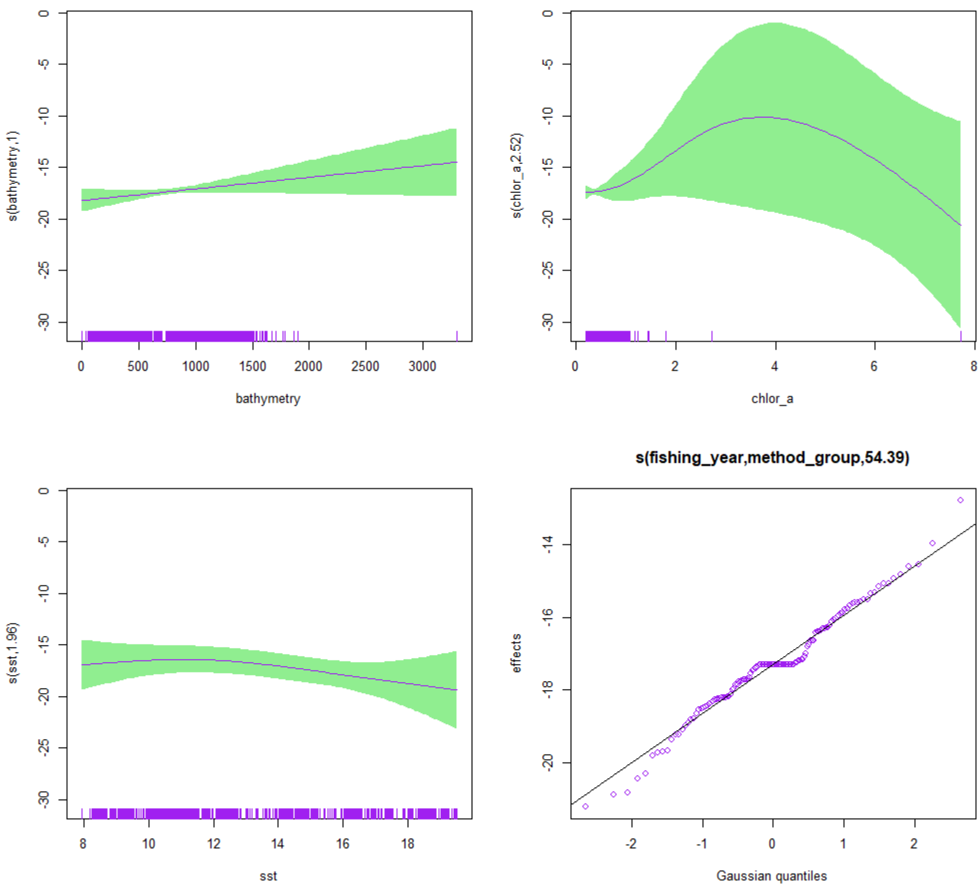

Figure 6.52: Partial effects from GAM fitted to gorgonian catch weigth data in all fishing methods.

6.7 Fisher-reported coral captures

Table 6.14: Fisher-reported coral captures between the 2008–09 and 2020–21 fishing years.

Species code	Coral group	Catch weight (t)
COU	Unspecified coral catch	82.265
STP	stony corals	8.800
SIA	stony corals	6.402
GDU	stony corals	5.844
ERO	stony corals	2.120
LPT	lace corals	1.000
COB	black corals	0.659
MOC	stony corals	0.401
COR	lace corals	0.334
ERR	lace corals	0.325
PAB	gorgonians	0.171
GOC	gorgonians	0.139
CBR	stony corals	0.111
COF	stony corals	0.031
STI	black corals	0.027
DDI	stony corals	0.025
BOO	gorgonians	0.025
THO	gorgonians	0.020
PRI	gorgonians	0.014
LLE	gorgonians	0.010
STL	lace corals	0.005
COO	lace corals	0.003
CHR	gorgonians	0.002
PMN	gorgonians	0.002
CUP	stony corals	0.002
LSE	black corals	0.001
DEN	black corals	0.001
ISI	gorgonians	0.001
ACN	gorgonians	0.000