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**Updated quantitative benthic impact assessment for
New Zealand and Australian bottom fisheries**

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Australian bottom fisheries**

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1. Purpose

The purpose of this paper is to present an update of the quantitative impact assessment component of the Cumulative Bottom Fishery Impact Assessment for Australian and New Zealand bottom fisheries, which was submitted to the 11th meeting of the SPRFMO Scientific Committee (SC) in 2023 ([SC11 – DW01_rev1](#)). This updated assessment was prepared as a response to the 2024 Scientific Committee Multiannual Workplan from the 12th Annual Meeting of the SPRFMO Commission which included a subtask of the Bottom Fishery Impact Assessment task, to “Update the quantitative benthic impact assessment for the 2023 BFIA”. The 2023 quantitative impact assessment provided an assessment of the current status of 10 Vulnerable Marine Ecosystem (VME) indicator taxa within the Fishery Management Areas (FMAs) of the Evaluated Area portion of SPRFMO, using the Relative Benthic Status (RBS) method. This paper provides an update of that assessment by applying an alternative application of the RBS method (dynamic RBS), incorporating bottom fishing impact data from recent fishing activity, re-assessing taxon-specific depletion and recovery values, re-evaluating relationships between estimated habitat suitability and observed abundance, and including assessments for an additional 7 VME indicator taxa.

2. Background

The Cumulative Bottom Fishery Impact Assessment for Australian and New Zealand bottom fisheries presented to SPRFMO Scientific Committee in 2023 (hereafter referred to as the 2023 BFIA; [SC11 – DW01_rev1](#)) provided an assessment of the Relative Benthic Status (RBS) of 10 VME indicator taxa, as defined in [CMM-03-2023](#) (Table 1), based on spatial predictions of habitat suitability, spatial estimates of bottom contact from trawl and longline fishing, and estimated VME indicator taxon-specific depletion and recovery rates. However the assessment was not able to incorporate impacts from recent bottom fishing in the Evaluated Area reported to SPRFMO subsequent to the previous (2020) assessment ([SC8-DW07 rev 1](#)), and was also not able to assess impacts to seven VME indicator taxa for which habitat suitability models had been developed and endorsed by the Scientific Committee in 2022 ([SC10-DW05](#), [SC10-Report](#)). In addition, it was recommended in [SC8-DW07 rev 1](#) that estimates of the VME indicator taxon-specific depletion and recovery rates be updated to consider any recent published information that may be relevant. There was also a need to determine appropriate depletion and recovery values for the additional taxa.

A further known limitation with the RBS assessment of status in the 2023 BFIA is that it is expected to have over-estimated impact and under-estimated equilibrium status due to the high projected future fishing impacts assumed, compared with the very low fishing effort (bottom trawling especially) that was actually reported subsequent to the last year of fishing data (2019) used in the assessment.

Table 1: Vulnerable Marine Ecosystem indicator taxa identified in [CMM-03-2022](#) and Fisheries New Zealand (FNZ) and Food and Agriculture Organization (FAO) codes.

Phylum	Lower taxonomic group	Qualifying taxa	FNZ Code	FAO Code
Porifera (sponges)	Demospongiae and Hexactinellida		DEM& HEX	PFR
Cnidaria	Scleractinia (Stony corals)	All taxa within the following genera: <i>Solenosmilia</i> ; <i>Goniocorella</i> ; <i>Enallopsammia</i> ; <i>Madrepora</i> ; <i>Oculina</i> ; <i>Lophelia</i>	SVA, GDU, ERO, MOC, OVI	CSS
	Antipatharia (Black corals)		COB	AQZ
	Alcyonacea* (Soft corals)	All taxa excluding Gorgonian Alcyonacea	ALCY	ALZ
	Gorgonian Alcyonacea* (tree-like forms, sea fans, sea whips, bottlebrush corals)	All taxa within the following suborders: Holaxonia; Calaxonia; Scleraxonia	GOC	GGW
	Pennatulacea* (Sea pens)	All taxa	PTU	NTW
	Actiniaria (Anemones)	All taxa	ANT	ATX
	Zoantharia (Hexacorals)	All taxa	ZAH	ZOT
	Hydrozoa (Hydroids)		HDR	HQZ
	Stylasteridae (Hydrocorals)	All taxa	COR	AXT
Bryozoa (Bryozoans)			COZ	BZN
Habitat indicators				
Echinodermata	Brisingida ('Armless' stars)	All taxa	BRG	BHZ
	Crinoidea (Sea lilies and feather stars)	All taxa	CRI	CWD

*Note: systematics of *Octocorallia* have since been revised using phylogenomic methods. See [McFadden et al. \(2022\)](#) for further details.

The current impact assessment is limited to the nine Fishery Management Areas (FMAs) within the Evaluated Area of SPRFMO within which bottom trawling is permitted in Bottom Trawl Management Areas (BTMAs) (Figure 1). The Evaluated Area is described in [SC8-DW07 rev 1](#) as the area “within which the distribution of VME indicator taxa has been mapped between depths of 200 m and 3000 m using predictive models (Georgian et al. 2019)”, and defined in [CMM-03-2023](#) as “Those parts of the Convention Area that are within the area starting at a point of 24°S latitude and 146°W, extending southward to latitude 57° 30S, then westward to 150°E longitude, northward to 55°S, westward to 143°E, northward to 24°S and eastward back to point of origin”. Midwater trawling and bottom longline fishing are also allowed within the BTMAs, and therefore these methods are incorporated into the assessment along with bottom trawling.

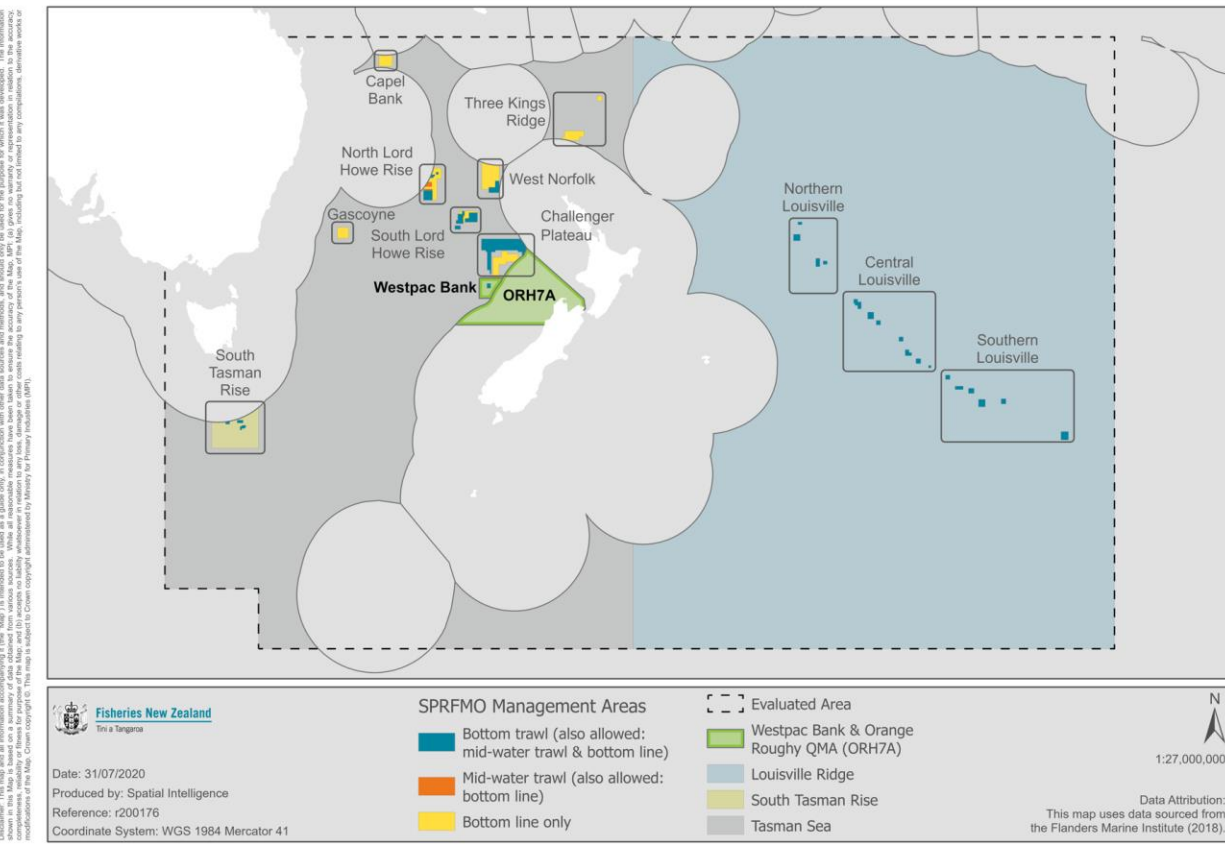
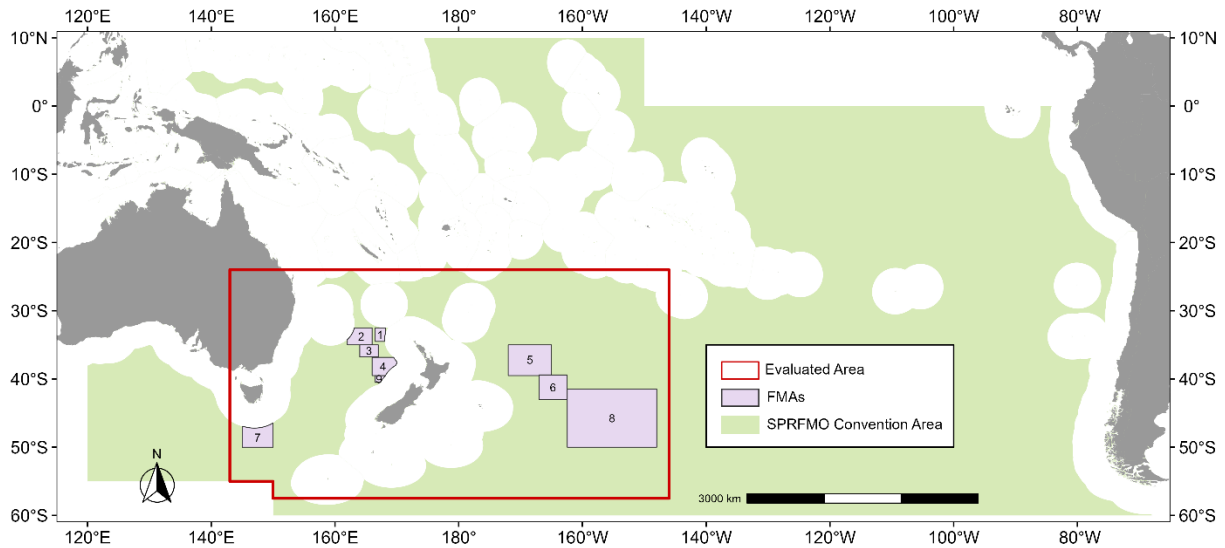


Figure 1: Top, The SPRFMO Convention Area showing the location of the Evaluated Area and the Fishery Management Areas defined under SPRFMO [CMM03a-2023](#) (purple polygons); Bottom, SPRFMO management areas open to different types of fisheries, and general fishery areas within the Evaluated Area. Note that areas open to bottom trawling are also open to all other fishing methods and areas open to midwater trawling are also open to bottom long lines. Boxes shown in solid black lines in the lower figure are a guide only, refer to the upper figure for FMA boundaries. FMAs numbered as 1) West Norfolk, 2) North Lord Howe Rise, 3) Central Lord Howe Rise, 4) Northwest Challenger, 5) North Louisville Ridge, 6) Central Louisville Ridge, 7) South Tasman Rise, 8) South Louisville Ridge, and 9) Westpac Bank.

3. Methods

3.1 Analytical methodology

The analytical method central to the impact assessment for VME indicator taxa in the 2023 BFIA was the Relative Benthic Status (RBS) approach (Pitcher et al. 2015, 2017).

This method estimates benthic status using the formula for the equilibrium of the Schaefer (1954) logistic population growth model and requires grids of total fishing effort (as Swept Area Ratios (SAR), essentially total annual fishing footprint combined without assuming any overlap), taxon-specific depletion rates (the proportion of benthic taxa that are damaged or destroyed by the passing of the bottom-contacting fishing gear), and taxon-specific recovery rates.

Previous BFIA assessments ([SC8-DW07 rev 1](#), [SC11 – DW01 rev1](#)) have applied the RBS method using the equilibrium solution of the Schaefer (1954) model, such that in habitats subject to sustained trawling, the long-term relative abundance of biota (B), as a fraction of carrying capacity (K) is estimated by:

$$B/K = 1 - F D/R \text{ where } F < R/D, \text{ otherwise } B/K=0$$

where B/K represents “relative benthic status” (RBS) of the seabed ranging from 0–1, R is the taxon-specific proportional recovery rate per year (0–1), D is the taxon- and gear-type specific depletion rate per trawl (0–1), and F is trawling intensity as swept-area ratio (SAR: the annual total area swept by trawl gear within a given grid-cell of seabed (km²), divided by the area of that grid-cell (1 km²)).

The ratio D/R represents sensitivity to trawling—the time interval between trawls (years) that would cause local extinction of the biota (RBS=0)—and R/D is the corresponding critical annual trawl intensity F at which a given sensitivity will have RBS=0. For RBS, SAR should be determined for grid cells of size ~1×1 km; a scale at which the distribution of most individual trawls has been shown to be random (e.g., Ellis et al. 2014), although this may not hold for the highly targeted fishing on some features.

This implementation of RBS requires only a single (annual mean) spatial distribution of trawling intensity and estimation of status is limited to a long-term equilibrium value. However, a second approach is noted by Pitcher et al. (2017) which uses an annual time series of trawling intensity, and instead of producing estimates of long-term relative status at equilibrium can provide estimates of status for each year of the time series, including future years if the time series supplied estimates future fishing intensity. This approach is referred to as dynamic RBS (dRBS):

$$\delta B/\delta t = RB(1 - B/K) - DFB$$

where $\delta B/\delta t$ is the rate of change in abundance B in time t.

The equilibrium implementation of RBS was presented for 10 VME indicator taxa in the 2023 BFIA. In this paper, dRBS status was calculated for these taxa as well as for non-gorgonian Alcyonacea and the six taxa for which habitat suitability models were subsequently produced, for a total of 17 VME indicator taxa.

3.2 Habitat suitability models

Spatial estimates of habitat suitability, including uncertainty, were unchanged from the 2023 BFIA, with complete details of model structure and outputs for all 17 taxa provided in Stephenson et al. (2021) and Bennion et al. (2024).

To enable results of the impact assessment to be considered as a proxy for abundance, transformations were made to the habitat suitability index values using the two approaches that were used for previous estimates of RBS ([SC8-DW07 rev 1](#), [SC11 – DW01 rev1](#)):

1. ROC-linear: A cut-off point on the Receiver Operating Characteristics (ROC) curve formulated using predicted and observed probabilities is determined where the specificity and sensitivity are at their optimal (false-positive and false-negative rates are at their lowest). All Habitat Suitability Index (HSI) values below this cut-off are set to zero, whilst all HSI values at or above the cut-off are assumed to have a linear relationship with abundance.
2. Power mean: HSI scores were transformed to estimates of abundance using power curves estimated using observed information on the abundance (number of individuals or coral heads per unit area) of VME indicator taxa within grid cells for which HSI predictions were available.

ROC-linear HSI transformations are relatively straightforward, requiring only the taxon-specific ROC model performance metrics and HSI grids. The ROC curve-based cut-offs (derived from the habitat suitability models of Stephenson et al. 2021 and Bennion et al. 2024) fall in a relatively narrow range, from a low of 0.38 (*Goniocorella dumosa*) to a high of 0.59 (Zoantharia and Brisingida) (Table 2).

Table 2: Thresholds used to transform habitat suitability index values, based on optimal specificity and sensitivity values on ROC curves derived from models for each of the 17 VME indicator taxa assessed.

Taxon	FAO code	ROC cut-off habitat suitability index value
<i>Solenosmilia variabilis</i>	CSS	0.46
<i>Madrepora oculata</i>	CSS	0.45
<i>Goniocorella dumosa</i>	CSS	0.38
<i>Enallopsammia rostrata</i>	CSS	0.50
Antipatharia	AQZ	0.52
Alcyonacea (excluding "Gorgonacea")	ALZ	0.50
"Gorgonacea"	GGW	0.51
Stylasteridae	AXT	0.46
Demospongiae	PFR	0.46
Hexactinellidae	PFR	0.45
Pennatulacea	NTW	0.45
Actiniaria	ATX	0.48
Zoantharia	ZOT	0.59
Hydrozoa	HQZ	0.49
Bryozoa	BHZ	0.48
Brisingida	BHZ	0.59
Crinoidea	CWD	0.47

Power curve HSI transformations, however, were re-calculated for this update using the Deep-Towed Imaging System (DTIS) camera-based abundance data assembled for recent VME indicator taxon abundance models (Bennion et al. 2024) (Figure 2). These data were more appropriate for comparing with habitat suitability estimates than the data used previously to calculate power curve transformations as they are limited to video surveys only (i.e., not including abundance estimates from physical sampling) and exclude Australian video survey data collected using different sampling protocols and largely from outside the depth and latitudinal/longitudinal ranges of the habitat suitability model predictions.

For each taxon, power transformations were explored using the same methodology previously accepted by the SC ([SC11 – DW01 rev1](#)). Firstly, for each taxon, HSI predictions were matched to DTIS observations by identifying the HSI grid cell that corresponded to each DTIS observation. A ‘super smoother’ (Friedman, 1984) was then run using the matched HSI predictions and DTIS observations to generate a smoothed profile of the DTIS observations. Each HSI prediction was weighted by the standard deviation of the predictions ($1/SD^2$) and DTIS observations were log transformed to reduce the skew. Various power transformations of the super smoothed profile of the DTIS observations were explored and modelled against HSI predictions. For each of the models, the power transformation with the highest least squares fit (R-squared closest to one), nearest one-to-one relationship (slope=1), and distance to optimal R-square and slope (smallest Euclidean distance) were identified. The mean power transformation was then calculated (Table 3 **Error! Reference source not found.**). HSI predictions were then power transformed using the mean power transformation to estimate abundance for each taxon.

Plots of the raw observed abundance profile and the predicted HSI are given in Annex 1. These plots show the ROC-linear cut-offs and modelled linear relationship, as well as the mean power transformations, for each taxon. In addition, each figure displays the observed abundance, the R-squared value for each model, and the data within and outside the SPRFMO Evaluated Area. Note, there are 832 DTIS observations, 139 inside the SPRFMO Evaluated Area and 693 outside the SPRFMO Evaluated Area in Exclusive Economic Zones (EEZs) (Figure 2). Of the 139 observations inside the Evaluated Area, 118 are from a 2014 survey of the Louisville Seamount Chain (45 from the Central Louisville FMA and 73 from the North Louisville FMA) (Clark et al. 2015), and the remaining 21 observations are from a 2007 survey on the Challenger Plateau (18 in the Northwest Challenger FMA and 3 in the Westpac Bank FMA) (Nodder et al. 2007). The Louisville Seamount Chain observations are from bottom depths of 645–1519 m, with only one deeper than the maximum fishable depth (1400 m, [SC11 – DW01 rev1](#)); the Challenger Plateau observations are from bottom depths of 492–1749 m, with two deeper than the fishable depth.

Table 3: Range of power transformations (low, mean and high) estimated for each of the 17 VME indicator taxon.

Taxon	Range of power		
	Low	Mean	High
1: <i>Solenosmilia variabilis</i>	7	7.7	8
2: <i>Madrepora oculata</i>	7	7.0	7
3: <i>Goniocorella dumosa</i>	23	23.3	24
4: <i>Enallopsammia rostrata</i>	6	6.0	6
5: Antipatharia	1	1.0	1
6: Alcyonacea (minus "Gorgonacea")	16	18.3	23
7: "Gorgonacea"	4	4.7	6
8: Stylasteridae	7	7.0	7
9: Demospongiae	9	9.7	11
10: Hexactinellidae	8	9.7	13
11: Pennatulacea	1	1.0	1
12: Actiniaria	1	1.7	2
13: Zoantharia	3	3.3	4
14: Hydrozoa	1	1.0	1
15: Bryozoa	1	1.0	1
16: Brisingida	8	10.0	14
17: Crinoidea	5	5.7	7

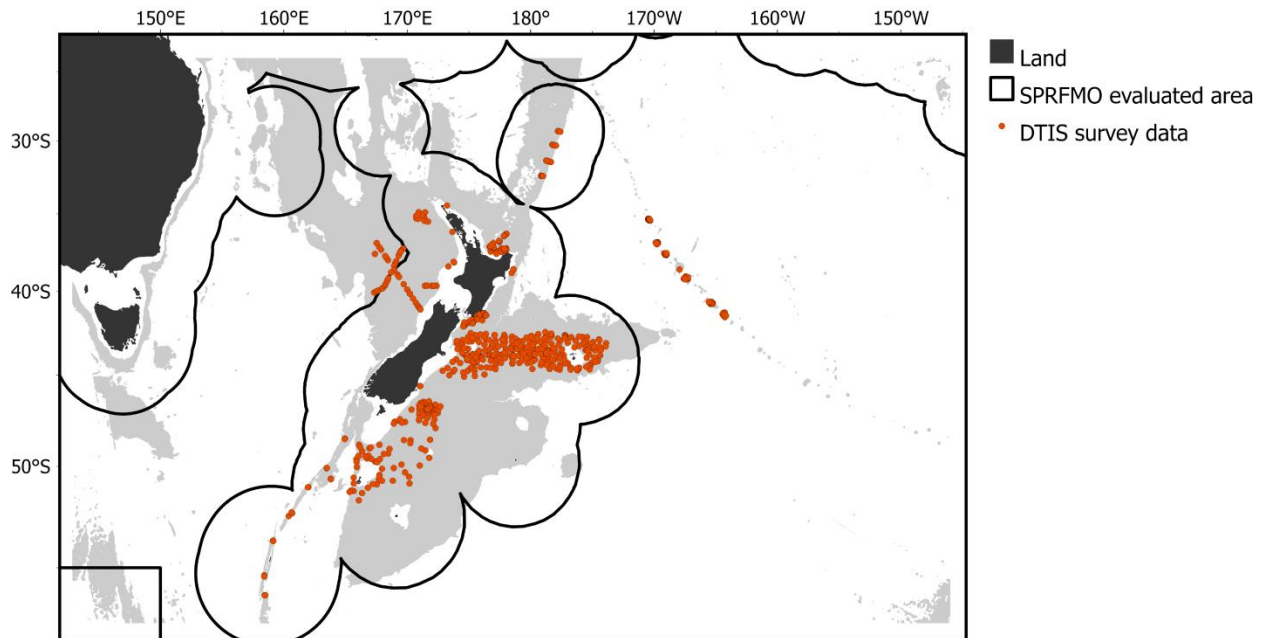


Figure 2: Map of Deep-Towed Imaging System (DTIS) seafloor video transect locations from which abundance data were used to produce Power curve transformations of VME indicator taxa Habitat Suitability Index values.

3.3. Spatial representation of fishing effort

Annual layers of the estimated spatial distribution of bottom-contacting fishing gear in the Evaluated Area were created from historic records of fishing activity reported by the main fishing countries in this area i.e., New Zealand and Australia. Other nations (including Japan, Russia, Ukraine, South Korea, Norway, South Africa, and China) have also fished in this area to an unknown extent (Gianni 2004, Clark et al. 2008), but data were not available to include in this assessment. The RBS assessment in the 2023 BFIA included fishing effort data for the years 1989 to 2019 inclusive. For this update all available fishing effort data for the following years (up to the end of 2023) were acquired and included in the assessment.

Annual grids of cumulative location-specific swept-area were calculated following methods outlined in Mormede et al. (2017). All available New Zealand and Australian recorded fishing events using bottom-contacting methods in the years 2020 to 2023 were obtained and assembled. Data were groomed to remove or correct any erroneous values and unwanted records (e.g., overly long trawls/sets, locations in too-deep water or outside of the Evaluated Area) then appended to the existing data set for the 1989 to 2019 period. The updated data set includes three fishing methods: bottom trawling, midwater trawling, and bottom longlining. Following the methodology in the 2023 BFIA, the start and end locations of fishing sets and trawls pre-2020 were jittered where necessary by 0.5 minutes (using a uniform random distribution) to spatially separate records overlying due to rounding of reported positions to the nearest minute of arc. Position data supplied for the new (2020–2023) fishing sets and trawls were not rounded and thus no jittering was required. Trawl positions were also adjusted where possible using recorded start and end positions, trawl geometry (i.e., assuming a warp to depth ratio of 2:1), and depth so as to represent the position of the trawl on the seafloor rather than the vessel position. Following Mormede et al. (2017), trawl and longline records were split into approximately 100 m long segments. For trawls the calculated tow distance, and hence the number of these segments, was based on speed and duration rather than start and end positions to account for trawls that vary off a direct course between the recorded start and end position. The width assigned to each trawl varied and was set according to the fishing method, bottom type, and nation (Australian trawl vessels have typically used narrower trawls) based on figures tabulated in Mormede et al. (2017) and unpublished notes from the SPRFMO trawl impact workshop in July 2017 (Table 4).

Because the extent and duration of bottom trawl gear contact with the seafloor depends on whether fishing was conducted on slopes or underwater topographical features, bottom trawls were designated as Underwater Topographical Feature (UTF) tows if the start position was within 3 n. miles of a hill (elevation 100–499 m), 5 n. miles of a knoll (elevation 500–999 m), or 8 n. miles of a seamount (elevation 1000 m or greater), and if trawl duration was less than 0.5 h; tows not meeting these criteria were designated SLOPE tows (after Roux et al. 2017). The position of UTF trawls with end position missing or equal to start position, and therefore lacking the direction component necessary for adjusting the gear offset to the vessel, were adjusted using the direction to the nearest UTF peak. Segment widths were further adjusted for UTF and midwater tows, to account for the lesser impact from the various components of the trawl (doors, sweeps/bridles, ground gear) due to the reduced period of seafloor contact by some components during the tow. For example, tows using midwater trawls to target

benthopelagic species only rarely touch the bottom and then only for very short time periods, and bottom trawl tows on UTFs are generally undertaken with the doors mostly off the bottom (Mormede et al. 2017). UTF segment widths were reduced by a ratio of 0.24/0.82 and midwater segment widths by a ratio of 0.001/0.82 (based on values in Mormede et al. (2017) and from the SPRFMO trawl impact workshop in July 2017).

The effective width of the area impacted by bottom longlines is largely determined by the lateral movement of the backbone during retrieval and that has been shown to vary according to depth. Segment widths were estimated according to a calculation derived from Welsford et al. (2013) and Darby (2010), and based on the depth of the set:

$$\text{Width} = \exp(2.4892514 - 0.0011380 * \text{Depth})$$

Impact widths are between 6 m and 10 m but can be up to 12 m for some shallower longline sets (Figure 3). Total fishing swept areas for each fishing method were derived from the segment data by assigning each segment to a cell of a standard 1x1 km grid in Mercator 41 projection with an extent defined by the Evaluated Area. The total cumulative bottom-contact swept area in each cell was calculated by adding the areas of all segments with midpoints within the cell (annually and overall).

Table 4: Nominal swept widths (m) applied to trawls by fishing type and nation.

	Australia	New Zealand
Slope tows	100	135
Feature tows	85	115
Midwater tows	30	30

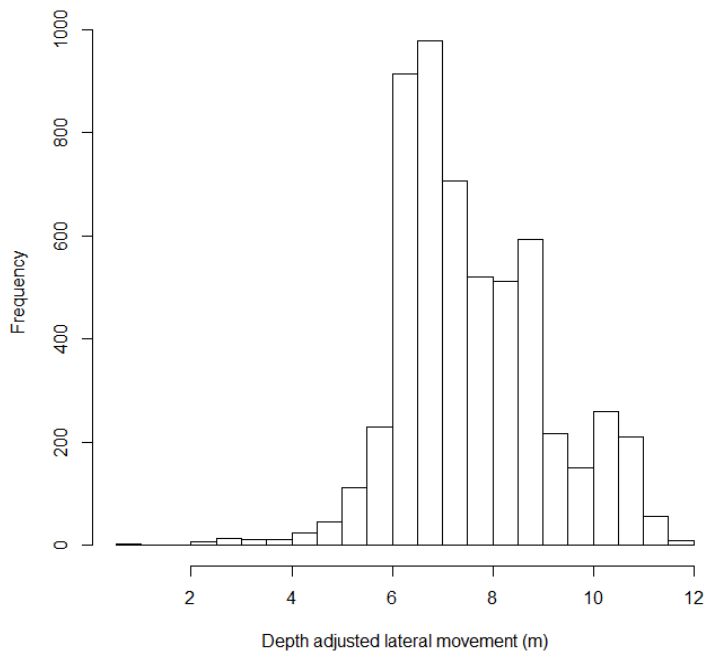


Figure 3: Distribution of estimated depth-adjusted longline impact widths.

3.4 Depletion and recovery

Values of depletion and recovery used in the 2023 BFIA considered data and published information from several studies, but these were based on relatively shallow water settings, and values were not provided for six species being assessed for this update. For this update more emphasis was placed on deriving values appropriate to the depth range associated with deeper fishing activities in the Evaluated Area. An examination of relevant literature provided few values that could be used to directly update those used previously. The papers examined mostly comprised meta-analyses of published experiments and studies (e.g., Sciberras et al. 2018, Hiddink et al. 2017) that were strongly focussed on shallow water settings and high-level taxa, habitats, and communities and therefore of little direct value. One study, however (Hiddink et al. 2019), examined the relationship between intrinsic recovery rates and longevity for some benthic invertebrate taxa, providing a potential method for estimating recovery for species with information on maximum age. Another study incorporated observed catch data from deep-sea commercial bottom trawling into modelled estimates of depletion for a few relevant taxa (Demospongiae, Hexactinellida, and Pennatulacea) (Rowden et al. 2024). In addition to these broader studies on depletion and recovery, there is also evidence from recent literature on individual species that indicates that many deep-sea VME indicator taxa (corals in particular) are slow-growing, long-lived, and have low fecundity and limited dispersal capabilities (summarised, for the wider New Zealand region, in Tracey and Hjørvarasdóttir 2021). When considering recovery for this assessment, it is not taken to mean complete restoration of the complex three-dimensional structure of some habitats they may form (e.g., coral mounds) which may take many centuries or to achieve (e.g., Sowers et al. 2024), but rather recovery of the abundance (number of individuals, coral heads, etc, per unit area) of the taxa concerned.

An 'expert elicitation' approach was used to obtain a full set of estimates of D and R values for each of the 17 VME indicator taxa being assessed. A survey questionnaire was sent to 26 scientists in New Zealand and overseas (including three in Australia). The chosen participants included fisheries scientists, benthic ecologists and taxonomists, coral age and growth specialists, and seafloor video analysts (many with expertise in more than one of these fields). Participants were asked to estimate values of depletion from the impacts of bottom trawls and longlines, and intrinsic rates of recovery, for each of the 17 VME indicator taxa being assessed. Although climate change may have a substantial influence on the future recovery potential of many VME indicator taxa (Anderson et al. 2022), experts were not asked to take these effects into account. In addition to the survey questionnaire, a summary of previous assessments and relevant literature was also provided to participants in a supplementary document. This document, along with the questionnaire, are provided in Annex 2 and Annex 3.

3.5 Application of the dRBS method

Two alternative calculations of dRBS were made for each taxon; one using the ROC-linear transformation of habitat suitability values and the other using the Power mean transformation. For the ROC-linear dRBS calculations the HSI values were down-weighted according to model uncertainty in the same manner as used in the 2020 and 2023 BFIA's. Values in each cell above the threshold were weighted by their respective uncertainty (CV) value by dividing by $1+CV$, in this way giving more weight to cells with low uncertainty and less weight to cells with high uncertainty. In addition, for each taxon and each

transformation alternative, sensitivity to D and R values was assessed by testing alternative ($\pm 20\%$) high and low values (a rule-of-thumb range as used as the basis for calculations applied in the 2020 and 2023 BFIA's where a larger dataset of values were examined ([SC8-DW07 rev 1](#), [SC11 – DW01 rev1](#)). The use of these sensitivities provides estimates of worse-case (higher D and lower R) and better-case (lower D and higher R) status.

A key advantage of the dynamic RBS method over the equilibrium RBS method used in the 2020 and 2023 BFIA's is that status can be estimated annually, and therefore projected future status can be estimated if future fishing effort scenarios are supplied. Therefore, the use of dRBS allows for a more complete use of the status threshold previously used by SPRFMO to assess the impact status of VME indicator taxa.

Because SPRFMO does not have agreed reference points for Significant Adverse Impacts (SAIs) to VME indicator taxa and/or habitats, interpretation of RBS results can only be done qualitatively until these have been developed, or by applying reference points used elsewhere. For the 2020 and 2023 BFIA, SPRFMO assessed status against an interim threshold value used by the Marine Stewardship Council (Marine Stewardship Council 2018). The assessment criteria given by the MSC state that, in the case of VMEs, RBS (biomass (B)/carrying capacity (K)) should be maintained at over 0.8 with “serious or irreversible harm” interpreted as reductions in habitat structure and function below 80% of the unimpacted level. They also require that “habitats are not impacted beyond the point at which they could recover to 80% (or more) of their unimpacted level within 5–20 years”, as per the *Guidelines for the Management of Deep-Sea Fisheries in the High Seas* definition of significant adverse impacts being more than on a temporary basis (FAO 2009).

Therefore, a forward projection of status was estimated whereby no fishing was predicted to occur for 20 years. In this scenario, fishing impacts for 2024 were assumed to be unchanged from 2023, and cessation of fishing would begin in 2025. Given the assumption (see above) that effort by Australian longlining vessels was at a similar level to that of 2022, for this purpose Australian bottom longline impacts for 2023 and 2024 were assumed to be equal to 2022.

A second forward projection of status was also estimated in which impacts were simulated such that sufficient trawl effort was made in each year after 2024 to catch the entire orange roughy catch limit in all management areas. This was done by scaling up the average trawl SAR for recent years (2008 to 2021) based on the total reported orange roughy catch across all FMAs and the current catch limits. An average SAR layer for the years 2008 to 2022 was used to simulate the annual impacts from bottom longlining (the date ranges differing between methods due to the year in which the most recent fishing events were reported).

The SPRFMO Commission has directed the SC to adopt FMAs as the appropriate scale of management for assessing the performance of spatial management areas. It is useful, however, to also assess status at other spatial scales, including inside and outside of fishable areas within FMAs, and so results are presented at three different spatial scales: within FMAs, within BTMAs in each FMA, and outside of BTMAs in each FMA.

4. Results

4.1 Fishing effort data

Most of the bottom trawl and bottom longline effort was attributable to New Zealand vessels in most years, with overall effort decreasing sharply since 2019. No bottom trawling was reported by either New Zealand or Australia in 2022 or 2023. No bottom longlining was reported by New Zealand for 2023, and although a small amount of Australian bottom longlining is known to have occurred in 2023 (Trent Timmis, ABARES, pers. comm.), details were not available from SPRFMO in time for this longlining to be included in the analysis (Table 5).

Table 5: Number of fishing events used in the analyses; by year, method, and nation (AUS = Australia, NZL = New Zealand).

Year	Number of trawls			Number of bottom longlines		
	AUS	NZL	Total	AUS	NZL	Total
1989	0	9	9	0	0	0
1990	0	254	254	0	0	0
1991	0	37	37	0	0	0
1992	0	150	150	0	2	2
1993	0	2 872	2 872	0	64	64
1994	0	3 960	3 960	0	0	0
1995	0	5 667	5 667	0	0	0
1996	52	4 219	4 271	0	6	6
1997	646	2 478	3 124	0	19	19
1998	1 504	2 002	3 506	0	5	5
1999	1 190	2 849	4 039	0	15	15
2000	930	1 960	2 890	5	8	13
2001	396	2 156	2 552	21	0	21
2002	554	3 517	4 071	22	0	22
2003	332	3 499	3 831	7	26	33
2004	251	2 741	2 992	3	102	105
2005	207	2 472	2 679	0	295	295
2006	874	1 413	2 287	28	669	697
2007	203	629	832	18	427	445
2008	0	239	239	85	245	330
2009	0	649	649	48	210	258
2010	0	1 183	1 183	49	66	115
2011	171	1 153	1 324	52	60	112
2012	393	713	1 106	58	131	189
2013	244	876	1 120	80	260	340
2014	102	403	505	49	307	356
2015	18	933	951	79	199	278
2016	49	980	1 029	90	135	225
2017	73	1 452	1 525	91	192	283
2018	0	1 041	1 041	111	172	283
2019	108	269	377	84	392	476
2020	0	348	348	10	206	216
2021	0	17	17	28	176	204
2022	0	0	0	55	125	180
2023	0	0	0	0	0	0

The bottom trawls undertaken during 2020 to 2023 and added to the dataset for this update derived from seven FMAs (Westpac Bank, Central Louisville, South Louisville, North Lord Howe, Central Lord Howe, Northwest Challenger, and West Norfolk), with differing distributions of effort by depth (Figure 4). Trawls were mostly limited to 900–1000 m depth in Westpac Bank and West Norfolk, shallower than 900 m in West Norfolk, and spread over broad depth range (from 550 m to 1200 m) across Central Louisville, South Louisville, Northwest Challenger; the target species being orange roughy (*Hoplostethus atlanticus*) in each of these FMAs. Trawls were shallowest in North Lord Howe (400–600 m) where trawls all targeted alfonsino (*Beryx* spp.).

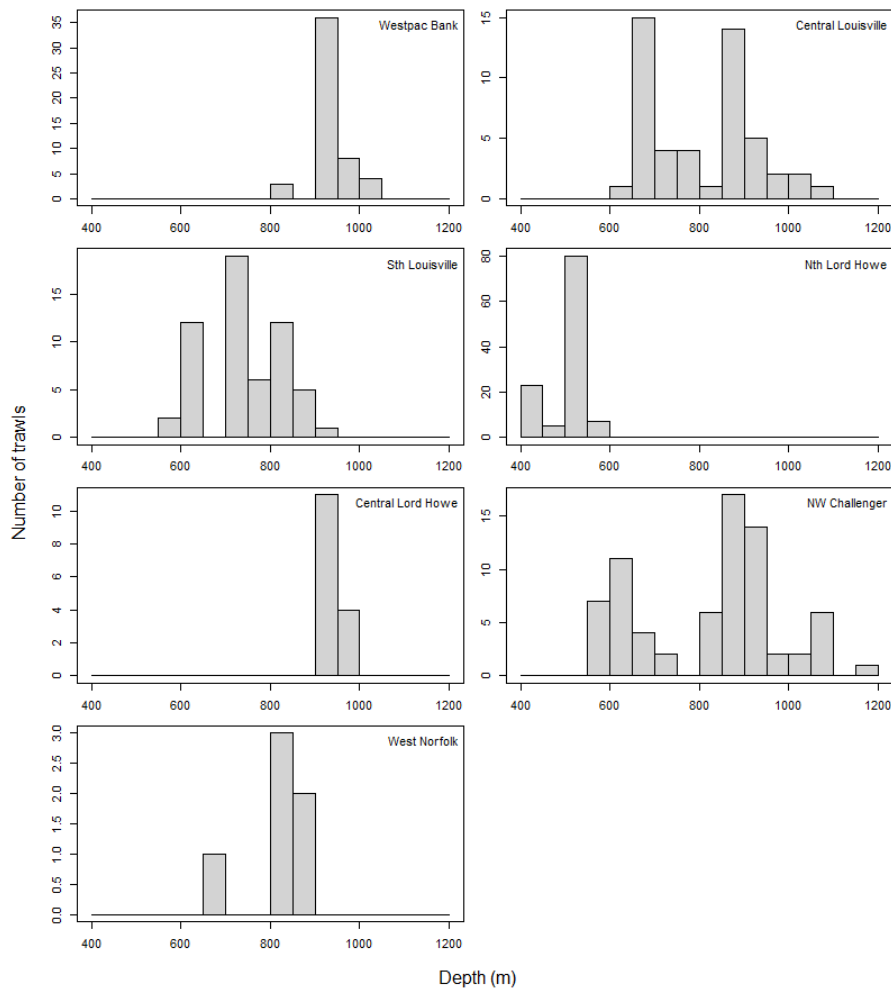


Figure 4: Number of bottom-contacting trawls carried out in the years 2020 to 2023 by Fishery Management Area, in 50 m depth divisions.

The bottom longline fishing effort for 2020 to 2023 added to the dataset for this update comes from four FMAs (Northwest Challenger, West Norfolk, North Louisville, and Three Kings). Note that bottom trawling is currently not permitted in the Three Kings FMA and in other FMAs the arrangement of bottom longline open areas differs from those of bottom trawling (see Figure 1). Fishing depths ranged from about 100 m

to 900 m, with the most effort and broadest depth range in West Norfolk FMA, and shallowest depth range and least effort in North Louisville FMA (Figure 5).

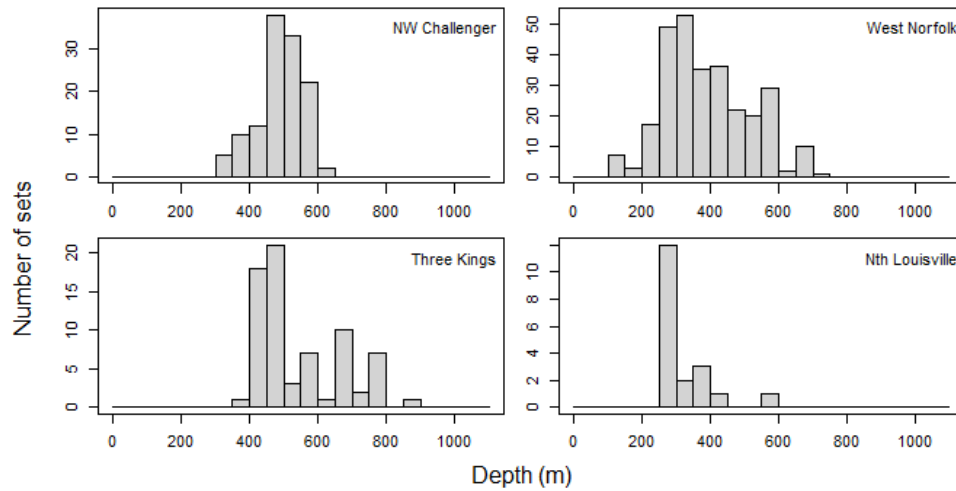


Figure 5: Number of bottom longline sets carried out in the years 2020 to 2023 by Fishery Management Area, in 50 m depth divisions.

4.2 Updated Swept Area Ratio (SAR) grids

The total accumulated footprint from bottom trawling inside the Evaluated Area in 1989–2023 was calculated to be 57 037 km². By comparison, the equivalent accumulated footprint from midwater trawling was 0.24 km² and the equivalent footprint from bottom longlining was 119.9 km². The very small footprint of midwater trawls stems from the trawl impact workshop conclusion that, on average, only 30% of midwater trawls contact the seafloor and that contact happens on average only twice per tow, for an average of 25 seconds each time.

The distribution of bottom trawl SAR values was strongly skewed, with a peak of values at between 0.1 and 0.2, and most values less than 2. There is a long tail in the distribution, however, with much higher values in some areas; Northwest Challenger in particular, with a maximum value of 102 (Figure 6).

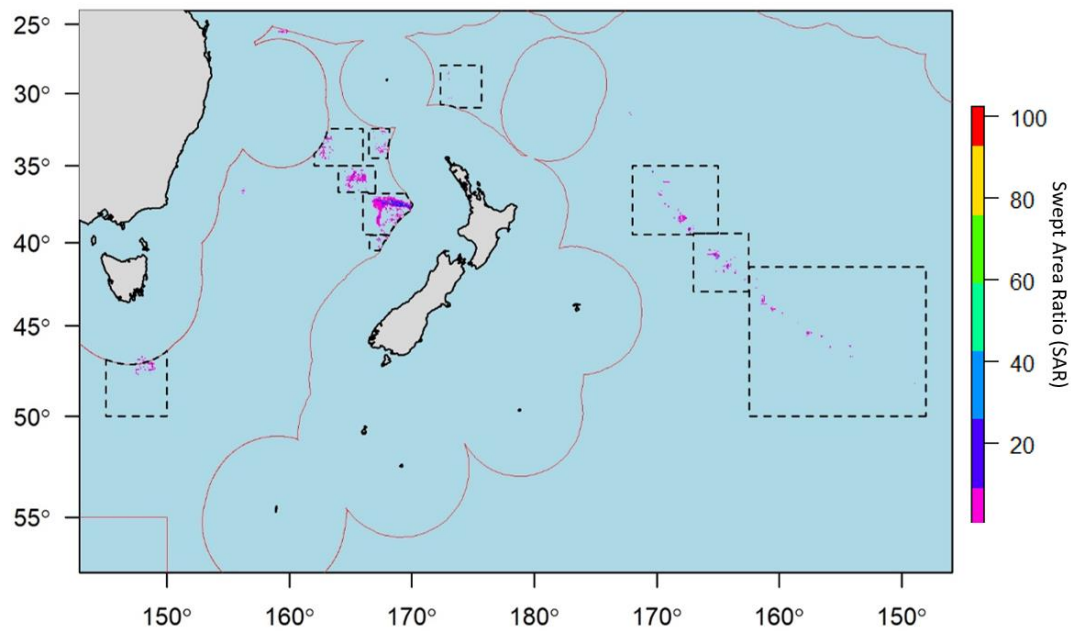
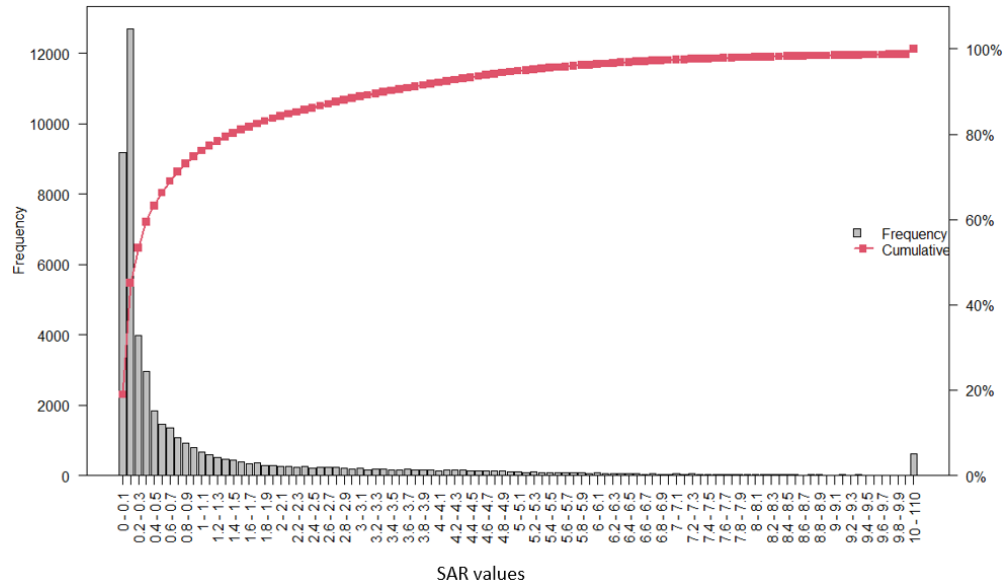


Figure 6: Distribution of bottom trawl Swept Area Ratio values across all 1x1 km cells of the SPRFMO Evaluated Area with recorded bottom trawl fishing between 1989 and 2023, with values over 10 combined into a single category (top), and their spatial distribution (bottom). Fishery Management Area boundaries shown as dashed lines; Exclusive Economic Zones shown as red lines.

As for bottom trawling, the distribution of bottom longline SAR values was strongly right-skewed, but the values themselves are an order of magnitude lower. A peak in SAR values occurs between 0.01 and 0.02, and the long tail includes values up to a maximum of about 0.5 (Figure 7).

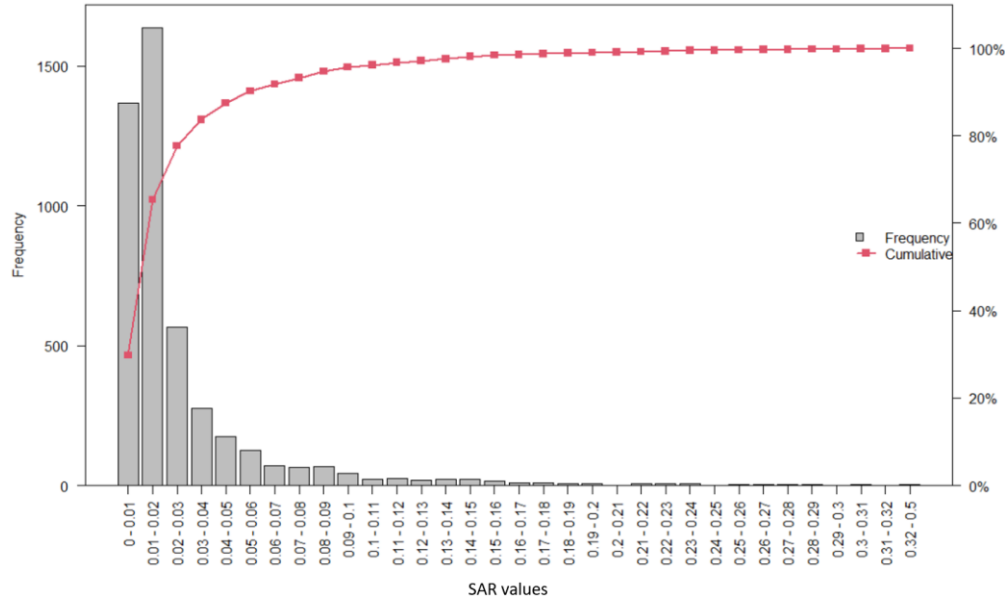


Figure 7: Distribution of bottom longline Swept Area Ratio values across all 1x1 km cells of the SPRFMO Evaluated Area with recorded bottom longline fishing between 1989 and 2023.

4.3 Expert elicitation estimates of depletion and recovery rates for VME indicator taxa

Responses to the survey questionnaire were received from 13 of the 26 experts approached, including representatives from each of the areas of expertise listed above and from both New Zealand and Australia. Not all respondents provided estimates of D for each fishing method and taxon or estimates of R for all taxa.

Across the 17 VME indicator taxa there were between 9 and 11 estimates of D for bottom trawling, 7–10 estimates of D for bottom longlining, and 8–11 estimates of R. Median values were calculated for each parameter and taxon, and sensitivities around these values were calculated as $\pm 20\%$, a rule-of-thumb range as used as the basis for calculations applied in the 2020 and 2023 BFIs where a larger dataset of values were examined (Table 6).

For the 11 VME indicator taxa in common with the previous assessments, the revised values of trawling D (ranging from 0.35 for Actiniaria to 0.71 for each of the four scleractinian taxa) were slightly higher than the earlier estimates except for Demospongiae, which was unchanged. Revised values of bottom longlining D (ranging from 0.03 for Stylasteridae to 0.27 for Antipatharia) were higher for 6 taxa, unchanged for 4 taxa, and lower for 1 taxon. Revised values of R (ranging from 0.10 for *Solenosmilia variabilis* to 0.36 for Pennatulacea) were lower for 7 taxa and unchanged for 4 taxa.

Overall, these revised values represent views of the experts that rates of depletion had previously been estimated as being too low for many taxa, especially for bottom trawling, and recovery rates had been

overestimated for most taxa. Estimates of D for the six additional VME indicator taxa were mostly within the range of (revised) values for the other 11 taxa, although the highest rates overall were for trawling impacts on Brisingida and Crinoidea (both 0.72).

Table 6: Trawl and longline fishing depletion (D) and recovery (R) rates for the 17 VME indicator taxa assessed, with sensitivities for the uncertainties in these values (low and high) as used in the calculation of dynamic Relative Benthic Status.

VME indicator taxon	Depletion (trawl)			Depletion (longline)			Recovery		
	D	D(low)	D(high)	D	D(low)	D(high)	R	R(low)	R(high)
<i>Solenosmilia variabilis</i>	0.71	0.56	0.85	0.06	0.04	0.07	0.10	0.08	0.12
<i>Madrepora oculata</i>	0.71	0.56	0.85	0.04	0.03	0.05	0.13	0.10	0.15
<i>Goniocorella dumosa</i>	0.71	0.56	0.85	0.04	0.03	0.05	0.20	0.16	0.24
<i>Enallopsammia rostrata</i>	0.71	0.56	0.85	0.04	0.03	0.05	0.17	0.13	0.20
Antipatharia	0.64	0.51	0.76	0.27	0.22	0.32	0.25	0.20	0.30
Alcyonacea (minus "Gorgonacea")	0.40	0.32	0.48	0.05	0.04	0.05	0.24	0.19	0.29
"Gorgonacea"	0.55	0.44	0.66	0.25	0.20	0.30	0.25	0.20	0.30
Stylasteridae	0.47	0.38	0.56	0.03	0.02	0.04	0.33	0.26	0.40
Demospongiae	0.38	0.30	0.46	0.14	0.11	0.17	0.24	0.19	0.28
Hexactinellidae	0.40	0.32	0.48	0.14	0.11	0.17	0.23	0.18	0.28
Pennatulacea	0.35	0.28	0.42	0.05	0.04	0.05	0.36	0.29	0.43
Actiniaria	0.35	0.28	0.42	0.05	0.04	0.06	0.50	0.40	0.59
Zoantharia	0.38	0.30	0.46	0.05	0.04	0.06	0.21	0.16	0.25
Hydrozoa	0.49	0.39	0.59	0.14	0.11	0.17	0.31	0.25	0.37
Bryozoa	0.45	0.36	0.53	0.09	0.07	0.11	0.26	0.20	0.31
Brisingida	0.72	0.58	0.86	0.15	0.12	0.18	0.45	0.36	0.54
Crinoidea	0.72	0.57	0.86	0.10	0.08	0.12	0.36	0.29	0.43

4.4 Assessment of RBS status

Dynamic RBS is presented for the 17 VME indicator taxa assessed for each of nine FMAs in Table 7–Table 15. Results are given for current status (at the end of 2023); for predicted future status if all bottom fishing were to cease from 2025, for a period of 20 years; and for future status with fishing (assuming sufficient trawl effort was made in each year after 2024 to catch the entire orange roughy catch limit in all management areas).

When the SAR in a cell exceeds $1/d$ in any year, $dRBS = 0$ (local extinction) and no future recovery is possible. Overall, for the BTMAs implemented under [CMM03-2023](#), results generally show that $dRBS$ exceeds 0.95 for most combinations of taxa, spatial scale, sensitivities, and temporal scale. Dynamic RBS status outside of BTMAs is 0.9 or greater in all cases and above 0.95 for all but one case. Detailed plots of status over time are shown in Figure 8 to Figure 15 for taxa where status under any scenario in any year falls below 0.8 within the FMA. Below is a summary of cases where status within FMAs is below 0.95:

- For the **North Lord Howe** FMA, current $dRBS$ for the stony coral *Goniocorella dumosa* was between 0.428 and 0.940, with lowest values under the Power mean habitat suitability

transformation option (Table 7). With the exception of the inside BTMAs with the high D/R scenario, forward projections show improved status after 20 years at all spatial scales, even with fishing (Figure 8).

- For the **Central Lord Howe** FMA, current dRBS for hydrocorals is 0.116 for ROC-linear and 0.801–0.822 for power mean transformations of habitat suitability (Table 8). Forward projections show little or no change in status under any scenario (Figure 9).
- For the **Northwest Challenger** FMA, current dRBS for the stony coral *Madrepora oculata* is between 0.848 and 0.924, with similar values for ROC-linear and Power mean transformations of habitat suitability (Table 9). Forward projections show improved status after 20 years in all cases and at all spatial scales, even with fishing (Figure 10). Current dRBS for the stony coral *Enallopsammia rostrata* is 0.809–0.911 within the FMA and very similar between ROC-linear and Power mean transformations of habitat suitability. Forward projections show slightly improved status after 20 years in all cases and at all spatial scales, even with fishing (Figure 11). Current status for Antipatharia (black corals) is 0.834–0.961 within the FMA, with slightly higher status for Power mean transformations of habitat suitability. Forward projections show slightly improved status after 20 years under no fishing, but slightly worsened status in most cases with fishing (Figure 12).
- For the **West Norfolk** FMA, current dRBS for *Goniocorella dumosa* ranges widely (0.069–0.878) and is much lower for Power mean than for ROC-linear transformation of habitat suitability (Table 11). Forward projections show only slightly improved status after 20 years in most cases, with worsened status with fishing in some cases. Future status within the FMA remains well below 0.8 for Power mean, and above 0.8 for ROC-linear transformation of habitat suitability, in all cases (Figure 13).
- For the **North Louisville** FMA, current dRBS for the stony coral *Solenosmilia variabilis* is 0.895–0.942 with similar values for ROC-linear and Power mean transformation of habitat suitability (Table 13). Forward projections show some improvement in status after 20 years in all cases and at all spatial scales, even with fishing.
- For the **Central Louisville** FMA, current dRBS for *Goniocorella dumosa* is 0.269–0.798 with much lower values for Power mean transformation of habitat suitability (Table 14). Forward projections show some improvement in status after 20 years in all cases and at all spatial scales, even with fishing, but in most cases not to above 0.8 within the FMA (Figure 14). Current dRBS for black corals is 0.850–0.944, and higher for Power mean than for ROC-linear transformations of habitat suitability. Forward projections show static or increased status after 20 years, in all cases, even with fishing (Figure 15). Current dRBS for hydrocorals is 0.895–0.929 with similar values for ROC-linear and Power mean transformations of habitat suitability. Forward projections show static or only slightly increased status after 20 years, in all cases, with or without fishing.
- For the **South Louisville** FMA, current dRBS for *Solenosmilia variabilis* is 0.893–0.953 and slightly greater for ROC-linear than for Power mean transformation of habitat suitability (Table 15). Forward projections show increased status after 20 years in all cases, even with fishing.

Table 7: Low, mean, and high dynamic Relative Benthic Status estimates of current status (C), future status after cessation of fishing from 2025 (FNF), and future status with fishing (FF) for the **North Lord Howe** Fishery Management Area (FMA) using Bottom Trawl management Areas (BTMAs) implemented under [CMM03-2023](#), using two alternative Habitat Suitability Index (HSI) transformations (ROC-linear and Power mean) for each Vulnerable Marine Ecosystem (VME) indicator taxon. Boxes in ROC-linear transformation columns marked “–” indicate no cells within the region with HSI > ROC cut-off. Greyed boxes indicate status below 0.8, with a detailed plot shown below for taxa where status falls below 0.8 in any year.

VME indicator taxon		FMA						Outside BTMAs						Inside BTMAs					
		ROC-linear			Power mean			ROC-linear			Power mean			ROC-linear			Power mean		
		C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF
Stony corals (<i>Solenosmilia variabilis</i>)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Mean	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Stony corals (<i>Madrepora oculata</i>)	Low	1.000	1.000	1.000	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Mean	1.000	1.000	1.000	0.999	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	1.000	1.000	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Stony corals (<i>Goniocorella dumosa</i>)	Low	0.731	0.847	0.831	0.428	0.642	0.611	0.999	1.000	1.000	0.999	1.000	1.000	0.633	0.791	0.769	0.420	0.637	0.606
	Mean	0.852	0.952	0.898	0.743	0.994	0.810	1.000	1.000	1.000	1.000	1.000	1.000	0.798	0.935	0.861	0.739	0.993	0.807
	High	0.940	0.971	0.935	0.926	0.999	0.876	1.000	1.000	1.000	1.000	1.000	1.000	0.919	0.961	0.912	0.925	0.999	0.874
Stony corals (<i>Enallopsammia rostrata</i>)	Low	1.000	1.000	1.000	0.999	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.994	0.999	0.994	0.984	0.993	0.984
	Mean	1.000	1.000	1.000	0.999	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.997	0.999	0.996	0.990	0.994	0.988
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	1.000	0.997	0.993	0.996	0.992
Black corals (Antipatharia)	Low	0.986	0.990	0.984	0.995	0.996	0.994	0.995	0.996	0.995	0.998	0.999	0.998	0.946	0.964	0.941	0.964	0.976	0.961
	Mean	0.989	0.991	0.987	0.996	0.997	0.995	0.996	0.996	0.995	0.999	0.999	0.998	0.958	0.970	0.952	0.972	0.980	0.968
	High	0.991	0.992	0.989	0.997	0.997	0.996	0.996	0.997	0.996	0.999	0.999	0.999	0.966	0.972	0.960	0.979	0.983	0.975
Alcyonacea (non-gorgonian)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Mean	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Gorgonians (gorgonian Alcyonacea)	Low	0.992	0.994	0.991	0.992	0.994	0.991	0.997	0.998	0.996	0.997	0.998	0.997	0.962	0.975	0.958	0.959	0.973	0.955
	Mean	0.993	0.995	0.992	0.993	0.995	0.992	0.997	0.998	0.997	0.997	0.998	0.997	0.971	0.979	0.966	0.968	0.977	0.964
	High	0.995	0.996	0.994	0.995	0.996	0.994	0.998	0.999	0.998	0.998	0.999	0.998	0.977	0.981	0.972	0.975	0.980	0.970
Hydrocorals (Stylasteridae)	Low	1.000	1.000	1.000	0.991	0.992	0.991	1.000	1.000	1.000	0.998	0.999	0.998	–	–	–	0.706	0.718	0.702
	Mean	1.000	1.000	1.000	0.992	0.992	0.991	1.000	1.000	1.000	0.999	0.999	0.999	–	–	–	0.715	0.721	0.710
	High	1.000	1.000	1.000	0.993	0.995	0.994	1.000	1.000	1.000	0.999	0.999	0.999	–	–	–	0.763	0.826	0.794
Sponges (Porifera Demospongiae)	Low	0.997	0.998	0.998	0.998	0.998	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.944	0.958	0.952	0.953	0.965	0.960
	Mean	0.998	0.998	0.998	0.998	0.999	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.953	0.961	0.956	0.961	0.967	0.963
	High	0.998	0.999	0.999	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.962	0.981	0.975	0.968	0.984	0.979
Sponges (Porifera Hexactinellida)	Low	1.000	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.964	0.968	0.960	0.963	0.968	0.960
	Mean	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.968	0.977	0.964	0.968	0.979	0.965
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.974	0.984	0.972	0.975	0.985	0.973
Sea pens (Pennatulacea)	Low	0.999	0.999	0.999	0.999	0.999	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.982	0.988	0.979	0.985	0.989	0.982
	Mean	0.999	1.000	0.999	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.988	0.992	0.984	0.989	0.992	0.986

VME indicator taxon		FMA						Outside BTMAs						Inside BTMAs							
		ROC-linear			Power mean			ROC-linear			Power mean			ROC-linear			Power mean				
		C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF		
	High	1.000	1.000	1.000	0.999	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.995	0.997	0.991	0.994	0.996	0.991
Anemones (Actiniaria)	Low	0.999	0.999	0.999	0.999	0.999	0.998	1.000	1.000	1.000	1.000	1.000	0.999	0.996	0.997	0.995	0.990	0.992	0.988		
	Mean	1.000	1.000	0.999	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.998	0.999	0.997	0.994	0.995	0.991		
	High	1.000	1.000	0.999	0.999	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.998	0.999	0.998	0.996	0.997	0.994		
Zoanthid hexacorals (Zoantharia)	Low	0.998	0.999	0.997	0.997	0.998	0.997	0.999	0.999	0.999	0.999	0.999	0.999	0.986	0.992	0.985	0.981	0.989	0.980		
	Mean	0.998	0.999	0.998	0.998	0.999	0.998	0.999	1.000	0.999	0.999	1.000	0.999	0.990	0.994	0.988	0.986	0.992	0.985		
	High	0.999	0.999	0.999	0.999	0.999	0.998	1.000	1.000	0.999	1.000	1.000	0.999	0.993	0.996	0.992	0.991	0.995	0.989		
Hydroids (Hydrozoa)	Low	0.999	0.999	0.999	0.998	0.998	0.998	1.000	1.000	1.000	0.999	1.000	0.999	0.936	0.952	0.939	0.974	0.981	0.971		
	Mean	0.999	0.999	0.999	0.998	0.999	0.998	1.000	1.000	1.000	1.000	1.000	0.999	0.946	0.956	0.945	0.980	0.984	0.976		
	High	0.999	1.000	0.999	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.954	0.964	0.955	0.985	0.988	0.982		
Bryozoans (Bryozoa)	Low	0.999	0.999	0.999	0.998	0.998	0.997	1.000	1.000	1.000	0.999	1.000	0.999	0.946	0.960	0.945	0.973	0.982	0.970		
	Mean	0.999	0.999	0.999	0.998	0.999	0.998	1.000	1.000	1.000	1.000	1.000	0.999	0.954	0.963	0.952	0.979	0.984	0.976		
	High	0.999	0.999	0.999	0.999	0.999	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.963	0.974	0.964	0.984	0.989	0.982		
Armless stars (Brisingida)	Low	0.997	0.997	0.997	0.998	0.998	0.998	0.999	0.999	0.999	0.999	1.000	0.999	0.958	0.964	0.953	0.963	0.968	0.959		
	Mean	0.998	0.998	0.997	0.998	0.999	0.998	0.999	0.999	0.999	1.000	1.000	0.999	0.966	0.970	0.961	0.970	0.973	0.966		
	High	0.998	0.998	0.998	0.999	0.999	0.998	0.999	0.999	0.999	1.000	1.000	1.000	0.974	0.976	0.969	0.977	0.979	0.973		
Sea lilies & feather stars (Crinoidea)	Low	0.997	0.998	0.997	0.998	0.998	0.998	0.999	0.999	0.999	0.999	0.999	0.999	0.943	0.954	0.938	0.942	0.951	0.937		
	Mean	0.998	0.998	0.998	0.998	0.998	0.998	0.999	0.999	0.999	0.999	0.999	0.999	0.955	0.961	0.949	0.953	0.959	0.948		
	High	0.998	0.999	0.998	0.999	0.999	0.998	1.000	1.000	0.999	1.000	1.000	0.999	0.965	0.969	0.960	0.962	0.966	0.958		

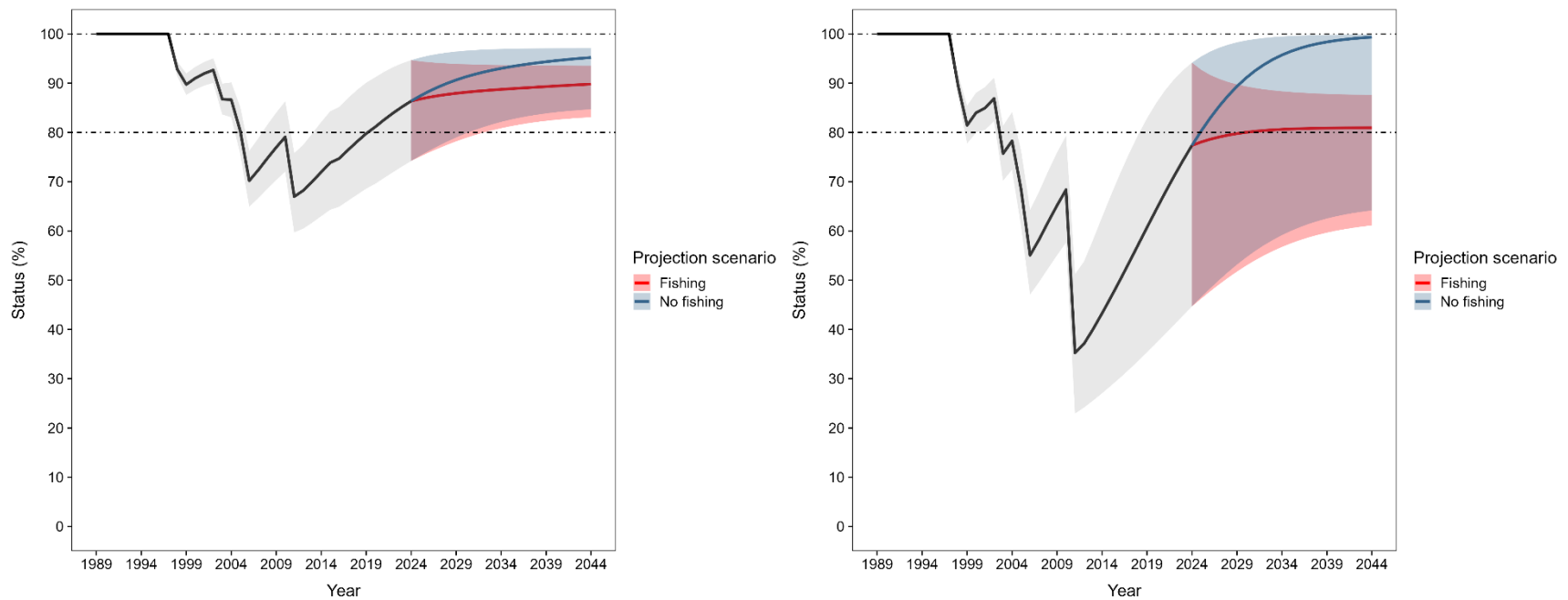


Figure 8: Estimated dynamic Relative Benthic Status (expressed as a percentage) for *Goniocorella dumosa* (Scleractinia) in the North Lord Howe Fishery Management Area from 1989 to 2044, using the ROC-linear (left) and Power mean (right) transformations of the Habitat Suitability Index values. The black lines indicates the “Mean” scenario and uses the primary values of depletion (D) and recovery (R), the lower extent of the shaded area represents the “Low” scenario and uses the +20% estimate of D and -20% estimate of R, and the upper extent of the shaded area represents the “High” scenario and uses the -20% estimate of D and +20% estimate of R (see Table 6). The “Fishing” projection assumes continued fishing between 2025 and 2044 at a constant level sufficient to take the current orange roughly catch limit in each FMA, and with recent average bottom longline effort; the “No fishing” projection assumes no bottom fishing between 2025 and 2044.

Table 8: Low, mean, and high dynamic Relative Benthic Status estimates of current status (C), future status after cessation of fishing from 2025 (FNF), and future status with fishing (FF) for the **Central Lord Howe** Fishery Management Area (FMA) using Bottom Trawl management Areas (BTMAs) implemented under [CMM03-2023](#), using two alternative Habitat Suitability Index (HSI) transformations (ROC-linear and Power mean) for each Vulnerable Marine Ecosystem (VME) indicator taxon. Boxes in ROC-linear transformation columns marked “–” indicate no cells within the region with HSI > ROC cut-off. Greyed boxes indicate status below 0.8, with a detailed plot shown below for taxa where status falls below 0.8 in any year.

VME indicator taxa habitat		FMA						Outside BTMAs						Inside BTMAs								
		ROC-linear			Power mean			ROC-linear			Power mean			ROC-linear			Power mean					
		C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF			
Stony corals (<i>Solenosmilia variabilis</i>)	Low	0.974	0.980	0.980	0.977	0.982	0.982	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.917	0.938	0.937	0.914	0.932	0.932
	Mean	0.979	0.985	0.985	0.981	0.986	0.985	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.935	0.953	0.952	0.930	0.946	0.945
	High	0.984	0.988	0.987	0.985	0.988	0.988	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.951	0.961	0.960	0.945	0.955	0.954
Stony corals (<i>Madrepora oculata</i>)	Low	0.960	0.970	0.969	0.967	0.975	0.974	0.999	1.000	1.000	1.000	0.999	1.000	1.000	1.000	1.000	0.881	0.909	0.906	0.892	0.919	0.915
	Mean	0.971	0.977	0.976	0.976	0.982	0.980	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.912	0.932	0.927	0.922	0.940	0.936
	High	0.977	0.981	0.979	0.981	0.984	0.983	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.930	0.942	0.938	0.938	0.948	0.944
Stony corals (<i>Goniocorella dumosa</i>)	Low	0.982	0.989	0.982	0.979	0.995	0.981	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.881	0.929	0.886	0.539	0.895	0.574
	Mean	0.985	0.990	0.985	0.987	0.997	0.987	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.905	0.934	0.903	0.712	0.933	0.703
	High	0.988	0.990	0.987	0.993	0.997	0.990	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.922	0.935	0.914	0.842	0.937	0.783
Stony corals (<i>Enallopsammia rostrata</i>)	Low	0.976	0.983	0.978	0.976	0.983	0.978	0.999	1.000	0.999	0.999	0.999	1.000	0.999	0.999	0.999	0.916	0.939	0.926	0.918	0.941	0.927
	Mean	0.982	0.987	0.983	0.983	0.987	0.983	1.000	1.000	0.999	1.000	1.000	0.999	1.000	0.999	0.999	0.939	0.953	0.941	0.941	0.954	0.942
	High	0.987	0.989	0.986	0.987	0.989	0.986	1.000	1.000	0.999	1.000	1.000	0.999	1.000	0.999	0.999	0.953	0.962	0.951	0.954	0.963	0.953
Black corals (Antipatharia)	Low	0.975	0.980	0.975	0.986	0.988	0.986	1.000	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.922	0.937	0.922	0.936	0.948	0.936
	Mean	0.980	0.984	0.979	0.989	0.990	0.988	1.000	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.937	0.948	0.934	0.949	0.957	0.946
	High	0.984	0.987	0.983	0.991	0.992	0.990	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.950	0.958	0.945	0.959	0.965	0.956
Alcyonacea (non-gorgonian)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.999
	Mean	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	1.000	1.000
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Gorgonians (gorgonian Alcyonacea)	Low	0.973	0.979	0.972	0.975	0.981	0.974	1.000	1.000	0.999	1.000	1.000	0.999	1.000	1.000	1.000	0.923	0.939	0.921	0.923	0.940	0.921
	Mean	0.979	0.983	0.977	0.980	0.984	0.978	1.000	1.000	0.999	1.000	1.000	0.999	1.000	1.000	1.000	0.938	0.950	0.933	0.938	0.951	0.933
	High	0.984	0.988	0.982	0.985	0.989	0.983	1.000	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.955	0.965	0.949	0.955	0.966	0.948
Hydrocorals (Stylasteridae)	Low	0.116	0.116	0.116	0.801	0.803	0.801	–	–	–	1.000	1.000	1.000	0.116	0.116	0.116	0.116	0.116	0.116	0.562	0.568	0.562
	Mean	0.116	0.116	0.116	0.806	0.810	0.806	–	–	–	1.000	1.000	1.000	0.116	0.116	0.116	0.116	0.116	0.116	0.575	0.582	0.575
	High	0.116	0.116	0.116	0.822	0.825	0.822	–	–	–	1.000	1.000	1.000	0.116	0.116	0.116	0.116	0.116	0.116	0.609	0.616	0.609
Sponges (Porifera Demospongiae)	Low	0.954	0.954	0.954	0.987	0.987	0.987	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000	0.329	0.339	0.338
	Mean	0.954	0.954	0.954	0.987	0.987	0.987	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000	0.341	0.343	0.343
	High	0.954	0.954	0.954	0.987	0.987	0.987	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000	0.349	0.350	0.350
Sponges (Porifera Hexactinellida)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.958	0.965	0.959	0.948	0.958	0.950
	Mean	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.965	0.970	0.966	0.957	0.964	0.958
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.970	0.972	0.970	0.964	0.967	0.963
Sea pens	Low	1.000	1.000	1.000	0.998	0.998	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.981	0.983	0.980

VME indicator taxa habitat		FMA						Outside BTMAs						Inside BTMAs					
		ROC-linear			Power mean			ROC-linear			Power mean			ROC-linear			Power mean		
		C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF
(Pennatulacea)	Mean	1.000	1.000	1.000	0.998	0.999	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	1.000	1.000	1.000	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Anemones (Actiniaria)	Low	0.982	0.982	0.981	0.995	0.995	0.995	1.000	1.000	1.000	1.000	1.000	1.000	0.943	0.944	0.942	0.973	0.974	0.970
	Mean	0.988	0.988	0.988	0.997	0.997	0.996	1.000	1.000	1.000	1.000	1.000	1.000	0.963	0.963	0.962	0.981	0.981	0.979
	High	0.992	0.992	0.991	0.998	0.998	0.997	1.000	1.000	1.000	1.000	1.000	1.000	0.975	0.975	0.973	0.986	0.986	0.984
Zoanthid hexacorals (Zoantharia)	Low	0.991	0.993	0.991	0.992	0.994	0.993	1.000	1.000	1.000	1.000	1.000	1.000	0.952	0.963	0.955	0.956	0.967	0.958
	Mean	0.994	0.995	0.994	0.995	0.996	0.994	1.000	1.000	1.000	1.000	1.000	1.000	0.966	0.973	0.967	0.969	0.976	0.969
	High	0.996	0.996	0.995	0.996	0.997	0.996	1.000	1.000	1.000	1.000	1.000	1.000	0.977	0.981	0.976	0.979	0.984	0.977
Hydroids (Hydrozoa)	Low	0.998	0.998	0.998	0.995	0.996	0.995	1.000	1.000	1.000	1.000	1.000	1.000	0.975	0.976	0.975	0.964	0.969	0.962
	Mean	0.998	0.998	0.998	0.996	0.997	0.996	1.000	1.000	1.000	1.000	1.000	1.000	0.979	0.981	0.979	0.971	0.975	0.968
	High	0.999	0.999	0.998	0.997	0.998	0.997	1.000	1.000	1.000	1.000	1.000	1.000	0.984	0.985	0.983	0.980	0.982	0.977
Bryozoans (Bryozoa)	Low	0.999	0.999	0.999	0.996	0.997	0.996	1.000	1.000	1.000	1.000	1.000	1.000	0.986	0.987	0.987	0.968	0.974	0.967
	Mean	0.999	0.999	0.999	0.997	0.997	0.997	1.000	1.000	1.000	1.000	1.000	1.000	0.988	0.989	0.989	0.975	0.980	0.974
	High	0.999	1.000	0.999	0.998	0.998	0.997	1.000	1.000	1.000	1.000	1.000	1.000	0.993	0.994	0.994	0.983	0.986	0.981
Armless stars (Brisingida)	Low	0.996	0.996	0.996	0.996	0.996	0.996	1.000	1.000	1.000	1.000	1.000	1.000	0.972	0.972	0.971	0.980	0.981	0.980
	Mean	0.997	0.997	0.997	0.997	0.997	0.997	1.000	1.000	1.000	1.000	1.000	1.000	0.979	0.979	0.978	0.986	0.986	0.985
	High	0.997	0.997	0.997	0.998	0.998	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.983	0.984	0.983	0.989	0.989	0.988
Sea lilies & feather stars (Crinoidea)	Low	0.998	0.998	0.998	0.997	0.997	0.997	1.000	1.000	1.000	1.000	1.000	1.000	0.979	0.979	0.979	0.978	0.978	0.978
	Mean	0.998	0.998	0.998	0.998	0.998	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.982	0.982	0.982	0.982	0.982	0.982
	High	0.998	0.998	0.998	0.998	0.998	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.985	0.985	0.985	0.984	0.984	0.984

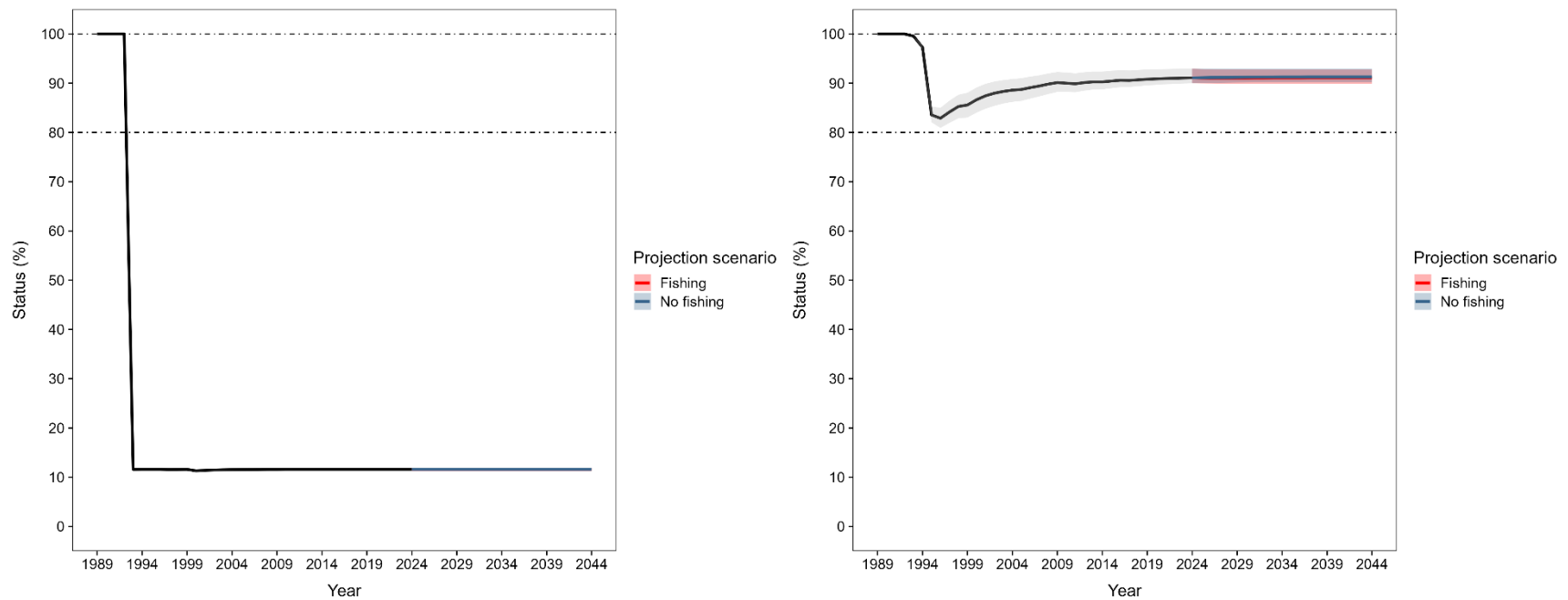


Figure 9: Estimated dynamic Relative Benthic Status (expressed as a percentage) for hydrocorals (Stylasteridae) in the Central Lord Howe Howe Fishery Management Area from 1989 to 2044, using the ROC-linear (left) and Power mean (right) transformations of the Habitat Suitability Index values. The black lines indicates the “Mean” scenario and uses the primary values of depletion (D) and recovery (R), the lower extent of the shaded area represents the “Low” scenario and uses the +20% estimate of D and -20% estimate of R, and the upper extent of the shaded area represents the “High” scenario and uses the -20% estimate of D and +20% estimate of R (see Table 6). The “Fishing” projection assumes continued fishing between 2025 and 2044 at a constant level sufficient to take the current orange roughly catch limit in each FMA, and with recent average bottom longline effort; the “No fishing” projection assumes no bottom fishing between 2025 and 2044.

Table 9: Low, mean, and high dynamic Relative Benthic Status estimates of current status (C), future status after cessation of fishing from 2025 (FNF), and future status with fishing (FF) for the **Northwest Challenger** Fishery Management Area (FMA) using Bottom Trawl management Areas (BTMAs) implemented under [CMM03-2023](#), using two alternative Habitat Suitability Index (HSI) transformations (ROC-linear and Power mean) for each Vulnerable Marine Ecosystem (VME) indicator taxon. Boxes in ROC-linear transformation columns marked “-” indicate no cells within the region with HSI > ROC cut-off. Greyed boxes indicate status below 0.8, with a detailed plot shown below for taxa where status falls below 0.8 in any year.

VME indicator taxa habitat		FMA						Outside BTMAs						Inside BTMAs					
		ROC-linear			Power mean			ROC-linear			Power mean			ROC-linear			Power mean		
		C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF
Stony corals (<i>Solenosmilia variabilis</i>)	Low	0.996	0.999	0.999	0.993	0.997	0.997	0.999	1.000	1.000	0.999	1.000	1.000	0.866	0.962	0.961	0.897	0.955	0.945
	Mean	0.998	1.000	1.000	0.995	0.998	0.998	0.999	1.000	1.000	0.999	1.000	1.000	0.924	0.989	0.988	0.932	0.975	0.967
	High	0.999	1.000	1.000	0.997	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.963	0.997	0.996	0.960	0.987	0.980
Stony corals (<i>Madrepora oculata</i>)	Low	0.848	0.906	0.871	0.861	0.914	0.883	0.995	0.999	0.999	0.996	0.999	0.999	0.741	0.839	0.779	0.748	0.842	0.786
	Mean	0.886	0.940	0.902	0.896	0.943	0.910	0.998	0.999	0.999	0.998	1.000	0.999	0.806	0.898	0.832	0.810	0.896	0.835
	High	0.918	0.963	0.927	0.924	0.963	0.931	0.999	1.000	1.000	0.999	1.000	1.000	0.860	0.936	0.875	0.861	0.932	0.874
Stony corals (<i>Goniocorella dumosa</i>)	Low	0.989	0.993	0.991	0.997	0.999	0.998	0.998	0.999	0.999	0.999	1.000	1.000	0.760	0.845	0.792	0.285	0.340	0.285
	Mean	0.992	0.995	0.993	0.998	0.999	0.998	0.999	0.999	0.999	0.999	1.000	1.000	0.826	0.886	0.838	0.316	0.366	0.315
	High	0.995	0.996	0.994	0.999	0.999	0.999	0.999	0.999	0.999	1.000	1.000	1.000	0.880	0.918	0.877	0.345	0.383	0.336
Stony corals (<i>Enallopsammia rostrata</i>)	Low	0.809	0.890	0.850	0.813	0.890	0.851	0.993	0.999	0.998	0.994	0.999	0.998	0.727	0.841	0.783	0.713	0.830	0.770
	Mean	0.867	0.924	0.888	0.868	0.924	0.888	0.997	0.999	0.999	0.998	0.999	0.999	0.809	0.890	0.838	0.797	0.883	0.827
	High	0.911	0.948	0.918	0.910	0.948	0.918	0.999	0.999	0.999	0.999	1.000	0.999	0.871	0.925	0.882	0.862	0.920	0.873
Black corals (Antipatharia)	Low	0.834	0.904	0.851	0.904	0.944	0.913	0.998	1.000	0.999	0.999	1.000	0.999	0.772	0.868	0.795	0.787	0.876	0.809
	Mean	0.887	0.932	0.887	0.935	0.961	0.935	0.999	1.000	0.999	1.000	1.000	0.999	0.845	0.906	0.844	0.855	0.915	0.857
	High	0.930	0.953	0.919	0.961	0.975	0.956	1.000	1.000	0.999	1.000	1.000	1.000	0.903	0.935	0.889	0.914	0.946	0.902
Alcyonacea (non-gorgonian)	Low	0.999	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.999	0.999	1.000	0.999
	Mean	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.999	0.999	1.000	0.999
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.999	0.999	1.000	0.999
Gorgonians (gorgonian Alcyonacea)	Low	0.972	0.988	0.977	0.962	0.980	0.966	0.999	1.000	0.999	0.999	1.000	0.999	0.913	0.962	0.929	0.888	0.943	0.900
	Mean	0.983	0.991	0.983	0.976	0.986	0.975	1.000	1.000	1.000	1.000	1.000	1.000	0.949	0.972	0.947	0.929	0.958	0.927
	High	0.989	0.993	0.987	0.985	0.990	0.982	1.000	1.000	1.000	1.000	1.000	1.000	0.966	0.978	0.960	0.956	0.970	0.947
Hydrocorals (Stylasteridae)	Low	0.942	0.947	0.946	0.979	0.980	0.979	0.945	0.951	0.950	0.982	0.983	0.983	0.275	0.275	0.275	0.898	0.908	0.896
	Mean	0.964	0.967	0.965	0.987	0.988	0.987	0.966	0.968	0.968	0.990	0.990	0.990	0.402	0.681	0.549	0.914	0.928	0.915
	High	0.977	0.978	0.977	0.990	0.991	0.990	0.979	0.979	0.979	0.993	0.993	0.993	0.611	0.681	0.594	0.928	0.932	0.923
Sponges (Porifera Demospongiae)	Low	0.997	0.999	0.997	0.996	0.999	0.996	1.000	1.000	1.000	1.000	1.000	1.000	0.925	0.976	0.929	0.943	0.983	0.945
	Mean	0.998	0.999	0.998	0.998	0.999	0.997	1.000	1.000	1.000	1.000	1.000	1.000	0.954	0.983	0.948	0.966	0.989	0.961
	High	0.999	0.999	0.998	0.998	0.999	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.970	0.985	0.960	0.979	0.991	0.971
Sponges (Porifera Hexactinellida)	Low	0.922	0.971	0.932	0.919	0.971	0.931	1.000	1.000	1.000	1.000	1.000	1.000	0.830	0.936	0.853	0.806	0.931	0.836
	Mean	0.958	0.984	0.957	0.958	0.985	0.957	1.000	1.000	1.000	1.000	1.000	1.000	0.909	0.966	0.906	0.900	0.965	0.896
	High	0.980	0.991	0.972	0.980	0.992	0.972	1.000	1.000	1.000	1.000	1.000	1.000	0.956	0.981	0.939	0.953	0.982	0.934
Sea pens	Low	0.995	0.997	0.993	0.986	0.993	0.984	1.000	1.000	1.000	1.000	1.000	1.000	0.971	0.986	0.966	0.952	0.974	0.942

VME indicator taxa habitat		FMA						Outside BTMAs						Inside BTMAs					
		ROC-linear			Power mean			ROC-linear			Power mean			ROC-linear			Power mean		
		C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF
(Pennatulacea)	Mean	0.998	0.999	0.996	0.993	0.995	0.989	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	0.999	0.999	0.998	0.996	0.997	0.992	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Anemones (Actiniaria)	Low	0.941	0.958	0.915	0.977	0.983	0.967	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Mean	0.969	0.974	0.944	0.987	0.989	0.978	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	0.982	0.983	0.962	0.992	0.992	0.985	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Zoanthid hexacorals (Zoantharia)	Low	0.879	0.954	0.894	0.921	0.970	0.931	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Mean	0.932	0.973	0.931	0.956	0.982	0.955	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	0.963	0.983	0.953	0.976	0.989	0.969	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Hydroids (Hydrozoa)	Low	0.999	1.000	0.999	0.984	0.991	0.984	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Mean	1.000	1.000	1.000	0.990	0.993	0.988	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	1.000	1.000	1.000	0.994	0.996	0.992	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Bryozoans (Bryozoa)	Low	1.000	1.000	1.000	0.984	0.992	0.985	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Mean	1.000	1.000	1.000	0.991	0.995	0.990	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	1.000	1.000	1.000	0.995	0.997	0.993	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Armless stars (Brisingida)	Low	0.992	0.994	0.991	0.993	0.994	0.992	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Mean	0.995	0.995	0.994	0.995	0.996	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	0.996	0.997	0.996	0.997	0.997	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sea lilies & feather stars (Crinoidea)	Low	1.000	1.000	1.000	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Mean	1.000	1.000	1.000	0.999	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

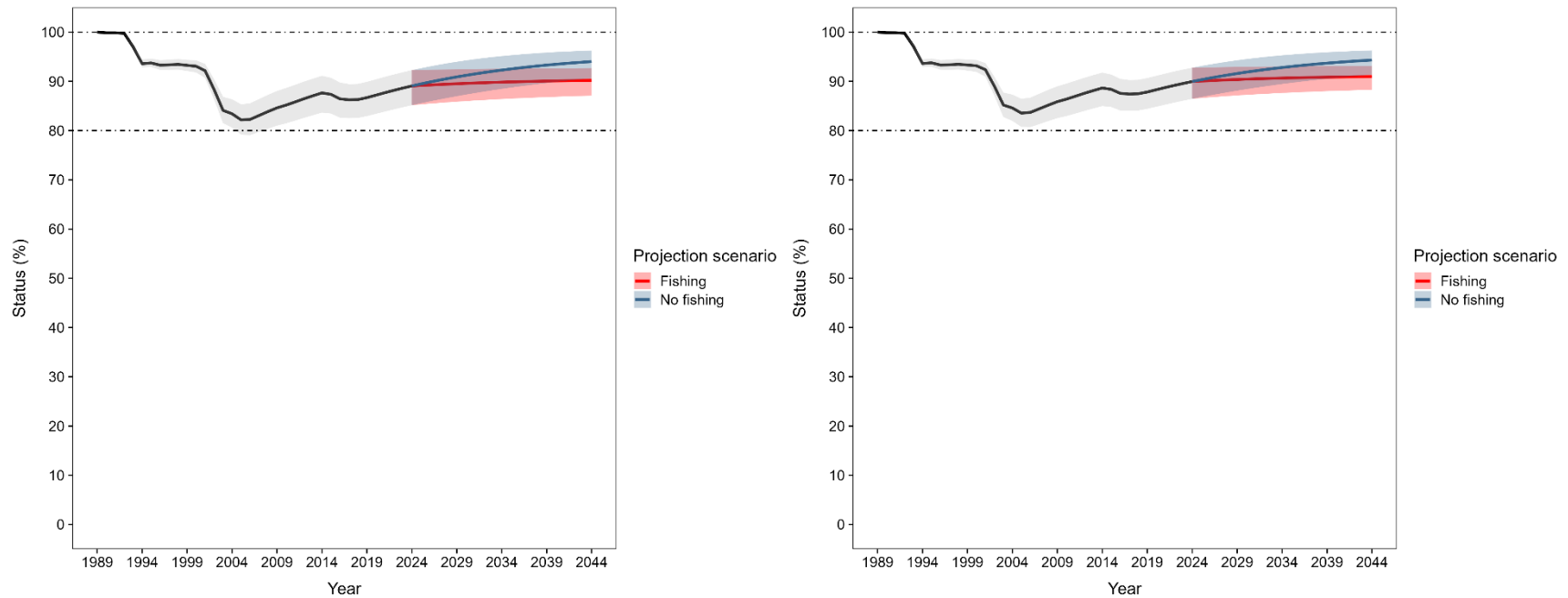


Figure 10: Estimated dynamic Relative Benthic Status (expressed as a percentage) for *Madrepora oculata* (Scleractinia) in the Northwest Challenger Fishery Management Area from 1989 to 2044, using the ROC-linear (left) and Power mean (right) transformations of the Habitat Suitability Index values. The black lines indicates the “Mean” scenario and uses the primary values of depletion (D) and recovery (R), the lower extent of the shaded area represents the “Low” scenario and uses the +20% estimate of D and -20% estimate of R, and the upper extent of the shaded area represents the “High” scenario and uses the -20% estimate of D and +20% estimate of R (see Table 6). The “Fishing” projection assumes continued fishing between 2025 and 2044 at a constant level sufficient to take the current orange roughy catch limit in each FMA, and with recent average bottom longline effort; the “No fishing” projection assumes no bottom fishing between 2025 and 2044.

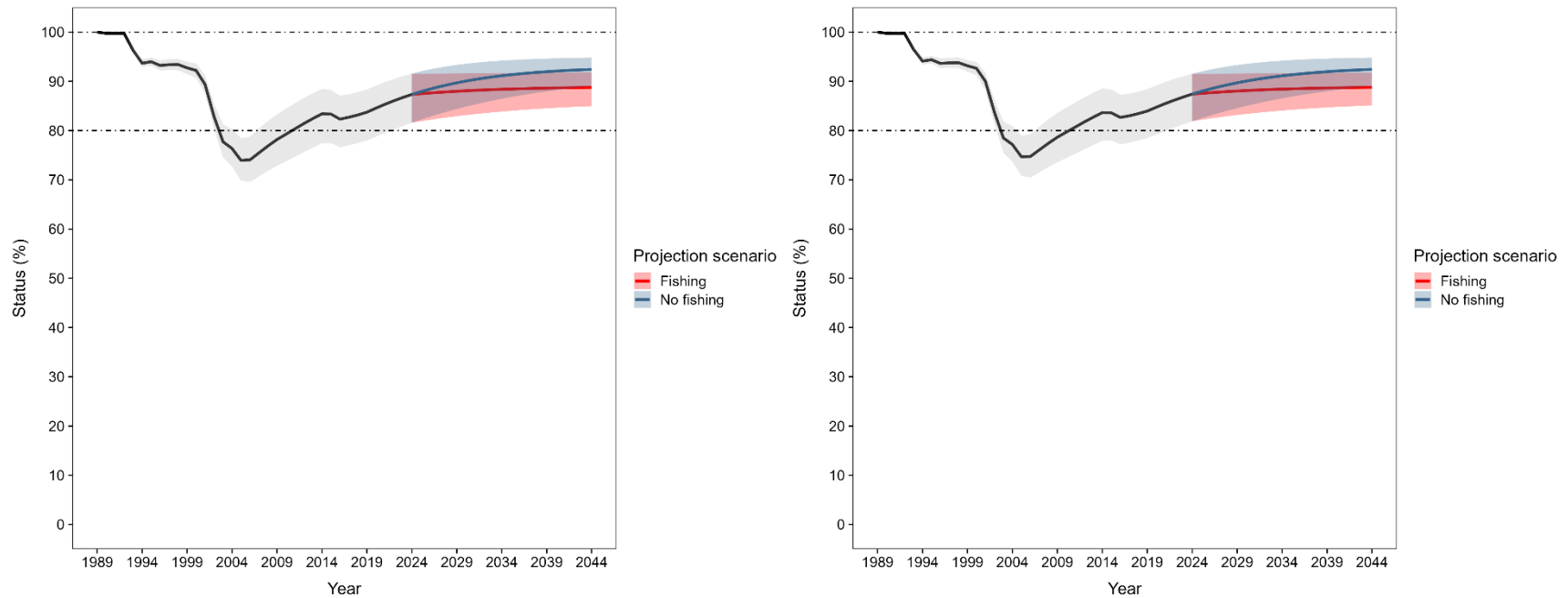


Figure 11: Estimated dynamic Relative Benthic Status (expressed as a percentage) for *Enallopsammia rostrata* (Scleractinia) in the Northwest Challenger Fishery Management Area from 1989 to 2044, using the ROC-linear (left) and Power mean (right) transformations of the Habitat Suitability Index values. The black lines indicates the “Mean” scenario and uses the primary values of depletion (D) and recovery (R), the lower extent of the shaded area represents the “Low” scenario and uses the +20% estimate of D and -20% estimate of R, and the upper extent of the shaded area represents the “High” scenario and uses the -20% estimate of D and +20% estimate of R (see Table 6). The “Fishing” projection assumes continued fishing between 2025 and 2044 at a constant level sufficient to take the current orange roughy catch limit in each FMA, and with recent average bottom longline effort; the “No fishing” projection assumes no bottom fishing between 2025 and 2044.

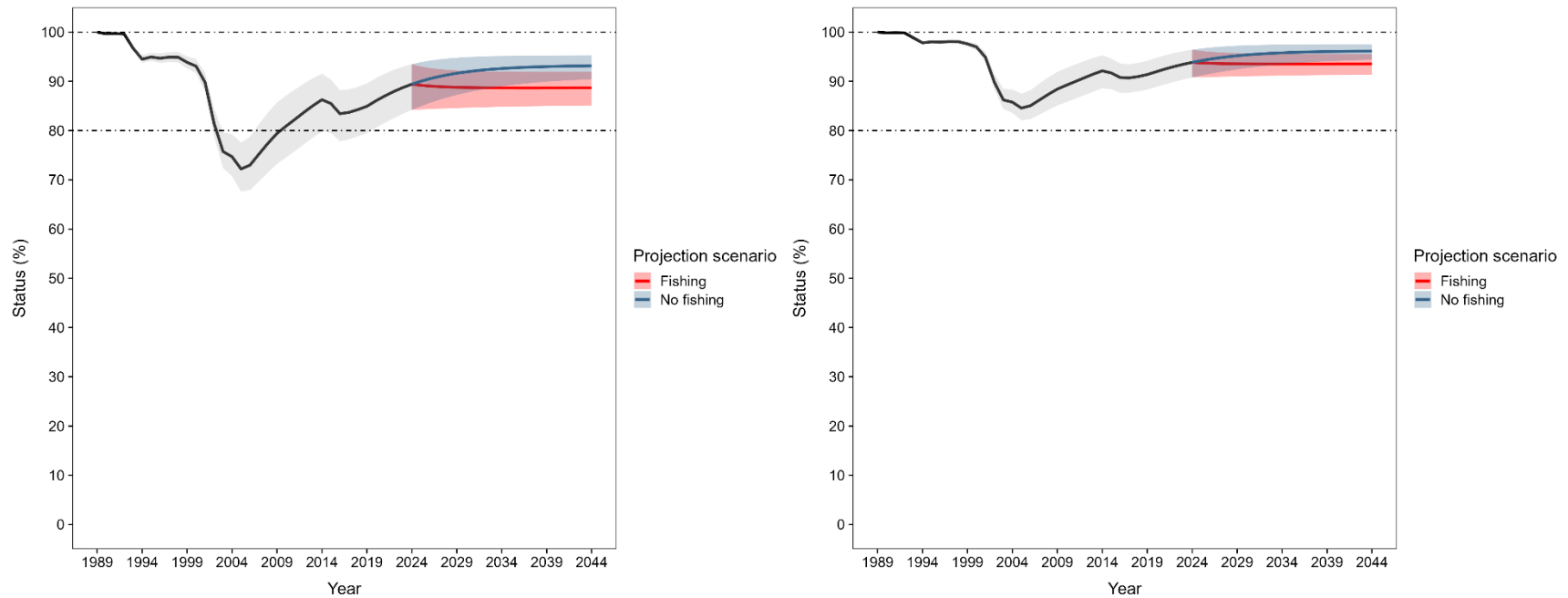


Figure 12: Estimated dynamic Relative Benthic Status (expressed as a percentage) for Antipatharia (black corals) in the Northwest Challenger Fishery Management Area from 1989 to 2044, using the ROC-linear (left) and Power mean (right) transformations of the Habitat Suitability Index values. The black lines indicates the “Mean” scenario and uses the primary values of depletion (D) and recovery (R), the lower extent of the shaded area represents the “Low” scenario and uses the +20% estimate of D and -20% estimate of R, and the upper extent of the shaded area represents the “High” scenario and uses the -20% estimate of D and +20% estimate of R (see Table 6). The “Fishing” projection assumes continued fishing between 2025 and 2044 at a constant level sufficient to take the current orange roughly catch limit in each FMA, and with recent average bottom longline effort; the “No fishing” projection assumes no bottom fishing between 2025 and 2044.

Table 10: Low, mean, and high dynamic Relative Benthic Status estimates of current status (C), future status after cessation of fishing from 2025 (FNF), and future status with fishing (FF) for the **Westpac Bank** Fishery Management Area (FMA) using Bottom Trawl management Areas (BTMAs) implemented under [CMM03-2023](#), using two alternative Habitat Suitability Index (HSI) transformations (ROC-linear and Power mean) for each Vulnerable Marine Ecosystem (VME) indicator taxon. Boxes in ROC-linear transformation columns marked “–” indicate no cells within the region with HSI > ROC cut-off; * indicates taxa with < 1% of their HSI within the FMA.

VME indicator taxa habitat		FMA						Outside BTMAs						Inside BTMAs					
		ROC-linear			Power mean			ROC-linear			Power mean			ROC-linear			Power mean		
		C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF
Stony corals (<i>Solenosmilia variabilis</i>)	Low	0.988	0.992	0.989	0.991	0.994	0.992	1.000	1.000	1.000	0.999	1.000	1.000	0.961	0.973	0.963	0.973	0.982	0.975
	Mean	0.990	0.994	0.991	0.993	0.996	0.994	1.000	1.000	1.000	1.000	1.000	1.000	0.968	0.979	0.970	0.978	0.987	0.980
	High	0.993	0.996	0.993	0.995	0.997	0.995	1.000	1.000	1.000	1.000	1.000	1.000	0.975	0.985	0.976	0.983	0.991	0.985
Stony corals (<i>Madrepora oculata</i>)	Low	0.992	0.997	0.994	0.993	0.997	0.994	0.998	1.000	1.000	0.998	1.000	1.000	0.951	0.977	0.959	0.949	0.973	0.956
	Mean	0.995	0.998	0.996	0.995	0.998	0.996	0.999	1.000	1.000	0.999	1.000	1.000	0.968	0.987	0.973	0.964	0.984	0.970
	High	0.997	1.000	0.998	0.997	1.000	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.982	0.999	0.988	0.979	0.997	0.986
Stony corals (<i>Goniocorella dumosa</i>)	Low	0.994	1.000	0.994	0.997	1.000	0.997	1.000	1.000	1.000	1.000	1.000	1.000	0.968	0.999	0.964	0.978	0.996	0.979
	Mean	0.997	1.000	0.996	0.999	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.983	1.000	0.976	0.989	1.000	0.988
	High	0.998	1.000	0.997	0.999	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.990	1.000	0.984	0.995	1.000	0.992
Stony corals (<i>Enallopsammia rostrata</i>)	Low	0.985	0.992	0.986	0.985	0.992	0.986	0.999	1.000	1.000	0.999	1.000	1.000	0.892	0.944	0.901	0.894	0.942	0.902
	Mean	0.990	0.996	0.991	0.990	0.996	0.991	1.000	1.000	1.000	1.000	1.000	1.000	0.928	0.969	0.938	0.927	0.967	0.937
	High	0.994	0.998	0.994	0.994	0.998	0.994	1.000	1.000	1.000	1.000	1.000	1.000	0.957	0.987	0.959	0.956	0.985	0.959
Black corals (Antipatharia)	Low	0.966	0.979	0.968	0.990	0.994	0.990	1.000	1.000	1.000	1.000	1.000	1.000	0.869	0.920	0.878	0.903	0.941	0.909
	Mean	0.976	0.985	0.976	0.993	0.996	0.993	1.000	1.000	1.000	1.000	1.000	1.000	0.908	0.942	0.910	0.932	0.958	0.933
	High	0.983	0.991	0.983	0.995	0.997	0.995	1.000	1.000	1.000	1.000	1.000	1.000	0.935	0.966	0.935	0.952	0.975	0.951
Alcyonacea (non-gorgonian)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Mean	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Gorgonians (gorgonian Alcyonacea)	Low	0.980	0.988	0.982	0.982	0.989	0.983	1.000	1.000	1.000	1.000	1.000	1.000	0.914	0.947	0.921	0.908	0.941	0.916
	Mean	0.985	0.992	0.986	0.987	0.992	0.987	1.000	1.000	1.000	1.000	1.000	1.000	0.938	0.964	0.940	0.932	0.959	0.935
	High	0.989	0.994	0.989	0.990	0.994	0.990	1.000	1.000	1.000	1.000	1.000	1.000	0.953	0.973	0.953	0.948	0.970	0.949
Hydrocorals* (Stylasteridae)	Low	0.900	1.000	0.926	0.986	0.997	0.988	1.000	1.000	1.000	1.000	1.000	1.000	0.479	0.998	0.615	0.918	0.983	0.931
	Mean	0.962	1.000	0.951	0.993	0.998	0.992	1.000	1.000	1.000	1.000	1.000	1.000	0.803	1.000	0.747	0.958	0.989	0.953
	High	0.982	1.000	0.968	0.996	0.999	0.995	1.000	1.000	1.000	1.000	1.000	1.000	0.908	1.000	0.831	0.978	0.995	0.970
Sponges (Porifera Demospongiae)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	–	–	–	1.000	1.000	1.000
	Mean	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	–	–	–	1.000	1.000	1.000
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	–	–	–	1.000	1.000	1.000
Sponges* (Porifera Hexactinellida)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.995	0.999	0.995
	Mean	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.997	0.999	0.997
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.998	0.999	0.998
Sea pens	Low	1.000	1.000	1.000	0.999	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.980	0.989	0.979

VME indicator taxa habitat		FMA						Outside BTMAs						Inside BTMAs							
		ROC-linear			Power mean			ROC-linear			Power mean			ROC-linear			Power mean				
		C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF		
(Pennatulacea)	Mean	1.000	1.000	1.000	1.000	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.987	0.995	0.986
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.993	0.998	0.991
Anemones (Actiniaria)	Low	1.000	1.000	1.000	0.999	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.979	0.988	0.977
	Mean	1.000	1.000	1.000	1.000	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.988	0.995	0.986
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.995	0.998	0.991
Zoanthid hexacorals (Zoantharia)	Low	0.994	0.997	0.994	0.995	0.998	0.995	1.000	1.000	0.999	1.000	1.000	1.000	0.922	0.964	0.927	0.932	0.969	0.937		
	Mean	0.996	0.998	0.996	0.997	0.999	0.997	1.000	1.000	1.000	1.000	1.000	1.000	0.946	0.980	0.948	0.953	0.982	0.954		
	High	0.997	0.999	0.997	0.998	1.000	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.964	0.992	0.967	0.968	0.993	0.971		
Hydroids (Hydrozoa)	Low	1.000	1.000	1.000	0.998	0.999	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.996	1.000	0.997	0.962	0.980	0.963		
	Mean	1.000	1.000	1.000	0.998	0.999	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.998	1.000	0.998	0.972	0.985	0.972		
	High	1.000	1.000	1.000	0.999	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.999	1.000	0.999	0.982	0.993	0.982		
Bryozoans* (Bryozoa)	Low	1.000	1.000	1.000	0.997	0.999	0.997	1.000	1.000	1.000	1.000	1.000	1.000	0.996	0.999	0.996	0.955	0.978	0.958		
	Mean	1.000	1.000	1.000	0.998	0.999	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.998	1.000	0.997	0.968	0.985	0.968		
	High	1.000	1.000	1.000	0.999	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.999	1.000	0.998	0.978	0.993	0.979		
Armless stars (Brisingida)	Low	0.998	0.999	0.998	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.976	0.980	0.975	0.988	0.990	0.988		
	Mean	0.999	0.999	0.999	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.980	0.982	0.979	0.991	0.992	0.990		
	High	0.999	0.999	0.999	0.999	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.983	0.985	0.982	0.992	0.993	0.991		
Sea lilies & feather stars (Crinoidea)	Low	0.998	0.999	0.998	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.972	0.981	0.972	0.981	0.987	0.981		
	Mean	0.999	0.999	0.999	0.999	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.983	0.989	0.982	0.989	0.993	0.988		
	High	0.999	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.988	0.992	0.987	0.992	0.995	0.991		

Table 11: Low, mean, and high dynamic Relative Benthic Status estimates of current status (C), future status after cessation of fishing from 2025 (FNF), and future status with fishing (FF) for the **West Norfolk** Fishery Management Area (FMA) using Bottom Trawl management Areas (BTMAs) implemented under [CMM03-2023](#), using two alternative Habitat Suitability Index (HSI) transformations (ROC-linear and Power mean) for each Vulnerable Marine Ecosystem (VME) indicator taxon. Boxes in ROC-linear transformation columns marked “-” indicate no cells within the region with HSI > ROC cut-off. Greyed boxes indicate status below 0.8, with a detailed plot shown below for taxa where status falls below 0.8 in any year.

VME indicator taxa habitat		FMA						Outside BTMAs						Inside BTMAs					
		ROC-linear			Power mean			ROC-linear			Power mean			ROC-linear			Power mean		
		C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF
Stony corals (<i>Solenosmilia variabilis</i>)	Low	0.993	0.996	0.993	0.992	0.996	0.992	0.999	1.000	0.999	0.999	1.000	0.999	0.976	0.987	0.975	0.973	0.985	0.973
	Mean	0.995	0.998	0.995	0.994	0.997	0.994	1.000	1.000	1.000	1.000	1.000	0.999	0.983	0.991	0.983	0.981	0.990	0.980
	High	0.997	0.999	0.997	0.996	0.998	0.996	1.000	1.000	1.000	1.000	1.000	1.000	0.989	0.995	0.989	0.987	0.994	0.987
Stony corals (<i>Madrepora oculata</i>)	Low	0.986	0.992	0.989	0.987	0.992	0.989	0.999	1.000	0.999	0.998	1.000	0.999	0.953	0.973	0.962	0.950	0.971	0.959
	Mean	0.991	0.995	0.993	0.991	0.995	0.993	0.999	1.000	1.000	0.999	1.000	1.000	0.968	0.985	0.976	0.965	0.983	0.973
	High	0.994	0.997	0.995	0.994	0.997	0.995	1.000	1.000	1.000	1.000	1.000	1.000	0.979	0.988	0.982	0.976	0.987	0.979
Stony corals (<i>Goniocorella dumosa</i>)	Low	0.797	0.847	0.808	0.069	0.090	0.079	0.998	1.000	1.000	0.998	1.000	1.000	0.684	0.762	0.701	0.035	0.057	0.046
	Mean	0.842	0.886	0.843	0.087	0.153	0.107	0.999	1.000	1.000	1.000	1.000	1.000	0.753	0.822	0.755	0.054	0.123	0.075
	High	0.878	0.905	0.869	0.163	0.360	0.242	1.000	1.000	1.000	1.000	1.000	1.000	0.810	0.852	0.796	0.133	0.337	0.214
Stony corals (<i>Enallopsammia rostrata</i>)	Low	0.969	0.984	0.974	0.973	0.986	0.977	0.997	1.000	0.998	0.998	1.000	0.998	0.948	0.972	0.956	0.947	0.971	0.954
	Mean	0.981	0.991	0.982	0.983	0.992	0.984	0.999	1.000	0.999	0.999	1.000	0.999	0.967	0.984	0.970	0.965	0.983	0.968
	High	0.988	0.993	0.986	0.989	0.994	0.988	1.000	1.000	0.999	1.000	1.000	0.999	0.979	0.988	0.977	0.978	0.987	0.976
Black corals (Antipatharia)	Low	0.981	0.987	0.981	0.994	0.996	0.994	1.000	1.000	1.000	1.000	1.000	0.999	0.924	0.945	0.923	0.961	0.973	0.960
	Mean	0.987	0.989	0.985	0.996	0.997	0.995	1.000	1.000	1.000	1.000	1.000	1.000	0.944	0.956	0.939	0.973	0.979	0.969
	High	0.990	0.992	0.989	0.997	0.998	0.997	1.000	1.000	1.000	1.000	1.000	1.000	0.960	0.969	0.955	0.981	0.985	0.977
Alcyonacea (non-gorgonian)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.998	1.000	1.000	0.999
	Mean	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	1.000	1.000	0.999
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	1.000	1.000	0.999
Gorgonians (gorgonian Alcyonacea)	Low	0.985	0.990	0.985	0.985	0.990	0.985	1.000	1.000	1.000	1.000	1.000	1.000	0.921	0.945	0.921	0.919	0.943	0.919
	Mean	0.989	0.992	0.988	0.989	0.992	0.988	1.000	1.000	1.000	1.000	1.000	1.000	0.942	0.956	0.937	0.940	0.954	0.935
	High	0.993	0.994	0.992	0.993	0.994	0.992	1.000	1.000	1.000	1.000	1.000	1.000	0.963	0.970	0.956	0.961	0.969	0.954
Hydrocorals (Stylasteridae)	Low	1.000	1.000	1.000	1.000	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.993	0.997	0.989	0.988	0.992	0.984
	Mean	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.996	0.997	0.992	0.993	0.995	0.989
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.998	0.999	0.995	0.996	0.997	0.993
Sponges (Porifera Demospongiae)	Low	0.999	0.999	0.999	0.999	0.999	0.999	0.999	1.000	0.999	0.999	1.000	0.999	0.890	0.891	0.890	0.907	0.908	0.907
	Mean	0.999	1.000	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.953	0.978	0.971	0.966	0.989	0.982
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.973	0.978	0.974	0.985	0.990	0.985
Sponges (Porifera Hexactinellida)	Low	0.999	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.988	0.991	0.988	0.986	0.989	0.986
	Mean	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.993	0.994	0.992	0.991	0.994	0.991
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.994	0.995	0.993	0.993	0.994	0.992
Sea pens	Low	1.000	1.000	1.000	1.000	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.996	0.997	0.994

VME indicator taxa habitat		FMA						Outside BTMAs						Inside BTMAs					
		ROC-linear			Power mean			ROC-linear			Power mean			ROC-linear			Power mean		
		C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF
(Pennatulacea)	Mean	1.000	1.000	1.000	1.000	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.997	0.997	0.995
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.997	0.997	0.996
Anemones (Actiniaria)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.998	0.999	0.996
	Mean	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.997
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.998
Zoanthid hexacorals (Zoantharia)	Low	0.997	0.999	0.997	0.997	0.999	0.997	1.000	1.000	1.000	1.000	1.000	1.000	0.978	0.990	0.979	0.980	0.990	0.980
	Mean	0.998	0.999	0.998	0.998	0.999	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.988	0.994	0.986	0.988	0.994	0.987
	High	0.999	1.000	0.999	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.994	0.997	0.991	0.993	0.996	0.991
Hydroids (Hydrozoa)	Low	0.998	0.999	0.998	0.998	0.998	0.997	1.000	1.000	1.000	1.000	1.000	1.000	0.984	0.987	0.981	0.983	0.987	0.980
	Mean	0.999	0.999	0.998	0.999	0.999	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.988	0.990	0.985	0.988	0.990	0.985
	High	0.999	0.999	0.999	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.993	0.993	0.990	0.993	0.993	0.989
Bryozoans (Bryozoa)	Low	0.998	0.999	0.998	0.998	0.999	0.997	1.000	1.000	1.000	1.000	1.000	1.000	0.982	0.987	0.980	0.981	0.987	0.979
	Mean	0.999	0.999	0.998	0.999	0.999	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.988	0.991	0.985	0.988	0.991	0.985
	High	0.999	0.999	0.999	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.992	0.994	0.990	0.992	0.994	0.989
Armless stars (Brisingida)	Low	0.999	0.999	0.998	0.999	0.999	0.998	1.000	1.000	0.999	1.000	1.000	0.999	0.996	0.997	0.993	0.997	0.998	0.995
	Mean	0.999	0.999	0.999	1.000	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.998	0.998	0.996	0.998	0.998	0.996
	High	1.000	1.000	0.999	1.000	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.998	0.998	0.997	0.999	0.999	0.997
Sea lilies & feather stars (Crinoidea)	Low	0.997	0.997	0.996	0.996	0.997	0.996	1.000	1.000	1.000	1.000	1.000	1.000	0.977	0.981	0.974	0.979	0.982	0.975
	Mean	0.998	0.998	0.997	0.998	0.998	0.997	1.000	1.000	1.000	1.000	1.000	1.000	0.984	0.986	0.980	0.985	0.986	0.981
	High	0.998	0.998	0.998	0.998	0.998	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.988	0.989	0.985	0.989	0.990	0.986

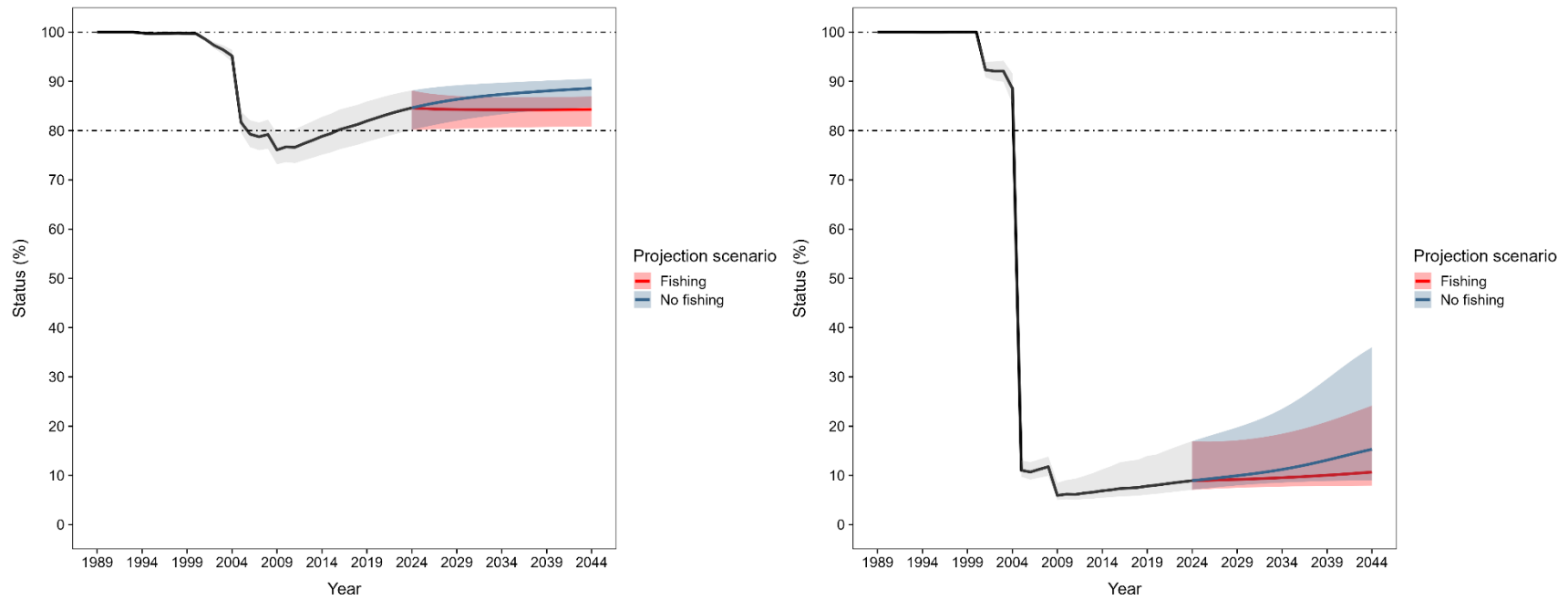


Figure 13: Estimated dynamic Relative Benthic Status (expressed as a percentage) for *Goniocorella dumosa* (Scleractinia) in the West Norfolk Fishery Management Area from 1989 to 2044, using the ROC-linear (left) and Power mean (right) transformations of the Habitat Suitability Index values. The black lines indicates the “Mean” scenario and uses the primary values of depletion (D) and recovery (R), the lower extent of the shaded area represents the “Low” scenario and uses the +20% estimate of D and -20% estimate of R, and the upper extent of the shaded area represents the “High” scenario and uses the -20% estimate of D and +20% estimate of R (see Table 6). The “Fishing” projection assumes continued fishing between 2025 and 2044 at a constant level sufficient to take the current orange roughy catch limit in each FMA, and with recent average bottom longline effort; the “No fishing” projection assumes no bottom fishing between 2025 and 2044.

Table 12: Low, mean, and high dynamic Relative Benthic Status estimates of current status (C), future status after cessation of fishing from 2025 (FNF), and future status with fishing (FF) for the **South Tasman Rise** Fishery Management Area (FMA) using Bottom Trawl management Areas (BTMAs) implemented under [CMM03-2023](#), using two alternative Habitat Suitability Index (HSI) transformations (ROC-linear and Power mean) for each Vulnerable Marine Ecosystem (VME) indicator taxon. Boxes in ROC-linear transformation columns marked “–” indicate no cells within the region with HSI > ROC cut-off. Greyed boxes indicate status below 0.8.

VME indicator taxa habitat		FMA						Outside BTMAs						Inside BTMAs					
		ROC-linear			Power mean			ROC-linear			Power mean			ROC-linear			Power mean		
		C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF
Stony corals (<i>Solenosmilia variabilis</i>)	Low	0.990	0.992	0.992	0.993	0.994	0.994	0.998	1.000	1.000	0.998	1.000	1.000	0.808	0.836	0.836	0.801	0.831	0.831
	Mean	0.991	0.993	0.993	0.994	0.995	0.995	0.999	1.000	1.000	0.999	1.000	1.000	0.832	0.854	0.854	0.826	0.849	0.849
	High	0.993	0.994	0.994	0.995	0.996	0.996	0.999	1.000	1.000	1.000	1.000	1.000	0.861	0.883	0.883	0.857	0.880	0.880
Stony corals (<i>Madrepora oculata</i>)	Low	1.000	1.000	1.000	0.999	1.000	1.000	0.998	1.000	1.000	0.998	1.000	1.000	0.997	1.000	1.000	0.987	0.992	0.992
	Mean	1.000	1.000	1.000	1.000	1.000	1.000	0.999	1.000	1.000	0.999	1.000	1.000	0.999	1.000	1.000	0.991	0.993	0.993
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.994	0.995	0.995
Stony corals (<i>Goniocorella dumosa</i>)	Low	0.973	0.974	0.974	0.974	0.975	0.975	0.999	1.000	1.000	0.999	1.000	1.000	0.000	0.000	0.000	0.134	0.136	0.136
	Mean	0.973	0.974	0.974	0.976	0.976	0.976	1.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000	0.181	0.187	0.187
	High	0.974	0.974	0.974	0.982	0.983	0.983	1.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000	0.394	0.398	0.398
Stony corals (<i>Enallopsammia rostrata</i>)	Low	0.978	0.982	0.982	0.980	0.984	0.984	0.998	1.000	1.000	0.997	1.000	1.000	0.930	0.942	0.942	0.936	0.948	0.948
	Mean	0.982	0.984	0.984	0.984	0.986	0.986	0.999	1.000	1.000	0.999	1.000	1.000	0.943	0.947	0.947	0.948	0.952	0.952
	High	0.986	0.987	0.987	0.988	0.989	0.989	1.000	1.000	1.000	0.999	1.000	1.000	0.954	0.957	0.957	0.960	0.962	0.962
Black corals (Antipatharia)	Low	0.971	0.973	0.973	0.997	0.997	0.997	1.000	1.000	1.000	1.000	1.000	1.000	0.780	0.790	0.790	0.929	0.932	0.932
	Mean	0.975	0.976	0.976	0.997	0.997	0.997	1.000	1.000	1.000	1.000	1.000	1.000	0.809	0.813	0.813	0.940	0.942	0.942
	High	0.979	0.979	0.979	0.998	0.998	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.838	0.839	0.839	0.950	0.950	0.950
Alcyonacea (non-gorgonian)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.984	0.985	0.985
	Mean	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.986	0.987	0.987
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.987	0.987	0.987
Gorgonians (gorgonian Alcyonacea)	Low	0.998	0.998	0.998	0.998	0.998	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.931	0.934	0.934	0.930	0.934	0.934
	Mean	0.998	0.998	0.998	0.998	0.998	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.941	0.943	0.943	0.940	0.942	0.942
	High	0.999	0.999	0.999	0.998	0.998	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.949	0.950	0.950	0.948	0.949	0.949
Hydrocorals (Stylasteridae)	Low	0.993	0.993	0.993	0.993	0.993	0.993	1.000	1.000	1.000	1.000	1.000	1.000	0.909	0.910	0.910	0.894	0.895	0.895
	Mean	0.994	0.994	0.994	0.995	0.995	0.995	1.000	1.000	1.000	1.000	1.000	1.000	0.923	0.924	0.924	0.916	0.917	0.917
	High	0.996	0.996	0.996	0.996	0.996	0.996	1.000	1.000	1.000	1.000	1.000	1.000	0.940	0.940	0.940	0.932	0.932	0.932
Sponges (Porifera Demospongiae)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.985	0.988	0.988
	Mean	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.988	0.988	0.988
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.988	0.988	0.988
Sponges (Porifera Hexactinellida)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.972	0.974	0.974
	Mean	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.977	0.978	0.978
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.979	0.979	0.979
Sea pens	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	–	–	–

VME indicator taxa habitat		FMA						Outside BTMAs						Inside BTMAs					
		ROC-linear			Power mean			ROC-linear			Power mean			ROC-linear			Power mean		
		C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF
(Pennatulacea)	Mean	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Anemones (Actiniaria)	Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Mean	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Zoanthid hexacorals (Zoantharia)	Low	0.998	0.999	0.999	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.884	0.892	0.892	0.948	0.954	0.954
	Mean	0.999	0.999	0.999	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.904	0.909	0.909	0.959	0.962	0.962
	High	0.999	0.999	0.999	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.918	0.919	0.919	0.966	0.966	0.966
Hydroids (Hydrozoa)	Low	1.000	1.000	1.000	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.904	0.907	0.907	0.946	0.948	0.948
	Mean	1.000	1.000	1.000	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.915	0.915	0.915	0.953	0.953	0.953
	High	1.000	1.000	1.000	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.933	0.933	0.933	0.962	0.962	0.962
Bryozoans (Bryozoa)	Low	0.999	0.999	0.999	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.876	0.882	0.882	0.945	0.949	0.949
	Mean	0.999	1.000	1.000	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.888	0.894	0.894	0.952	0.955	0.955
	High	1.000	1.000	1.000	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.912	0.913	0.913	0.962	0.962	0.962
Armless stars (Brisingida)	Low	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.927	0.927	0.927	0.926	0.926	0.926
	Mean	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.939	0.939	0.939	0.938	0.938	0.938
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.946	0.946	0.946	0.946	0.946	0.946
Sea lilies & feather stars (Crinoidea)	Low	0.999	0.999	0.999	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.884	0.885	0.885	0.887	0.888	0.888
	Mean	0.999	0.999	0.999	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.896	0.897	0.897	0.899	0.900	0.900
	High	0.999	0.999	0.999	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.908	0.908	0.908	0.910	0.910	0.910

Table 13: Low, mean, and high dynamic Relative Benthic Status estimates of current status (C), future status after cessation of fishing from 2025 (FNF), and future status with fishing (FF) for the **North Louisville** Fishery Management Area (FMA) using Bottom Trawl management Areas (BTMAs) implemented under [CMM03-2023](#), using two alternative Habitat Suitability Index (HSI) transformations (ROC-linear and Power mean) for each Vulnerable Marine Ecosystem (VME) indicator taxon. Boxes in ROC-linear transformation columns marked “-” indicate no cells within the region with HSI > ROC cut-off; * indicates taxa with < 1% of their HSI within the FMA.

VME indicator taxa habitat		FMA						Outside BTMAs						Inside BTMAs					
		ROC-linear			Power mean			ROC-linear			Power mean			ROC-linear			Power mean		
		C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF
Stony corals (<i>Solenosmilia variabilis</i>)	Low	0.901	0.929	0.928	0.895	0.925	0.924	0.923	0.945	0.944	0.916	0.940	0.939	0.844	0.888	0.885	0.838	0.884	0.882
	Mean	0.923	0.945	0.943	0.918	0.942	0.941	0.940	0.957	0.956	0.934	0.953	0.952	0.878	0.915	0.911	0.874	0.912	0.909
	High	0.942	0.960	0.958	0.938	0.957	0.956	0.954	0.969	0.968	0.950	0.966	0.965	0.909	0.936	0.933	0.905	0.932	0.930
Stony corals (<i>Madrepora oculata</i>)	Low	0.999	1.000	1.000	0.993	0.996	0.996	1.000	1.000	1.000	0.998	0.999	0.999	0.998	1.000	1.000	0.983	0.990	0.988
	Mean	1.000	1.000	1.000	0.996	0.997	0.997	1.000	1.000	1.000	0.999	0.999	0.999	0.999	1.000	1.000	0.989	0.993	0.991
	High	1.000	1.000	1.000	0.997	0.998	0.998	1.000	1.000	1.000	0.999	0.999	0.999	1.000	1.000	1.000	0.992	0.996	0.994
Stony corals (<i>Goniocorella dumosa</i>)	Low	0.975	0.985	0.979	0.987	0.998	0.989	0.996	1.000	0.998	0.989	1.000	0.990	0.929	0.954	0.938	0.969	0.985	0.973
	Mean	0.984	0.990	0.985	0.995	0.999	0.992	0.999	1.000	0.998	0.996	1.000	0.994	0.952	0.968	0.956	0.981	0.990	0.982
	High	0.988	0.990	0.987	0.998	0.999	0.995	1.000	1.000	0.999	0.999	1.000	0.996	0.962	0.968	0.960	0.986	0.990	0.985
Stony corals* (<i>Enallopsammia rostrata</i>)	Low	0.994	1.000	1.000	0.960	0.980	0.979	1.000	1.000	1.000	0.957	0.978	0.977	0.982	0.999	0.999	0.971	0.989	0.988
	Mean	0.998	1.000	1.000	0.977	0.987	0.986	1.000	1.000	1.000	0.975	0.986	0.985	0.995	1.000	1.000	0.986	0.992	0.991
	High	0.999	1.000	1.000	0.987	0.993	0.992	1.000	1.000	1.000	0.985	0.992	0.991	0.998	1.000	1.000	0.992	0.995	0.994
Black corals (Antipatharia)	Low	0.947	0.957	0.954	0.971	0.975	0.974	0.964	0.972	0.971	0.981	0.984	0.984	0.904	0.917	0.913	0.934	0.943	0.940
	Mean	0.961	0.966	0.964	0.978	0.980	0.979	0.975	0.980	0.979	0.985	0.988	0.987	0.926	0.932	0.928	0.949	0.954	0.951
	High	0.974	0.975	0.974	0.984	0.985	0.985	0.985	0.987	0.986	0.991	0.991	0.991	0.944	0.946	0.943	0.962	0.963	0.962
Alcyonacea (non-gorgonian)	Low	1.000	1.000	1.000	0.997	0.998	0.998	1.000	1.000	1.000	0.998	0.998	0.998	1.000	1.000	1.000	0.996	1.000	0.997
	Mean	1.000	1.000	1.000	0.998	0.998	0.998	1.000	1.000	1.000	0.998	0.998	0.998	1.000	1.000	1.000	0.999	1.000	0.998
	High	1.000	1.000	1.000	0.999	0.999	0.999	1.000	1.000	1.000	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	0.999
Gorgonians (gorgonian Alcyonacea)	Low	0.974	0.979	0.978	0.975	0.980	0.979	0.974	0.979	0.978	0.976	0.981	0.981	0.974	0.978	0.977	0.968	0.973	0.971
	Mean	0.982	0.985	0.984	0.982	0.985	0.984	0.982	0.985	0.984	0.984	0.986	0.986	0.982	0.984	0.982	0.977	0.979	0.977
	High	0.988	0.989	0.988	0.988	0.989	0.988	0.988	0.989	0.988	0.989	0.990	0.989	0.988	0.989	0.987	0.984	0.985	0.984
Hydrocorals (Stylasteridae)	Low	0.957	0.961	0.959	0.955	0.959	0.958	0.967	0.971	0.970	0.965	0.969	0.968	0.926	0.930	0.927	0.924	0.927	0.924
	Mean	0.969	0.970	0.969	0.968	0.969	0.968	0.977	0.978	0.977	0.976	0.976	0.976	0.945	0.946	0.944	0.943	0.944	0.942
	High	0.977	0.978	0.977	0.977	0.978	0.977	0.984	0.984	0.984	0.984	0.984	0.983	0.958	0.959	0.957	0.956	0.957	0.955
Sponges (Porifera Demospongiae)	Low	0.936	0.955	0.952	0.933	0.951	0.949	0.943	0.962	0.960	0.942	0.962	0.960	0.912	0.926	0.923	0.905	0.919	0.917
	Mean	0.956	0.962	0.960	0.952	0.957	0.955	0.964	0.971	0.969	0.962	0.968	0.966	0.926	0.929	0.926	0.919	0.922	0.920
	High	0.972	0.976	0.975	0.967	0.970	0.969	0.979	0.983	0.981	0.974	0.977	0.976	0.950	0.953	0.951	0.946	0.949	0.948
Sponges (Porifera Hexactinellida)	Low	0.993	0.994	0.994	0.996	0.996	0.996	0.994	0.995	0.995	0.996	0.996	0.996	0.989	0.992	0.991	0.995	0.997	0.996
	Mean	0.995	0.996	0.995	0.997	0.997	0.997	0.995	0.996	0.996	0.997	0.997	0.997	0.993	0.995	0.993	0.997	0.998	0.997
	High	0.997	0.997	0.997	0.998	0.999	0.998	0.997	0.997	0.997	0.998	0.999	0.999	0.996	0.997	0.996	0.998	0.999	0.998
Sea pens*	Low	0.994	0.995	0.994	0.990	0.990	0.990	0.994	0.994	0.994	0.992	0.993	0.992	0.997	0.997	0.997	0.980	0.981	0.980

VME indicator taxa habitat		FMA						Outside BTMAs						Inside BTMAs					
		ROC-linear			Power mean			ROC-linear			Power mean			ROC-linear			Power mean		
		C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF
(Pennatulacea)	Mean	0.996	0.996	0.996	0.993	0.993	0.992	0.995	0.995	0.995	0.994	0.995	0.994	0.998	0.998	0.998	0.985	0.986	0.985
	High	0.998	0.998	0.998	0.995	0.995	0.995	0.998	0.998	0.998	0.996	0.996	0.996	0.998	0.999	0.998	0.990	0.990	0.990
Anemones* (Actiniaria)	Low	–	–	–	0.986	0.986	0.986	–	–	–	0.987	0.987	0.987	–	–	–	0.982	0.982	0.982
	Mean	–	–	–	0.990	0.990	0.990	–	–	–	0.991	0.991	0.990	–	–	–	0.987	0.987	0.986
	High	–	–	–	0.994	0.994	0.993	–	–	–	0.994	0.994	0.994	–	–	–	0.992	0.992	0.992
Zoanthid hexacorals (Zoantharia)	Low	1.000	1.000	1.000	0.989	0.993	0.992	1.000	1.000	1.000	0.993	0.995	0.995	0.999	1.000	0.999	0.973	0.980	0.978
	Mean	1.000	1.000	1.000	0.993	0.995	0.994	1.000	1.000	1.000	0.996	0.997	0.996	1.000	1.000	0.999	0.983	0.987	0.986
	High	1.000	1.000	1.000	0.996	0.997	0.996	1.000	1.000	1.000	0.997	0.998	0.998	1.000	1.000	1.000	0.990	0.991	0.990
Hydroids (Hydrozoa)	Low	0.986	0.987	0.986	0.984	0.986	0.985	0.990	0.990	0.990	0.989	0.990	0.990	0.972	0.974	0.972	0.966	0.969	0.967
	Mean	0.989	0.989	0.989	0.988	0.988	0.988	0.992	0.992	0.992	0.992	0.993	0.992	0.978	0.978	0.977	0.973	0.974	0.972
	High	0.992	0.992	0.991	0.991	0.991	0.991	0.994	0.994	0.994	0.994	0.994	0.994	0.985	0.985	0.984	0.982	0.982	0.981
Bryozoans (Bryozoa)	Low	0.986	0.989	0.988	0.984	0.987	0.987	0.991	0.993	0.992	0.989	0.992	0.992	0.970	0.975	0.973	0.965	0.971	0.969
	Mean	0.990	0.991	0.991	0.989	0.990	0.990	0.993	0.994	0.994	0.993	0.994	0.993	0.979	0.981	0.980	0.975	0.978	0.976
	High	0.993	0.994	0.993	0.992	0.993	0.992	0.995	0.995	0.995	0.995	0.995	0.995	0.986	0.987	0.986	0.984	0.985	0.984
Armless stars (Brisingida)	Low	0.982	0.982	0.982	0.983	0.983	0.983	0.990	0.990	0.990	0.991	0.991	0.991	0.938	0.939	0.936	0.943	0.944	0.942
	Mean	0.983	0.984	0.983	0.985	0.985	0.985	0.990	0.990	0.990	0.991	0.991	0.991	0.946	0.946	0.943	0.951	0.951	0.949
	High	0.987	0.987	0.987	0.989	0.989	0.988	0.992	0.992	0.992	0.993	0.993	0.993	0.961	0.961	0.959	0.965	0.966	0.964
Sea lilies & feather stars (Crinoidea)	Low	0.982	0.983	0.983	0.984	0.985	0.984	0.989	0.990	0.989	0.990	0.991	0.991	0.956	0.958	0.957	0.961	0.963	0.961
	Mean	0.985	0.985	0.985	0.986	0.987	0.986	0.991	0.991	0.991	0.991	0.991	0.991	0.963	0.964	0.963	0.967	0.968	0.967
	High	0.988	0.988	0.988	0.989	0.989	0.989	0.992	0.992	0.992	0.993	0.993	0.993	0.972	0.972	0.971	0.976	0.976	0.975

Table 14: Low, mean, and high dynamic Relative Benthic Status estimates of current status (C), future status after cessation of fishing from 2025 (FNF), and future status with fishing (FF) for the **Central Louisville** Fishery Management Area (FMA) using Bottom Trawl management Areas (BTMAs) implemented under [CMM03-2023](#), using two alternative Habitat Suitability Index (HSI) transformations (ROC-linear and Power mean) for each Vulnerable Marine Ecosystem (VME) indicator taxon. Boxes in ROC-linear transformation columns marked “–” indicate no cells within the region with HSI > ROC cut-off. Greyed boxes indicate status below 0.8, with a detailed plot shown below for taxa where status falls below 0.8 in any year.; * indicates taxa with <1% of their HSI within the FMA.

VME indicator taxa habitat		FMA						Outside BTMAs						Inside BTMAs					
		ROC-linear			Power mean			ROC-linear			Power mean			ROC-linear			Power mean		
		C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF
Stony corals (<i>Solenosmilia variabilis</i>)	Low	0.808	0.837	0.833	0.772	0.805	0.800	0.986	0.992	0.992	0.984	0.990	0.990	0.686	0.731	0.724	0.664	0.712	0.704
	Mean	0.835	0.862	0.857	0.803	0.835	0.829	0.990	0.994	0.994	0.989	0.993	0.993	0.729	0.771	0.764	0.710	0.754	0.747
	High	0.865	0.888	0.884	0.839	0.866	0.861	0.994	0.997	0.997	0.993	0.996	0.996	0.777	0.814	0.807	0.761	0.799	0.792
Stony corals* (<i>Madrepora oculata</i>)	Low	1.000	1.000	1.000	0.983	0.988	0.987	1.000	1.000	1.000	0.997	0.998	0.998	0.998	1.000	1.000	0.950	0.963	0.961
	Mean	1.000	1.000	1.000	0.987	0.990	0.989	1.000	1.000	1.000	0.998	0.999	0.998	0.999	1.000	1.000	0.962	0.969	0.968
	High	1.000	1.000	1.000	0.990	0.992	0.991	1.000	1.000	1.000	0.999	1.000	1.000	1.000	1.000	1.000	0.970	0.975	0.973
Stony corals (<i>Goniocorella dumosa</i>)	Low	0.728	0.749	0.745	0.269	0.290	0.284	0.972	0.978	0.978	0.926	0.946	0.944	0.592	0.621	0.614	0.259	0.279	0.273
	Mean	0.761	0.774	0.770	0.306	0.329	0.325	0.978	0.981	0.981	0.946	0.956	0.954	0.640	0.658	0.652	0.296	0.319	0.315
	High	0.798	0.805	0.802	0.352	0.356	0.353	0.988	0.989	0.989	0.967	0.970	0.969	0.692	0.703	0.698	0.343	0.347	0.344
Stony corals* (<i>Enallopsammia rostrata</i>)	Low	0.998	1.000	1.000	0.937	0.942	0.941	–	–	–	0.995	0.997	0.997	0.998	1.000	1.000	0.871	0.881	0.879
	Mean	1.000	1.000	1.000	0.949	0.954	0.953	–	–	–	0.996	0.997	0.997	1.000	1.000	1.000	0.895	0.906	0.904
	High	1.000	1.000	1.000	0.956	0.958	0.957	–	–	–	0.998	0.999	0.999	1.000	1.000	1.000	0.909	0.912	0.911
Black corals (Antipatharia)	Low	0.850	0.859	0.857	0.919	0.925	0.923	0.986	0.987	0.987	0.996	0.997	0.997	0.688	0.707	0.703	0.824	0.836	0.832
	Mean	0.871	0.875	0.874	0.932	0.934	0.933	0.990	0.991	0.990	0.998	0.998	0.998	0.729	0.738	0.735	0.850	0.856	0.853
	High	0.890	0.893	0.892	0.944	0.946	0.945	0.995	0.996	0.996	0.999	0.999	0.999	0.766	0.771	0.768	0.877	0.880	0.877
Alcyonacea* (non-gorgonian)	Low	0.999	1.000	1.000	0.994	0.995	0.994	1.000	1.000	1.000	1.000	1.000	1.000	0.999	1.000	1.000	0.988	0.990	0.989
	Mean	1.000	1.000	1.000	0.998	0.999	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.996	0.997	0.996
	High	1.000	1.000	1.000	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.998	0.999	0.998
Gorgonians* (gorgonian Alcyonacea)	Low	0.944	0.950	0.948	0.947	0.953	0.951	1.000	1.000	1.000	0.999	0.999	0.999	0.844	0.862	0.855	0.864	0.878	0.872
	Mean	0.958	0.965	0.963	0.959	0.964	0.962	1.000	1.000	1.000	1.000	1.000	1.000	0.884	0.901	0.896	0.894	0.906	0.901
	High	0.972	0.975	0.973	0.971	0.973	0.971	1.000	1.000	1.000	1.000	1.000	1.000	0.922	0.929	0.924	0.923	0.928	0.924
Hydrocorals (Stylasteridae)	Low	0.895	0.898	0.895	0.899	0.902	0.899	1.000	1.000	1.000	1.000	1.000	1.000	0.869	0.872	0.869	0.875	0.878	0.874
	Mean	0.907	0.909	0.907	0.911	0.913	0.911	1.000	1.000	1.000	1.000	1.000	1.000	0.884	0.887	0.884	0.889	0.892	0.889
	High	0.926	0.926	0.925	0.929	0.929	0.928	1.000	1.000	1.000	1.000	1.000	1.000	0.908	0.908	0.906	0.912	0.913	0.910
Sponges* (Porifera Demospongiae)	Low	0.933	0.943	0.942	0.955	0.963	0.962	1.000	1.000	1.000	1.000	1.000	1.000	0.914	0.928	0.926	0.936	0.948	0.947
	Mean	0.948	0.959	0.957	0.966	0.972	0.971	1.000	1.000	1.000	1.000	1.000	1.000	0.934	0.948	0.944	0.952	0.961	0.959
	High	0.961	0.964	0.963	0.974	0.976	0.975	1.000	1.000	1.000	1.000	1.000	1.000	0.950	0.954	0.952	0.963	0.966	0.965
Sponges* (Porifera Hexactinellida)	Low	0.995	0.996	0.996	0.997	0.998	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.987	0.990	0.988	0.994	0.996	0.995
	Mean	0.997	0.998	0.997	0.998	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.992	0.993	0.992	0.996	0.997	0.996
	High	0.998	0.998	0.998	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.994	0.994	0.993	0.997	0.997	0.997
Sea pens*	Low	0.999	0.999	0.999	0.978	0.979	0.979	1.000	1.000	1.000	1.000	1.000	1.000	0.998	0.998	0.998	0.945	0.948	0.946

VME indicator taxa habitat		FMA						Outside BTMAs						Inside BTMAs					
		ROC-linear			Power mean			ROC-linear			Power mean			ROC-linear			Power mean		
		C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF
(Pennatulacea)	Mean	0.999	0.999	0.999	0.984	0.984	0.983	1.000	1.000	1.000	1.000	1.000	1.000	0.998	0.998	0.998	0.958	0.959	0.957
	High	0.999	0.999	0.999	0.988	0.989	0.988	1.000	1.000	1.000	1.000	1.000	1.000	0.998	0.998	0.998	0.971	0.971	0.970
Anemones* (Actiniaria)	Low	–	–	–	0.952	0.953	0.951	–	–	–	1.000	1.000	1.000	–	–	–	0.903	0.904	0.901
	Mean	–	–	–	0.962	0.962	0.961	–	–	–	1.000	1.000	1.000	–	–	–	0.922	0.923	0.921
	High	–	–	–	0.972	0.972	0.971	–	–	–	1.000	1.000	1.000	–	–	–	0.942	0.943	0.941
Zoanthid hexacorals* (Zoantharia)	Low	0.992	0.997	0.996	0.959	0.965	0.963	0.997	1.000	1.000	0.998	0.999	0.999	0.966	0.980	0.980	0.899	0.913	0.909
	Mean	0.996	0.997	0.997	0.969	0.972	0.971	0.999	1.000	1.000	1.000	1.000	1.000	0.979	0.981	0.981	0.922	0.930	0.927
	High	0.997	0.997	0.997	0.976	0.978	0.977	1.000	1.000	1.000	1.000	1.000	1.000	0.980	0.981	0.981	0.941	0.945	0.942
Hydroids* (Hydrozoa)	Low	0.978	0.979	0.978	0.956	0.958	0.957	1.000	1.000	1.000	0.999	0.999	0.999	0.951	0.953	0.951	0.900	0.905	0.902
	Mean	0.981	0.981	0.980	0.963	0.964	0.963	1.000	1.000	1.000	1.000	1.000	1.000	0.957	0.959	0.957	0.915	0.918	0.916
	High	0.986	0.986	0.985	0.971	0.972	0.971	1.000	1.000	1.000	1.000	1.000	1.000	0.968	0.969	0.968	0.935	0.936	0.934
Bryozoans* (Bryozoa)	Low	0.967	0.970	0.969	0.955	0.959	0.958	0.999	0.999	0.999	0.999	0.999	0.999	0.924	0.930	0.928	0.897	0.906	0.903
	Mean	0.973	0.974	0.973	0.963	0.965	0.964	1.000	1.000	1.000	1.000	1.000	1.000	0.936	0.939	0.937	0.914	0.919	0.916
	High	0.980	0.980	0.980	0.972	0.973	0.972	1.000	1.000	1.000	1.000	1.000	1.000	0.952	0.953	0.952	0.935	0.937	0.935
Armless stars* (Brisingida)	Low	0.969	0.970	0.969	0.968	0.969	0.968	1.000	1.000	1.000	1.000	1.000	1.000	0.923	0.924	0.923	0.919	0.921	0.920
	Mean	0.974	0.974	0.974	0.973	0.973	0.973	1.000	1.000	1.000	1.000	1.000	1.000	0.935	0.936	0.935	0.933	0.933	0.932
	High	0.979	0.979	0.979	0.979	0.979	0.979	1.000	1.000	1.000	1.000	1.000	1.000	0.949	0.949	0.948	0.946	0.946	0.945
Sea lilies & feather stars* (Crinoidea)	Low	0.963	0.964	0.963	0.971	0.972	0.972	0.999	0.999	0.999	0.999	0.999	0.999	0.913	0.915	0.913	0.933	0.935	0.933
	Mean	0.969	0.969	0.969	0.977	0.977	0.976	0.999	0.999	0.999	0.999	0.999	0.999	0.928	0.928	0.927	0.945	0.946	0.944
	High	0.975	0.975	0.974	0.981	0.981	0.981	1.000	1.000	1.000	1.000	1.000	1.000	0.941	0.941	0.940	0.956	0.956	0.955

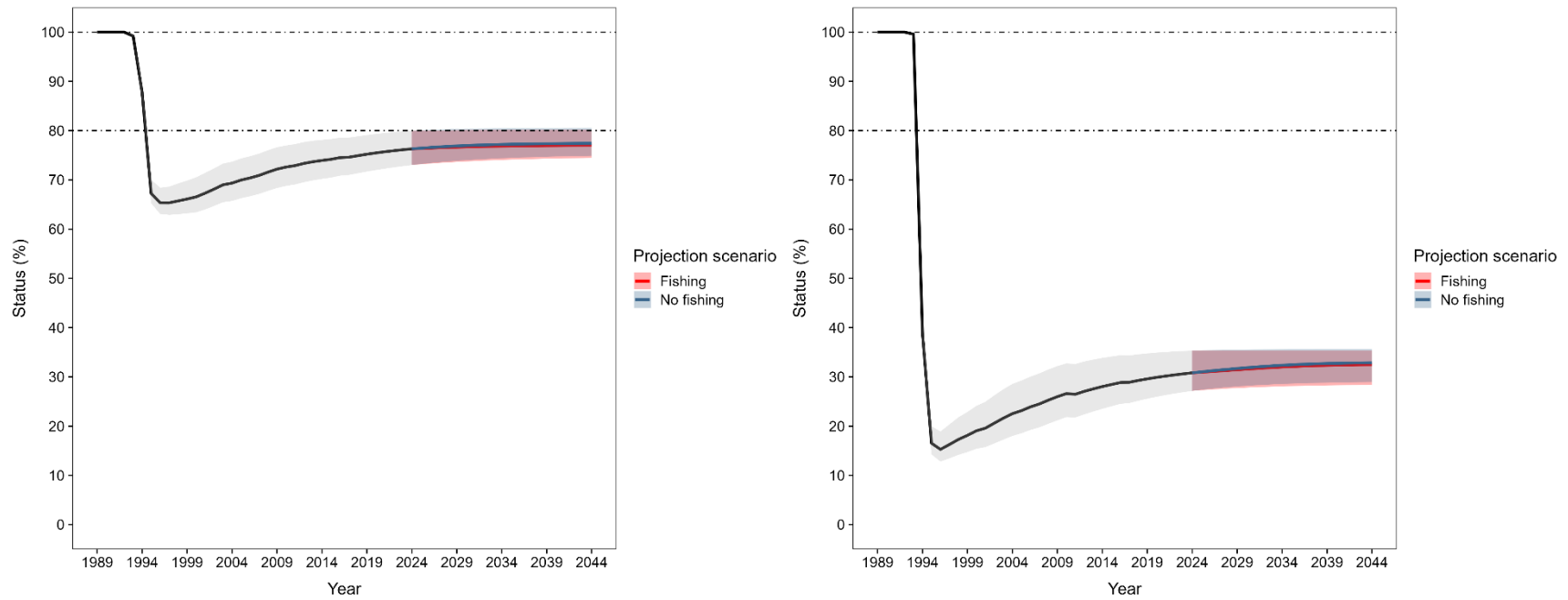


Figure 14: Estimated dynamic Relative Benthic Status (expressed as a percentage) for *Goniocorella dumosa* (Scleractinia) in the Central Louisville Fishery Management Area from 1989 to 2044, using the ROC-linear (left) and Power mean (right) transformations of the Habitat Suitability Index values. The black lines indicates the “Mean” scenario and uses the primary values of depletion (D) and recovery (R), the lower extent of the shaded area represents the “Low” scenario and uses the +20% estimate of D and -20% estimate of R, and upper extent of the shaded area represents the “High” scenario and uses the -20% estimate of D and +20% estimate of R (see Table 6). The “Fishing” projection assumes continued fishing between 2025 and 2044 at a constant level sufficient to take the current orange roughy catch limit in each FMA, and with recent average bottom longline effort; the “No fishing” projection assumes no bottom fishing between 2025 and 2044.

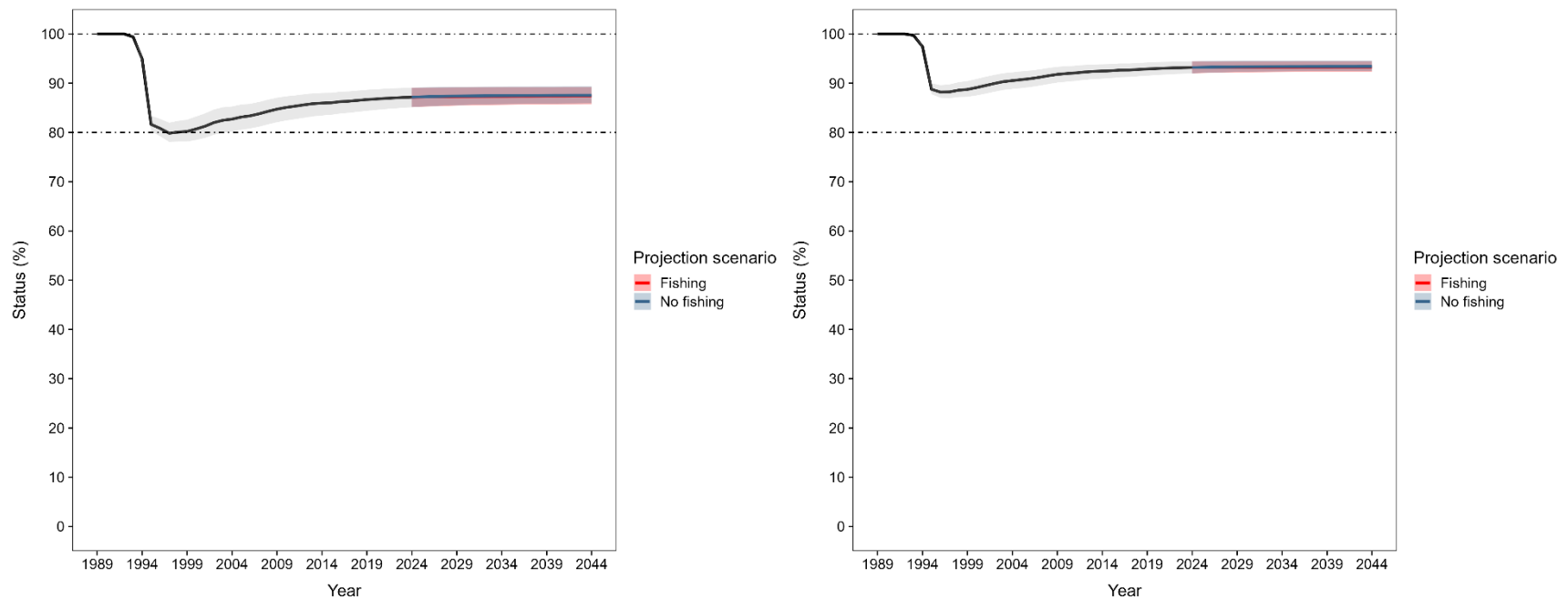


Figure 15: Estimated dynamic Relative Benthic Status (expressed as a percentage) for Antipatharia (black corals) in the Central Louisville Fishery Management Area from 1989 to 2044, using the ROC-linear (left) and Power mean (right) transformations of the Habitat Suitability Index values. The black lines indicates the “Mean” scenario and uses the primary values of depletion (D) and recovery (R), the lower extent of the shaded area represents the “Low” scenario and uses the +20% estimate of D and -20% estimate of R, and the upper extent of the shaded area represents the “High” scenario and uses the -20% estimate of D and +20% estimate of R (see Table 6). The “Fishing” projection assumes continued fishing between 2025 and 2044 at a constant level sufficient to take the current orange roughy catch limit in each FMA, and with recent average bottom longline effort; the “No fishing” projection assumes no bottom fishing between 2025 and 2044.

Table 15: Low, mean, and high dynamic Relative Benthic Status estimates of current status (C), future status after cessation of fishing from 2025 (FNF), and future status with fishing (FF) for the **South Louisville** Fishery Management Area (FMA) using Bottom Trawl management Areas (BTMAs) implemented under [CMM03-2023](#), using two alternative Habitat Suitability Index (HSI) transformations (ROC-linear and Power mean) for each Vulnerable Marine Ecosystem (VME) indicator taxon. Boxes in ROC-linear transformation columns marked “–” indicate no cells within the region with HSI > ROC cut-off; * indicates taxa with < 1% of their HSI within the FMA.

VME indicator taxa habitat		FMA						Outside BTMAs						Inside BTMAs					
		ROC-linear			Power mean			ROC-linear			Power mean			ROC-linear			Power mean		
		C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF
Stony corals (<i>Solenosmilia variabilis</i>)	Low	0.912	0.939	0.936	0.893	0.926	0.923	0.983	0.993	0.993	0.976	0.990	0.989	0.876	0.913	0.908	0.860	0.900	0.896
	Mean	0.932	0.955	0.952	0.918	0.945	0.942	0.990	0.996	0.996	0.985	0.993	0.993	0.904	0.934	0.930	0.891	0.925	0.921
	High	0.953	0.971	0.968	0.944	0.965	0.962	0.994	0.998	0.998	0.991	0.996	0.996	0.933	0.958	0.954	0.925	0.952	0.948
Stony corals* (<i>Madrepora oculata</i>)	Low	0.996	0.999	0.999	0.996	0.999	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.905	0.987	0.987	0.987	0.995	0.994
	Mean	0.999	1.000	1.000	0.998	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.966	0.998	0.998	0.993	0.997	0.996
	High	0.999	1.000	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.987	1.000	1.000	0.996	0.999	0.998
Stony corals (<i>Goniocorella dumosa</i>)	Low	0.932	0.946	0.942	0.957	0.968	0.963	0.994	0.997	0.997	0.998	1.000	1.000	0.895	0.916	0.910	0.932	0.948	0.940
	Mean	0.948	0.958	0.955	0.970	0.975	0.972	0.996	0.997	0.997	0.999	1.000	1.000	0.920	0.936	0.930	0.951	0.960	0.954
	High	0.963	0.968	0.966	0.975	0.977	0.974	0.998	0.999	0.999	1.000	1.000	1.000	0.943	0.950	0.946	0.959	0.963	0.958
Stony corals* (<i>Enallopsammia rostrata</i>)	Low	–	–	–	0.981	0.989	0.988	–	–	–	0.999	0.999	0.999	–	–	–	0.964	0.979	0.977
	Mean	–	–	–	0.988	0.993	0.993	–	–	–	0.999	0.999	0.999	–	–	–	0.977	0.987	0.985
	High	–	–	–	0.994	0.997	0.996	–	–	–	1.000	1.000	1.000	–	–	–	0.989	0.993	0.992
Black corals (Antipatharia)	Low	0.920	0.933	0.929	0.971	0.977	0.975	0.994	0.996	0.996	0.998	0.998	0.998	0.892	0.910	0.904	0.951	0.960	0.957
	Mean	0.939	0.947	0.944	0.980	0.982	0.981	0.996	0.996	0.996	0.998	0.998	0.998	0.918	0.929	0.924	0.965	0.970	0.968
	High	0.954	0.958	0.955	0.986	0.987	0.986	1.000	1.000	1.000	1.000	1.000	1.000	0.938	0.942	0.939	0.975	0.977	0.975
Alcyonacea* (non-gorgonian)	Low	0.997	1.000	0.999	0.997	1.000	0.999	0.991	1.000	0.998	0.992	1.000	0.998	0.998	1.000	0.999	0.999	1.000	0.999
	Mean	0.999	1.000	0.999	0.999	1.000	0.999	0.998	1.000	0.999	0.998	1.000	0.999	0.999	1.000	0.999	0.999	1.000	0.999
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	1.000	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000
Gorgonians* (gorgonian Alcyonacea)	Low	0.969	0.974	0.972	0.974	0.979	0.977	0.998	0.999	0.999	0.997	0.998	0.998	0.951	0.959	0.956	0.958	0.965	0.963
	Mean	0.977	0.979	0.978	0.981	0.984	0.982	0.999	1.000	1.000	0.999	1.000	1.000	0.964	0.967	0.964	0.969	0.972	0.971
	High	0.984	0.985	0.984	0.988	0.989	0.988	1.000	1.000	1.000	1.000	1.000	1.000	0.975	0.976	0.975	0.979	0.981	0.980
Hydrocorals (Stylasteridae)	Low	0.976	0.976	0.976	0.981	0.981	0.981	1.000	1.000	1.000	0.998	0.999	0.999	0.973	0.973	0.973	0.976	0.977	0.977
	Mean	0.985	0.989	0.989	0.990	0.992	0.992	1.000	1.000	1.000	0.999	0.999	0.999	0.983	0.988	0.988	0.987	0.991	0.990
	High	0.989	0.989	0.989	0.993	0.993	0.993	1.000	1.000	1.000	0.999	0.999	0.999	0.988	0.988	0.988	0.991	0.991	0.991
Sponges* (Porifera Demospongiae)	Low	0.981	0.981	0.981	0.977	0.983	0.983	1.000	1.000	1.000	0.999	1.000	1.000	0.806	0.806	0.806	0.911	0.935	0.935
	Mean	0.981	0.981	0.981	0.985	0.985	0.985	1.000	1.000	1.000	1.000	1.000	1.000	0.806	0.806	0.806	0.940	0.943	0.942
	High	0.994	0.994	0.994	0.993	0.993	0.993	1.000	1.000	1.000	1.000	1.000	1.000	0.933	0.940	0.940	0.971	0.973	0.973
Sponges* (Porifera Hexactinellida)	Low	0.997	0.997	0.997	0.997	0.998	0.998	1.000	1.000	1.000	1.000	1.000	1.000	0.988	0.989	0.989	0.990	0.991	0.991
	Mean	0.999	0.999	0.999	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.995	0.995	0.995	0.996	0.996	0.996
	High	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	1.000	1.000	0.999	1.000	1.000
Sea pens*	Low	1.000	1.000	1.000	0.997	0.997	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.994	0.995	0.994

VME indicator taxa habitat		FMA						Outside BTMAs						Inside BTMAs					
		ROC-linear			Power mean			ROC-linear			Power mean			ROC-linear			Power mean		
		C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF	C	FNF	FF
(Pennatulacea)	Mean	1.000	1.000	1.000	0.998	0.998	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	High	1.000	1.000	1.000	0.999	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Anemones* (Actiniaria)	Low	-	-	-	0.993	0.993	0.993	-	-	-	1.000	1.000	1.000	-	-	-	0.988	0.988	0.988
	Mean	-	-	-	0.995	0.995	0.995	-	-	-	1.000	1.000	1.000	-	-	-	0.992	0.992	0.991
	High	-	-	-	0.996	0.996	0.996	-	-	-	1.000	1.000	1.000	-	-	-	0.994	0.994	0.993
Zoanthid hexacorals* (Zoantharia)	Low	0.994	0.994	0.994	0.992	0.995	0.994	1.000	1.000	1.000	0.999	1.000	1.000	0.981	0.982	0.982	0.984	0.989	0.988
	Mean	0.994	0.994	0.994	0.995	0.996	0.996	1.000	1.000	1.000	1.000	1.000	1.000	0.982	0.982	0.982	0.989	0.992	0.991
	High	0.994	0.994	0.994	0.997	0.997	0.997	1.000	1.000	1.000	1.000	1.000	1.000	0.982	0.982	0.982	0.993	0.995	0.994
Hydroids * (Hydrozoa)	Low	0.995	0.995	0.995	0.989	0.991	0.990	0.998	0.999	0.999	0.999	0.999	0.999	0.991	0.992	0.991	0.980	0.983	0.981
	Mean	0.996	0.996	0.996	0.992	0.993	0.992	1.000	1.000	1.000	1.000	1.000	1.000	0.993	0.993	0.993	0.985	0.986	0.985
	High	0.998	0.998	0.998	0.995	0.995	0.995	1.000	1.000	1.000	1.000	1.000	1.000	0.996	0.996	0.995	0.991	0.991	0.990
Bryozoans (Bryozoa)	Low	0.991	0.993	0.992	0.988	0.991	0.990	0.999	1.000	1.000	0.999	1.000	1.000	0.982	0.986	0.985	0.978	0.982	0.981
	Mean	0.994	0.995	0.994	0.992	0.993	0.993	1.000	1.000	1.000	1.000	1.000	1.000	0.988	0.990	0.989	0.985	0.987	0.986
	High	0.996	0.996	0.996	0.995	0.995	0.995	1.000	1.000	1.000	1.000	1.000	1.000	0.992	0.993	0.992	0.990	0.991	0.990
Armless stars* (Brisingida)	Low	0.992	0.992	0.992	0.991	0.992	0.991	0.998	0.998	0.998	0.998	0.998	0.998	0.987	0.987	0.987	0.986	0.987	0.986
	Mean	0.994	0.994	0.994	0.993	0.993	0.993	0.998	0.998	0.998	0.998	0.998	0.998	0.991	0.991	0.990	0.990	0.990	0.989
	High	0.997	0.997	0.997	0.996	0.996	0.996	0.999	0.999	0.999	0.999	0.999	0.999	0.995	0.995	0.995	0.994	0.994	0.994
Sea lilies & feather stars (Crinoidea)	Low	0.990	0.990	0.990	0.991	0.992	0.991	0.998	0.998	0.998	0.998	0.998	0.998	0.982	0.983	0.982	0.984	0.985	0.984
	Mean	0.992	0.993	0.992	0.993	0.994	0.993	0.998	0.998	0.998	0.998	0.998	0.998	0.987	0.987	0.986	0.989	0.989	0.989
	High	0.995	0.996	0.995	0.996	0.996	0.996	1.000	1.000	1.000	1.000	1.000	1.000	0.991	0.992	0.991	0.993	0.993	0.993

5. Discussion

This revised assessment of relative benthic status for VME indicator taxa within the Fishery Management Areas (FMAs) of the Evaluated Area portion of SPRFMO brings together updated information on several aspects of the input parameters, including: fishing impacts from bottom trawling and bottom longlining for the four years since the last complete assessment; recently completed habitat suitability models that allow for status estimation for an additional seven VME indicator taxa; an expert elicitation process for revising and updating depletion and recovery rates for 17 VME indicator taxa; and a re-assessment of the relationship between modelled habitat suitability and observed abundance.

Perhaps the key element of this updated assessment, however, is the use of an alternative implementation of RBS (dynamic RBS) that incorporates a time series of estimates of spatial impacts (rather than a single spatial layer representing average impacts for the period examined as used previously to calculate equilibrium RBS) so that status can be estimated for individual years, including projected status into the future. Although the use of this alternative method limits comparison of estimated status with that presented in the 2023 BFIA, this update represents a substantial improvement in the interpretability and potential utility of outputs, where an estimate of status is available for a specific point in time rather than (in equilibrium RBS) for an unspecified time in the future when an equilibrium status has been achieved for a constant level of spatial impact. Dynamic RBS also does not require the manipulation and partitioning of historic and future spatial impact levels that were applied to the equilibrium RBS assessment in the 2020 and 2023 BFIA's to account for the considerable annual variation in historical fishing impacts.

The revised inputs and model development will have influenced the estimation of status to different extents and in different ways, but together they have allowed for a more complete and up to date impact assessment that can more clearly highlight taxa and management areas for which status of VME indicator taxa may be below agreed threshold status levels, and the degree to which recovery of status may be possible into the future, including under different fishing effort scenarios. However, there is still a substantial degree of uncertainty associated with the estimated status due to the inherent uncertainty within the input parameters, and this was acknowledged here by the application of a range of sensitivities in the estimation of status in each case.

Uncertainty in the input habitat suitability models stems from a range of sources, including lower than ideal levels of sampling, uneven distribution of taxon sample sites, uncertainty in environmental predictor variables, missing environmental predictor variables, and the model structure itself. Some of this uncertainty is captured specifically in spatial layers of the coefficient of variation (CV) associated with each model, and this was incorporated into the dRBS assessment primarily through down-weighting HSI values in the ROC-linear transformation assessment. The use of habitat suitability models to estimate abundance is in itself a source of uncertainty, with some poor correlations shown here between predicted habitat suitability and observed abundance. The SPRFMO Commission recognizes the benefits in using abundance models in place of habitat suitability models for the estimation of RBS, with a Bottom Fishery Impact Assessment subtask in the 2024 Scientific Committee Multi-annual Workplan ([COMM 12 – Report ANNEX](#)

4a) to validate abundance models currently under production for VME indicator taxa using independent data.

There remains considerable uncertainty around the estimates of taxon-specific depletion and recovery rates, likely more than for any other input into the RBS assessment. Although the survey of experts for revising these rates was valuable and likely resulted in improved estimates for these inputs, this cannot be easily verified. The uncertainty associated with the depletion and recovery inputs was only able to be accounted for in this assessment by providing sensitivities around status estimates for best case (low D/high R) and worst case (high D/low R) based on an arbitrary $\pm 20\%$ of median values. It is unknown whether these ranges are sufficient to account for the uncertainty in the values assigned to the individual stony coral taxa assessed (e.g., *Goniocorella dumosa*), and this worsens for taxa which comprise multiple species, for example Hydroids or Bryozoans both of which are represented by over 100 species in the study area (Bennion et al. 2024). Further improvement on this aspect of RBS estimation will ideally require dedicated experimental work to determine depletion and recovery parameters for benthic fauna in deep-sea environments, as well as continued studies on growth, reproduction, dispersal capabilities, and other ecological aspects of the constituent species of the taxa assessed.

The assessment of relative benthic status is more usefully based on the estimation of abundance of taxa, as Conservation and Management Measures typically try to maintain or increase the abundance of vulnerable or threatened species. For this reason, habitat suitability values were transformed in this assessment to better reflect abundance using two approaches, ROC-linear and Power mean transformations, with uncertainty in the relationship between habitat suitability and abundance acknowledged by presenting results using these two alternatives, and not considering a case using raw HSI values. Assessed relative benthic status was not greater for one method over the other overall, with similar results achieved for the two methods for most VME indicator taxa, even when status was substantially reduced. There were some exceptions to this, however, with appreciably lower status for *Goniocorella dumosa* (Scleractinia) in several FMAs, and higher status for Antipatharia in one FMA, when using the Power mean transformation of habitat suitability.

The ability to estimate relative benthic status annually, and to predict future status under alternative future fishing scenarios with dynamic RBS has allowed an assessment of whether status is below a given acceptable threshold (e.g., the 0.8 or 80% value used by MSC and adopted by SPRFMO) and of the time required for recovery of status to a level above this threshold on cessation of fishing to determine if a presumed impact is temporary. In most FMAs, and for most VME indicator taxa, current relative benthic status is estimated to be well above 0.8 and typically between 0.95 and 1.00. However, for a few taxa in some FMAs, current status is below these levels. These are *Goniocorella dumosa* (Scleractinia) in North Lord Howe, West Norfolk, and Central Louisville; *Madrepora oculata* (Scleractinia) in Northwest Challenger; *Enallopsammia rostrata* (Scleractinia) in Northwest Challenger; hydrocorals (Stylasteridae) in Central Lord Howe and Central Louisville; black corals (Antipatharia) in Northwest Challenger and Central Louisville; and *Solenosmilia variabilis* (Scleractinia) in North and South Louisville.

Future projections without fishing largely predict increasing status for taxa that have been impacted to levels below 0.8, in most cases to well above 0.8 and still climbing (albeit sometimes very slowly) after 20 years, and show similar results for each HSI transformation option. One exception to this finding is for hydrocorals in the Central Lord Howe FMA for which the ROC-linear HSI transformation option indicated no recovery after a strong initial decline in status but the Power mean sensitivity indicated only a brief period where status falls below 0.8. In this case, status is preserved for the Power mean option because a substantial proportion of the habitat suitability is in areas where values fall below the ROC-linear cut-off, and these areas are impacted less by early trawl fishing effort. Similar contrasts exist between transformation options for projections of *Goniocorella dumosa* in the West Norfolk and Central Louisville FMAs, but in these cases the Power mean option is the more pessimistic of the two. The Power mean option also shows a stronger decline in status for *Goniocorella dumosa* in the North Lord Howe FMA but predicts recovery to a similar level to that of the ROC-linear option after 20 years. The main reason for these results is that ROC cut-off for *Goniocorella dumosa* is relatively low (lower than for any other taxon) and, in some FMAs more than others, many more non-zero cells are retained for the calculations, while the Power mean transformation strongly reduces lower values for this taxon. This means that fishing impacts in certain years can cause a large overall decline in status for the Power mean option while the ROC-linear is much less affected. Future projections indicate that improvement of status after strong declines can still occur with continued fishing (at an average level of bottom longline effort and constant levels of annual bottom trawl effort sufficient to catch orange roughy catch limits) but generally not for scenarios with worst case D and R values. It is important to note that the future fishing scenario used here is only a coarse representation of possible future fishing effort, limiting fishing to current open areas and current catch limits, both of which could change substantially over the next 20 years. Lack of complete catch data at the individual fishing event level also precluded a more nuanced formulation of future fishing effort, in which catches in each FMA could be recreated by sampling from historical fishing events, so that it was necessary here to use an effort scalar based on catches and catch limits across all FMAs combined.

6. Recommendations

It is recommended that the Scientific Committee:

- **Notes:**
 - That the quantitative benthic impact assessment component of the 2023 Cumulative BFIA has been updated, using an alternative implementation of RBS.
 - That the update incorporates bottom fishing impact data from recent fishing activity, re-assesses taxon-specific depletion and recovery values, re-evaluates relationships between estimated habitat suitability and observed abundance, and includes assessments for the full suite of 17 modelled VME indicator taxa.
 - That the forward projection scenarios have been updated to reflect changes in catch limits, although there is a high level of uncertainty in estimates of future fishing effort.
- **Agrees:**
 - That the revised methods used in the update are consistent with the requirements of the BFIA and should be applied to the review and update of the BFIA scheduled for 2026.

- That, with respect to impacts on VMEs:
 - the estimation of present status of most VME indicator taxa in most areas is qualitatively favourable across a range of sensitivity analyses,
 - however, for some taxa in some FMAs the qualitative assessment is less favourable (e.g., for the stony coral *Goniocorella dumosa* in the North Lord Howe, West Norfolk, and Central Louisville FMAs, and Stylasteridae in the Central Lord Howe FMA).
- To determine the suitability of the ongoing use of the MSC thresholds (status level and timeframe) for identifying SAIs with dRBS, or recommends to the Commission that it add to the SC multi-annual workplan a task to refine these thresholds.
- **Recommends:**
 - That the revised benthic impact assessment is added as an addendum to the Cumulative Bottom Fishery Impact Assessment for Australian and New Zealand bottom fisheries, 2023 (AUS/NZL).
 - That the Commission adds to the SC multi-annual workplan a task to further develop and validate abundance models for VME indicator taxa so that they can be used in future updates of the benthic impact assessment to reduce the need for data transformations.
 - That the Commission adds to the SC multi-annual workplan a task to conduct research to improve the reliability and estimation of uncertainty for the D and R values that inform the calculation of dRBS.

7. Acknowledgements

Funding for this updated assessment was provided by Fisheries New Zealand, Ministry for Primary Industries under project SPR2023-01. The authors acknowledge the useful input received from members of the Fisheries New Zealand South Pacific Working Group. We are especially grateful to the 13 scientists who provided their valuable expertise in estimating depletion and recovery rates for the VME indicator taxa assessed here. These were: Malcolm Clark, Ashley Rowden, Kareen Schnabel, Jennifer Beaumont, Niki Davey, Megan Carter, Matt Bennion, Owen Anderson (NIWA); Jordi Tablada, Shane Geange, Lyndsey Holland (DOC); Franzis Althaus (CSIRO); Katie Bigham (University of Washington, Washington, USA (ex NIWA)).

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9. Annex 1

Comparison of model predictions of habitat suitability with observed abundances from analysis of Deep Towed Imaging System (DTIS) video transect data (plots found overleaf).

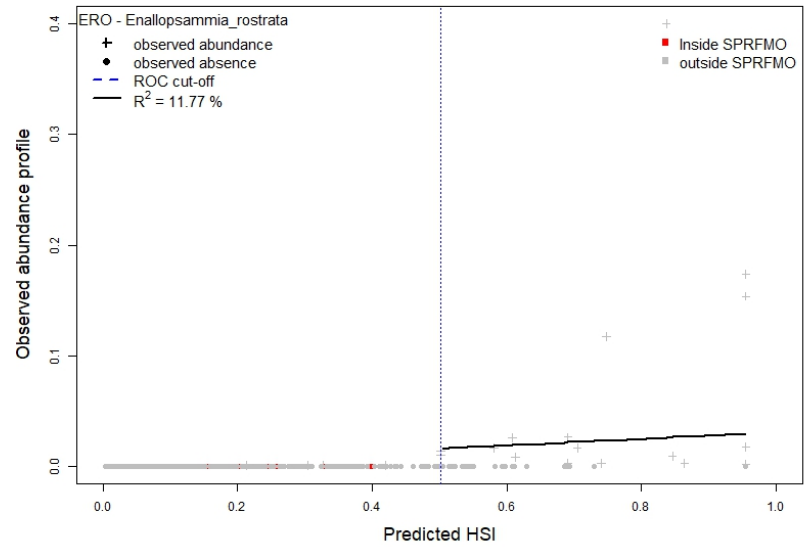
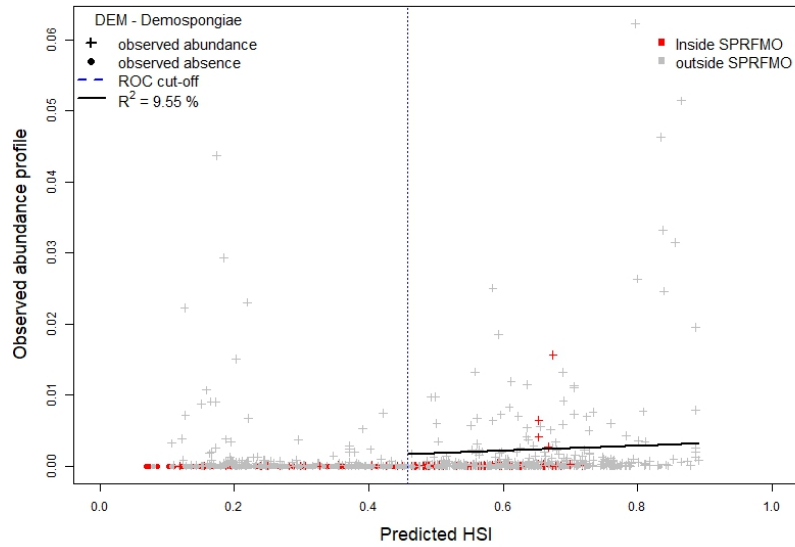
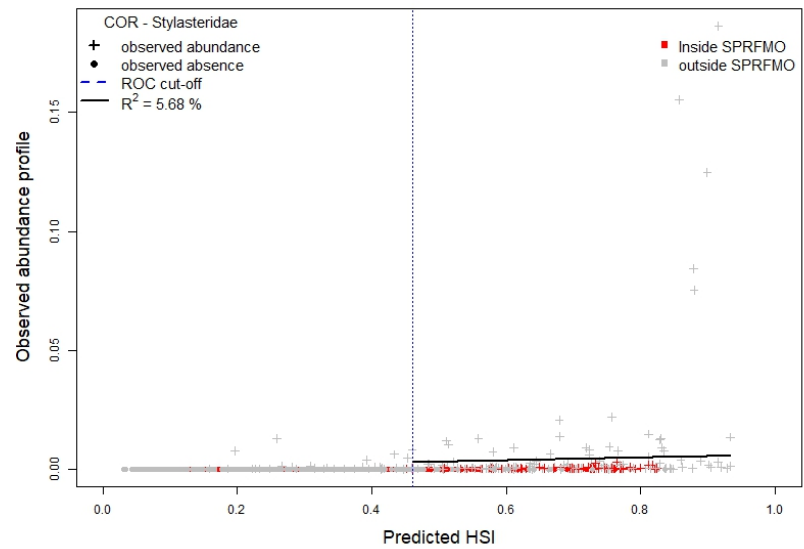
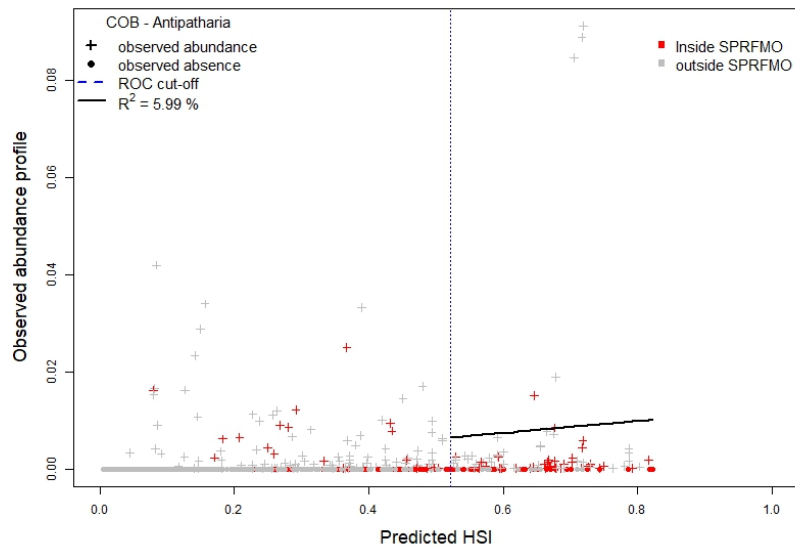


Figure A1: Predicted habitat suitability vs observed abundance, showing a linear fit for HSI values above the VME indicator taxon specific ROC cut-off, shown as a dotted vertical line.

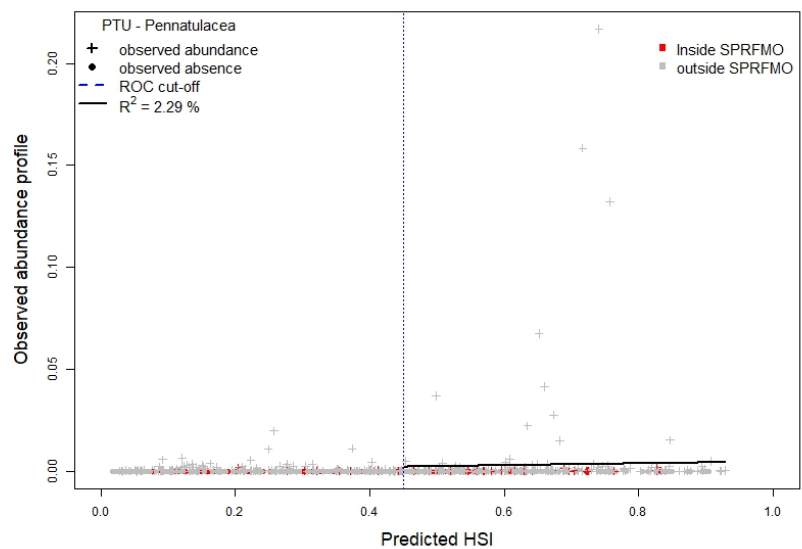
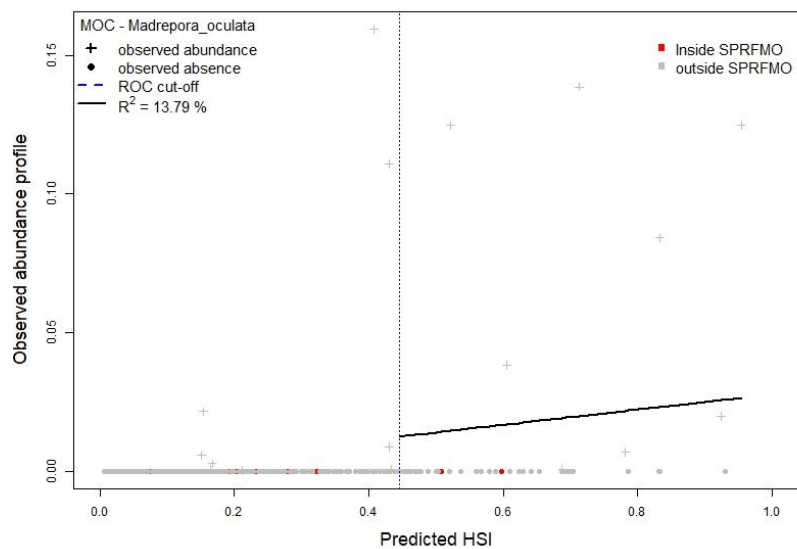
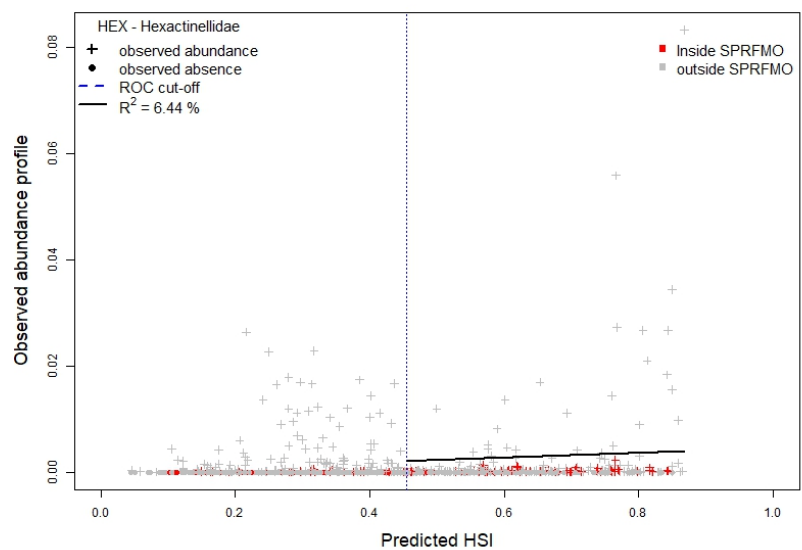
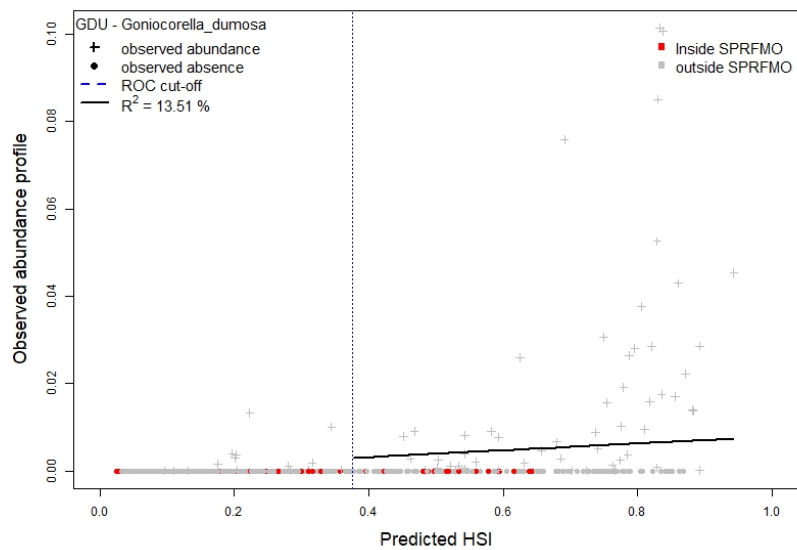


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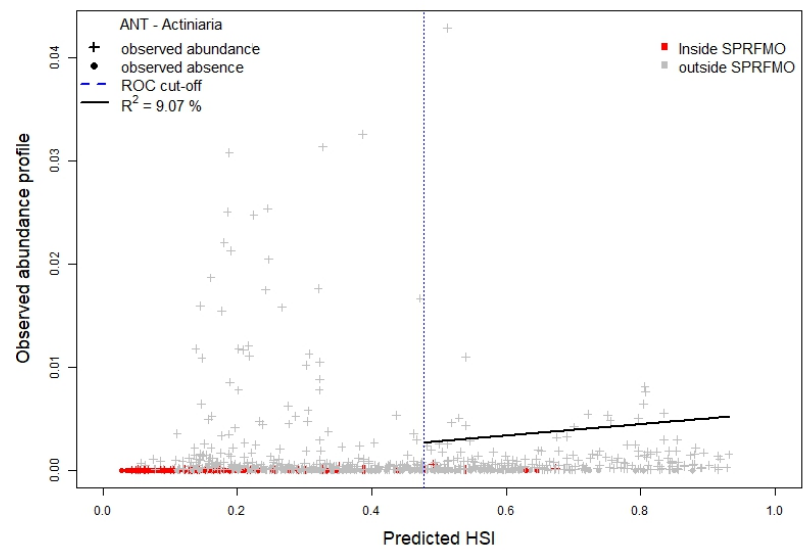
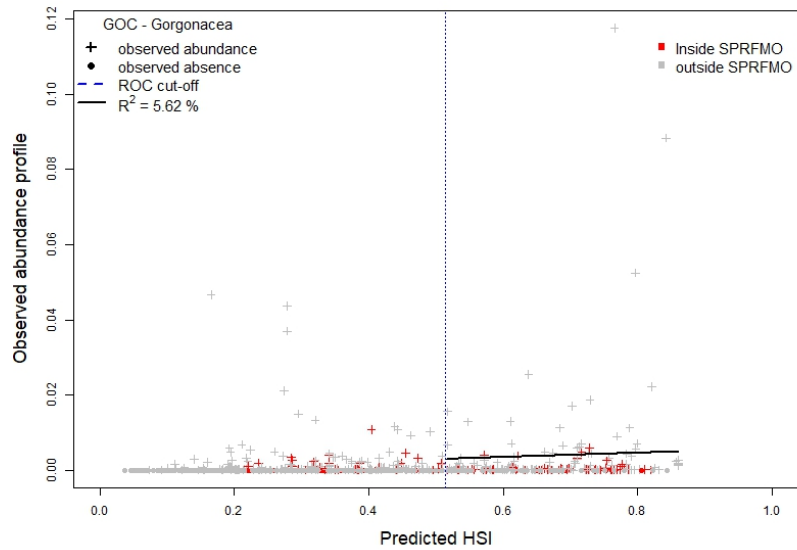
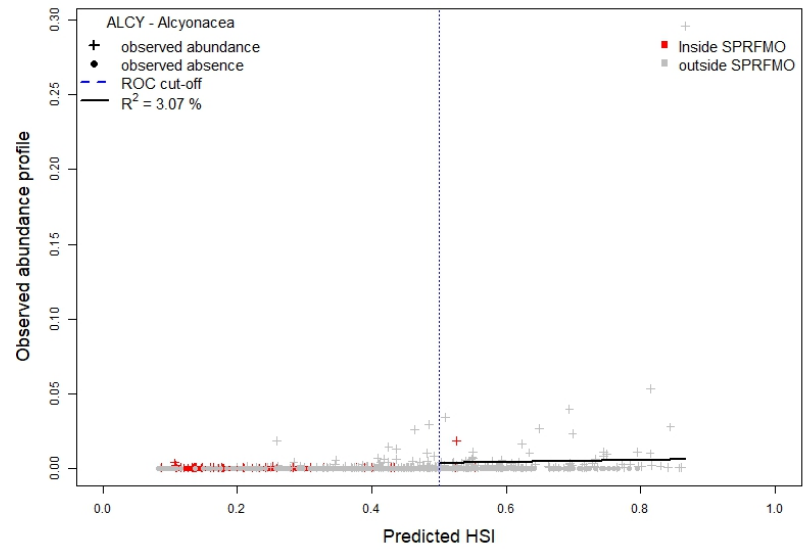
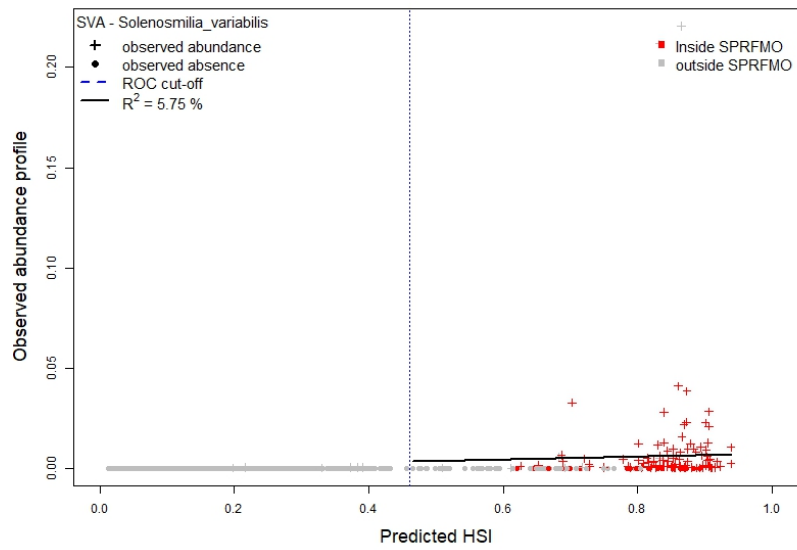


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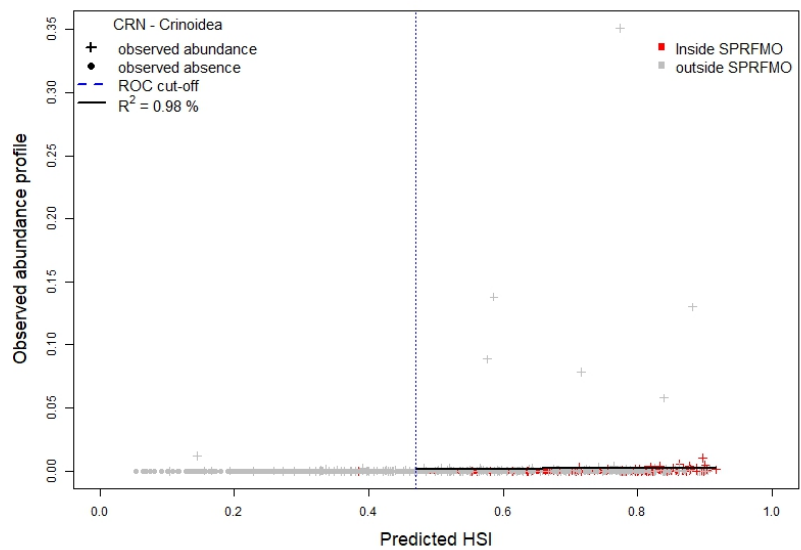


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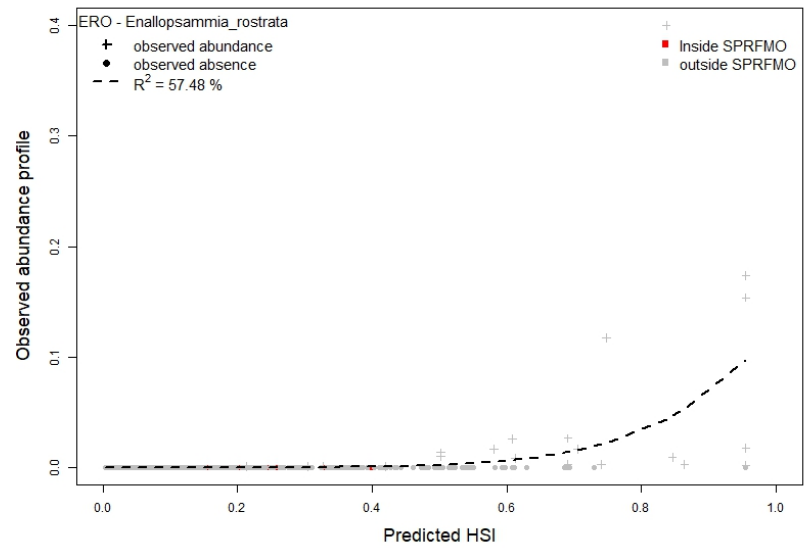
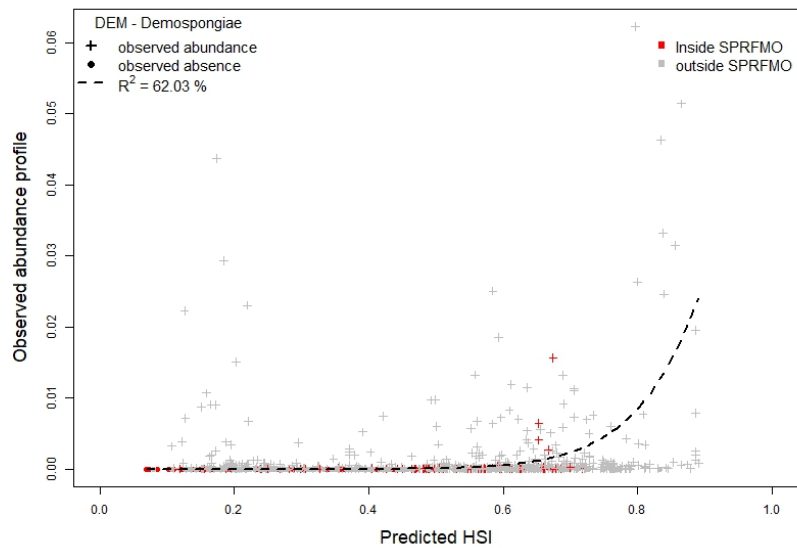
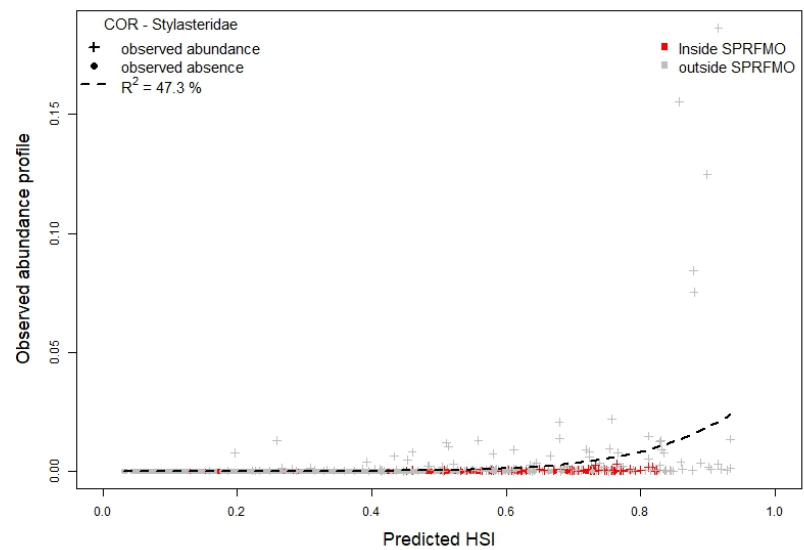
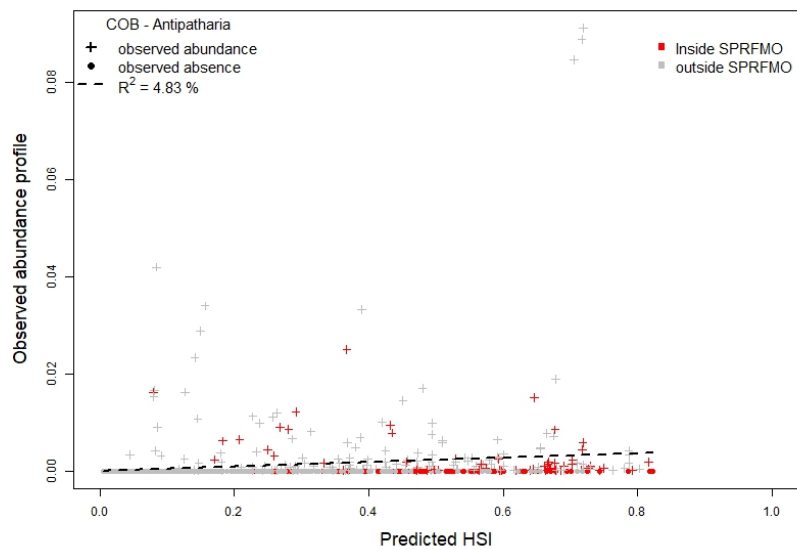


Figure A2: Predicted habitat suitability vs observed abundance, showing a Power mean fit (dashed line) to the data points.

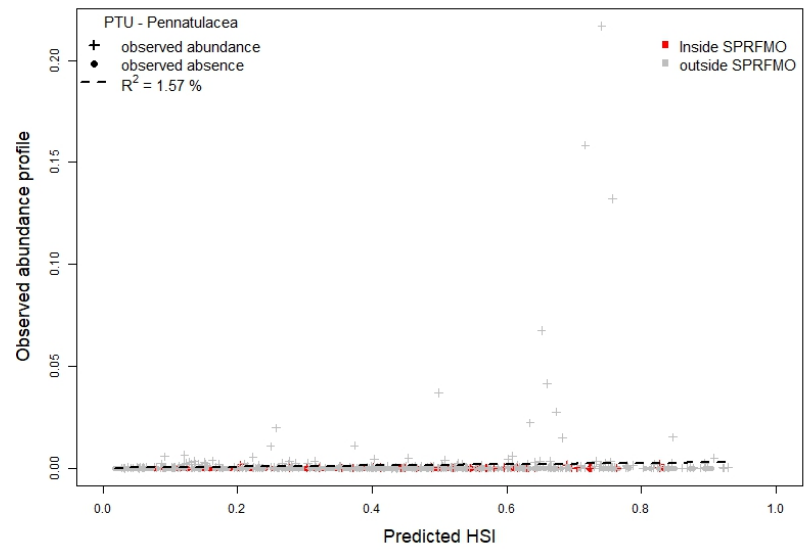
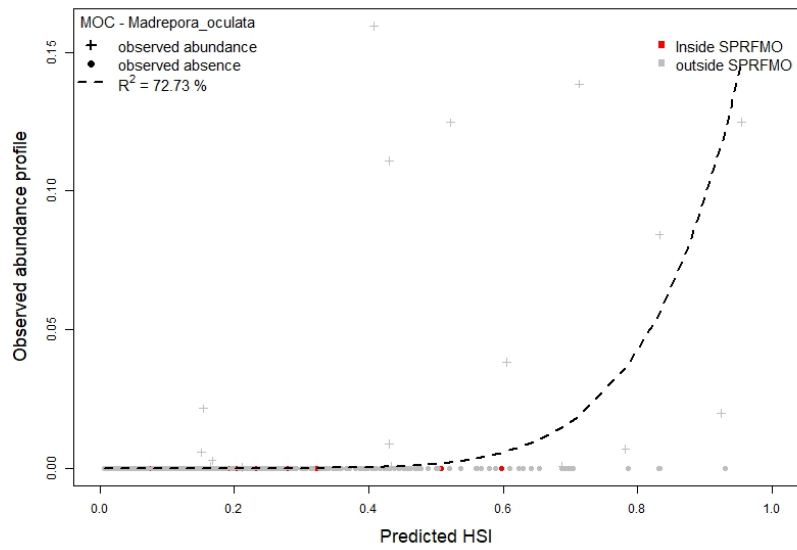
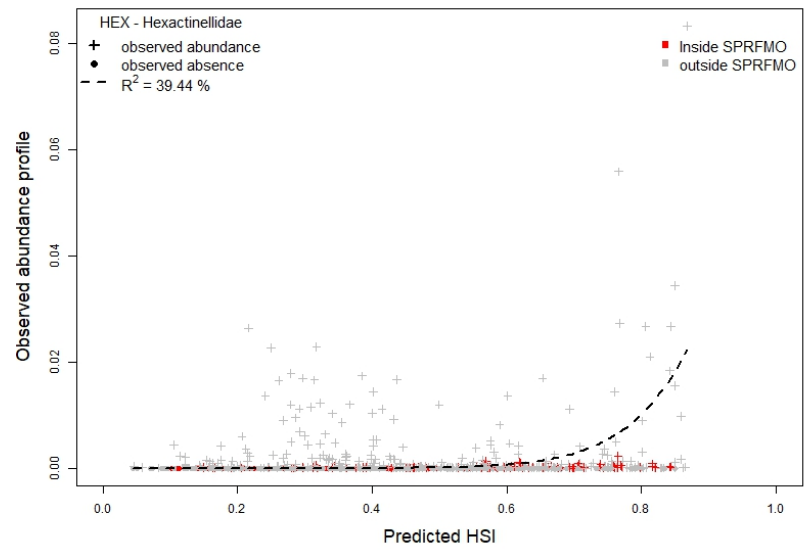
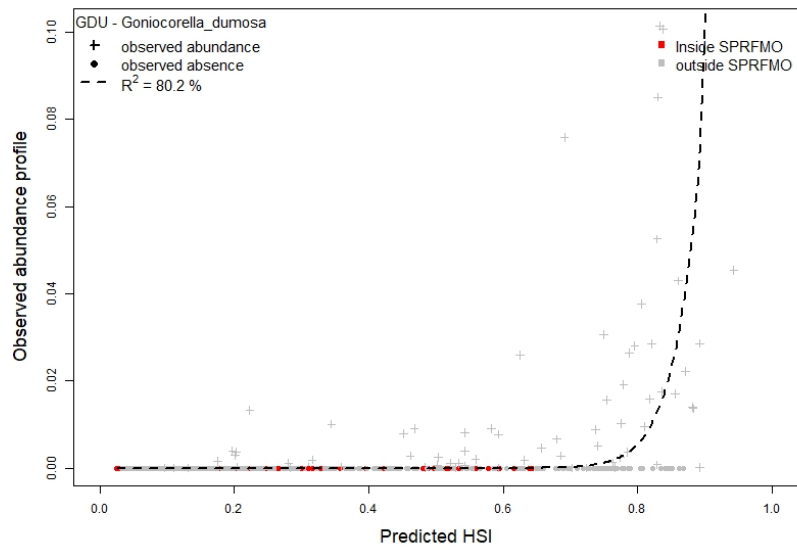


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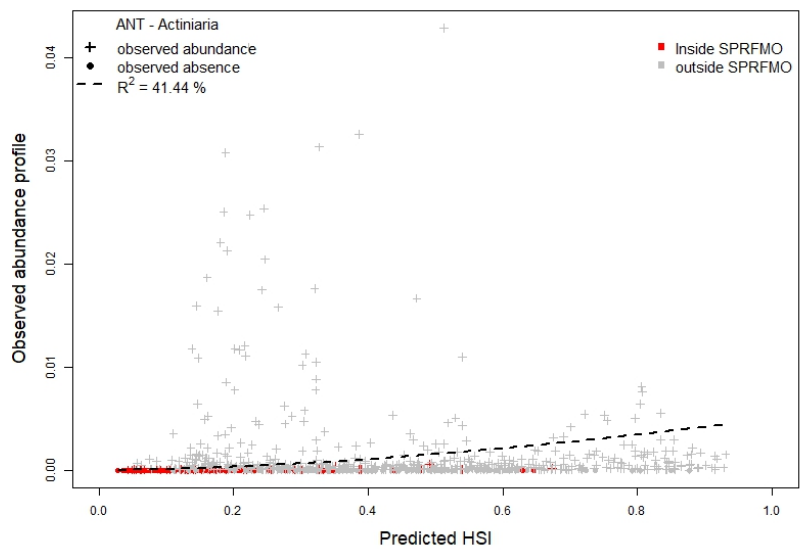
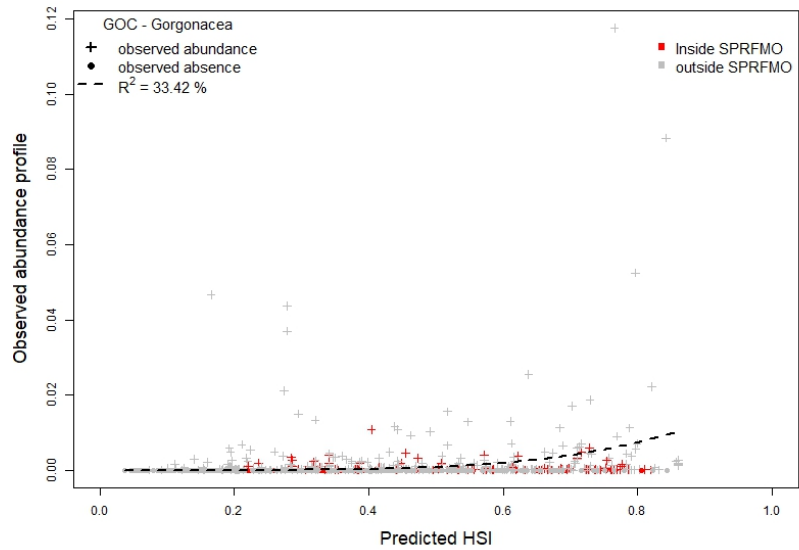
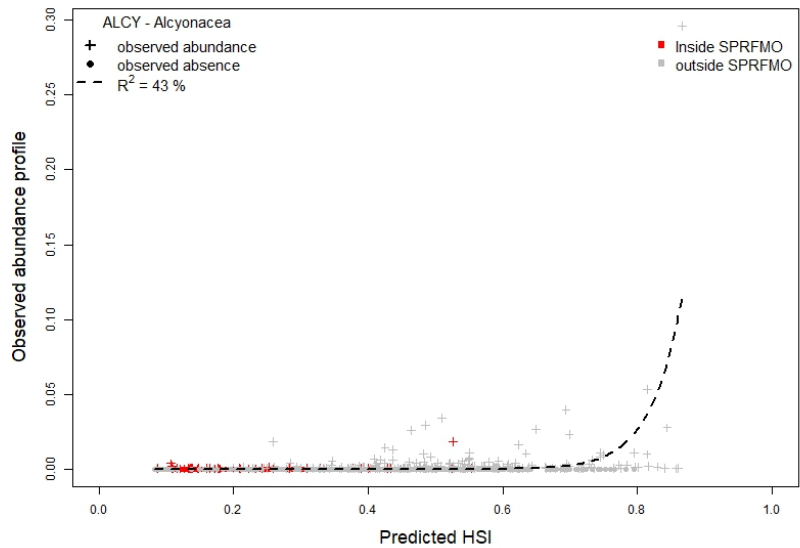
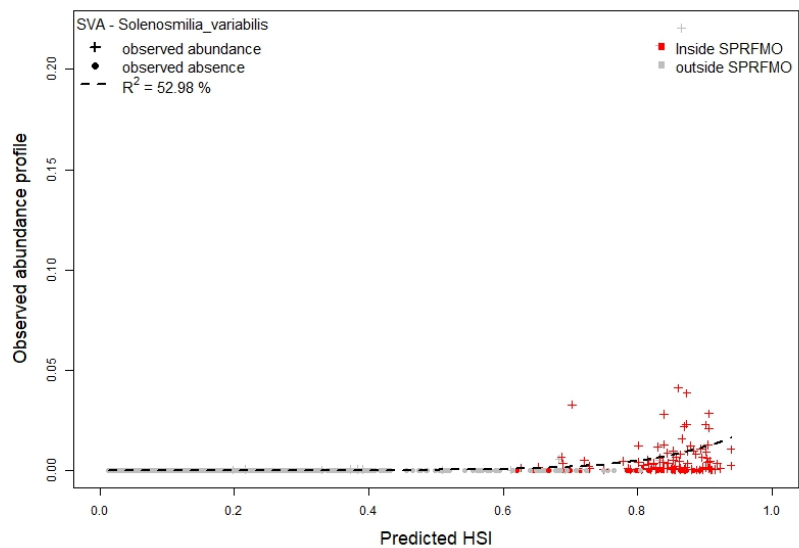


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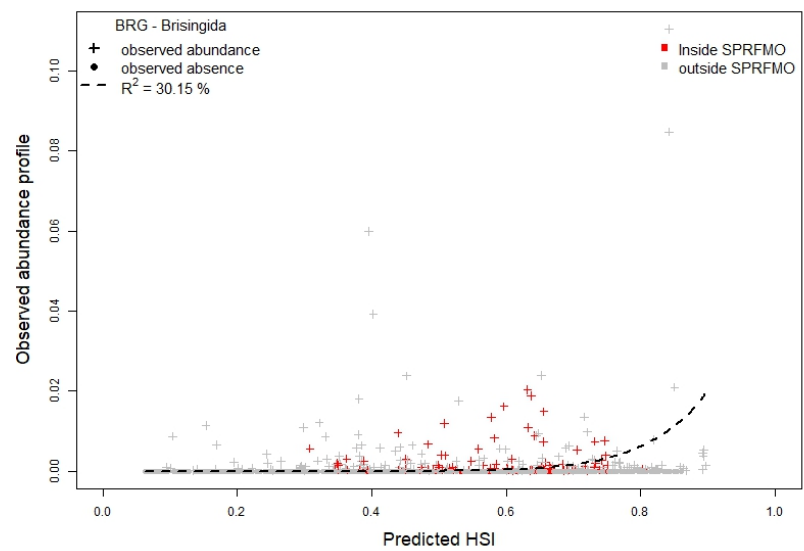
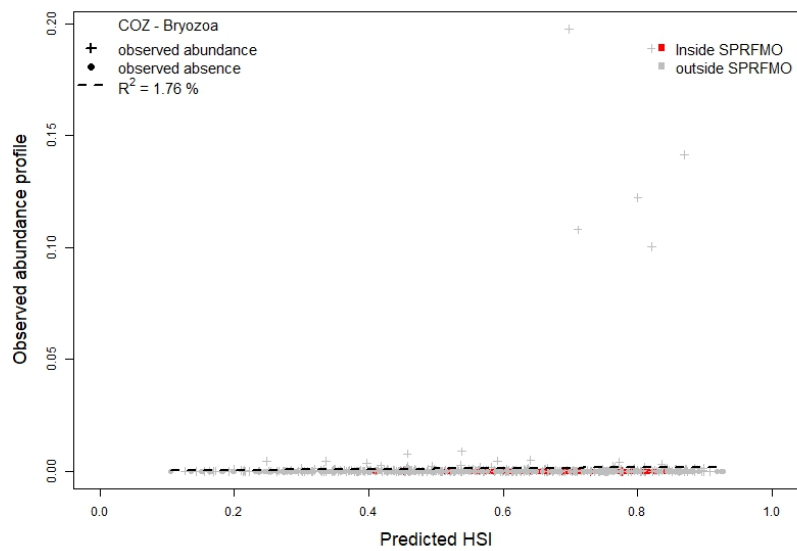
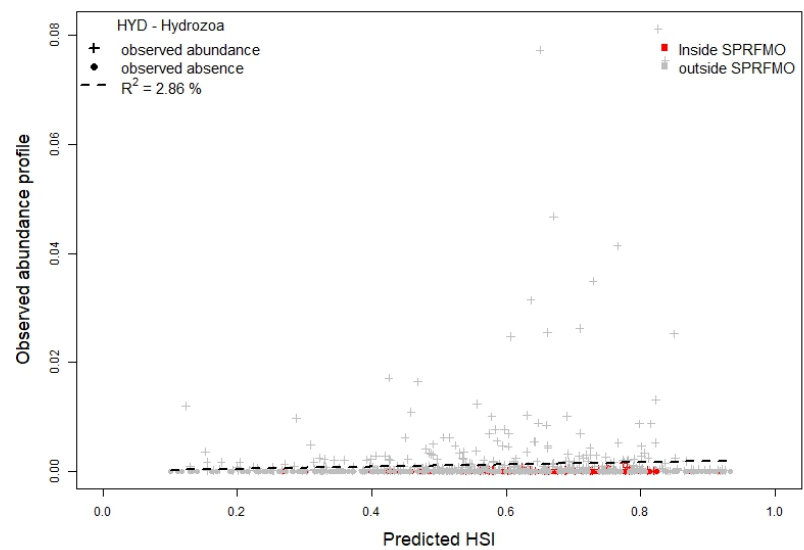
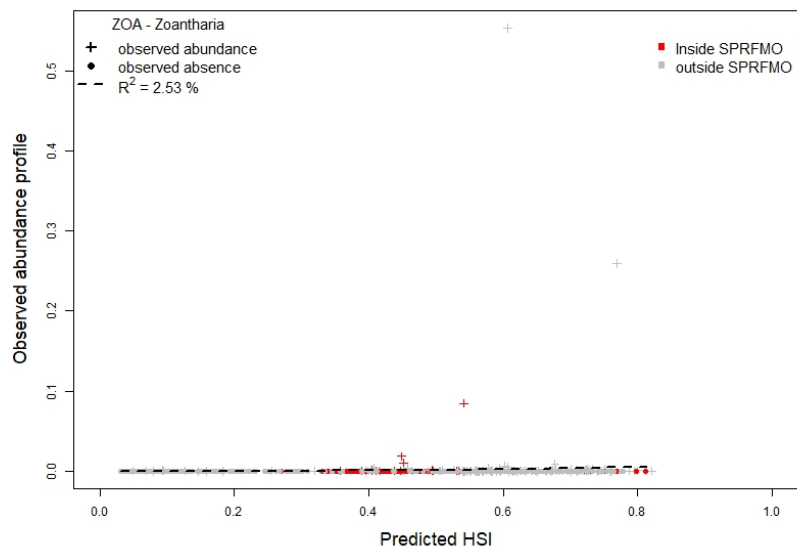


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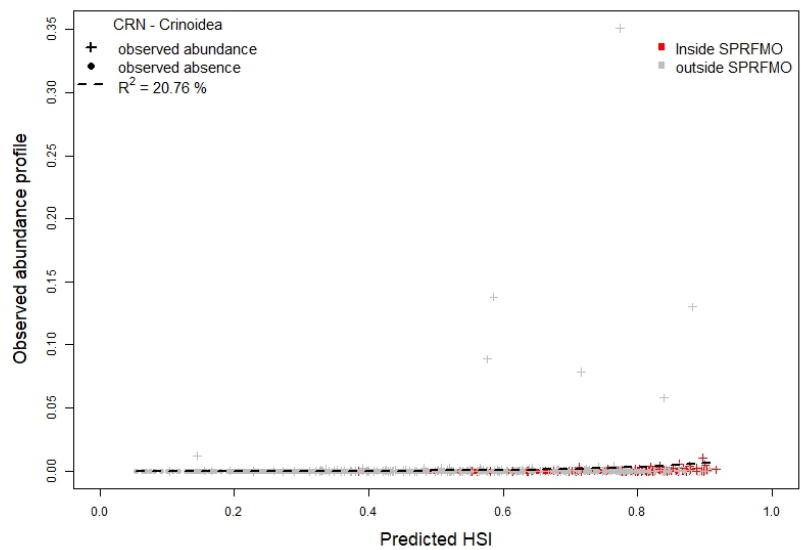


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10. Annex 2

Depletion and recovery survey of experts – questionnaire sent to participants

Expert assessment of depletion rates of VME indicator taxa due to bottom trawling and bottom longlining, and rates of recovery

NIWA scientists are preparing a quantitative spatial assessment of the current status of benthic invertebrate VME indicator taxa in a subset of the SPRFMO Convention Area, in depths below 200 m (see map in “additional information” document). This assessment uses an approach called Relative Benthic Status (RBS) which requires, among other things, taxon-specific estimates of depletion rate (d) due to the passing of a trawl or the sweep of a bottom longline over the seafloor, and intrinsic rates of recovery (R) from such impacts.

Definition of d and R

d = the mortality rate (0–1) suffered by a taxon due to the single pass of a bottom trawl (considering all components, i.e., groundrope, sweeps/bridles, and doors, taken together) or the sweeping of a longline backbone across the seafloor. Note that the area impacted by a trawl or longline from a single fishing event need not be considered as it is calculated separately in RBS, taking into account different trawl types and, for longlines, depths.

R = the intrinsic proportional recovery rate (0–1) of a taxon per year, considering factors such as longevity, growth rates, reproductive mode, substrate requirements (broad or narrow), and any observational data (e.g., time series).

There are only a few empirical studies that have been able to satisfactorily measure rates of depletion and recovery for benthic invertebrates, especially those species designated under SPRFMO as VME indicator taxa. Existing assessments of RBS have been produced for 11 of 17 taxa based on knowledge or estimates of d and R that have been extracted from these studies including some re-assessment of available data.

We now wish to re-assess estimates of RBS for these 11 taxa, as well as estimate RBS for 6 additional taxa not included in the existing assessment, including a re-consideration of d and R values based on the knowledge of experts in relevant fields such as: the deep-sea benthic environment; benthic ecology; invertebrate taxonomy, form, function, growth, and reproduction; and including at least a basic knowledge of likely impacts from deep-sea bottom trawl and longline operations.

The table below provides a starting point for the revision, with values of d and R for bottom trawling and longlining as used for taxa in the existing assessment (white cells), along with initial values to consider for the new taxa (green cells) from the same studies (specifically those of Welsford et al. 2013 and Mormede et al. 2017) underlying values for existing assessment taxa.

Taxon	Taxon Code	Bottom trawling		Longlining	
		d	R	d	R
<i>Solenosmilia variabilis</i>	SVA/CSS	0.67	0.20	0.03	0.20

<i>Madrepora oculata</i>	MOC/CSS	0.67	0.20		0.03	0.20
<i>Goniocorella dumosa</i>	GDU/CSS	0.67	0.20		0.03	0.20
<i>Enallopsammia rostrata</i>	ERO/CSS	0.67	0.20		0.03	0.20
Antipatharia	COB/AQZ	0.50	0.33		0.27	0.33
Alcyonacea (minus "Gorgonacea")	ALCY/ALZ	0.35	0.24		0.03	0.24
"Gorgonacea"	GOC/GGW	0.50	0.27		0.27	0.27
Stylasteridae	COR/AXT	0.41	0.33		0.03	0.33
Demospongiae	DEM/PFR	0.38	0.24		0.14	0.24
Hexactinellidae	HEX/PFR	0.38	0.24		0.14	0.24
Pennatulacea	PTU/NTW	0.34	0.39		0.03	0.39
Actiniaria	ANT/ATX	0.35			0.05	
Zoantharia	ZOA/ZOT	0.38				
Hydrozoa	HYD/HQZ	0.49			0.14	
Bryozoa	COZ/BHZ	0.45			0.09	
Brisingida	BRG/BHZ	0.82				
Crinoidea	CRN/CWD	0.82				

What we are asking of you is: to provide an estimate of d and R (i.e., with minimal reference, if any, to published studies) for any or all of the taxa in the table above, based on your expert knowledge/intuition/opinion. You may take note of the range of values already provided in the table above and consider, for the new taxa especially, similarities among taxa in form, fragility, or life history. You can also consider the strategy recently used to estimate d and R values for RBS as part of a risk assessment for protected New Zealand corals, as well as any useful information you might find in the summary of relevant studies, as provided in the separate "Additional Information" document.

Please insert your estimates of d and R in the table below.

Taxon	Taxon Code	Bottom trawling		Longlining	
		MPI/SPRFMO	d	R	d
<i>Solenosmilia variabilis</i>	SVA/CSS				
<i>Madrepora oculata</i>	MOC/CSS				
<i>Goniocorella dumosa</i>	GDU/CSS				
<i>Enallopsammia rostrata</i>	ERO/CSS				
Antipatharia	COB/AQZ				
Alcyonacea (minus "Gorgonacea")	ALCY/ALZ				
"Gorgonacea"	GOC/GGW				
Stylasteridae	COR/AXT				
Demospongiae	DEM/PFR				
Hexactinellidae	HEX/PFR				
Pennatulacea	PTU/NTW				
Actiniaria	ANT/ATX				
Zoantharia	ZOA/ZOT				

Hydrozoa	HYD/HQZ					
Bryozoa	COZ/BHZ					
Brsingida	BRG/BHZ					
Crinoidea	CRN/CWD					

Please return this document to owen.anderson@niwa.co.nz by 14 June 2024

Thank you!

Your input will be acknowledged (unless you choose otherwise) in a resulting report to be presented to the SPRFMO Scientific Committee later in 2024.

11. Annex 3

Depletion and recovery survey of experts – additional information sent to participants

Additional information

What is the RBS method?

Relative Benthic Status (RBS) (Pitcher et al. 2017).

This method requires spatial estimates of fishing effort and taxon relative abundance (from species distribution models, SDMs), along with taxon and gear-specific estimates of depletion (d) and recovery (R) rates.

Two implementations of RBS are possible:

1. Equilibrium solution of RBS as used in current BFIA which only requires a mean spatial distribution of fishing effort

$$B/K = 1 - Fd/R \text{ where } F < R/d, \text{ otherwise } B/K = 0$$

Where:

B is the long-term relative abundance of biota

K is the carrying capacity (maximum/natural population size, represented by the SDMs)

d is the taxon-specific depletion rate per fishing impact event (trawl or bottom longline)

R is the taxon-specific proportional recovery rate per year

F is trawling effort as swept-area ratio (SAR).

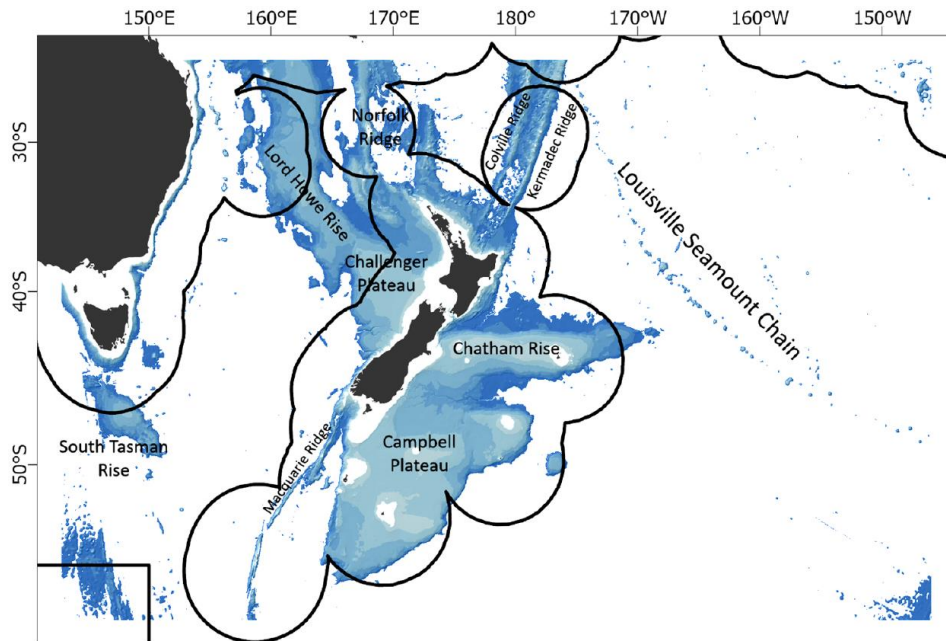
2. Dynamic RBS (which uses a timeseries of annual fishing effort and can provide annual estimates of relative abundance up to the end of the timeseries)

$$\delta B / \delta t = RB(1 - B/K) - dFB$$

Where:

$\delta B / \delta t$ is the rate of change in abundance B in time t

SPRFMO Convention Area and Assessed area



The assessed area comprises all regions of this map outside of the EEZ (black line) of all countries.

Risk Assessment for New Zealand protected corals

A review of the d and R values for many of the 11 current taxa was recently conducted to inform a risk assessment for protected coral taxa under a New Zealand Department of Conservation (DOC) project (DOC23304_INT2022-04). An expert panel of NIWA staff went through the following process:

- A check of the relative values of R used in the existing SPRFMO assessment across the various coral taxa to gauge an initial general order and range of values.
- Age: consideration of maximum likely age as a proxy for overall productivity (i.e., higher maximum age = lower R). See below for more details.
- Growth: growth rates as an indication of how quickly a species (or group of species considered together) can grow to a size or build structures equivalent to those of pre-trawl damage.
- Spawning: whether the taxon comprises mostly broadcast spawners with the potential to rapidly recolonise more distant locations or whether they are brooders with a short dispersal range.
- Substratum preference: strict or broad.
- Recovery time: based on observations (especially from camera survey time series, e.g. the Graveyard seamounts on the Chatham Rise), expert knowledge, and a reality-check based on preliminary $dRBS$ analysis (esp the below plot based on *Goniocorella dumosa* d and R values) – i.e., is it reasonable to expect recovery to be close to pre-impact levels after 10 or 20 years? Or would it take longer? Or much longer?
- Expert opinion.

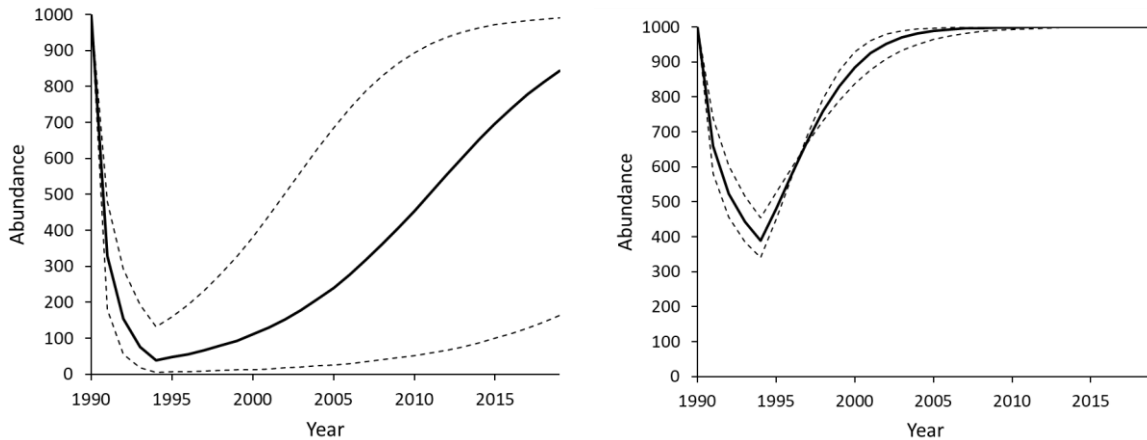


Figure 1: Plot of change in abundance over time as modelled by dRBS. Left, *Goniocorella dumosa* (a species with high depletion (d) and low recovery (R) values); Right, Pennatulacea (with low d and high R). Sensitivities (d and R adjusted by approximately $\pm 20\%$ to make best/worst case scenarios) are shown as dashed lines. In these examples an initial hypothetical population of 1000 individuals experiences a high trawl impact ($SAR=1$) for 4 years, followed by a long period of no fishing.

Outcome of the expert assessment (text from DOC project, slightly edited)

Revised d values

- A gradient of R values was estimated, with *Solenosmilia variabilis* (SVA) having the lowest R value and Stylasteridae (COR) having the highest. This reflected SVA representing large, matrix-forming reef corals, with the active polyps having low growth rates, common asexual budding (even though they are also broadcast spawners), and recruitment observations on the Chatham Rise Graveyard seamounts indicating a 20-year period from being trawled to just visible recruitment with small growing fragments. The other extreme has small hydrocorals (COR ?) which were observed to be a 'weedy' species with rapid colonisation of bare rocky areas.
- *Goniocorella dumosa* (GDU) was ranked with the second lowest R value, reflecting being a brooder, but able to settle on a wide variety of substrate (based on adult distribution) including gravel as well as hard substratum and overlain with sediment. This species also has faster growth than SVA.
- Gorgonian octocoral taxa show roughly similar age and growth characteristics across the taxa (although variable with region). These were deemed to lie in the mid-range of R values.
- Black corals (Antipatharia) were ranked with a higher R than all taxa except COR, because of broadcast spawning, and faster growth rates than the previous cluster.
- A potential recovery of SVA within a few decades following a strong decrease in abundance was deemed to be unrealistic given biological and observational data, and expert opinion. Recovery would be many decades-over a century assuming recovery to a reef-like structure, even though not accumulated on dead matrix to anywhere near the extent of pre-trawled reefs. In keeping with these observations, a value of 0.1 was estimated for R .
- At the other extreme, it was believed hydrocorals could repopulate an area and grow rapidly to a reasonable size, within just several years (as indicated by Graveyard surveys). They were considered somewhat equivalent to sea pens and that was the basis for the actual R value.

- Most other taxa groups were thought to likely have recovery to a reasonable individual size over several decades.
- An important consideration was recovery to what state? With SVA the reef structure could be based on dead matrix several centuries old. With gorgonian-black coral individuals, how large should they be to be termed an adult and hence able to support a sustainable population. With GDU type thickets, as well as the size of individual colonies, how many should there be?
- The final list of R values were considered to be more realistic than those used in the initial SPRFMO assessment, and better represent the likely *relative* gradient in biological recovery dynamics across taxa. However, there was little confidence that *absolute* values were accurate. There is likely to be much variability in recovery, based on the considerations above, but the extent of depletion also has a strong bearing on settlement and recruitment that is poorly understood.

Revised R values for DOC

Species_SpeciesGroup	Species_Code	Previous R	New R
<i>Solenosmilia variabilis</i>	SVA/CSS	0.20	0.10
<i>Goniocorella dumosa</i>	GDU/CSS	0.20	0.20
"Gorgonacea"	GOC/GGW	0.27	0.25
Antipatharia	COB/AQZ	0.39	0.30
Stylasteridae	COR/AXT	0.33	0.39

Revised d values

Relative rates of d were only briefly discussed in the DOC project. the only value of d that was changed was for the gorgonian family (Primnoidae). This change was based on gorgonian's being a typically rigid form of fan-like corals in New Zealand waters (rather than flexible gold coral type forms) and their d value was, therefore, increased from 0.35 proposed to 0.50.

Summary of relevant recent papers on depletion (d) and recovery (R)

1. Wellsford et al. 2013 (Appendix 13)

This paper examined vulnerability of benthic habitats to demersal fishing (trawls, longlines, & traps) in the Southern Ocean part of the Australian EEZ (essentially Patagonian toothfish (BLL, deep) and mackerel icefish (TWL, shallower, <300 m) fisheries). Wellsford et al. 2013 focussed more on depletion than recovery. They used video and still cameras, along with other published data and preserved fresh specimens, to develop a model estimating mortality probability. The relevant taxa examined were: DEM and HEX, ANT, Scleractinia as a whole, Alcyonacea and Gorgonacea (the latter Order being valid at the time), ZOA, COR, COZ. Therefore, we can get some starting values for the new taxa ZOA and COZ from this study (see column M_1 of the two tables below – one for TWL (Table A13.6) and one for BLL (Table A13.8))

They found that *Gorgonians had the highest estimated probabilities of death or damage from all gear types because of their high exposure and brittleness.*

Table A13.6. Estimated probabilities of mortality (*M*) and sub-lethal damage (*D*) to benthic invertebrates after 1, 2 and 3 overlapping demersal trawls, and the minimum number of hauls for *M* to exceed 0.95.

Taxon	<i>M</i> ₁	<i>D</i> ₁	<i>M</i> ₂	<i>D</i> ₂	<i>M</i> ₃	<i>D</i> ₃	Minimum trawls for <i>M</i> _n >0.95
Demospongiae	0.42	0.14	0.78	0.13	0.93	0.05	4
Actiniaria	0.35	0.10	0.82	0.13	0.96	0.03	3
Scleractinia	0.25	0.10	0.64	0.17	0.83	0.11	5
Alcyonacea	0.35	0.10	0.82	0.13	0.96	0.03	3
Gorgonacea	0.72	0.18	0.97	0.03	1.00	0.00	2
Hydroidolina	0.49	0.14	0.87	0.10	0.97	0.02	3
Serpulidae	0.27	0.03	0.93	0.07	1.00	0.00	2
Bryozoa	0.45	0.05	0.95	0.05	1.00	0.00	2
Cirripedia	0.45	0.05	0.95	0.05	1.00	0.00	2
<i>Ctenocidaris nutrix</i>	0.30	0.12	0.66	0.16	0.85	0.10	5
Euryalida	0.25	0.10	0.64	0.17	0.83	0.11	5
Pterobranchia	0.24	0.08	0.71	0.16	0.90	0.07	4
Asciacea	0.30	0.10	0.73	0.15	0.91	0.07	4

Table A13.8 Estimated probabilities of mortality (*M*) and sub-lethal damage (*D*) to benthic invertebrates due to interactions with the mainline of a demersal longline after 1, 5 and 10 overlapping sets, and the minimum number of sets for *M* to exceed 0.95.

Taxon	<i>M</i> ₁	<i>D</i> ₁	<i>M</i> ₅	<i>D</i> ₅	<i>M</i> ₁₀	<i>D</i> ₁₀	Minimum sets for <i>M</i> _n >0.95
Demospongiae	0.14	0.14	0.68	0.23	0.91	0.08	12
Actiniaria	0.05	0.10	0.40	0.40	0.67	0.29	25
Scleractinia	0.03	0.06	0.38	0.40	0.67	0.30	25
Alcyonacea	0.03	0.06	0.38	0.40	0.67	0.30	25
Gorgonacea	0.27	0.18	0.85	0.11	0.98	0.02	8
Hydroidolina	0.14	0.14	0.68	0.23	0.91	0.08	12
Serpulidae	0.12	0.08	0.82	0.13	0.98	0.02	8
Bryozoa	0.09	0.06	0.81	0.14	0.98	0.02	8
Cirripedia	0.09	0.06	0.81	0.14	0.98	0.02	8
<i>Ctenocidaris nutrix</i>	0.02	0.04	0.37	0.40	0.66	0.30	25
Euryalida	0.02	0.04	0.37	0.40	0.66	0.30	25
Pterobranchia	0.04	0.04	0.63	0.25	0.90	0.09	13
Asciacea	0.10	0.10	0.66	0.24	0.91	0.08	12

2. Mormede et al. (2017)

Depletion from the impact of the passing of a trawl was estimated from a combination of the separate components of a trawl (doors, sweep/bridles, ground gear), where some trawls were not in contact with the bottom at all times. This was done according to 3 functional groups of taxa (Large, Erect, Hard, Sessile (LEHS); Small, Fragile, Encrusting (SFE); and Deep Burrowing Infauna, (DBI)) and estimated separately for bottom tows on the slope and on under topographical features (UTFs) (slope tows have a wider effective width than UTF tows but this is taken into account in the BFIA analyses when calculating SAR, therefore, a single value can be used for bottom tows). We can use this approach to get some

starting values for the new taxa that fall into one of these categories. Impacts from bottom longlines were not considered in this paper, and recovery was not taken into account in this method.

3. Pitcher et al. (2017), Pitcher et al. (2015)

These papers developed and described the RBS method. Pitcher et al (2017) and Pitcher et al (2015) used d and R values from other studies including the Great Barrier Reef and a meta-analysis of 39 published (pre-2000) studies (Collie et al 2000). Pitcher et al. (2017) re-analysed data from these (see methods in [SC11 DW01 rev](#)) but we don't have access to these data and, in any case, there is probably little value in re-analysing them.

4. Sciberras et al. (2018)

A meta-analysis of 122 experiments looking at d and R from fishing impacts. but this study does not give much obvious detail on taxa relevant here with mostly higher-level taxa examined, and several bottom fishing methods of which otter trawling was one, but not BLL. Also, 89% of the studies were in depths of <40 m. Perhaps a useful default value for depletion can be derived: "*A gear pass reduced benthic invertebrate abundance by 26%*". Perhaps because of the very shallow settings, for otter trawling depletion rates were minimal (statistically insignificant) and recovery rates were fast. Some recovery rates (slopes) were provided by broad taxon (relevant ones being Hydrozoa (0.0246), Bryozoa (-0.0203), and Porifera (-0.0067)). Negative values = negative recovery?! So not much use...and interesting to note in the acknowledgments that funding provided for this paper mostly came from commercial fishing companies, including 3 NZ companies.

Attempts to dig deeper into the contributing studies were made. All but 1 of the studies were in depths less than 100 m, and that one did not provide any useful data.

5. Hiddink et al. (2017)

A meta-analysis of studies of trawling impacts of "whole communities" of seabed macroinvertebrates. Nothing at a useful taxonomic scale for our purposes, but a potentially useful overall stat: "*Otter trawls caused the least depletion, removing 6% of biota per pass and penetrating the seabed on average down to 2.4 cm*"

Four of the studies were in 100 m or more, but none were over 150 m, or relevant (infaunal, not the taxa we are interested in, no d/R type info).

6. Hiddink et al (2019)

This is another meta-analysis that looks at the relationship between recovery rates (the intrinsic rate of increase in populations, R) and longevity. Maximum ages are rarely known but may be assigned to taxa based on knowledge from related species. They used RBS formula ($RBS=B/K=1-Fd/R$) not to calculate RBS but to calculate r , given an unfished state ($F=0$).

"*Tillin et al. (2006) demonstrated that benthic epifauna with $T_{max} > 10$ years decreased in abundance with trawling, but that no such reduction occurred for fauna in the same areas with $T_{max} < 2$ years.*"

The estimated R for taxa with a T_{max} (max age) of >10 years (their oldest category) was 0.34 year^{-1} with a median time to recovery (from 0.5K to 0.95K) of 8.7 years. Although the taxa examined in this study only partly overlap with those we are concerned with here, they provide a useful equation that we could use: $R = 5.31/\text{longevity}$. So, a species with max age = 10 years will have $r = 5.31/10 = 0.53$; max age = 100 years gives an R of $= 5.31/100 = 0.053$. For comparison the range of R values for the taxa we have already estimates for is 0.20 to 0.39.

They note that “For taxa that form biogenic structures the recovery rate of the biogenic structures will be slower than the recovery rates of the individual organisms that make up the structures (Rijnsdorp et al., 2016).”

Also, while they provide this equation ($R = 5.31/\text{longevity}$) they don't give it much attention (it only appears in a figure caption) and note several caveats (most importantly the lack of precise longevity estimates). Therefore, I think it should be just used as a guide. Anyhow, here are some examples from the SW Pacific with Max Age values taken from Tracey and Hjørvarsdóttir (2019).

As was the case for Hiddink et al. (2017) and the other meta-analyses, most studies here were shallow, the few that were deeper were not useful – for similar reasons.

Table 2: Estimated r for coral taxa with published longevity values (Tracey and Hjørvarsdóttir 2019) based on Hiddink et al. (2019) ($R = 5.31/\text{longevity}$)

Taxon	Max Age	R
<i>Solenosmilia variabilis</i>	120	0.044
<i>Solenosmilia variabilis</i>	300	0.018
<i>Solenosmilia variabilis</i>	271	0.020
<i>Madrepora oculata</i>	1123	0.005
<i>Madrepora oculata</i>	921	0.006
<i>Goniocorella dumosa</i>	422	0.013
Black coral (unspecified)	330	0.016
Black coral (unspecified)	307	0.017
<i>Antipatharia</i> (Chathams)	2672	0.002
<i>Antipatharia</i> (Fiordland)	263	0.020
<i>Antipathella fiordensis</i>	129	0.041
<i>Antipathes</i> (Chathams)	380	0.014
<i>Leiopathes secunda</i> (BoP)	1269	0.004
<i>Leiopathes secunda</i> (BoP)	1960	0.003
<i>Leiopathes</i> spp. (BoP)	2901	0.002
<i>Bathypathes patula</i> (Chathams)	481	0.011
<i>Bathypathes patula</i> (BoP)	380	0.014
<i>Keratoisis</i> spp. (Tasmania)	400	0.013
<i>Keratoisis</i> spp. (Chathams)	305	0.017
<i>Keratoisis</i> spp. (Campbell)	38	0.140
<i>Lepidisis</i> spp. (NZ)	58	0.092
<i>Paragorgia arborea</i> (NZ)	500	0.011

7. Pitcher et al. (2022)

A global (but not high-seas) RBS analysis that is habitat-based and has little direct information on d and R values.

8. Rowden et al. (2024)

Depletion rates for a broad range (9) of trawl gear types were estimated from historic observer data for four taxa, Anthozoa, Demospongiae, Hexactinellida, and Pennatulacea on the Chatham Rise using a

Bayesian estimation model fitted to observed catches. Values of d for Demospongiae ranged from 0.25 to 0.40 for the main gear types; from 0.11 to 0.43 for Hexactinellida for the 4 gear types retained in that analysis; were highly variable among gear types (between 0.02 and 0.74) for Anthozoa; while model convergence was not achieved for Pennatulacea.

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