

Characterisation of protected coral interactions – final results

(INT2021-02)

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Objectives

- To improve our understanding of the historical and current extent of and variation in protected coral bycatch across multiple fisheries and fishing methods.
 - To improve our understanding of the risks of fishing to protected corals and how those risks vary temporally and spatially.
 - To understand which coral taxa are most vulnerable to interactions with commercial fisheries.
 - To inform focus areas / fisheries for mitigation efforts.
 - To inform development of a risk assessment.
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- Previous assessment done for trawl fisheries between 2007–08 and 2009–10 fishing years (Tracey et al., 2011)
 - This assessment: 2007–08 and 2019–20 fishing years; trawl fisheries and other fisheries

Analysis steps

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

Overview

1. Data
2. Capture summaries
3. Model results
4. Discussion
5. Dashboard demonstration

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Data

- Fishing years: 2007–08 to 2019–20
- COD:
 - 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)
 - **observer-reported captures that have been subsequently verified by an expert**
- Fisher-reported captures and Outside EEZ reported captures:
 - species identifications are potentially less reliable
 - reported at a higher taxonomic level
 - data is self-selected and could be subject to under-reporting
 - **may cover a greater breadth of fishing activities**

Data – COD (Data quality)

Data cleaning/imputation

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

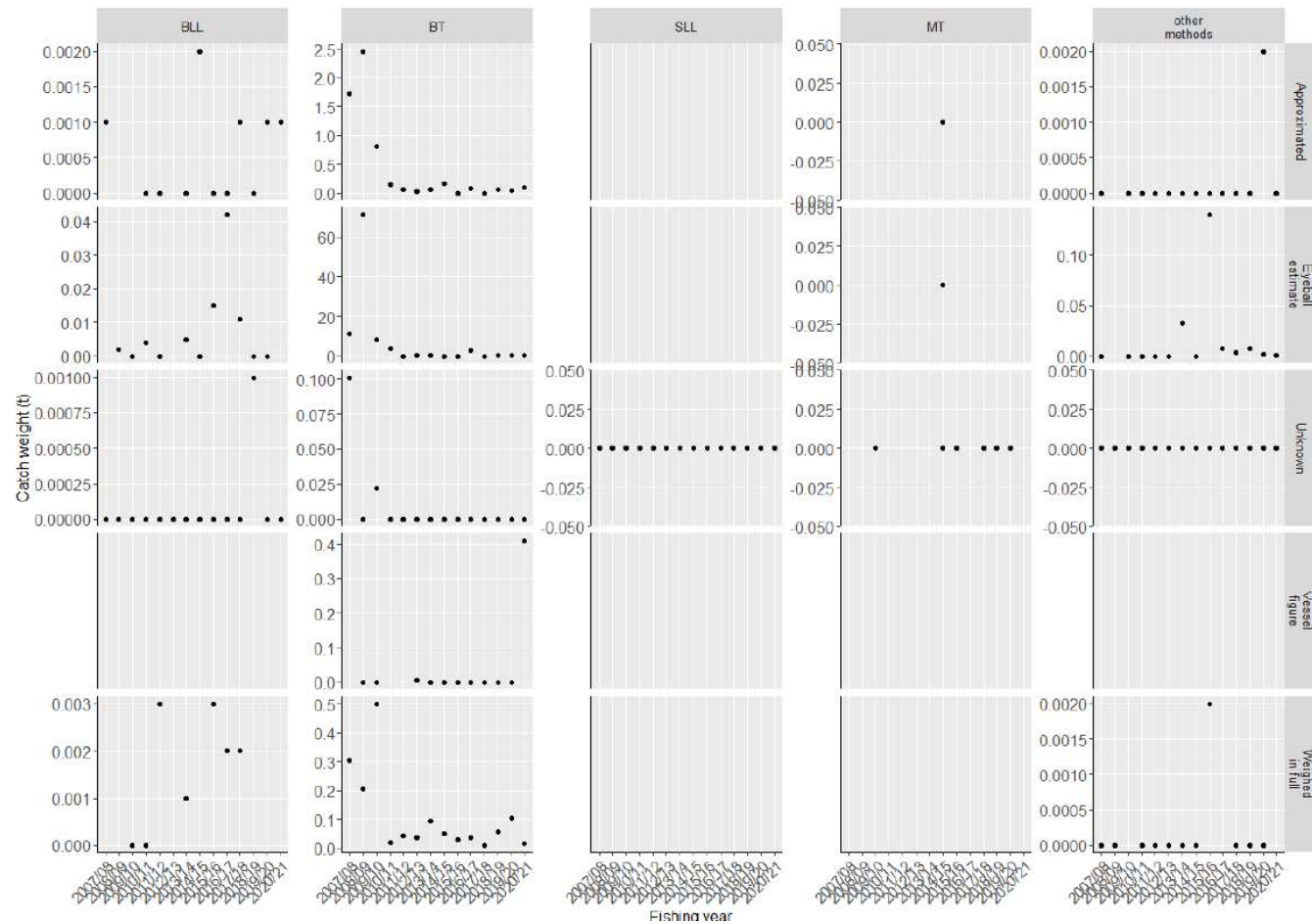
Data – COD (Data quality)

Methods used by observers to determine coral catch weights

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

Data – COD (Data quality)

Observed catch weight by fishing method & approach to determine catch weight



Data – COD (observed coral captures)

Coral catch by fishing method and target fishery (for bottom trawling)

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

Data – COD (observed coral captures)

Reported coral catch weights
(in tonnes) by fishing method
and management area

	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

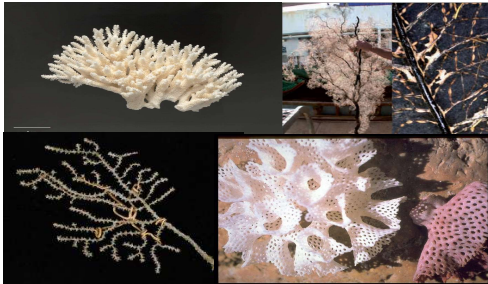
Data – COD (observed coral captures)

Number of observed fishing events with coral catch by management area and target species

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

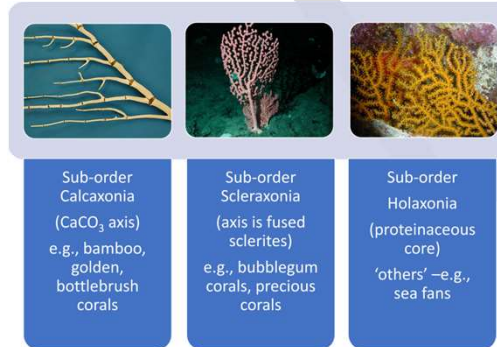
Data – COD (observed coral captures)

Reported coral catch weights by protected coral groups and fishing method



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

Reported coral catch weights by morphological groups and fishing method



Sub-order
Calcaxonina
(CaCO₃ axis)
e.g., bamboo,
golden,
bottlebrush
corals

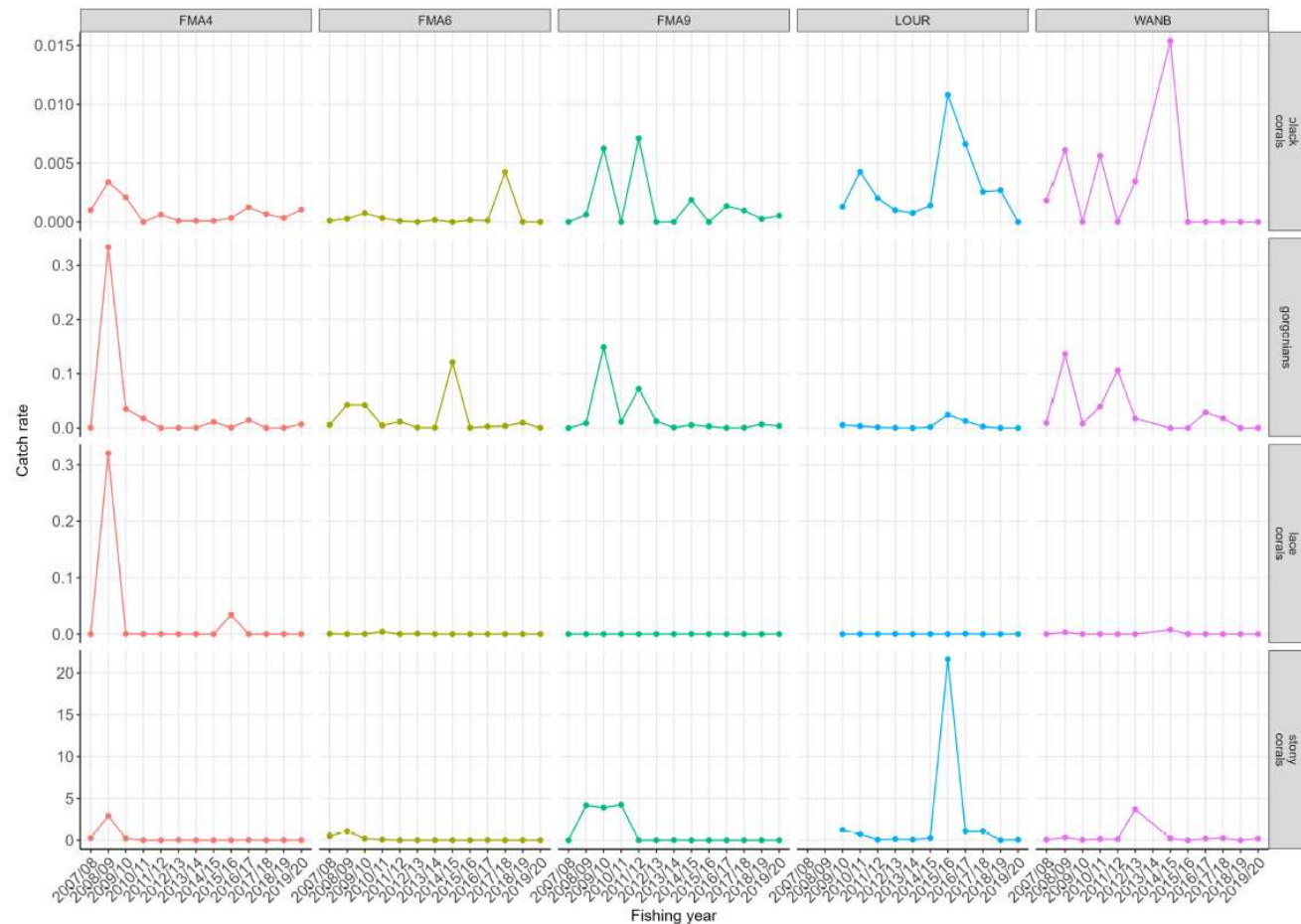
Sub-order
Scleraxonia
(axis is fused
sclerites)
e.g., bubblegum
corals, precious
corals

Sub-order
Holaxonia
(proteinaceous
core)
'others' –e.g.,
sea fans

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 - calcaxonina	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

Data – COD (observed coral captures)

Observed coral capture rates (bottom trawl only; tonnes per 100 tows) for areas with highest mean total coral catch rate across all protected coral species groups between the 2007–08 and 2019–20 fishing years



Data – Fisher-reported

Comparison of fisher-reported vs. observer-reported total coral captures per fishing year

Fishing year	Fisher-reported catch weight (t)	Observer-reported 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

Model -Methods

- Zero-inflated data
- Hence, two separate models fitted:
 1. logistic generalized additive model (GMA) to presence-absence data for coral catch on each fishing event
 2. GAM fitted to Box-Cox transformed catch weight data on fishing events with observed coral catch

Re 2:

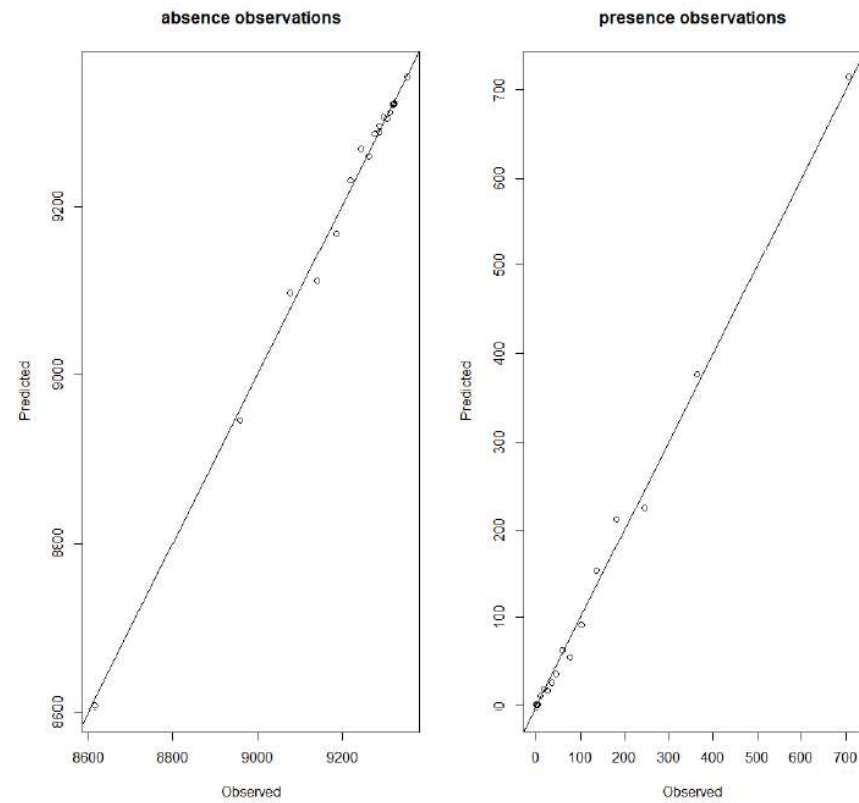
- Poor predictive ability (overpredicting low catch weights & under-predicting high catch weight) – Box-Cox transformation (and any other transformation or alternative distribution) not sufficient to account for highly skewed data.
- In addition, catch weight are highly variable probably because of inconsistent and subjective method to determine catch weights

Re 1:

$$\log\left(\frac{P}{1-P}\right) \sim s(\text{bathymetry}, k = 4) + s(\text{chlor}_a, k = 4) + s(\text{sst}, k = 4) + s(\text{fishing_year}, \text{method_group}, \text{bs} = \text{"re"}) + \text{method_group} + \text{month} + \text{start_obs_fma}$$

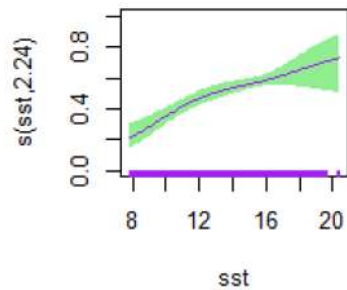
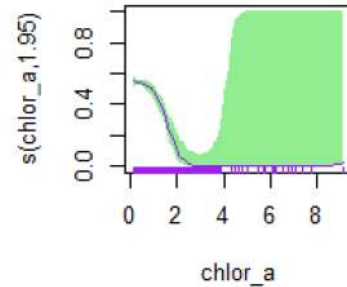
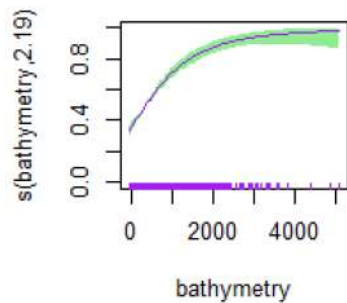
Model – Predictive checking

Hosmer-Lemeshow test

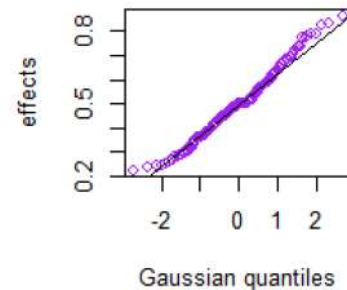


Model - Estimates

Stony corals



(fishing_year, method_group, ε



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

Model - Estimates

Model fitted separately to branching and cup-forming stony corals

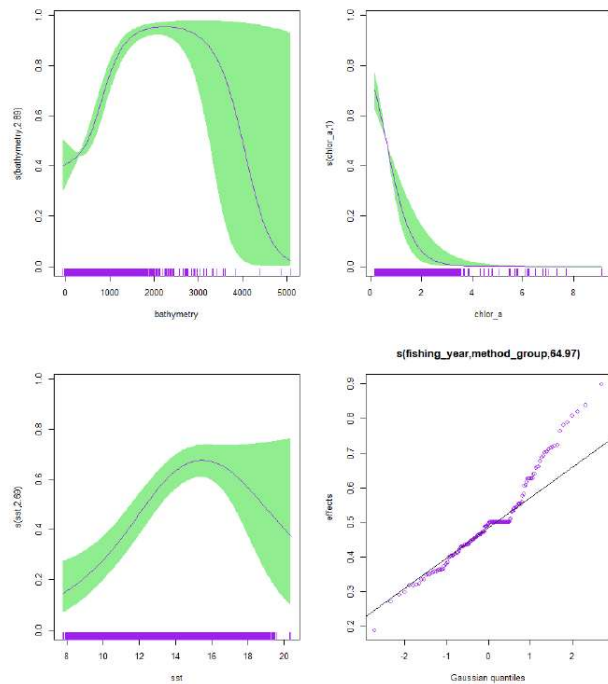


Figure 4.9: Partial effects from logistic GAM fitted to presence-absence data of branching stony coral captures in all fishing methods.

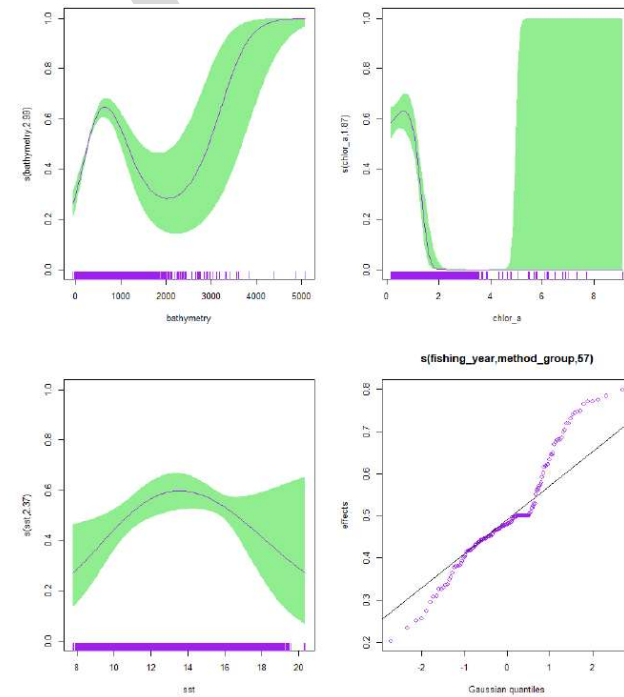
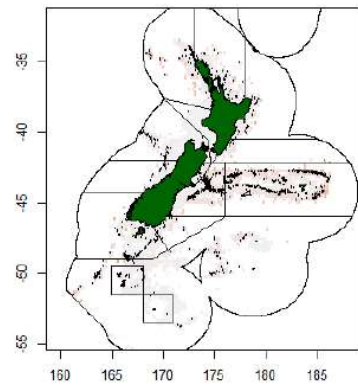


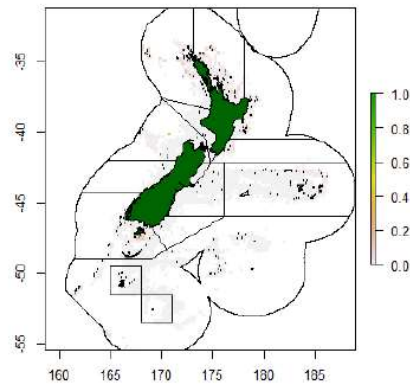
Figure 4.10: Partial effects from logistic GAM fitted to presence-absence data of cup-forming stony coral captures in all fishing methods.

Model – Predicted catch probability on observed events

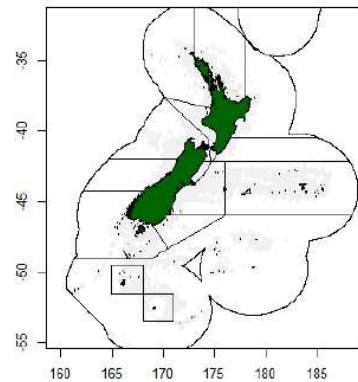
Average probability of stony coral catch



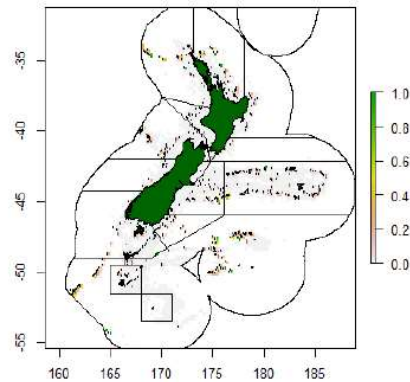
Average probability of black coral catch



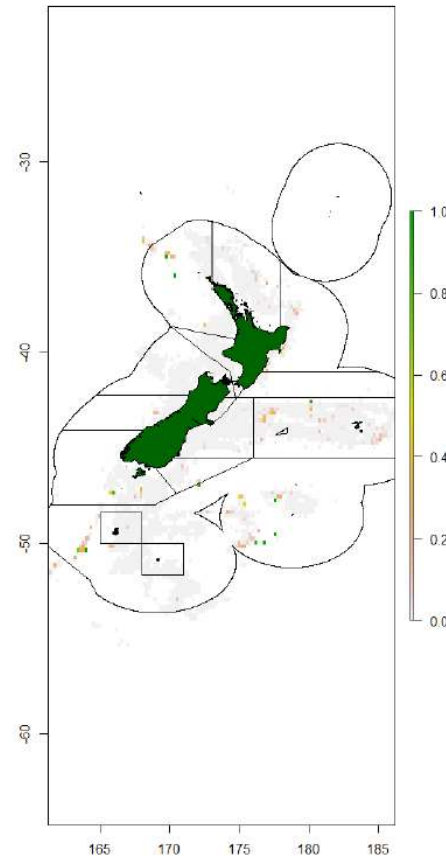
Average probability of lace coral catch



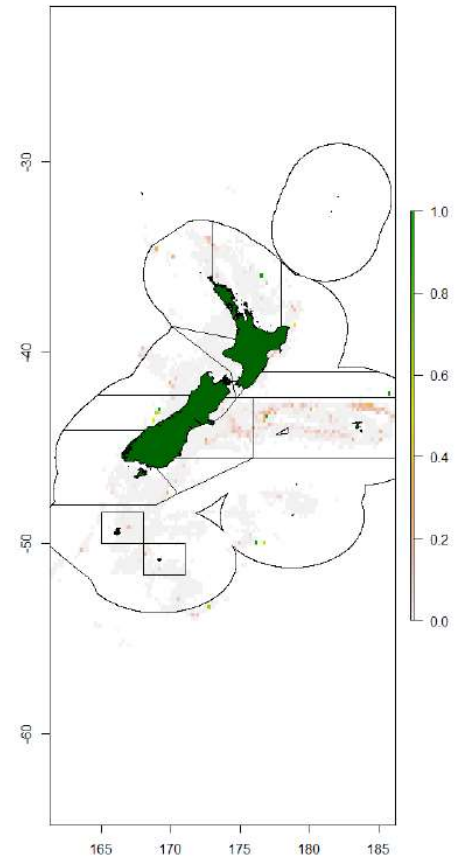
Average probability of gorgonian catch



Average probability of stony (branching) coral catch



Average probability of stony (cup) coral catch



Discussion

- 99% of reported coral catch between 2007–08 and 2019–20 fishing years found in bottom trawl fisheries
- Predominantly stony corals in bottom trawl fisheries targeting orange roughy in FMA4
- Supported by statistical models

- Most coral capture events without documented methodology for determination of coral catch weights
- Highest catch weights based on eyeball estimates
- Hence, catch weights are unsuited for assessing fishery-coral interactions
- Standardized observer protocols required to collect data on coral catch weight

- Currently, presence-absence of coral catch best proxy for fishery-coral interactions
- However, presence-absence of coral catch is not a good measure for actual impact but can point to areas of high risk that require further investigation

App demonstration

