# Understanding coral bycatch

## Assessing large catches

*Report prepared for Project INT2023-10, Conservation Services Programme, Department of Conservation*

*May 2025*

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NIWA CLIENT REPORT No: 2025053WN
Report date: May 2025
NIWA Project: DOC24308

| Revision | Description | Date |
|---|---|---|
| Version 0.1 | Draft in preparation/in review | 13 March 2025 |
| Version 1.0 | Final version sent to client | 19 March 2025 |
| Version 1.1 | Revisions after review by client | 23 May 2025 |

| Quality Assurance Statement | | |
|---|---|---|
| | Reviewed by: | Darren Stevens |
| | Formatting checked by: | Jess Moffat |
| | Approved for release by: | Judy Sutherland |

# Contents



## Tables



## Figures

# Executive summary

All coral species in Orders Antipatharia and Scleractinia as well as gorgonian corals in Order Alcyonacea and hydrocorals in Family Stylasteridae are protected under the Wildlife Act 1953. This protection prohibits intentional damage and removal. To better enable delivery of this protection, we need to continually seek to improve our knowledge of these corals – in particular their diversity, distribution, abundance, and vulnerability to human activities.

Coral species are frequently taken as bycatch in commercial fisheries and when this occurs on vessels with scientific observers on board care is taken to identify them as accurately as possible and record the weight of the catch. Frequently observers also retain a sample of the corals caught, especially when identification is uncertain, for examination by expert taxonomists ashore. The coral catch data collected by observers has been used to address many of the gaps in our knowledge, and thus it is vital that the data obtained are as accurate as possible. Records of large catches of coral are particularly valuable as these provide a strong indication of locations of high coral abundance. However, occasional errors in the recording of catch weights are likely to have occurred in the past, and continue to occur, due to recording or transcribing mistakes including the use of an incorrect taxonomic code and mis-weighing or mis-entering measured weights.

In this study a close examination of reported coral catches was made to improve understanding of the extent of genuine large catches and to build a more confident picture of coral bycatch across the New Zealand region, including the location of "hot-spots" of coral abundance. Further benefits include improved catch information for cross-validation of coral abundance models, and provision of guidance for verification of future reported large coral catches when loading observer records into database tables.

A complete extract of historic observed protected coral catches was obtained from the observer (*COD*) database, and a further set of coral catch data was obtained from research trawl records. These data were used together to establish weight thresholds signifying a "large" catch of coral for the purposes of mapping such occurrences and setting or updating values for flagging suspiciously large catches when loading future data into database tables.

A range of datasets and methods for verification of these large catches was developed. These included examination of:

1. Observer trip reports, diaries, and logbooks
2. Observer photographs
3. Vessel-reported coral catches from matched fishing events
4. Spatial comparison with locations of high abundance predicted in species distribution models
5. Spatial comparison with underwater topographical features (seamounts, etc.)

These verification methods were applied to observed catch records and maps produced for all protected coral taxa to provide a more reliable picture of coral captures in the New Zealand region, especially large catches. Revised large catch threshold values were set so that all 98 recording codes for protected coral taxa are included, updating existing values (many of which were set too high) and providing values for many more recent codes for which no value had been set.

# 1 Introduction

Corals (Phylum Cnidaria), especially cold-water corals, are a key component of benthic invertebrate communities, and many species provide structure and habitat around which these communities are built. Within the New Zealand EEZ and TS, there is substantial overlap between cold-water corals and offshore bottom-contacting fisheries for many fish and invertebrate species. A wide range of coral species are protected under the Wildlife Act 1953, which prohibits intentional damage, and retention of accidental catch. These protected corals comprise four groups: black corals (Order Antipatharia), gorgonian alcyonaceans (a subset of the Order Alcyonacea), stony corals (Order Scleractinia), and stylasterids hydrocorals (Family Stylasteridae).

To adequately protect these corals, it is necessary to have a sound understanding of a broad range of factors including species diversity and distribution, productivity, inherent vulnerability (e.g., fragility, rarity), impacts from climate change (especially ocean warming and acidification), and impacts from fishing and other seabed-related activities. Many of these aspects have been addressed in recent years through spatial modelling of protected coral habitat suitability, including future habitat suitability under predicted climate change scenarios (e.g., Anderson et al. 2022), species abundance models (Anderson et al. 2023), coral growth and reproduction (e.g., Beaumont et al. 2024), assessment of risk from bottom trawling to protected corals (Clark et al. 2024), and the production of species identification guides (e.g., Tracey et al. 2011a, Observer Coral ID Guide[1]) and a comprehensive state of knowledge report (Tracey and Hjorvarsdottir 2019). Many of these studies rely on accurate information associated with species captures to provide reliable outputs useful for conservation management. Assessment and verification of species identification by observers has been undertaken through a recent study in which observers made at-sea identifications based on training and available identification guides, then retained specimens for verification by experts onshore (Tracey et al. 2011b). There is also an ongoing programme under which observers take photographs of coral bycatch (with or without retaining a specimen) and provide these photos to experts for confirmation of their identification (e.g., Connell et al. 2024).

Results from these studies have shown that identification accuracy is highly variable especially at lower taxonomic resolution (genus and species level) and, as well as misidentifications, errors in the recording of species names and weights are also possible. In most cases, however, coral catches observed in commercial fisheries are immediately returned to the sea without any confirmatory identification from independent experts. Therefore, from reported figures alone it can be difficult to differentiate a genuine substantial catch of coral from one that is potentially erroneous due to human error, misunderstanding, or misinterpreting (e.g., handwriting). In this study a closer examination of reported coral catches was made to improve understanding of the extent of genuine large catches, both historically and currently, to build a more confident picture of coral bycatch across the EEZ that will improve knowledge of coral “hot-spots” and aid cross-validation of coral abundance models, and to provide guidance for verification of future reported large coral catches when loading observer records into the *COD* database.

## 1.1 Project objective

To improve our understanding and ground truthing processes for reporting of coral bycatch by fisheries observers, and to assess and map reported large catches of coral across the EEZ.

[1] https://www.doc.govt.nz/globalassets/documents/conservation/marine-and-coastal/marine-conservation-services/resources/resources-for-fishers/csp-fishers-guide-to-protected-coral-2024.pdf

# 2 Methods

The approach used to address the project objective consisted of several steps.

Firstly, a complete dataset of all protected coral catches from records made by government fisheries observers on commercial vessels was assembled from trawl catch tables in the *COD* database. Corals are occasionally caught in the New Zealand ling bottom longline fishery, but the total catch between 2002 and 2018 was less than 100 kg (Finucci et al. 2020), therefore line catches of corals were not considered in this study.

Records of protected coral catches from research trawls were then used in conjunction with the observer data to establish weight thresholds that signified a "large" catch. These thresholds can also be used for setting/updating values to flag dubious values when loading future catches into *COD*.

Sets of data that could be used to help verify large catches were then assembled; these included observer trip reports and diaries, fisher-reported catch records, and species distribution models for various coral taxa. Observer records of large coral catches were then designated as verified or not, depending on some confirmation from these data sources.

Maps were then produced for all protected coral taxa for which there were available data, arranged into groupings matching the taxonomic resolution of observer reporting, to illustrate the historical locations of all large catches, based on the thresholds established.

Finally, recommendations for the checking of large protected coral catches retrieved from the *COD* database were made.

## 2.1 Assembly of observed coral catches (*COD* database)

All observed historical catch records with a MPI 3-letter species code for which the description field denoted the Phylum Cnidaria (*description* = "N-") were obtained from the *COD* database along with all relevant associated parameters (e.g., vessel ID, location, fishing method, depth, etc.) for these fishing events. This extract therefore provided an initial dataset that included all coral taxa, not just protected species, and spanned the entire period of the observer programme, from 1986 to the present day. Outputs were run through basic data grooming procedures to correct errors that could affect parameters useful for verification from other sources – positions, depths, and dates in particular – and to remove non-protected cnidarians. Recorded gear codes and methods were also examined in order to differentiate fishing operations that contacted the seabed from those in which the fishing gear was off the seabed at all times and therefore would not be able to catch coral. This is particularly important in fisheries where midwater trawls are often used and are fished either close to the seabed or directly on the seabed, or a combination of both. This information was used later in the process to help verify coral catches (see Section 2.5.2).

## 2.2 Examination of research trawl catches

The most reliable records of deepwater coral catches associated with bottom fishing in New Zealand waters are likely to come from research trawl surveys, for which records of catch are stored on the *Trawl* database managed by NIWA. Trawl surveys have been conducted by NIWA and predecessor organisations over many decades, and although coral catches have always been recorded, taxonomic resolution in earlier years was limited by the poorer knowledge of this group in New Zealand waters. Finer taxonomic information was also a relatively low priority in earlier years of the developing offshore, deepwater fisheries.

An extract of all research trawl records of coral catches (all taxa) was made from the *Trawl* database. This comprised any historical catch of cnidarians (*description* = “N-“) along with all relevant fishing event parameters as for the *COD* extracts above. Non-protected taxa were then removed and figures prepared to show the distribution of catches, especially larger catches, to illustrate the range of catch weights for each taxon (3-letter code), and to look for any patterns in the level of protected species catches over time. It should be noted, however, when comparing research trawl catches to commercial fishery catches, that research trawls tend to be shorter than commercial trawls so that a research trawl (typically an hour or less) is likely to on average have a smaller coral bycatch than a commercial trawl that can be several hours (occasionally over 10 hours) long.

## 2.3 Determination of thresholds for “large” catches of protected corals

Current *COD* data loading protocols incorporate weight thresholds for a variety of coral taxa, as defined by 48 separate MPI 3-letter codes (all protected taxa). These thresholds, set in September 2011, range from a minimum of 10 kg (several taxa) to a maximum of 15 000 kg (for the branching coral *Solenosmilia variabilis*). Threshold values at this time were most likely set to the maximum of historic values for the taxon in the COD database. Under the current protocols, when data loading procedures encounter a benthic catch record which exceeds a weight threshold for the reported taxon the Research Data Management (RDM) team at Fisheries New Zealand (FNZ) are notified. RDM then confer with the fisheries observer services team to assess the record, checking for any observer image, logbook data, and independent records from fisher reports that may corroborate the catch (Peta Abernethy (RDM) pers. comm.). RDM will then respond to the data loader (currently NIWA) advising as to whether a data correction is required; this would usually entail a change in the catch weight or a change in the species code.

The current weight thresholds may now be considered out of date, as there has been a considerable amount of taxonomic research on corals in New Zealand in recent years, with many more 3-letter codes created as a result, and substantially more catch weight data now available to base these thresholds on. There are now 146 MPI 3-letter codes for coral taxa (Phylum Cnidaria); 98 of these relate to protected coral taxa.

The range of catch weights associated with each 3-letter code (or combination of codes) used for recording coral catches in both the *COD* and *Trawl* databases were examined. Initial summaries showed that the distribution of catch weights tended to be strongly skewed for most taxa, with many small catches reported and a few very large ones (those we are most interested in verifying). After analysing a range of taxon-specific catch distributions from both data sources, and also considering the practicality of undertaking a verification process for large numbers of records during future data loading, values representing the 95$^{th}$ percentile of catch weights were calculated for a wide range of protected coral groups. These values were calculated separately for *COD* and *Trawl* data and then an average of the two values was used as a threshold value for a large catch.

## 2.4 Assembly of data used to aid verification of large coral catches

### 2.4.1 Observer trip reports, diaries, logbooks, and photographs

As well as recording target and non-target species catches and other incidental information on a series of paper or electronic forms that are ultimately loaded into *COD*, observers record further details of a voyage in a formal trip report as well as in less formal logbooks and diaries. With limited resources it was not possible to examine these other data sources for every trip that caught any amount of coral, or even for any trip that caught 10 kg or more of coral (the nominal weight used above for commercial records) in a single event. However, there were 50 trips identified from the *COD* extract in which there was at least 1 coral catch of over 100 kg recorded. Any and all trip reports, observer logbooks, and observer diaries were requested from Fisheries New Zealand for these trips, and each source (where available) was examined for corroborating evidence for these large catches.

Observers are also encouraged to take photographs of corals that are caught and returned to the sea, to aid confirmation of their at-sea identification by experts onshore. For the last several years DOC has funded these identifications, with up to 200 images per year assessed by specialist coral taxonomists covering the full range of protected coral groups (Connell et al. 2024). This collection of images, catalogued by NIWA under contract to DOC, were searched for any instances of obviously large catches (e.g., the report cover image) and matched to *COD* database records using the trip and station number recorded with the image.

### 2.4.2 Fisheries bycatch reporting

All commercial fishing operators are required to report details of their catch and bycatch, including any protected species, under the Fisheries (Reporting) Regulations 2017. Fisheries New Zealand maintains a database to store the information recorded in these reports.

An extract of vessel-reported coral catches (all coral taxa – as for the observer data extract) was obtained from Fisheries New Zealand (under RepLog 15873). This extract comprised all historical fishing event records stored in the Enterprise Data Warehouse (EDW) where cnidarians (*description* = "N-") were caught, along with all relevant fishing event parameters as for the *COD* extract. Taking a value of 10 kg as a nominal minimum weight for a large catch of any taxon, to avoid a cumbersomely large extract, only reported coral catches at or above this weight were requested.

### 2.4.3 Coral abundance modelling

An indication of the locations where there may be an increased likelihood of large catches of protected corals may be usefully provided by recent species distribution models which predict abundance for a range of taxa across the New Zealand region and indicate locations of likely coral hot-spots (Anderson et al. 2023). The models produced in this study were the first to use high-accuracy species count data from seafloor imagery to produce broad-scale predictions of coral abundance.

The modelled taxa in this study included two branching stony coral species (*Solenosmilia variabilis*, *Goniocorella dumosa*), two solitary stony coral taxa (Caryophylliidae, *Flabellum* spp.), gorgonian alcyonaceans (formerly the order Gorgonacea), three gorgonian subgroups (Keratoisididae/Mopseidae (bamboo corals), Primnoidae, *Radicipes* spp.), black corals (Antipatharia), hydrocorals (Stylasteridae), and the unprotected sea-pens (Pennatulacea, now Pennatuloidea). Separate models were produced for 15 coral taxa in total, with predictions combined to provide a map of coral hot-spot locations (Figure 1).

From these models, where available for the taxon in question, the predicted abundance at the capture location of the observed coral catches was obtained and compared with the recorded weight. It should be noted that these data cannot be relied on heavily to confirm or discount a large coral catch as the models are at a relatively coarse scale and, apart from *Solenosmilia variabilis* and *Goniocorella dumosa*, are not species specific, but they do provide a degree of supporting evidence in addition to reported information.

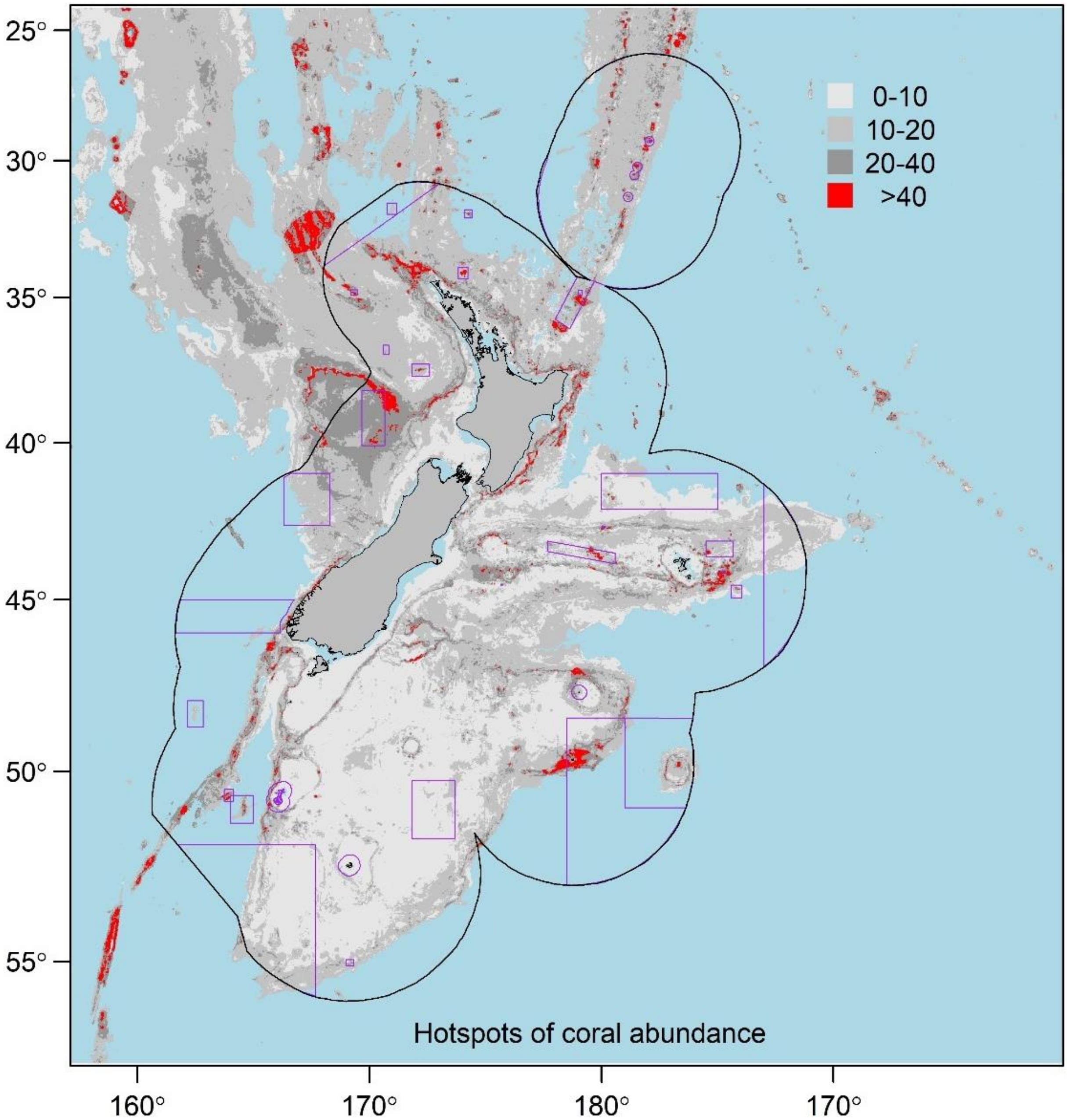


**Figure 1:** **Locations of high abundance of selected protected coral taxa.** Estimated numbers of individuals or coral heads/1000 m$^2$ were summed across 15 taxa (*Solenosmilia variabilis*, *Goniocorella dumosa*, *Enallopsammia rostrata*, *Madrepora oculata*, Caryophyllidae, *Stephanocyathus* spp., *Flabellum* spp., Alcyonacea, bamboo corals, Primnoidae, Paragorgiidae, *Radicipes* spp., Antipatharia, Stylasteridae, and Pennatulacea (not protected)). Reproduced from Anderson et al. 2023.

### 2.4.4 Seamounts

Deep-sea corals are known to be strongly associated with seamounts and other underwater features (Tracey et al. 2011c, Tracey & Hjorvarsdottir 2019). Because of this, if a reported large catch of coral was spatially associated with a known underwater feature this was considered more likely to be correct than if the location was on a flat continental shelf or slope seafloor. Therefore, the location of all observer-reported large catches were spatially overlaid on a recent compilation of seamount, hill, and knoll features for the New Zealand region (Clark et al. 2022).

## 2.5 Verification procedure

### 2.5.1 Defining large coral catches

As this project is primarily interested in the verification and mapping of large catches of coral, it is first necessary to produce a definition of a large catch, specific to each taxonomic group of protected corals. To do this we examined the range of catch weights associated with each 3-letter code (or combination of codes) used for recording coral catches in both the *COD* and *Trawl* databases. After analysing a range of taxon-specific catch distributions from both data sources, and also looking ahead to take into account the practicality of undertaking a verification process for a large numbers of records during future data loading, we selected the 95$^{th}$ percentile of catch weights as being the most appropriate value and calculated this for a wide range of protected coral groups. These values were calculated separately for *COD* and *Trawl* data and an average of the two values taken to use as a threshold value for a large catch.

### 2.5.2 Verification of large catches

For the purposes of mapping large observed coral catches it is useful to separate those catches with supporting evidence from other sources from those without. Unsupported records may still be correct, but a more reliable and nuanced picture of the distribution of corals is possible if this distinction is made. The following procedures were used for this purpose:

1. Confirmation from observer trip reports

If a trip report, logbook, or diary contained any commentary regarding a large catch of coral from a particular station number on the trip, or such a catch (with weight) was included in the tables of specimen/sample collection or non-fish bycatch usually included in the trip reports, this was considered as a verification of a large catch.

2. Confirmation from observer photographs of protected coral catches

Any observed coral catch of a weight greater than the assigned threshold for the recorded taxon was considered verified if a photograph in the NIWA catalogue of observer images clearly showed a large catch of coral associated with the trip and station in question. Due to inconsistent accuracy of identification by observers, an exact match of identification between the image and the *COD* entry was not required for this purpose – as long as it was clear from the catch records and images that a mix-up with another coral catch (from the same or different event) was unlikely.

3. Agreement with vessel-reported catches

Large *observed* catches were compared to *vessel-reported* catches for the same fishing event, where possible. Unfortunately, fishing events in the *COD* and EDW reporting systems and databases are not linked by a common key, therefore a process of matching events was required. This was achieved using the *vessel_key* field (a unique key that *is* common to both reporting systems), fishing event date, fishing event time (up to 2 hours difference allowed to account for NZST/NZDT differences), along with an assessment of spatial concordance. An observed coral catch of a weight greater than the assigned threshold for the recorded taxon was taken as verified by this method if there was a matching reported catch and the weight of that catch was also above the threshold.

4. Agreement with abundance models

For those taxa where predictions of abundance from a species distribution model were available, the predicted abundance at the location of the coral capture was obtained from the relevant raster layer. In this case, an observed coral catch of a weight greater than the assigned threshold for the recorded taxon was considered verified if the predicted abundance at that location was at or above the 90$^{th}$ percentile of abundance values across all cells of the prediction grid.

5. Agreement with seamount location

Each observed coral catch record was designated as on or off a seamount, hill, or knoll (collectively known as underwater topographical features, UTFs) by comparing its location to the location of the basal footprint of all known UTFs in the region. An observed coral catch of a weight greater than the assigned threshold for the recorded taxon was considered verified if the location of the catch was within the basal polygon of any UTF identified in a spatial database of such features (Clark et al. 2022).

For the purposes of producing maps of the distribution of large protected coral catches, final confirmation of a large catch was given if it met any one of the verification methods in 1–5 above and, in addition, the observer recorded the fishing gear as being on the seafloor at some stage during the deployment (noting that this detail is recorded for every trawl). This was necessary as some fisheries (e.g. the hoki and arrow squid target fisheries) use midwater nets which may contact the seafloor at times during the trawl, or may not contact the seafloor at all.

## 2.6 Mapping large coral catches

Maps were produced to illustrate the distribution of large catches for each individual protected coral grouping for which separate thresholds were determined. The spatial extent of these maps include the New Zealand EEZ as well as parts of the wider New Zealand region beyond the EEZ where fishing has been reported for the high seas, including parts of the Northwest Challenger Plateau, the Lord Howe Rise and Norfolk Ridge in the Tasman Sea, and the Louisville Seamount Chain in the Pacific Ocean to the east of New Zealand. The location of all observer-reported catches of the taxon were plotted on these maps, regardless of weight, with catches at or above the threshold for a large catch highlighted, with additional highlighting for those large catches which were verified according to the process described above.

In addition, for taxa with spatial abundance predictions available from the models of Anderson et al. (2023), the area encompassed by predicted abundance at or above the 95$^{th}$ percentile is also indicated.

# 3 Results

## 3.1 Historic coral catches from observed trawls

The extract from *COD* included 50 277 observed records of coral catches from 35 281 separate fishing events, comprising 110 individual 3-letter coral codes. About a quarter (13 405) of the records were of protected coral taxa (70 codes), the remaining (unprotected) records mainly comprised codes relating to anemones and jellyfish.

The most commonly recorded coral code was COU, a catch-all code (but conveniently comprising all and only protected coral taxa) more frequently used in the 1990s before the availability of comprehensive identification guides and the associated proliferation of more specific codes for cnidarians. There were over 2300 records of this code with a maximum recorded catch of 20 t (Table 1, Figure 2). Codes for all stony corals (SIA, maximum catch 6000 kg), and black corals (COB, maximum catch 420 kg) were also frequently used (over 1100 records of each) most likely because these could be distinguished reasonably confidently from each other, and from other taxa, with little knowledge or training in coral taxonomy. The single species most frequently recorded was the stony coral *Goniocorella dumosa* (GDU), a common species on the heavily fished Chatham Rise, with over 1000 records and a maximum catch of 7 t.

**Table 1: Summary of observer-recorded protected coral catches in commercial fisheries (1990–2024).** Taxa are ordered from most to least recorded code; scientific and common names are as defined in FNZ databases.

| Code | Common name | Scientific name | Other names | Count | Max single catch (kg) |
|---|---|---|---|---|---|
| COU | True coral (unidentified) | Gorgonian octocorals in Order Alcyonacea Scleractinia (Order) Antipatharia (Order) Stylasteridae (Family) | | 2339 | 20000 |
| SIA | Stony corals | Scleractinia | | 1185 | 6000 |
| COB | Black coral | Antipatharia | | 1125 | 420 |
| GDU | Bushy hard coral | *Goniocorella dumosa* | Branching coral | 1089 | 7000 |
| GOC | Gorgonian octocoral | Gorgonian corals in Orders Malacalcyonacea and Scleralcyonacea | Gorgonian | 782 | 80 |
| COF | Solitary coral | *Flabellum* spp. | | 719 | 445 |
| BOO | Bamboo coral | *Keratoisis* spp. | | 536 | 859 |
| DDI | Solitary coral | *Desmophyllum dianthus* | | 457 | 2500 |
| STP | Solitary bowl coral | *Stephanocyathus platypus* | | 447 | 10 |
| THO | Bottlebrush coral | *Thouarella* spp. | Sea fan | 387 | 40 |
| ISI | Bamboo corals | Bamboo corals in Families Keratoisididae and Mopseidae | | 339 | 50 |
| PAB | Bubblegum coral | *Paragorgia* spp. | | 338 | 480 |
| CBB | Coral rubble | | | 337 | 8000 |
| CBD | Coral rubble - dead | | | 311 | 6000 |
| ERO | Branching coral | *Enallopsammia rostrata* | | 308 | 2500 |
| CHR | Golden coral | *Chrysogorgia* spp. | | 299 | 400 |

| Code | Common name | Scientific name | Other names | Count | Max single catch (kg) |
|---|---|---|---|---|---|
| SVA | Branching coral | *Solenosmilia variabilis* | | 279 | 15000 |
| LSE | Black coral | *Leiopathes secunda* | | 222 | 8 |
| LLE | Bamboo coral | *Lepidisis* spp. | | 209 | 30 |
| DEN | Black coral | *Dendrobathypathes* spp. | | 126 | 800 |
| CBR | Stony branching corals | Dendrophylliidae Oculinidae (Families) and some spp. in Caryophyllidae (Family) | | 121 | 60 |
| COR | Stylasterid | Stylasteridae | Stylasterid hydrocoral | 119 | 2000 |
| PMN | *Primnoa* spp. | *Primnoa* spp. | Gorgonian | 117 | 40 |
| PRI | Primnoidae | Primnoidae | Sea fan | 102 | 4 |
| CAY | Solitary coral | *Caryophyllia* spp. | | 99 | 300 |
| MOC | Branching coral | *Madrepora oculata* | | 97 | 2500 |
| BTP | Black coral | *Bathypathes* spp. | | 93 | 6.9 |
| LEI | Black coral | *Leiopathes* spp. | | 82 | 9 |
| MTL | Metallic coral | *Metallogorgia* spp. | | 77 | 1 |
| LPT | Spiny lace coral | *Lepidotheca* spp. | | 52 | 500 |
| PLE | Sea fans | Paramuriceidae Euplexauridae Astrogorgiidae Plexauridae (Families) | Gorgonian sea fans | 47 | 15 |
| CLL | Precious coral | *Corallium* spp. | | 46 | 40 |
| CUP | Stony cup corals | Flabellidae Fungiacyathidae (Families) and some spp. in Caryophyllidae (Family) | | 46 | 115 |
| ERR | Red hydrocorals | *Errina* spp. | | 42 | 25 |
| ACN | Bushy bamboo coral | *Acanella* spp. | | 41 | 80 |
| PTP | Black coral | *Parantipathes* spp. | | 41 | 1 |
| CTP | Gorgonians | *Calyptrophora* spp. | | 37 | 2 |
| TEO | Black coral | *Telopathes tasmaniensis* | | 35 | 2.6 |
| CRE | White hydrocoral | *Calyptopora reticulata* | | 33 | 4 |
| IRI | Iridescent coral | *Iridogorgia* spp. | | 25 | 4 |
| STI | Black coral | *Stichopathes* spp. | | 24 | 10 |
| ATP | Black coral | *Antipathes* spp. | | 21 | 8 |
| DDP | Black coral | *Dendropathes* spp. | | 17 | 1 |
| MIN | Worm-commensal bamboo coral | *Minuisis* spp. | | 17 | 40 |
| AHL | Black coral | *Antipathella* spp. | | 14 | 5.5 |
| TDP | Black coral | *Triadopathes* spp. | | 14 | 1.6 |
| LIL | Black coral | *Lillipathes* spp. | | 12 | 1.5 |
| CLG | Gorgonian | *Callogorgia* spp. | | 10 | 1 |
| NAR | Rasta coral | *Narella* spp. | Gorgonian | 9 | 100 |
| CRY | Starry white hydro coral | *Cryptelia* spp. | | 8 | 1 |
| MEF | Branching sea fan coral | *Metafannyella* spp. | | 8 | 1 |

| Code | Common name | Scientific name | Other names | Count | Max single catch (kg) |
|---|---|---|---|---|---|
| OVI | Branching coral | *Oculina virgosa* | | 8 | 60 |
| PRG | Plexaurid sea fan | *Paramuricea* spp. | | 8 | 30 |
| PLL | Gorgonians | *Plumarella* spp. | | 7 | 1 |
| ISP | Bamboo coral | *Isidella* spp. | | 6 | 3 |
| ACC | Acanthogorgiid coral | *Acanthogorgia* spp. | | 5 | 0.2 |
| STL | Rose lace corals | *Stylaster* spp. | | 4 | 13 |
| TPT | Black coral | *Trissopathes* spp. | | 4 | 1 |
| ICI | Anthothelid coral | *Iciligorgia* spp. | | 3 | 1 |
| JAS | Bamboo coral | *Jasonisis* spp. | | 3 | 0.1 |
| TOK | Branching bushy coral | *Tokoprymno* spp. | | 3 | |
| AND | Anthothelid coral | Anthothelidae | | 2 | |
| CIR | Whip corals | *Cirrhipathes* spp. | Wire corals | 2 | 2 |
| DSY | Bottlebrush coral | *Dasystenella* spp. | | 2 | 1 |
| RAD | Whip-like golden coral | *Radicipes* spp. | | 2 | 1 |
| SLP | Black coral | *Stylopathes* spp. | | 2 | 0.2 |
| LPP | Bushy lace coral | *Lepidopora* spp. | | 1 | 0.1 |
| PLD | Primnoid sea fan | *Parastenella* spp. | | 1 | |
| STS | | *Stephanocyathus spiniger* | | 1 | 71 |
| TYL | Black coral | *Tylopathes* spp. | | 1 | |

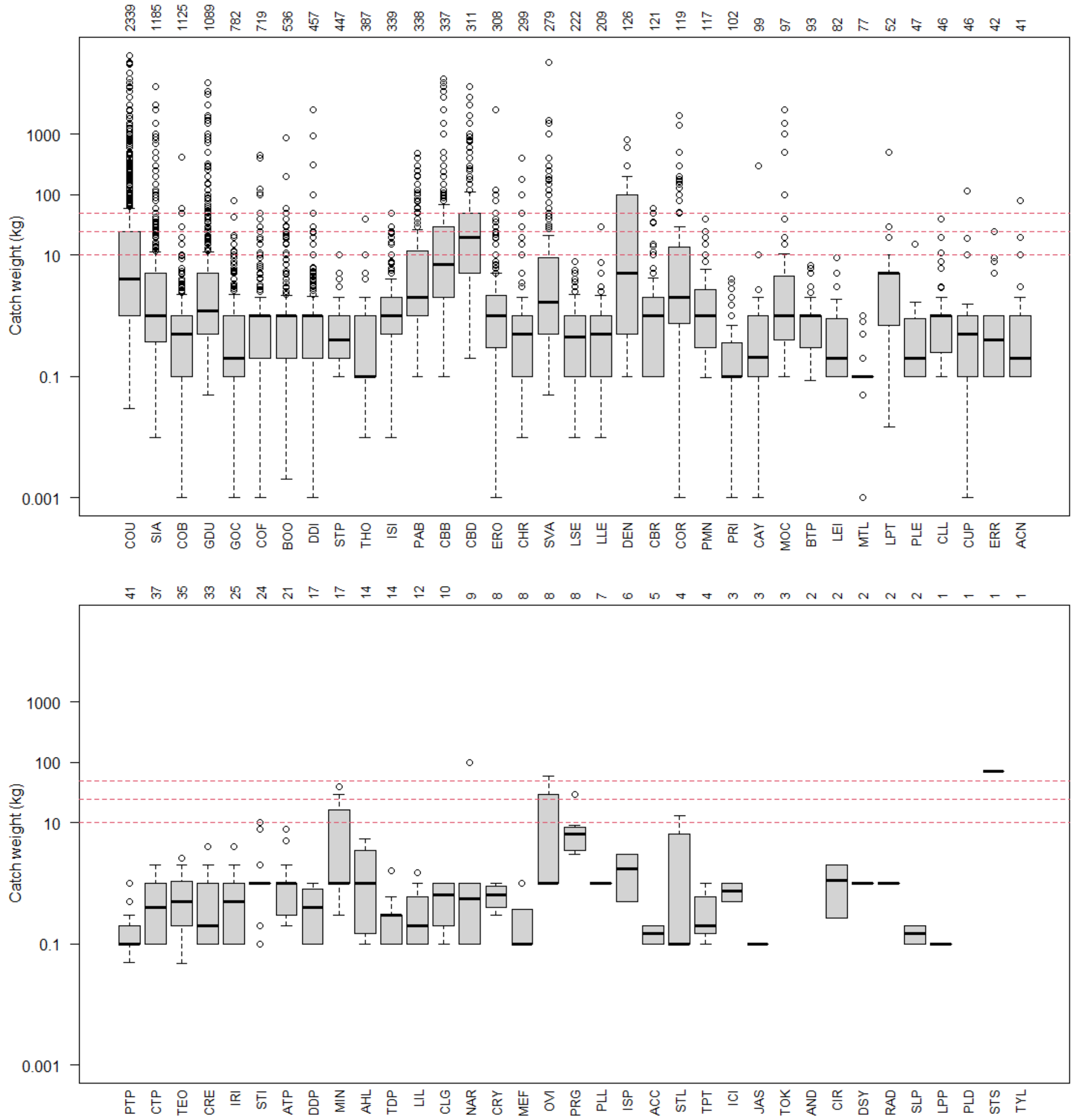


**Figure 2: Distribution of observer-recorded weights of protected coral catches, by taxon.** Taxa are ordered from highest to lowest number of records (numbers above plots), with the lower plot a continuation of the upper plot. The box and whisker plots show medians and lower and upper quartiles in the box, whiskers extending up to 1.5 × the interquartile range, and outliers individually plotted. Note the y-axes are on a log scale. Dashed red lines show catch levels of 10, 25, and 50 kg. See Table 1 for explanation of species codes.

The annual distribution of observed catch weights of protected corals was examined to look for any trends over time that might indicate a “fishing-down” of areas of substantial coral aggregations (Figure 3). Although there is a clear indication of larger catches being more frequent earlier in the time series, with a decrease in mean catch weights through the late 1990s and early 2000s, this trend may be partly confounded by changes in how coral catches were recorded. Earlier recording of coral catches by observers was more limited to a few generic codes, with weights for small catches of a variety of species lumped together on catch forms. As coral taxonomic knowledge improved, especially in the early 2000s, with more codes available and identification guides being produced and provided to observers, individual coral catches were more frequently recorded separately – leading to lower mean catch weights. Nevertheless, we know from other research that there has been considerable decreases in coral abundance in many locations where deepwater fisheries overlap with coral habitat, especially around seamounts (Clark et al. 2016, Clark et al. 2019), and reductions in coral bycatch by commercial vessels, especially where the same grounds are repeatedly fished, are likely to have been substantial.

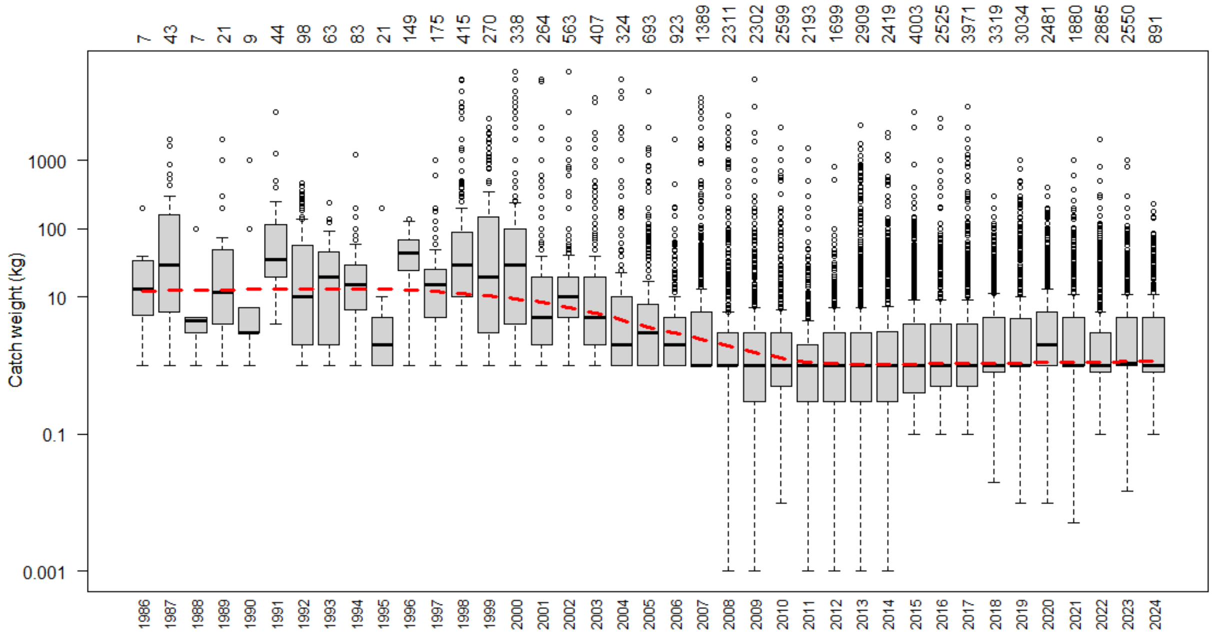


**Figure 3: Distribution of observer-recorded weights of protected coral catches, by year.** Taxa are ordered along the x-axis from earliest to most recent years, with the number of records shown above the plot. The box and whisker plots show medians and lower and upper quartiles in the box, whiskers extending up to 1.5 × the interquartile range, and outliers individually plotted. Note the y-axes are on a log scale. The dashed red line shows a smoothed fit to the annual median values.

Protected corals were caught in commercial fisheries across a wide geographical range (Figure 4). The areas with the greatest concentration of records include the Chatham Rise, the Stewart-Snares shelf, northern parts of the Campbell and Bounty Plateaus, the southern Challenger Plateau, and the ridge/seamount systems around the periphery of the EEZ and beyond – especially the Macquarie Ridge, West Norfolk Ridge, and Louisville Seamount Chain. Larger (unverified) catches mostly related to the same locations.

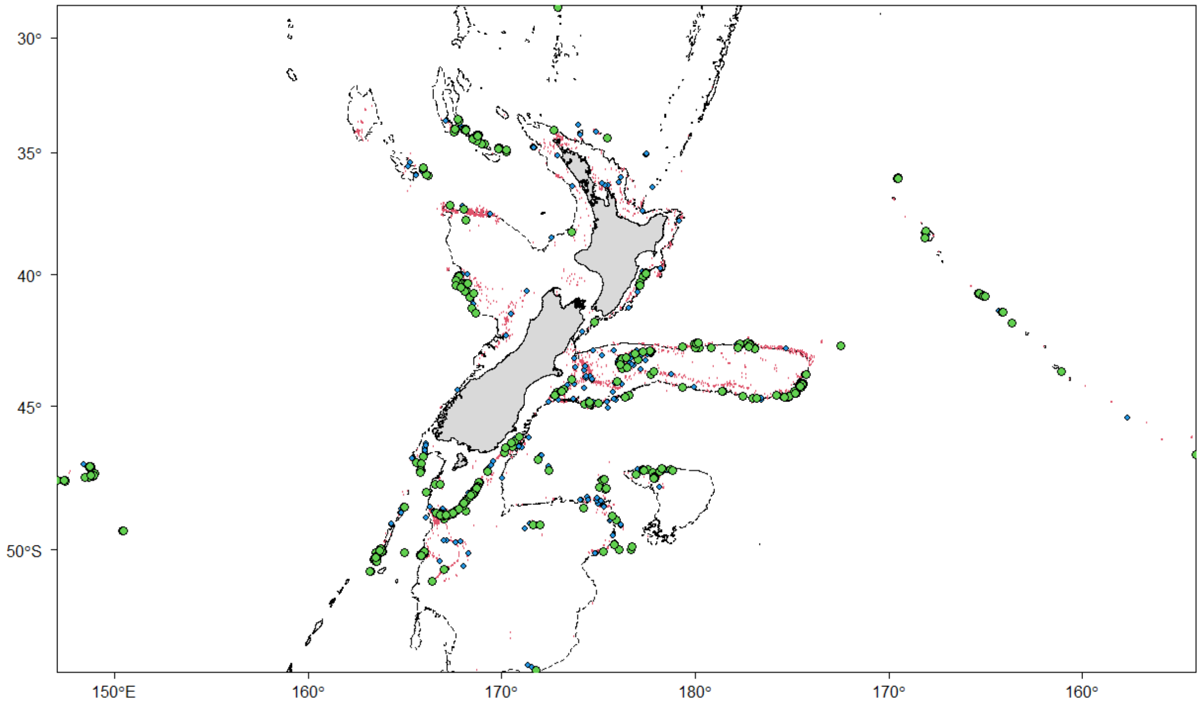


**Figure 4: Location of all protected coral catches from observed commercial trawls between 1986 and 2024.** Red dots, all records; blue dots, catches > 10 kg; green dots, catches > 50 kg. Dashed line shows 1000 m contour.

## 3.2 Historic coral catches from research trawls

Research scientists recorded 1672 protected coral catches from trawl surveys, the earliest from an RV *Ikatere* survey in 1972 off Otago. The spatial distribution of these catches somewhat mirrors the focal areas for research surveys, rather than describing the distribution of corals in general, with a high concentration of records on the Chatham Rise and to a lesser extent the Campbell Plateau (Figure 7). It is worth noting, however, that development of greater familiarity with survey areas over time has led to increased avoidance of the type of rough terrain that tends to damage trawl gear but also provide preferred habitat for many corals. Research survey catches of a weight greater than 10 kg were relatively uncommon, but many of these were greater than 50 kg, especially around the Graveyard Hills on the north Chatham Rise around longitude 180˚. Other catches greater than 50 kg were only recorded from a station south of Stewart Island and another from off the west coast of the North Island.

These catches are represented by 55 separate 3-letter codes, ranging from high level codes such as COU (all protected corals) to the species level (9 individual species were recorded). Of these catches, there were 65 greater than 10 kg and 33 greater than 50 kg. The most recorded coral taxon, COU, was used over 400 times; the maximum weight recorded (2000 kg) is likely to have included a mixture of live corals and dead coral matrix, the same is likely for the 3000 kg maximum catch of the scleractinian coral *Desmophyllum dianthus* and the 400 kg catch of *Solenosmilia variabilis*. Other taxa with notably large maximum catches were CBB (coral rubble, 450 kg) and CBD (coral rubble – dead, 220 kg) (Table 2). Large catches of stylasterids (COR), such as the 213 kg maximum catch recorded for this taxon, seem unlikely for these small, non-matrix-forming species, and may be due to occasional use of the potentially confusing 3-letter code (COU) in place of COR to represent any protected coral when a large catch of branching scleractinians has been taken. Note that only 19 of the 55 codes have been used more than 10 times by research scientists, and 20 codes have been used only once or twice. At-sea identification of corals is highly dependent on the expertise of the scientists on a particular research survey and even with the increasing availability of detailed identification guides, fine taxonomic level identifications are not always possible or achievable given time restraints on busy surveys and the difficulty for non-specialists to differentiate among taxa with similar morphological characters.

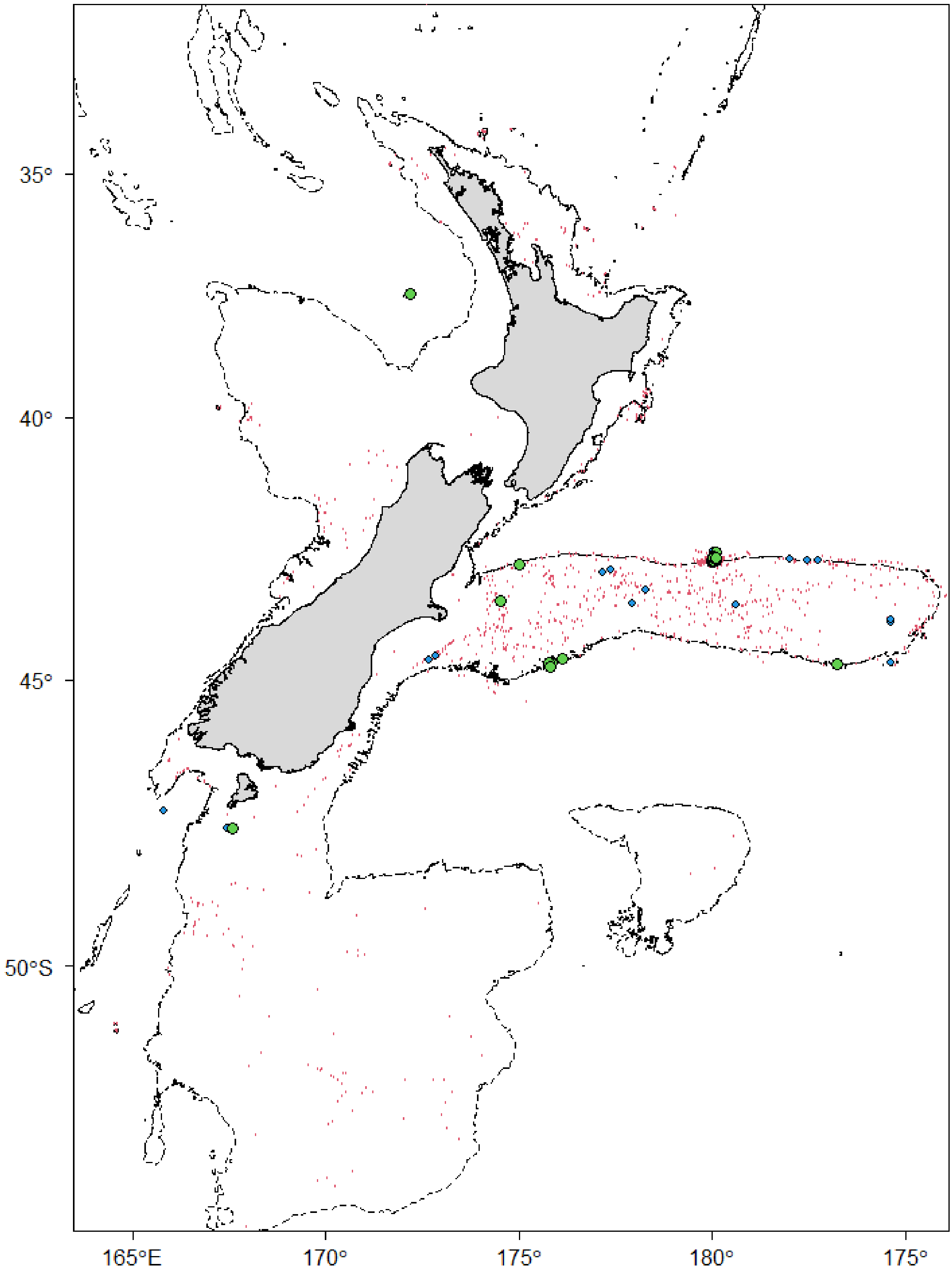


**Figure 5: Location of all protected coral catches from research trawls between 1972 and 2024.** Red dots, all records; blue dots, catches > 10 kg; green dots, catches > 50 kg. Dashed line shows 1000 m contour.

**Table 2: Summary of research trawl-recorded protected coral catches (1961–2024).** Taxa are ordered from most to least recorded code; scientific and common names are as defined in FNZ databases[2]. For taxa where no weights have been recorded, Max catch is marked "–".

| Code | Common name | Scientific name | Number of catches | Max catch (kg) |
|---|---|---|---|---|
| COU | True coral (unidentified) | Gorgonian octocorals in Order Alcyonacea Scleractinia (Order) Antipatharia (Order) Stylasteridae (Family) | 417 | 2000 |
| COF | Flabellum coral | *Flabellum* spp. | 243 | 35.8 |
| GDU | Bushy hard coral | *Goniocorella dumosa* | 131 | 13 |
| STP | Solitary bowl coral | *Stephanocyathus platypus* | 127 | 2.1 |
| GOC | Gorgonian octocoral | Gorgonian corals in Orders Malacalcyonacea and Scleralcyonacea | 122 | 0.9 |
| COR | Stylasterids (hydrocorals) | Stylasteridae | 75 | 213.4 |
| SIA | Stony corals | Scleractinia | 68 | 60 |
| COB | Black coral | Antipatharia | 61 | 20 |
| DDI | Solitary coral | *Desmophyllum dianthus* | 60 | 3000 |
| THO | Bottlebrush coral | *Thouarella* spp. | 56 | 2.2 |
| BOO | Bamboo coral | *Keratoisis* spp. | 38 | 3 |
| CBB | Coral rubble | | 31 | 450 |
| LLE | Bamboo coral | *Lepidisis* spp. | 29 | 1 |
| PRI | Primnoidae | Primnoidae | 22 | 0.5 |
| ISI | Bamboo corals | Bamboo corals in Families Keratoisididae and Mopseidae | 19 | 1.5 |
| RAD | Whip-like golden coral | *Radicipes* spp. | 19 | 0.3 |
| CHR | Golden coral | *Chrysogorgia* spp. | 13 | 0.2 |
| ERR | Red hydrocorals | *Errina* spp. | 12 | 1.7 |
| CAY | Solitary coral | *Caryophyllia* spp. | 11 | 0.7 |
| PAB | Bubblegum coral | *Paragorgia* spp. | 9 | 15.7 |
| PLE | Sea fans | Paramuriceidae Euplexauridae Astrogorgiidae Plexauridae (Families) | 9 | 2.5 |
| SVA | Branching coral | *Solenosmilia variabilis* | 9 | 400 |
| CRE | White hydrocoral | *Calyptopora reticulata* | 8 | 0.9 |
| MEF | Branching sea fan coral | *Metafannyella* spp. | 8 | 0.1 |
| CLG | Gorgonian coral | *Callogorgia* spp. | 7 | 0.2 |
| BTP | Black coral | *Bathypathes* spp. | 6 | 1.2 |
| LSE | Black coral | *Leiopathes secunda* | 6 | 2 |
| MOC | Branching coral | *Madrepora oculata* | 6 | 3.1 |
| CUP | Stony cup corals | Flabellidae Fungiacyathidae (Families) and some spp. in Caryophyllidae (Family) | 4 | 4.1 |
| PMN | Primnoid coral | *Primnoa* spp. | 4 | 2.7 |
| SLP | Black coral | *Stylopathes* spp. | 4 | 0.8 |

[2] https://marlin.niwa.co.nz/species_codes

| Code | Common name | Scientific name | Number of catches | Max catch (kg) |
|---|---|---|---|---|
| CBD | Coral rubble - dead | | 3 | 220 |
| ERO | Deepwater branching coral | *Enallopsammia rostrata* | 3 | 0.8 |
| LPT | Spiny lace coral | *Lepidotheca* spp. | 3 | 1 |
| ACN | Bushy bamboo coral | *Acanella* spp. | 2 | 1 |
| CLL | Precious coral | *Corallium* spp. | 2 | 1 |
| ICI | Anthothelid coral | *Iciligorgia* spp. | 2 | – |
| ISP | Bamboo coral | *Isidella* spp. | 2 | 0.1 |
| MIN | Worm-commensal bamboo coral | *Minuisis* spp. | 2 | 0.1 |
| MTL | Metallic coral | *Metallogorgia* spp. | 2 | 0.3 |
| NAR | Rasta coral | *Narella* spp. | 2 | 0.1 |
| PTP | Black coral | *Parantipathes* spp. | 2 | 0.1 |
| STI | Black coral | *Stichopathes* spp. | 2 | 0.2 |
| CBR | Stony branching corals | Dendrophylliidae Oculinidae (Families) and some spp. in Caryophyllidae (Family) | 1 | 1.1 |
| CTP | | *Calyptrophora* spp. | 1 | – |
| DDP | Black coral | *Dendropathes* spp. | 1 | 0.1 |
| IRI | Iridescent coral | *Iridogorgia* spp. | 1 | – |
| LEI | Black coral | *Leiopathes* spp. | 1 | 0.1 |
| LIL | Black coral | *Lillipathes* spp. | 1 | 1 |
| MRI | Plexaurid sea fan | *Muriceides* spp. | 1 | 0.2 |
| OVI | Branching coral | *Oculina virgosa* | 1 | 0.3 |
| SWI | Plexaurid sea fan | *Swiftia* spp. | 1 | – |
| TDP | Black coral | *Triadopathes* spp. | 1 | 0.1 |
| TPT | Black coral | *Trissopathes* spp. | 1 | 0.3 |

An illustration of the range of protected coral catch weights reported on research trawl surveys is shown in Figure 6. Catches of over 100 kg per tow have been recorded for 7 taxa, but upper quartiles are mostly less than 10 kg and only exceed this level for the coral rubble codes CBB and CBD. Other than for these two codes, median values are low (less than 0.6 kg) and often equal to 0.1 kg. This is due to the difficulty of recording small catch weights at sea, especially with scales set up to preferentially weigh larger catches of fish; for very small catch items survey staff usually manually enter a default value of 0.1 kg.

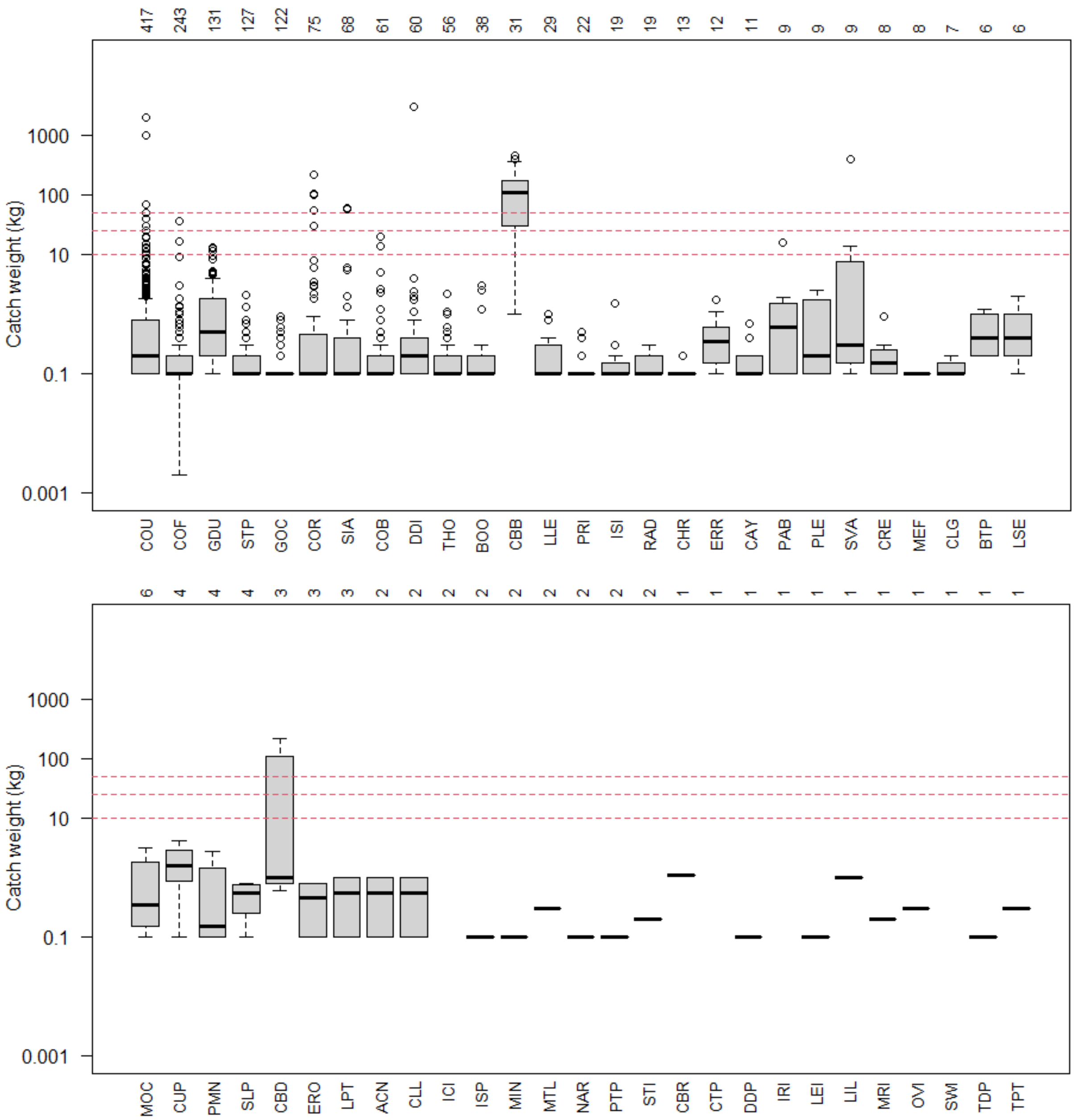


**Figure 6: Distribution of research trawl-recorded weights of protected coral catches, by taxon.** Taxa are ordered from highest to lowest number of records (numbers above plots). The box and whisker plots show medians and lower and upper quartiles in the box, whiskers extending up to 1.5 × the interquartile range, and outliers individually plotted. Note the y-axes are on a log scale. Dashed red lines show catch levels of 10, 25, and 50 kg. See Table 2 for explanation of species codes.

The distribution of research survey catch weights of protected corals was examined by year in the same way as described for observer data (Figure 7). This shows a similar pattern of more frequent larger catches earlier in the time series, but for the same reasons, i.e., coral catches of various species combined into a single code for recording and increasing taxonomic knowledge over time, this apparent trend should be treated with some caution.

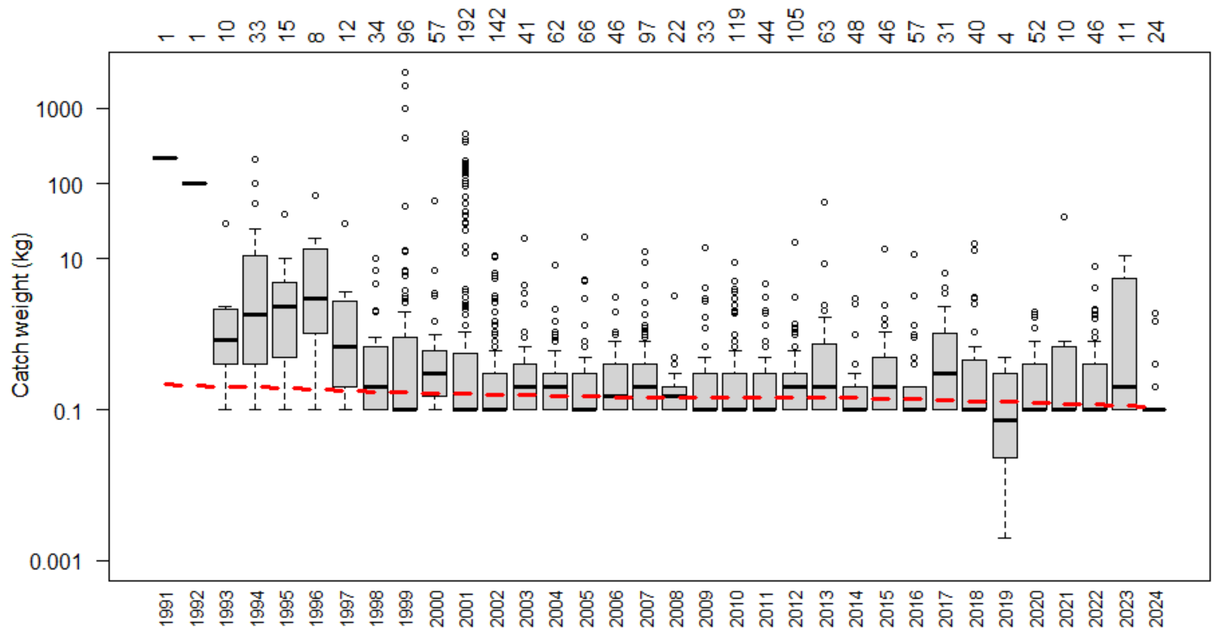


**Figure 7: Distribution of research trawl-recorded weights of protected coral catches, by year.** Taxa are ordered along the x-axis from earliest to most recent years, with the number of records shown above the plot. The box and whisker plots show medians and lower and upper quartiles in the box, whiskers extending up to 1.5 × the interquartile range, and outliers individually plotted. Note the y-axes are on a log scale. The dashed red line shows a smoothed fit to the annual median values.

## 3.3 Determination of weight thresholds

There were insufficient records to calculate meaningful catch weight percentiles for many of the taxa represented by the 98 protected coral taxa 3-letter codes, in both the observer and research trawl data. Catch records were therefore combined into groups at a higher taxonomic level where necessary and 95$^{th}$ percentiles calculated by group, with the result assigned to all component taxa. Using this approach, data from all black corals (20 codes), cup corals (14 codes), gorgonian corals excluding bamboo corals (38 codes), bamboo corals (8 codes), and stylasterid hydrocorals (8 codes) were combined – and updated large catch thresholds produced for all 98 protected coral taxa codes (Table 3). For most of the 48 codes for which there is an existing threshold in the *COD* data loading protocols the revised values are considerably lower, for example the thresholds for Antipatharia decrease from 10 or 50 kg down to 4 kg and coral rubble (alive, 1000 kg; dead, 2000 kg) values reduce to 312 kg and 324 kg, respectively. Only the thresholds for the branching scleractinian *Oculina virgosa* (OVI), a little-used catch-all code for stony branching corals (CBR), and four stylasterids codes (CRE, ERR, LPT, STL) increased.

**Table 3: Proposed catch weight thresholds for observer reported catches of protected corals.** The revised thresholds are an average of 95th percentiles from observer and research trawl databases.

| Species code | Name | Group | Current threshold (kg) | Revised threshold (kg) |
|---|---|---|---|---|
| AHL | *Antipathella* spp. | Antipatharia | | 4 |
| ATP | *Antipathes* spp. | Antipatharia | | 4 |
| BTP | *Bathypathes* spp. | Antipatharia | 10 | 4 |
| CIR | *Cirrhipathes* spp. | Antipatharia | 10 | 4 |
| COB | Antipatharia | Antipatharia | 50 | 4 |
| DDP | *Dendropathes* spp. | Antipatharia | | 4 |
| DEN | *Dendrobathypathes* spp. | Antipatharia | 10 | 4 |
| LEI | *Leiopathes* spp. | Antipatharia | 10 | 4 |
| LIL | *Lillipathes* spp. | Antipatharia | | 4 |
| LSE | *Leiopathes secunda* | Antipatharia | 50 | 4 |
| MYR | *Myriopathes* spp | Antipatharia | | 4 |
| PTP | *Parantipathes* spp. | Antipatharia | 10 | 4 |
| SLP | *Stylopathes* spp. | Antipatharia | | 4 |
| SRO | *Saropathes* spp. | Antipatharia | | 4 |
| STI | *Stichopathes* spp. | Antipatharia | 50 | 4 |
| TDP | *Triadopathes* spp. | Antipatharia | | 4 |
| TEO | *Telopathes tasmaniensis* | Antipatharia | | 4 |
| TLP | *Telopathes* spp | Antipatharia | | 4 |
| TPT | *Trissopathes* spp. | Antipatharia | 10 | 4 |
| TYL | *Tylopathes* spp. | Antipatharia | | 4 |
| CBB | Coral rubble | Coral rubble | 1000 | 312 |
| CBD | Coral rubble - dead | Coral rubble - dead | 2000 | 324 |
| CAY | *Caryophyllia* spp. | Cup coral | 300 | 3 |
| CLA | *Cladopsammia* spp. | Cup coral | | 3 |
| CMB | *Caryophyllia* (*Caryophyllia*) *ambrosia* | Cup coral | | 3 |
| CUP | Stony cup corals | Cup coral | 10 | 3 |
| CUR | *Culicia rubeola* | Cup coral | | 3 |
| DDB | *Dendrophyllia* spp. | Cup coral | | 3 |
| DDI | *Desmophyllum dianthus* | Cup coral | 500 | 3 |
| EJA | *Eguchipsammia japonica* | Cup coral | | 3 |
| FUG | *Fungiacyathus* spp. | Cup coral | | 3 |
| STP | *Stephanocyathus platypus* | Cup coral | 10 | 3 |
| STS | *Stephanocyathus spiniger* | Cup coral | 100 | 3 |
| ERO | *Enallopsammia rostrata* | *Enallopsammia* | 500 | 28 |
| COF | *Flabellum* spp. | *Flabellum* | 100 | 3 |
| FAP | *Flabellum* (*Ulocyathus*) *apertum* | *Flabellum* | | 3 |

| Species code | Name | Group | Current threshold (kg) | Revised threshold (kg) |
|---|---|---|---|---|
| JAA | *Javania* spp. | *Flabellum* | | 3 |
| GDU | *Goniocorella dumosa* | *Goniocorella* | 500 | 28 |
| ACC | *Acanthogorgia* spp. | Gorgonian | | 10 |
| ACD | Acanthogorgiidae | Gorgonian | | 10 |
| ANA | *Anthogorgia* spp. | Gorgonian | | 10 |
| ANB | *Anthothela* spp. | Gorgonian | | 10 |
| AND | Anthothelidae | Gorgonian | | 10 |
| ASD | *Astrogorgia* spp. | Gorgonian | | 10 |
| CHR | *Chrysogorgia* spp. | Gorgonian | 100 | 10 |
| CLG | *Callogorgia* spp. | Gorgonian | 10 | 10 |
| CLL | *Corallium* spp. | Gorgonian | 10 | 3 |
| CTP | *Calyptrophora* spp. | Gorgonian | | 10 |
| DSY | *Dasystenella* spp. | Gorgonian | | 10 |
| GOC | Gorgonian octocoral | Gorgonian | 10 | 10 |
| ICI | *Iciligorgia* spp. | Gorgonian | | 10 |
| IRI | *Iridogorgia* spp. | Gorgonian | 10 | 10 |
| MEF | *Metafannyella* spp. | Gorgonian | | 10 |
| MRI | *Muriceides* spp. | Gorgonian | | 10 |
| MTL | *Metallogorgia* spp. | Gorgonian | 10 | 10 |
| NAR | *Narella* spp. | Gorgonian | 10 | 10 |
| PAB | *Paragorgia* spp. | Gorgonian | 480 | 3 |
| PLD | *Parastenella* spp. | Gorgonian | | 10 |
| PLE | Sea fans | Gorgonian | 10 | 10 |
| PLG | *Plumigorgia* spp. | Gorgonian | | 10 |
| PLL | *Plumarella* spp. | Gorgonian | 10 | 10 |
| PLO | *Placogorgia* spp. | Gorgonian | | 10 |
| PML | *Primnoella* spp. | Gorgonian | | 10 |
| PMN | *Primnoa* spp. | Gorgonian | 40 | 10 |
| PRF | *Paracis* spp. | Gorgonian | | 10 |
| PRG | *Paramuricea* spp. | Gorgonian | | 10 |
| PRH | *Primnoella* | Gorgonian | | 10 |
| PRI | Primnoidae | Gorgonian | 10 | 10 |
| RAD | *Radicipes* spp. | Gorgonian | | 10 |
| SWI | *Swiftia* spp. | Gorgonian | | 10 |
| THO | *Thouarella* spp. | Gorgonian | 10 | 10 |
| TOK | *Tokoprymno* spp. | Gorgonian | | 10 |
| TRH | *Trachymuricea* spp. | Gorgonian | | 10 |
| VCT | *Victorgorgia* spp. | Gorgonian | | 10 |

| Species code | Name | Group | Current threshold (kg) | Revised threshold (kg) |
|---|---|---|---|---|
| VIC | Victorgorgiidae | Gorgonian | | 10 |
| VIL | *Villogorgia* spp. | Gorgonian | | 10 |
| ACN | *Acanella* spp. | Isididae | 20 | 5 |
| BOO | *Keratoisis* spp. | Isididae | 100 | 5 |
| ISI | Bamboo corals | Isididae | 50 | 5 |
| ISP | *Isidella* spp. | Isididae | | 5 |
| JAS | *Jasonisis* | Isididae | | 5 |
| LLE | *Lepidisis* spp. | Isididae | 10 | 5 |
| MIN | *Minuisis* spp. | Isididae | 40 | 5 |
| PAN | *Primnoisis antarctica* | Isididae | | 5 |
| MOC | *Madrepora oculata* | *Madrepora* | 2500 | 100 |
| OVI | *Oculina virgosa* | *Oculina* | 10 | 51 |
| SIA | Scleractinia | Scleractinia | 6000 | 62 |
| SVA | *Solenosmilia variabilis* | *Solenosmilia* | 15000 | 202 |
| CBR | Stony branching corals | Stony branching corals | 10 | 120 |
| COO | *Conopora* spp. | Stylasteridae | | 67 |
| COR | Stylasteridae | Stylasteridae | 1000 | 67 |
| CRE | *Calyptopora reticulata* | Stylasteridae | 10 | 67 |
| CRY | *Cryptelia* spp. | Stylasteridae | | 67 |
| ERR | *Errina* spp. | Stylasteridae | 10 | 67 |
| LPP | *Lepidopora* spp. | Stylasteridae | | 67 |
| LPT | *Lepidotheca* spp. | Stylasteridae | 50 | 67 |
| STL | Stylaster spp. | Stylasteridae | 10 | 67 |
| COU | True coral (unidentified) | True coral | 1000 | 230 |

## 3.4 Verification of large observed catches

### 3.4.1 Observer trip reports, logbooks, diaries

Fisheries New Zealand staff searched for any observer logbook or diary entries associated with the 50 trips identified above (Section 2.4.1) that made mention of a large coral catch but found nothing of use. The detailed trip reports searched for these 50 trips were more useful, but provided comments or tables of data that confirmed only 11 of the large catches recorded in the paper or electronic forms.

### 3.4.2 Observer photographs

Photographs taken by observers of coral catches were more useful overall than the trip reports. Approximation of weights from examination of images (several hundred were available) enabled confirmation of 64 large coral catches.

### 3.4.3 Vessel-reported catches

There were 976 vessel-reported records of coral catches 10 kg or heavier from 975 fishing events (i.e., for one fishing event there was a catch of 10 kg or more recorded for two coral taxa). Of these 976 catches, 818 were protected species. The fishing method for all records was trawling, mostly bottom trawling but including some midwater trawls that clearly contacted the seabed at some point. Matching of the fishing events associated with the coral catches between the *COD* and EDS databases was only partly successful. Of the 818 vessel-reported protected coral species catches, 690 (84%) of the equivalent records in the *COD* database were identified. Agreement between the two recording systems was highly variable; only 18% of the catch values agreed exactly, only about a quarter of the vessel-reported catch weights were within 25% of the observer-reported value, and for 29 records there was no recorded catch in *COD* that matched the vessel-reported code. More often than not (68% of the matched records) the vessel reported catch was larger than the observer-reported value. However, for the purposes of validating large observed coral catches the data were useful, with 148 records for which both the observer and vessel values were above the threshold value for a large catch of the taxon concerned.

### 3.4.4 Coral abundance models

There were 918 observed protected coral catches above the threshold weight for a large catch for the taxon. Of these, 144 (16%) were at locations within predicted ‘hot-spots’ of abundance for the taxon, i.e., spatial cells in which models predicted the highest abundance for the taxon (over the 95$^{th}$ percentile) across the entire New Zealand region. The alignment of large catches with abundance model predictions varied among taxonomic groups, from a low of 5% of black coral catches recorded from these high abundance areas to a high of 70% for *Flabellum* spp. cup corals.

### 3.4.5 Seamount locations

Observed coral records (of any weight) were associated with 135 separate UTFs. Of the 918 observed protected coral catches above the threshold weight for a large catch for the taxon, 162 were made within the polygon defining the basal boundary of one of these UTFs. A range of taxonomic codes were recorded on these features, mainly comprising black corals, gorgonian corals (especially bamboo and bubblegum corals), and stony corals (especially *Goniocorella dumosa*).

## 3.5 Mapping large coral catch distributions

Maps showing the distribution of protected corals caught in commercial fishing trawls and recorded by observers were produced for 18 groups of corals (Figure 8 to Figure 25).

### 3.5.1 Black corals

Records of black corals (Antipatharia) were widespread around the region, with large catches (>4 kg) recorded in most of the locations where smaller catches were made with the exception of a few areas including the east coast of the North Island and the central Chatham Rise. Large catches with verification were widespread from the Chatham Rise north but noticeably absent in the south (Figure 8).

### 3.5.2 Stony cup corals

Caryophyllid cup corals (Caryophylliidae) were similarly widespread, with large catches (>3 kg) (both verified and unverified) found in many locations, from the Campbell Plateau in the south to the north of the North Island; there was a concentration of verified large catches on the northwest Chatham Rise (Figure 9). There was also a strong concentration of verified large catches of *Flabellum* spp. cup corals on the Chatham Rise, but in this case in the west and south of this feature (Figure 10). Records of *Flabellum* spp. cup corals were mainly limited to the Chatham Rise although there were records across most latitudes including verified large catches off Northland and east of the Auckland Islands (Figure 10). Cup corals were less frequently recorded using the generic code CUP (stony cup corals) and the map for this code adds little to the overall picture for cup corals except to provide a verified large catch east of the Chatham Rise (Figure 11).

### 3.5.3 Branching stony corals

Verified records of large catches (>28 kg) of the branching stony coral *Goniocorella dumosa* were considerably widespread across the extent of the mapped region, from the West Norfolk Ridge in the North to the Macquarie Ridge and Campbell plateau in the South, the Chatham Rise in the middle, and the Louisville Seamount Chain in the east (Figure 12). It is interesting to note that the only research survey to sample the fished seamounts in this chain did not find this species (Clark et al. 2015). Records of another key branching coral species, *Solenosmilia variabilis*, were slightly fewer than *Goniocorella dumosa*, with verified records limited to a few locations on the southern and eastern periphery of the region within the EEZ as well as the Louisville Seamount Chain (where Clark et al. 2015 *did* record this species) (Figure 13). Records of *Enallopsammia rostrata* (Figure 14) and *Madrepora oculata* (Figure 15) were sparser still, but fairly widespread for both species, with verified large catches mostly limited to the Chatham Rise, although there was one verified record of *Enallopsammia rostrata* from the West Norfolk Ridge. There were very few records of the less common *Oculina virgosa*, although these were also spread widely, with only a single large catch (unverified) reported (Figure 16).

The catch-all code for stony branching corals (CBR) was less used than other more specific codes for these corals and, although records were fairly widespread, no large catches were recorded (Figure 17).

### 3.5.4 Gorgonian corals

There were numerous observer records of bamboo corals (Keratoisididae/Mopseidae), distributed around all the major features of the region (Figure 18), with concentrations of large catches (>5 kg) on the West Norfolk Ridge and Lord Howe Rise in the north, on the southern Chatham Rise, and on the Bounty and Campbell Plateaus in the south. Numerous verified large catches of bamboo corals were identified, in each of these areas. Catches of Primnoid gorgonians were also widespread, with a similar distribution to bamboo corals, although only a few large catches (>10 kg) were reported by observers and most of these, on the West Norfolk Ridge, Chatham Rise, and Bounty Plateau, were verified (Figure 19). The code for unspecified gorgonian corals (GOC) has had considerable usage, with numerous records in all parts of the study region. Large catches (>10 kg), mostly verified, have been recorded mainly from the West Norfolk Ridge, the south Chatham Rise, the Bounty Plateau, and the Puysegur Banks (Figure 20).

### 3.5.5 Stylasterid hydrocorals

Records of stylasterids were scattered across the study area, with no particular concentration in any location (Figure 21). Several large catches (>67 kg) were reported. Those that were verified were on the eastern Chatham Rise, off Hawke Bay on the east coast of the North Island, and on the northwest Challenger Plateau.

### 3.5.6 Coral rubble - live

Records of coral rubble were widespread, with concentrations on the Chatham Rise, southern plateaus, the Louisville Seamount Chain, and the West Norfolk Ridge (Figure 22). Large catches (>312 kg) were reported in most of these general locations, but verified only on the Louisville Seamount Chain.

### 3.5.7 Coral rubble – dead

Records of dead coral rubble showed a similar distribution to those of live rubble, but lacked representation in the north and on the Louisville Seamount Chain (Figure 23). Large catches (>324 kg) were reported mostly from the eastern Chatham Rise, Stewart-Snares Shelf, and Macquarie Ridge but were verified only at several locations west of the Auckland Islands and in the vicinity of the Andes Seamounts southeast of the Chatham Islands.

### 3.5.8 True coral

Records of “true corals” were more numerous than any others, due to the convenience of using this code to at least record captures of protected corals when finer taxonomic resolution was not possible. The accuracy of identification at this level is also likely to be high so that the mapped distribution of catches may be particularly useful for protected coral taxa as a whole. Large catches of protected corals reported under this code (>230 kg) were widespread, although few were recorded from the Campbell and Bounty Plateaus, with verified catches reported from the Puysegur and Macquarie Ridge in the south, the seamounts east of the Chatham Islands, the Northwest Challenger Plateau, West Norfolk Ridge, and northern Louisville Seamount Chain (Figure 24).

### 3.5.9 Scleractinia

Records of Scleractinia were widespread around the region, reflecting the extensive distribution of this broad group and the frequency with which this code was used by observers (Figure 25). Large, verified catches (>62kg) were reported from the West Norfolk Ridge, Louisville Seamount Chain, northern and eastern Chatham Rise, and Macquarie Ridge, with one or two unverified catches in other locations (eastern Campbell Plateau, northwest Challenger Plateau, and Lord Howe Rise).

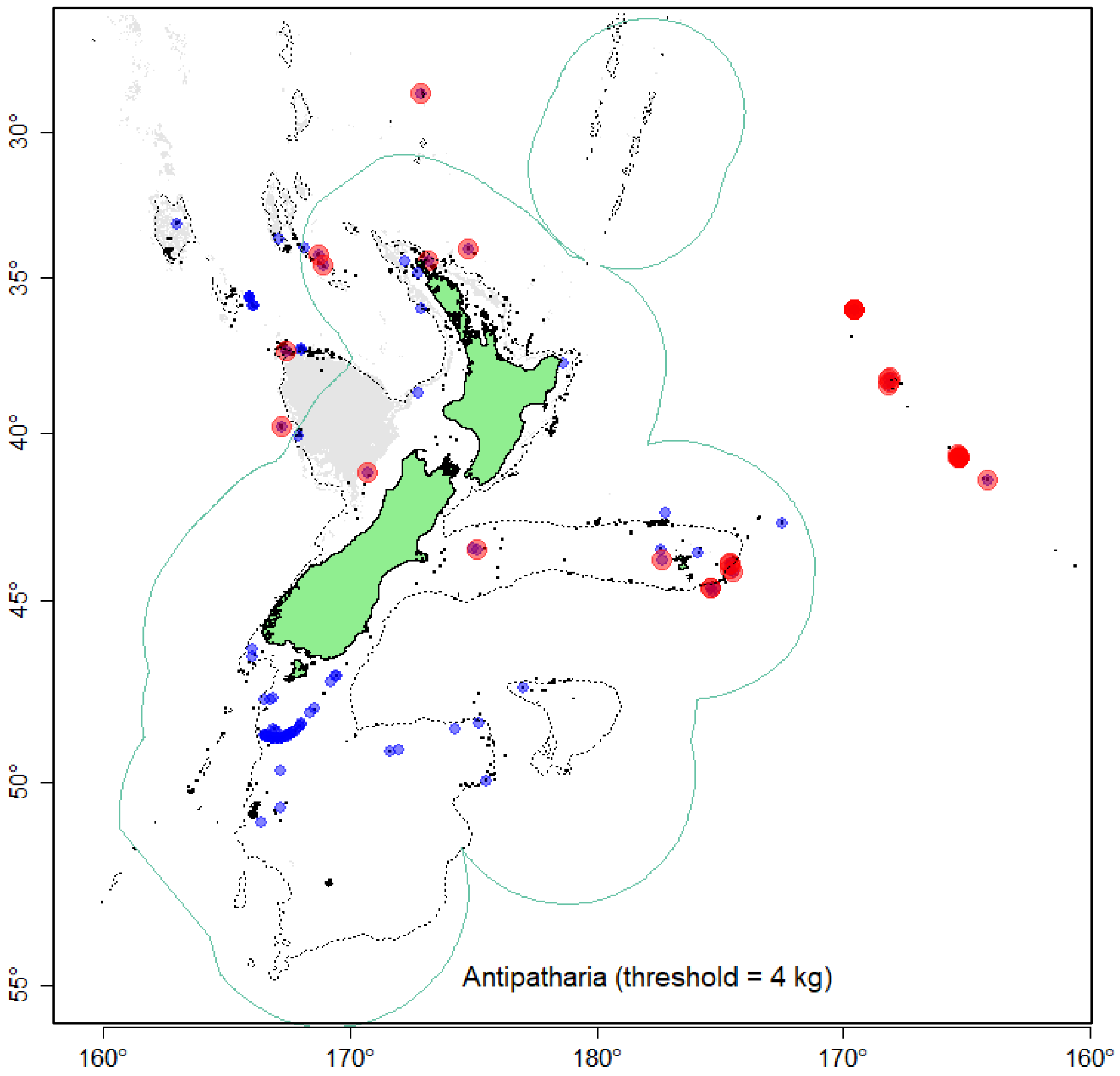


**Figure 8: Observed catches of Antipatharia (black coral).** Black dots, catches below weight threshold; blue dots, catches above threshold, unverified; red dots, catches above threshold, verified. Area of predicted abundance above 95th percentile (from Anderson et al. 2023) shown in grey. New Zealand EEZ boundary shown in teal, dashed black line is the 1000 m contour.

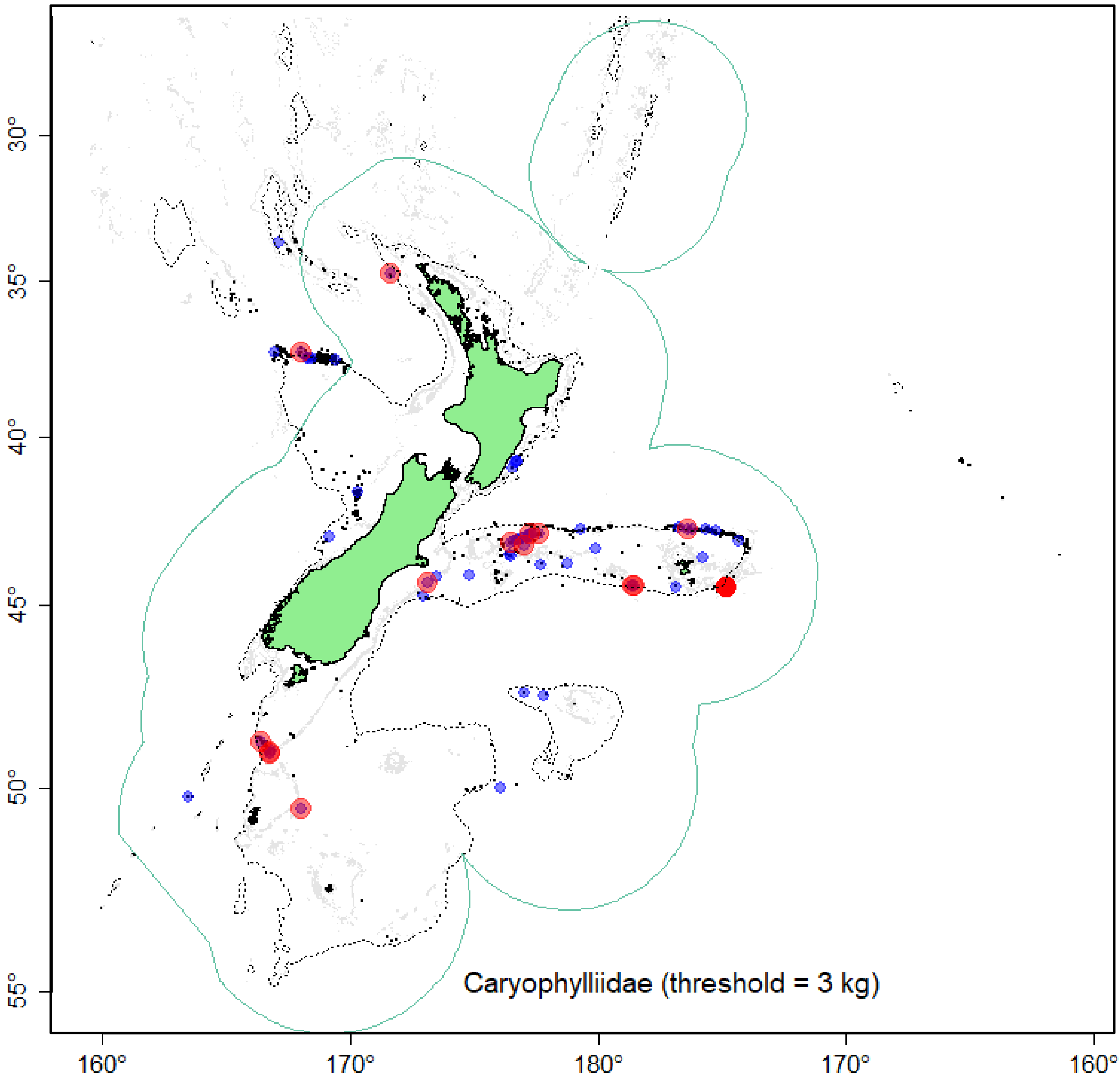


**Figure 9: Observed catches of Caryophyllidae (cup corals).** Black dots, catches below weight threshold; blue dots, catches above threshold, unverified; red dots, catches above threshold, verified. Area of predicted abundance above 95th percentile (from Anderson et al. 2023) shown in grey. New Zealand EEZ boundary shown in teal, dashed black line is the 1000 m contour.

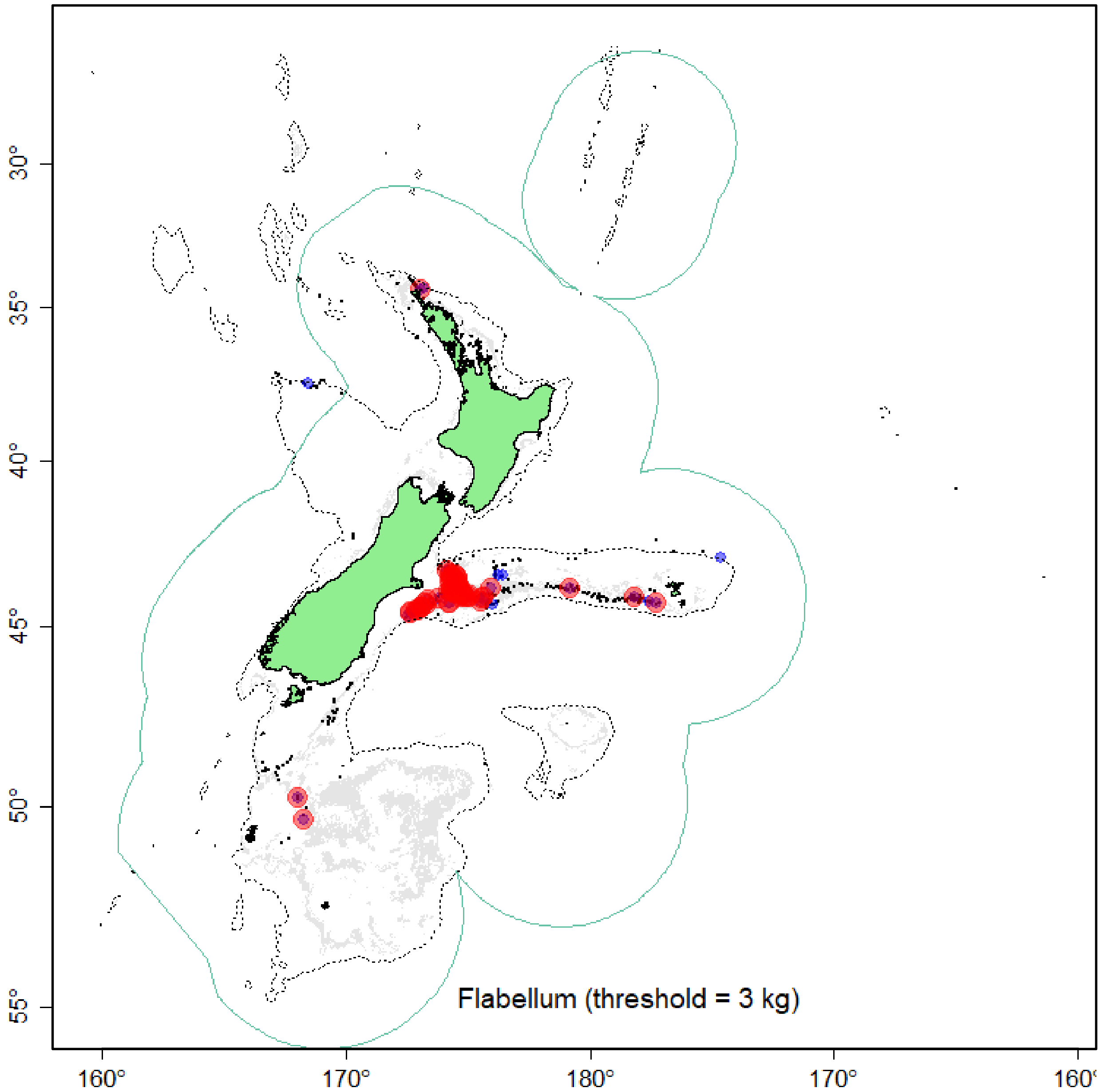


**Figure 10: Observed catches of *Flabellum* spp. (cup corals).** Black dots, catches below weight threshold; blue dots, catches above threshold, unverified; red dots, catches above threshold, verified. Area of predicted abundance above 95th percentile (from Anderson et al. 2023) shown in grey. New Zealand EEZ boundary shown in teal, dashed black line is the 1000 m contour.

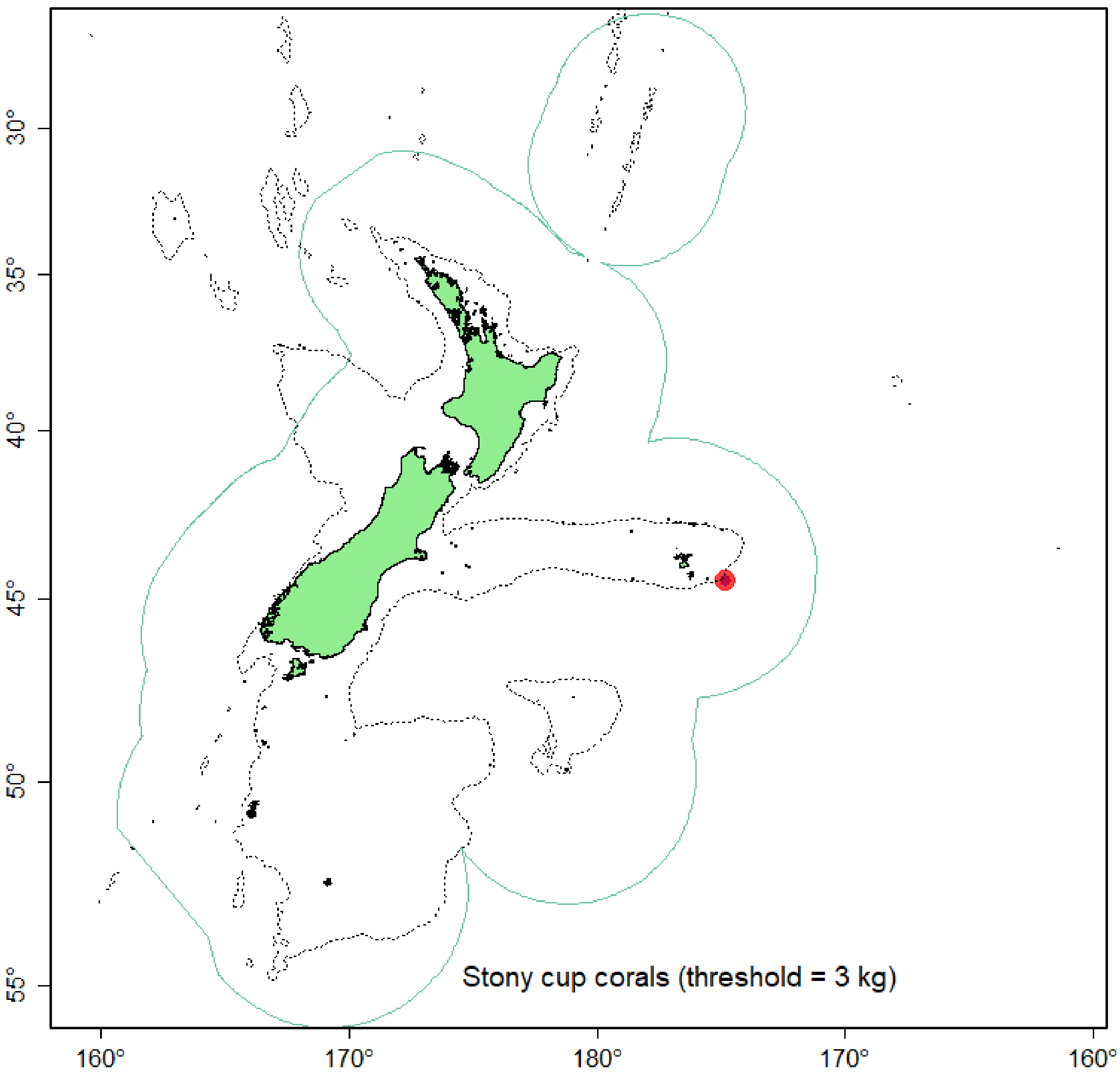


**Figure 11: Observed catches of stony cup corals (unidentified cup corals).** Black dots, catches below weight threshold; blue dots, catches above threshold, unverified; red dots, catches above threshold, verified. New Zealand EEZ boundary shown in teal, dashed black line is the 1000 m contour.

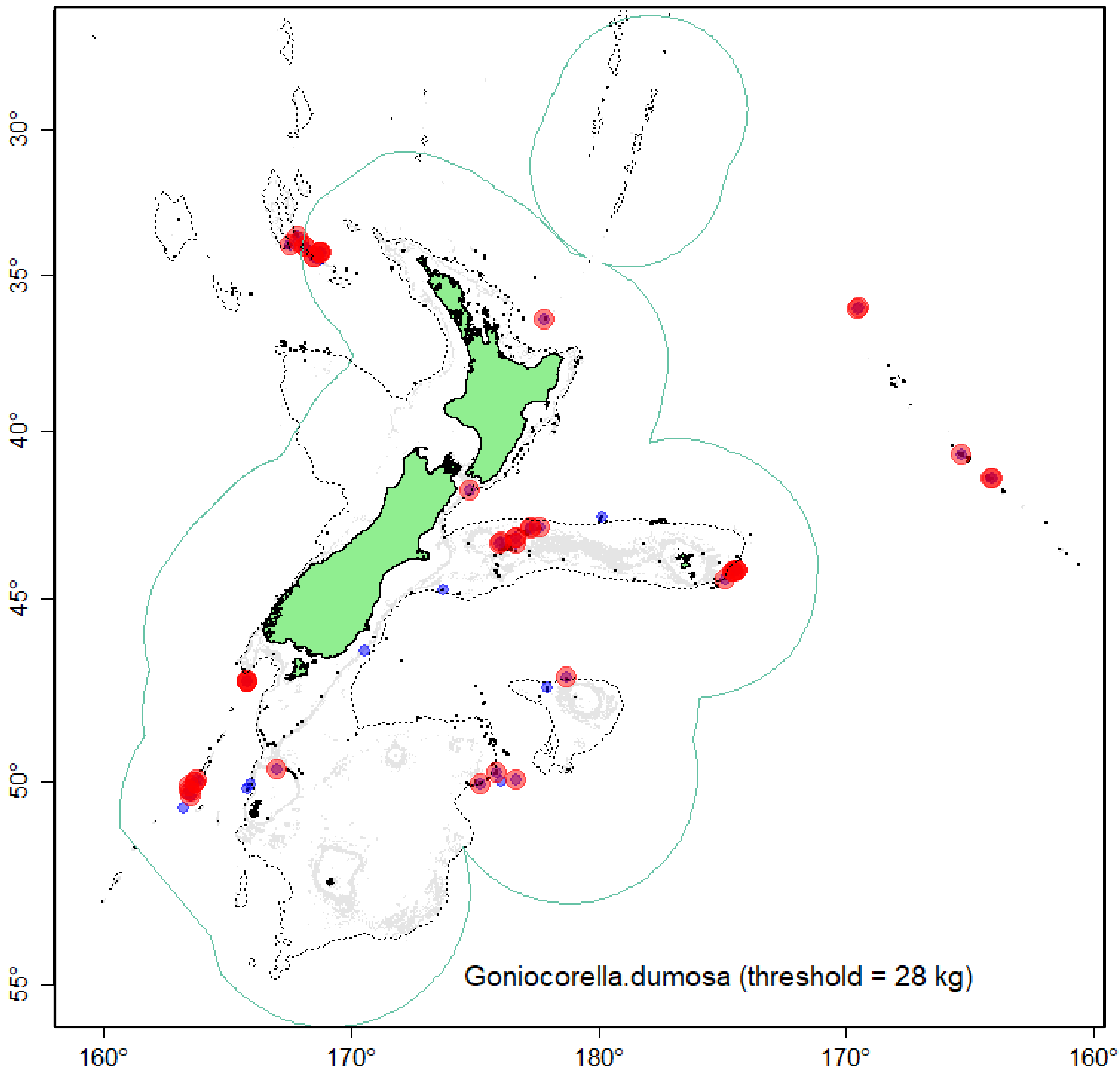


**Figure 12: Observed catches of *Goniocorella dumosa* (branching scleractinian).** Black dots, catches below weight threshold; blue dots, catches above threshold, unverified; red dots, catches above threshold, verified. Area of predicted abundance above 95th percentile (from Anderson et al. 2023) shown in grey. New Zealand EEZ boundary shown in teal, dashed black line is the 1000 m contour.

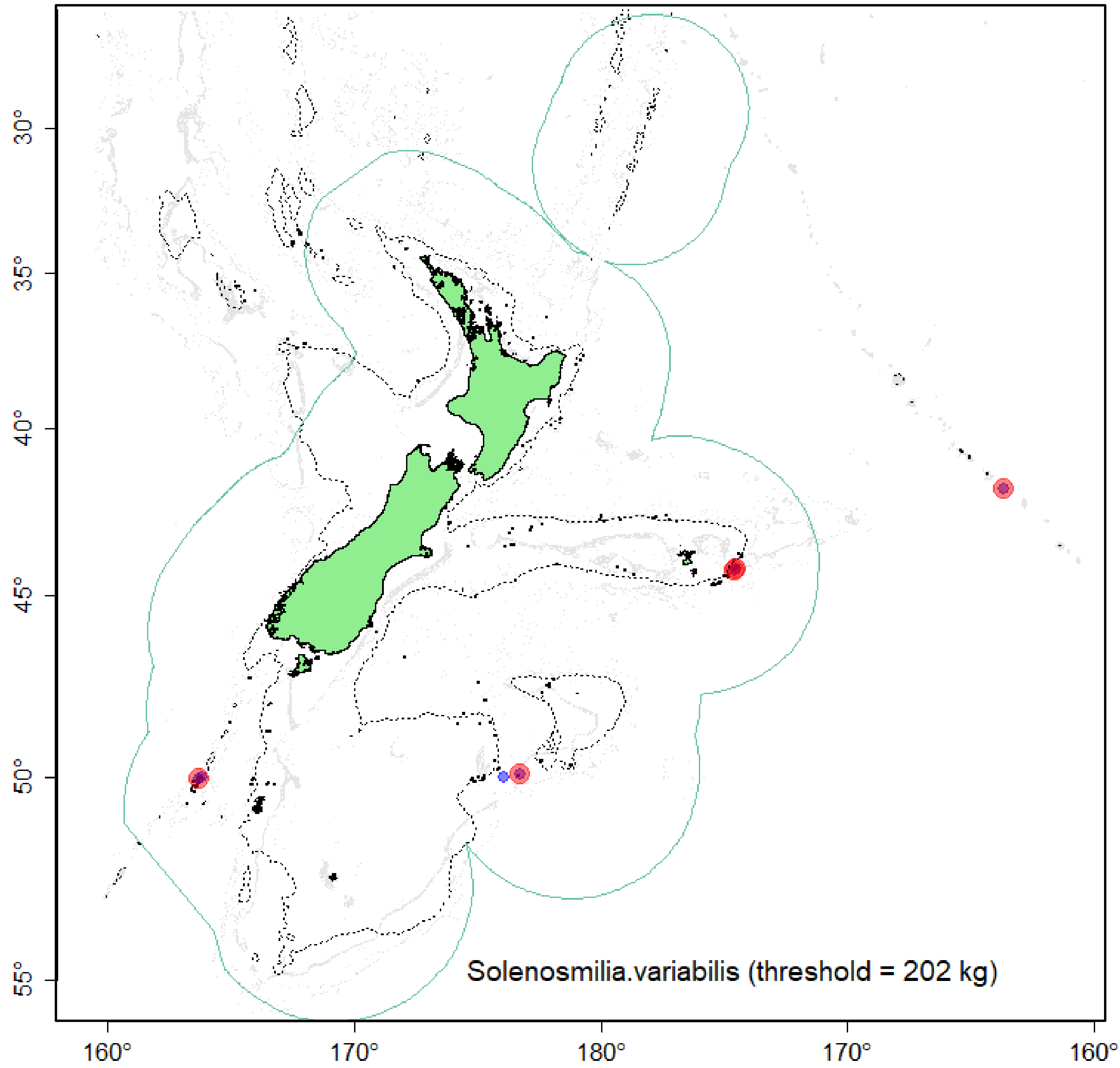


**Figure 13: Observed catches of *Solenosmilia variabilis* (branching stony coral).** Black dots, catches below weight threshold; blue dots, catches above threshold, unverified; red dots, catches above threshold, verified. Area of predicted abundance above 95th percentile (from Anderson et al. 2023) shown in grey. New Zealand EEZ boundary shown in teal, dashed black line is the 1000 m contour.

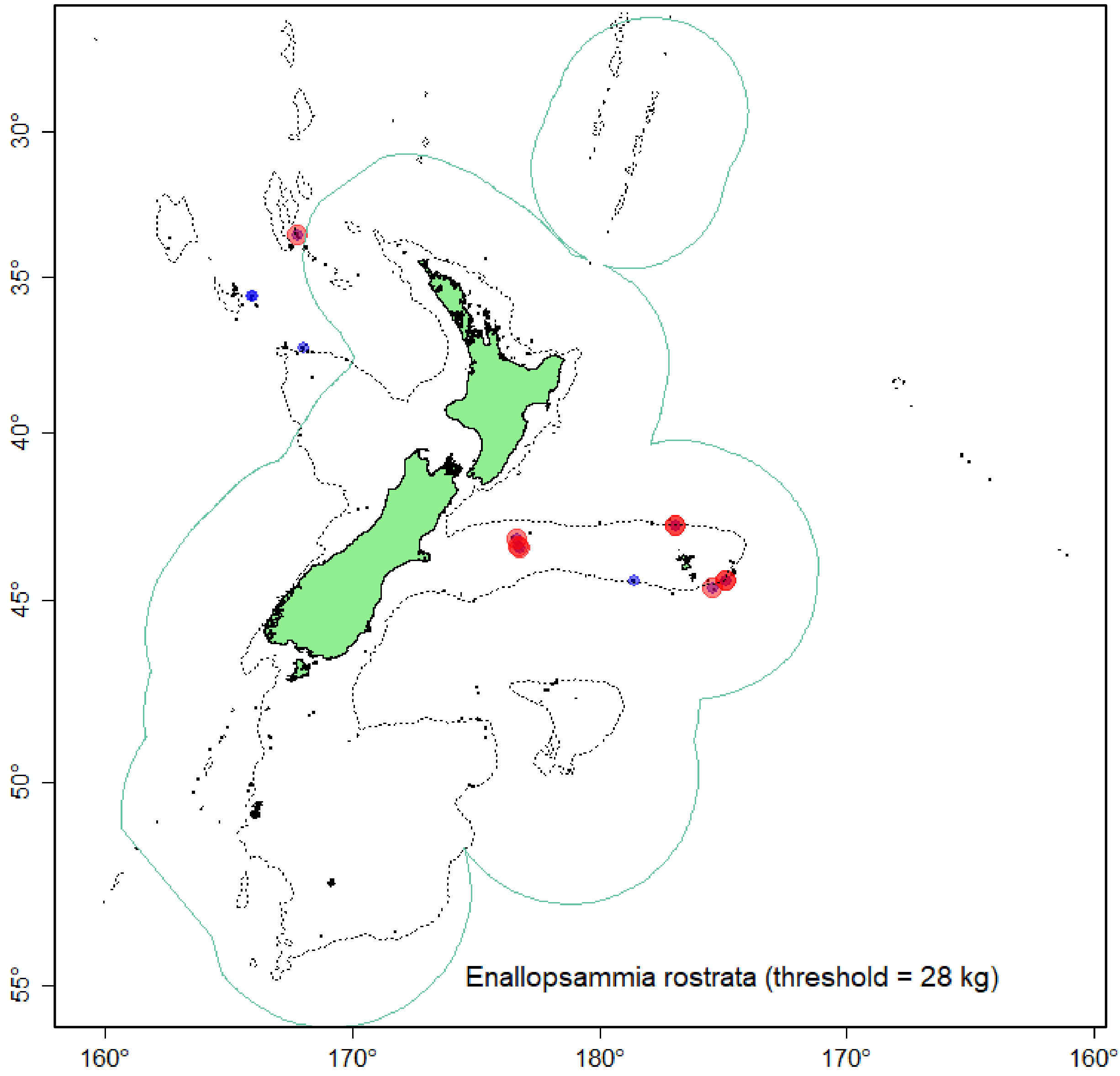


**Figure 14: Observed catches of *Enallopsammia rostrata* (branching stony coral).** Black dots, catches below weight threshold; blue dots, catches above threshold, unverified; red dots, catches above threshold, verified. New Zealand EEZ boundary shown in teal, dashed black line is the 1000 m contour.

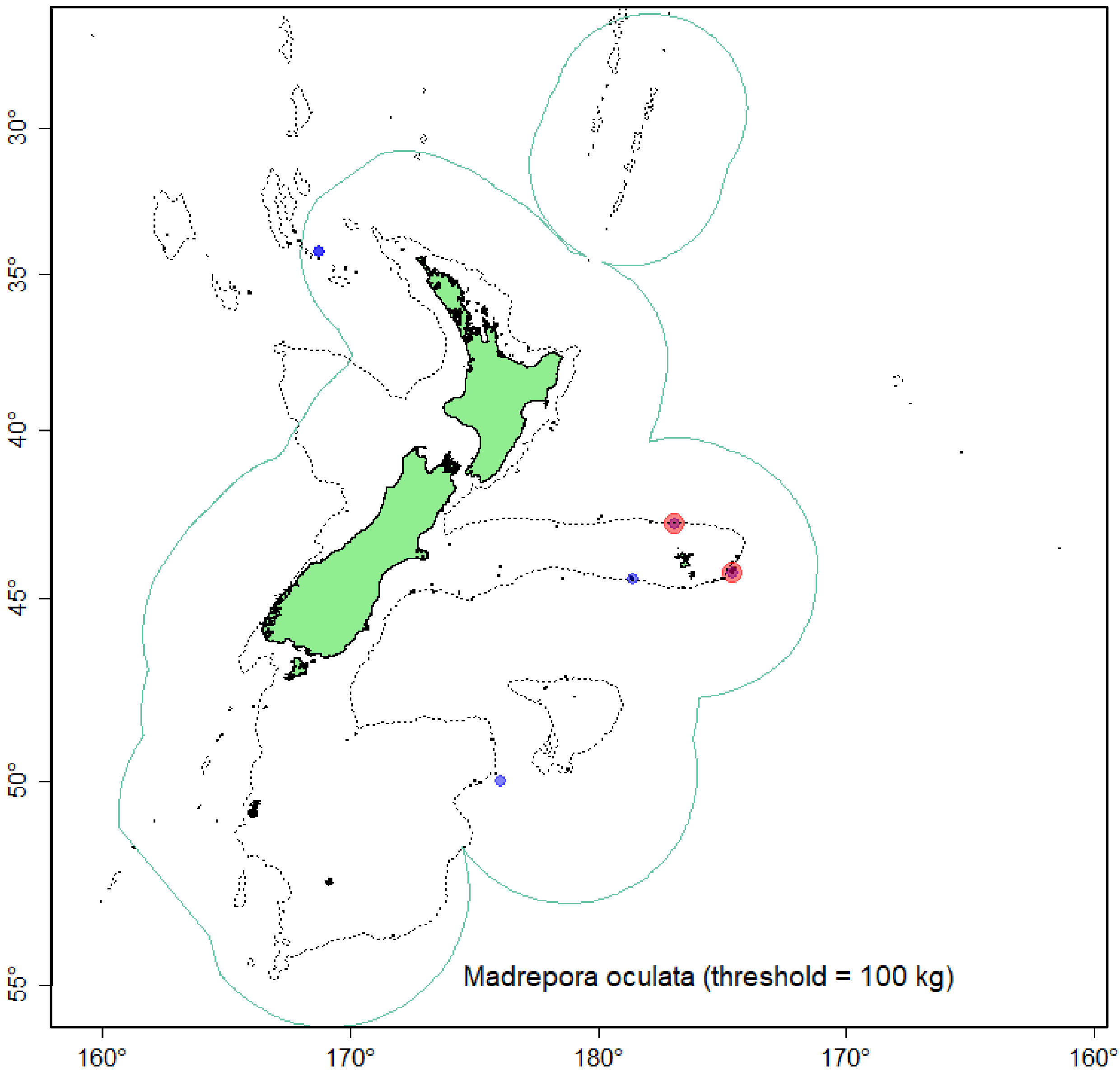


**Figure 15: Observed catches of *Madrepora oculata* (branching stony coral).** Black dots, catches below weight threshold; blue dots, catches above threshold, unverified; red dots, catches above threshold, verified. New Zealand EEZ boundary shown in teal, dashed black line is the 1000 m contour.

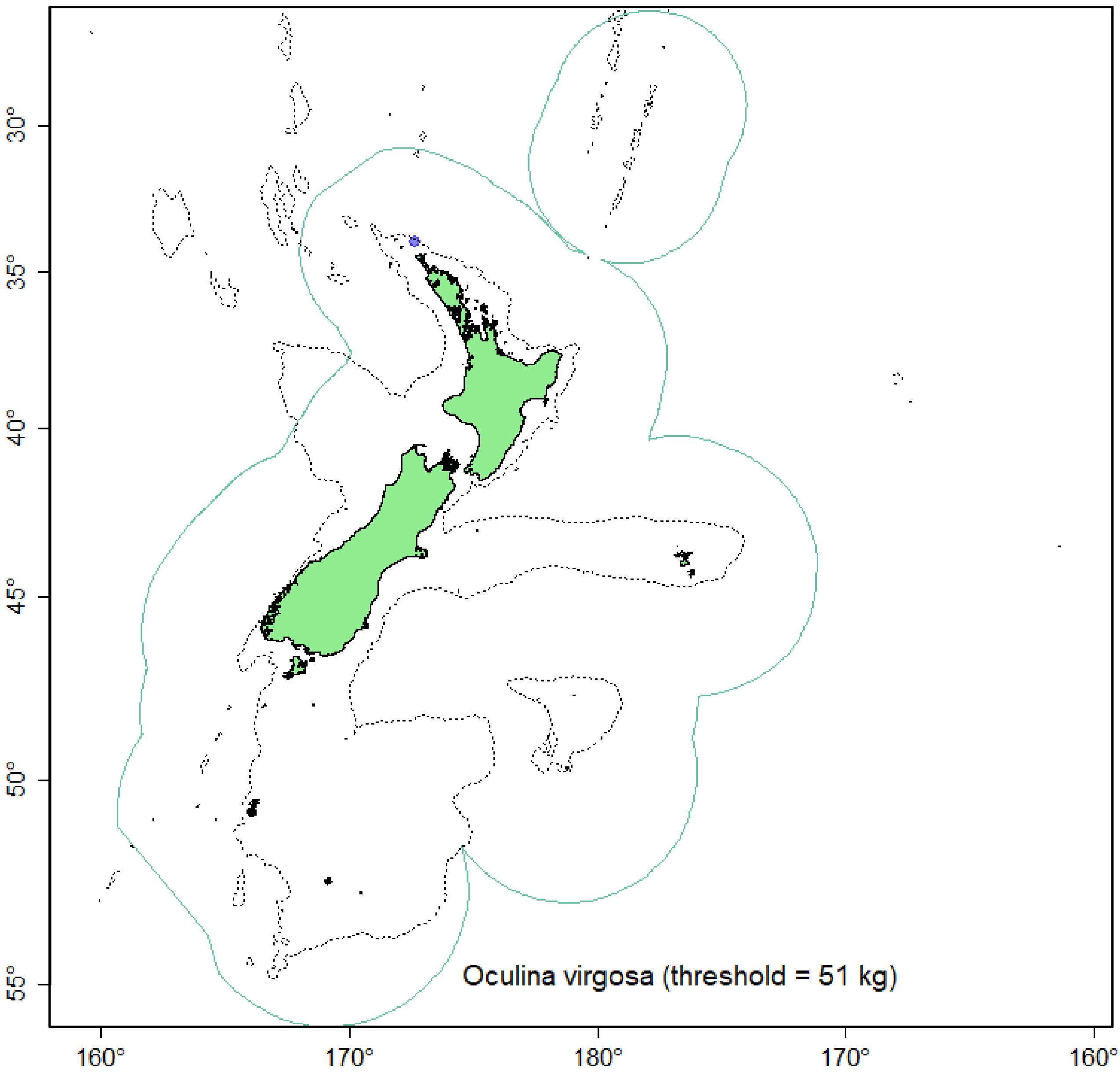


**Figure 16: Observed catches of *Oculina virgosa* (branching stony coral).** Black dots, catches below weight threshold; blue dots, catches above threshold, unverified; red dots, catches above threshold, verified. New Zealand EEZ boundary shown in teal, dashed black line is the 1000 m contour.

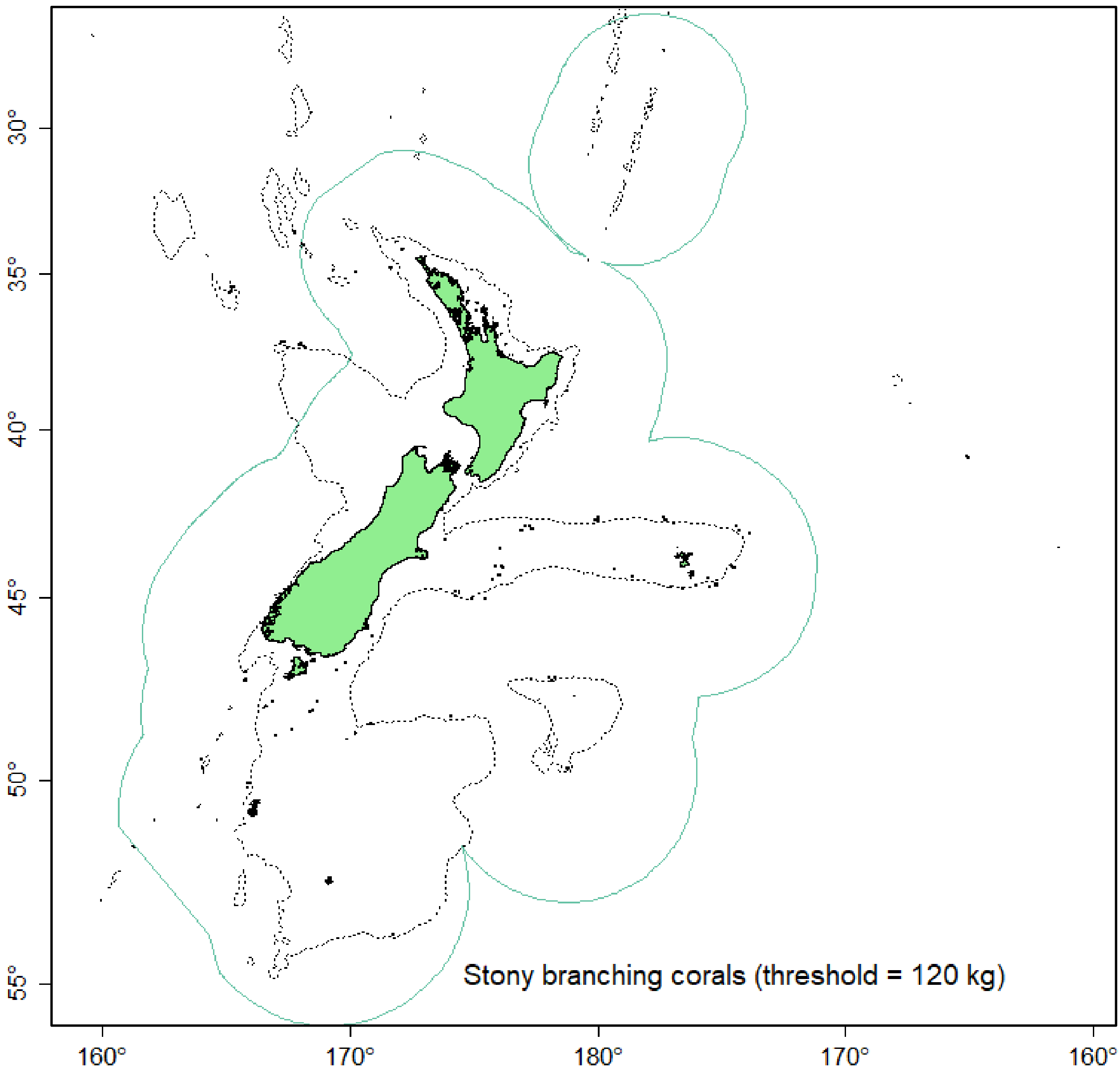


**Figure 17: Observed catches of unidentified branching scleractinians (stony corals).** Black dots, catches below weight threshold; blue dots, catches above threshold, unverified; red dots, catches above threshold, verified. New Zealand EEZ boundary shown in teal, dashed black line is the 1000 m contour.

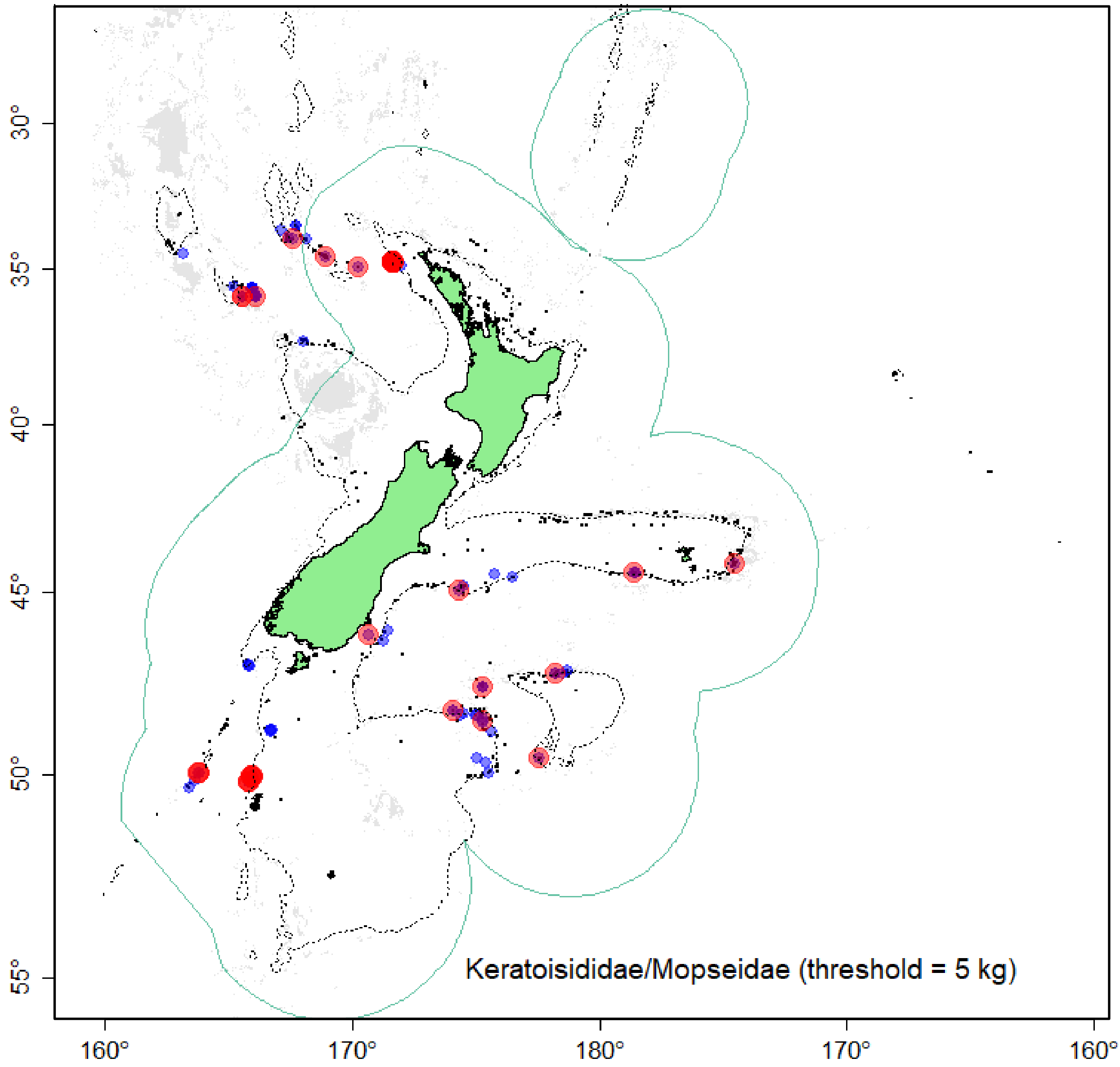


**Figure 18: Observed catches of Keratoisididae/Mopseidae (bamboo corals).** Black dots, catches below weight threshold; blue dots, catches above threshold, unverified; red dots, catches above threshold, verified. Area of predicted abundance above 95th percentile (from Anderson et al. 2023) shown in grey. New Zealand EEZ boundary shown in teal, dashed black line is the 1000 m contour.

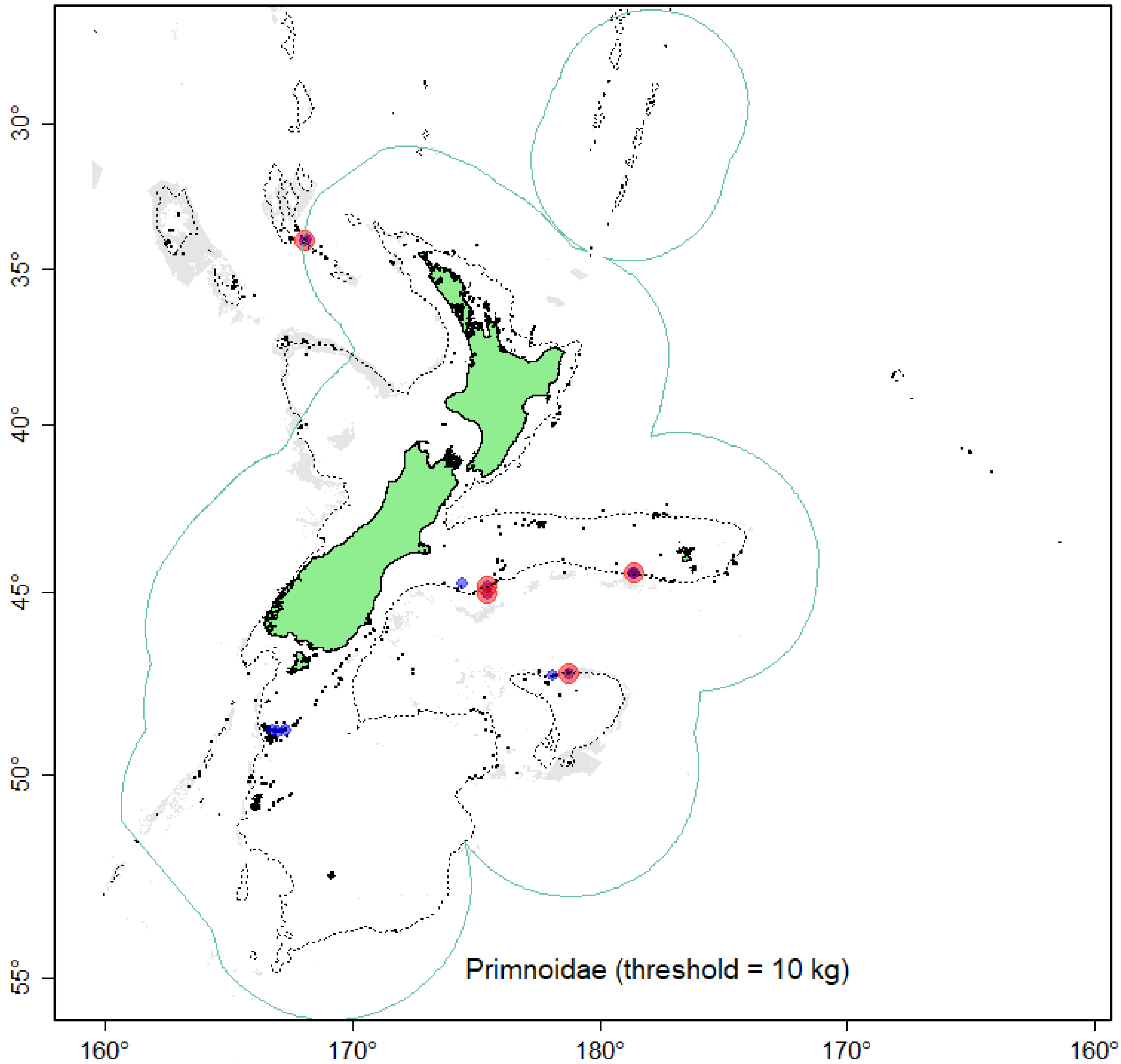


**Figure 19: Observed catches of Primnoidae.** Black dots, catches below weight threshold; blue dots, catches above threshold, unverified; red dots, catches above threshold, verified. Area of predicted abundance above 95th percentile (from Anderson et al. 2023) shown in grey. New Zealand EEZ boundary shown in teal, dashed black line is the 1000 m contour.

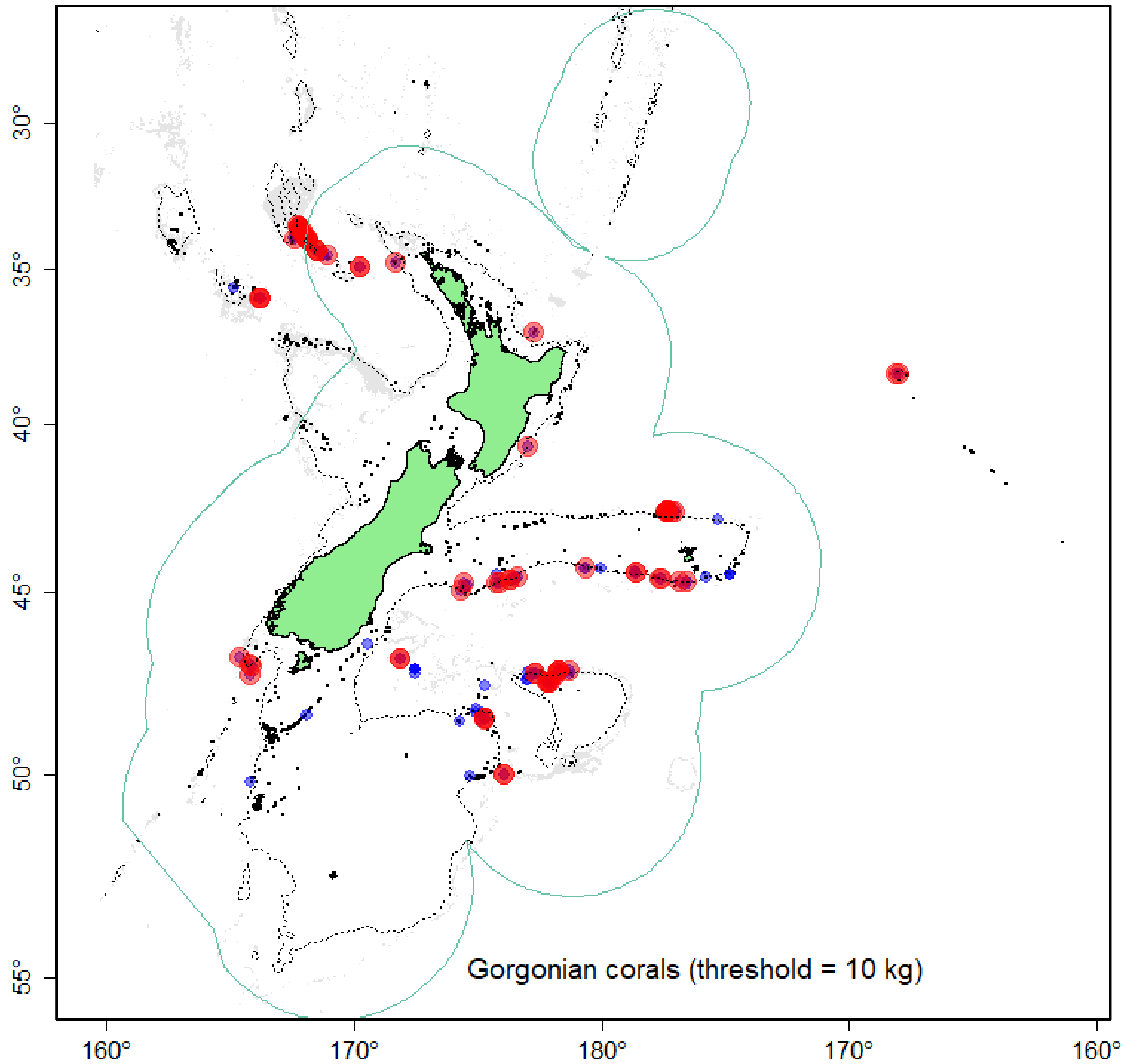


**Figure 20: Observed catches of Gorgonian corals (sea fans, sea whips).** Black dots, catches below weight threshold; blue dots, catches above threshold, unverified; red dots, catches above threshold, verified. Area of predicted abundance above 95th percentile (from Anderson et al. 2023) shown in grey. New Zealand EEZ boundary shown in teal, dashed black line is the 1000 m contour.

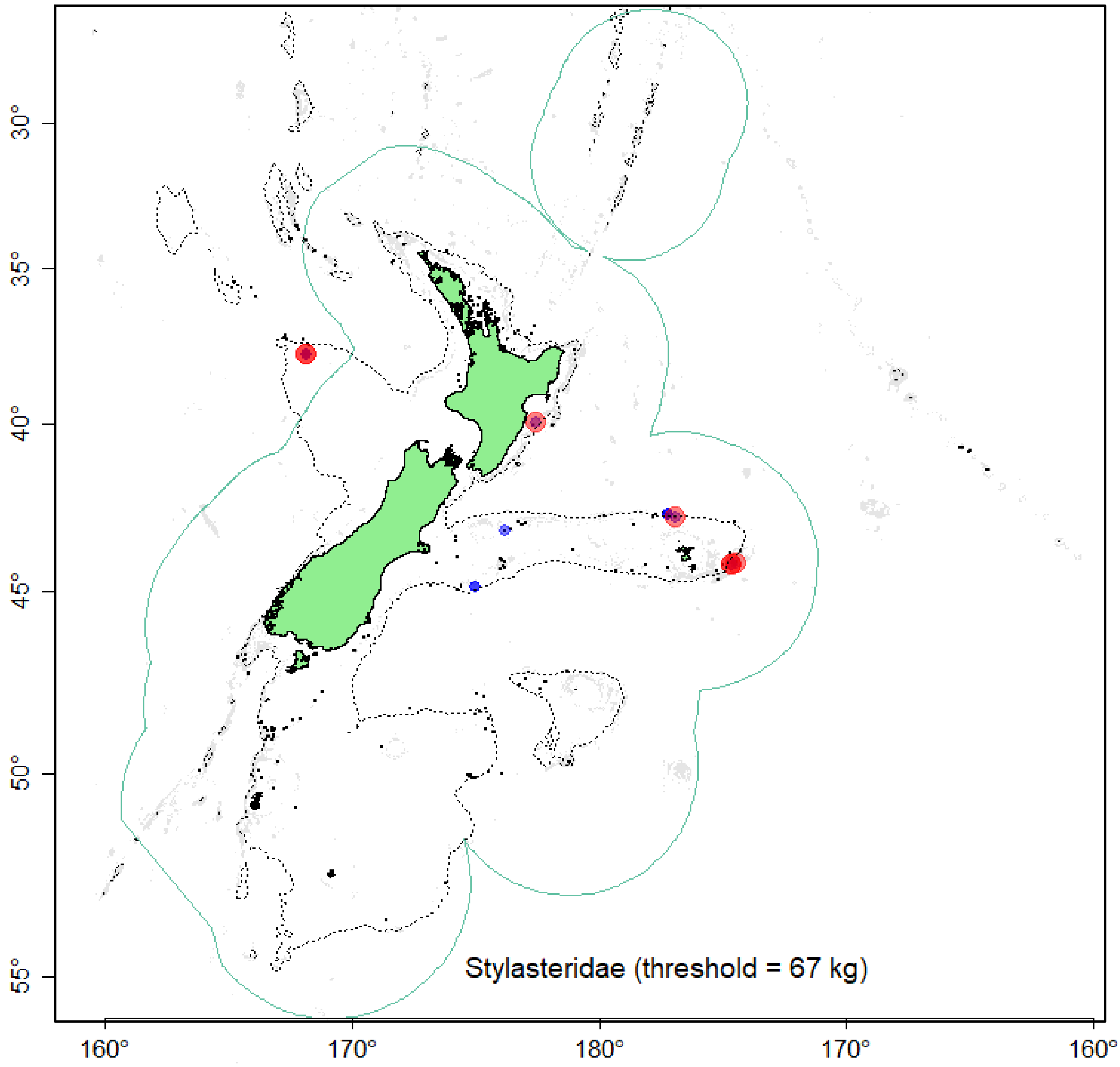


**Figure 21: Observed catches of Stylasteridae (hydrocorals).** Black dots, catches below weight threshold; blue dots, catches above threshold, unverified; red dots, catches above threshold, verified. Area of predicted abundance above 95th percentile (from Anderson et al. 2023) shown in grey. New Zealand EEZ boundary shown in teal, dashed black line is the 1000 m contour.

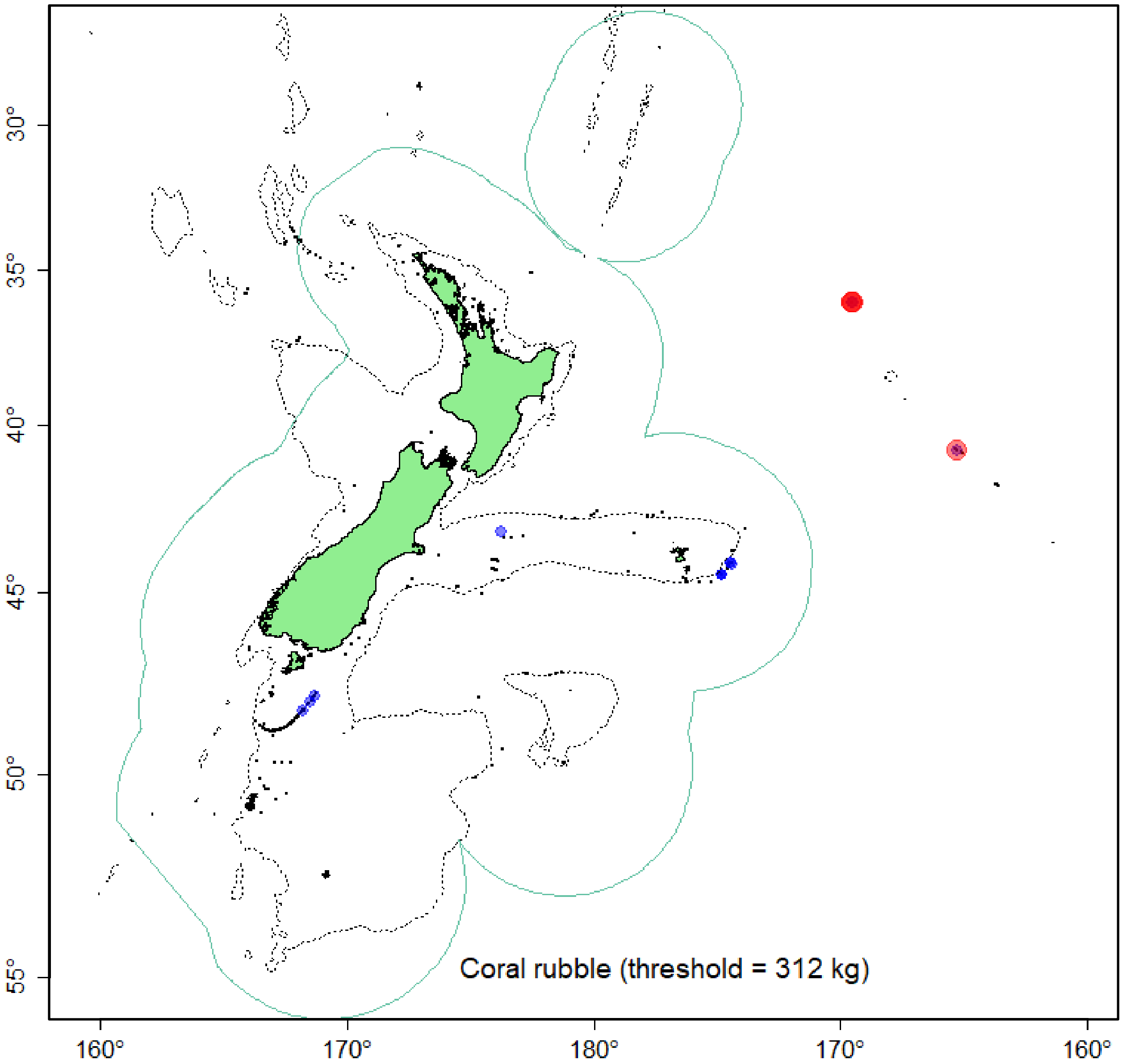


**Figure 22: Observed catches of coral rubble (live).** Black dots, catches below weight threshold; blue dots, catches above threshold, unverified; red dots, catches above threshold, verified. New Zealand EEZ boundary shown in teal, dashed black line is the 1000 m contour.

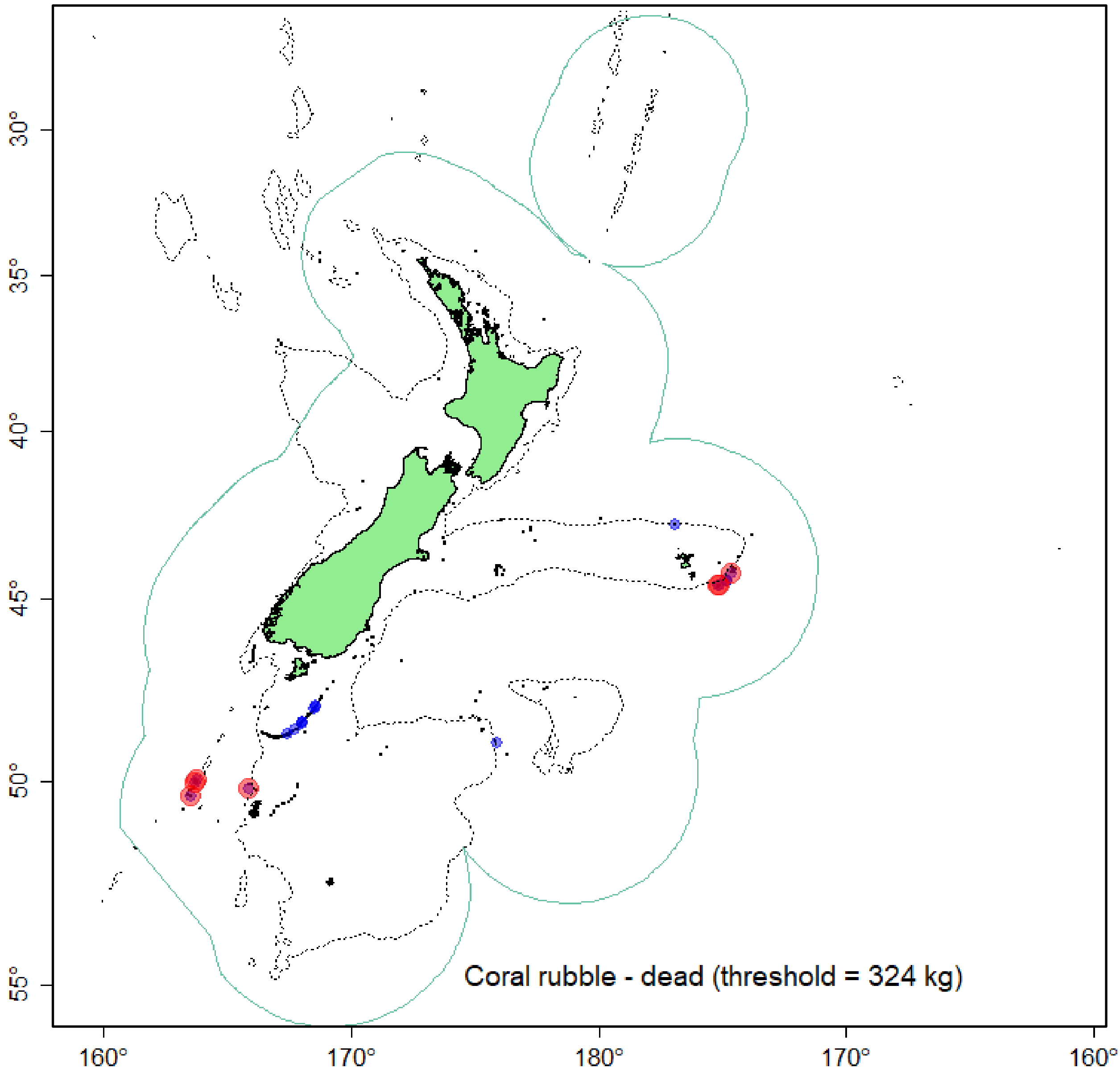


**Figure 23: Observed catches of coral rubble (dead).** Black dots, catches below weight threshold; blue dots, catches above threshold, unverified; red dots, catches above threshold, verified. New Zealand EEZ boundary shown in teal, dashed black line is the 1000 m contour.

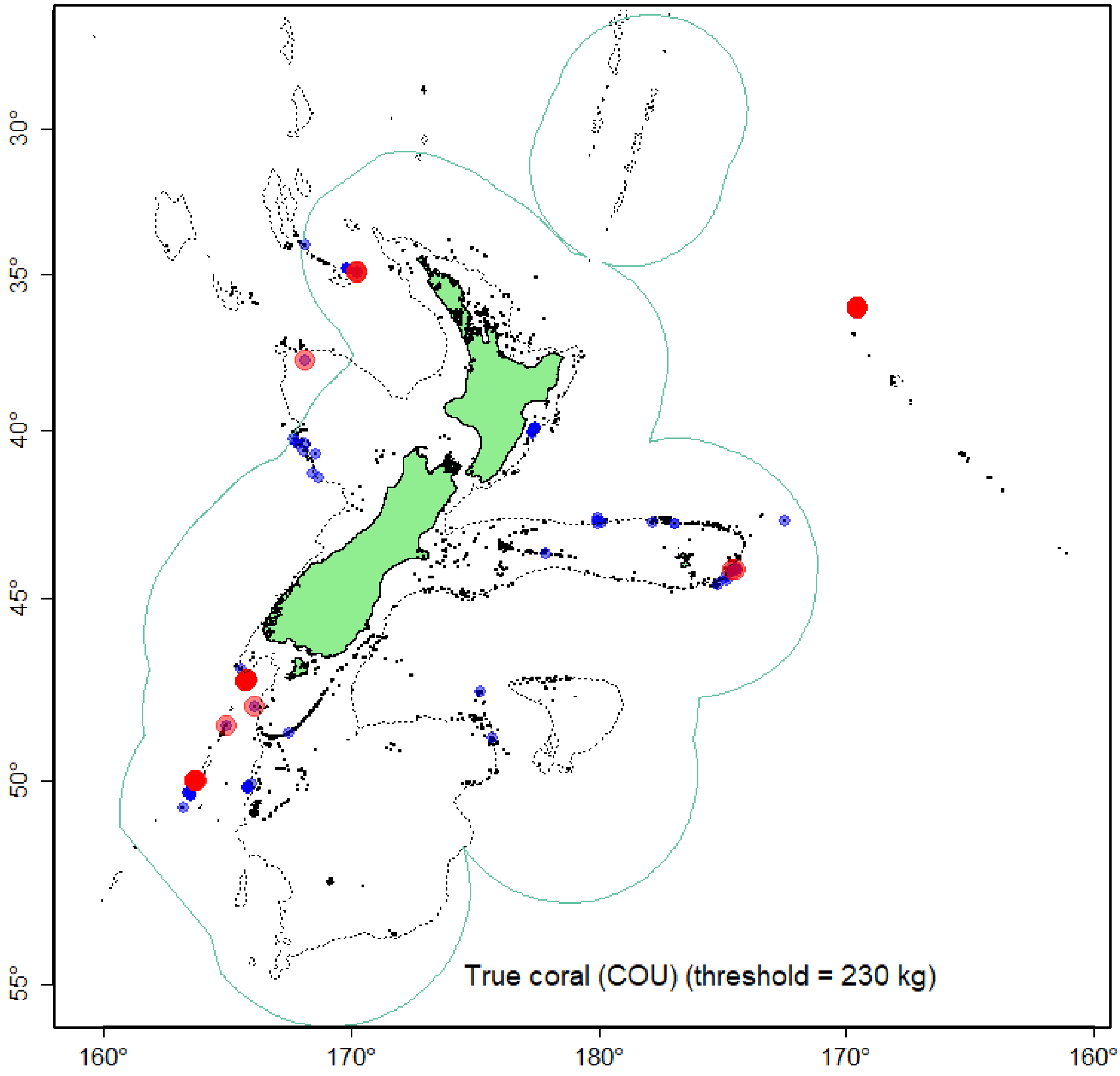


**Figure 24: Observed catches of "true corals" (all protected corals).** Black dots, catches below weight threshold; blue dots, catches above threshold, unverified; red dots, catches above threshold, verified. New Zealand EEZ boundary shown in teal, dashed black line is the 1000 m contour.

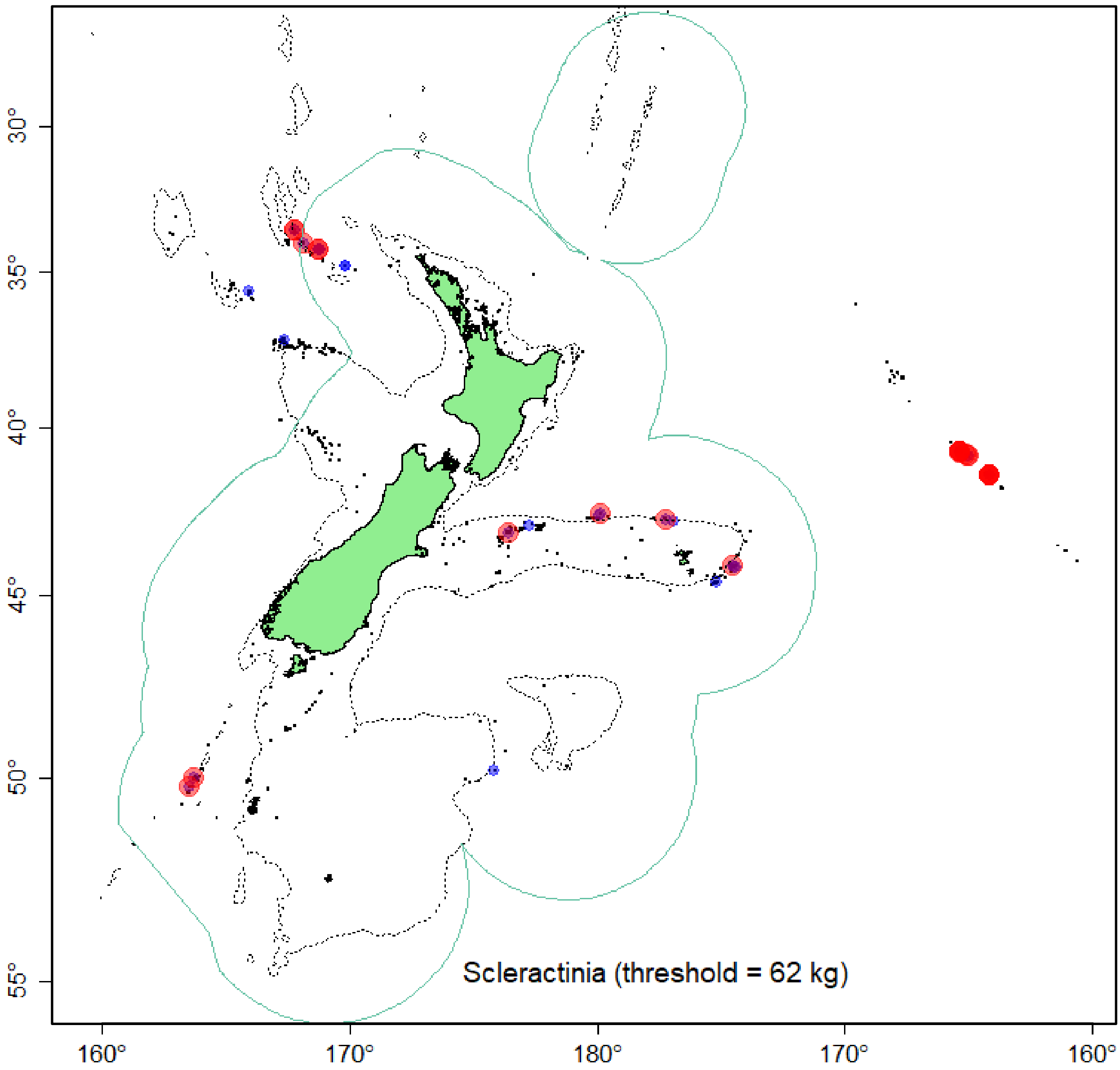


**Figure 25: Observed catches of Scleractinia (unidentified stony corals).** Black dots, catches below weight threshold; blue dots, catches above threshold, unverified; red dots, catches above threshold, verified. New Zealand EEZ boundary shown in teal, dashed black line is the 1000 m contour.

## 3.6 Procedure for checking large catches during data loading

The key tool for raising a flag for a large catch of protected coral during the process of loading observer data into the *COD* database is the catch weight threshold assigned to each 3-letter species code in the loading scripts. Up until now thresholds have only been available for 48 of the 98 species codes in use, and many of these were set to values that were too high to capture all but the very largest of recorded weights. The proposed new threshold weights should be considered by RDM for use in place of current values, and newly established values assigned to those codes for which they were previously missing, so that henceforth catch weights of all protected coral can be vetted appropriately during data loading.

A catch weight above the threshold for a taxon could always potentially represent a recording error by the observer, even if not corroborated by any of the verification methods outlined above, and in any case conducting the full array of verification methods described above may not be realistic given the time that would be required to do so. In these cases, we suggest that RDM be informed and requested to confirm with the observer services team whether the recorded weight can be verified. These reported values may be retained in the database or substituted with a revised value (or instead the species code may be revised if evidence supports this), with a note added in the comment field describing the response from RDM (verified, unverified, code revised) and an additional "*Above threshold (Y/N)"* field to aid in determining the legitimacy of the catch weight for downstream analysis. The original values recorded by the observer are not lost, however, as a complete set of the raw data collected on each observed trip are retained in loading tables in the *COD* database and can be retrieved by researchers if required.

For researchers wanting to use protected coral catch data obtained from *COD*, the verification procedures outlined in this report can be applied in any combination, and with any relative weighting, deemed appropriate for the purposes the data are being used for. For instance, records with catch weights above the threshold for the taxon might be excluded from a data extract, or included in the selection but with the weight set to missing or to the threshold value. Alternatively, for more thorough quality control (not withstanding that already undertaken by RDM), records above thresholds can be checked against any or all of the verification criteria described in this report, and included or excluded on this basis.

Although not investigated here, in some cases it may seem obvious that the large catch is due to the use of an incorrect code for the species and also what code should have been used, e.g. a large catch of SVA (*Solenosmilia variabilis*) accidentally entered instead of SWA (silver warehou) when targeting SWA with otherwise no record of SWA catch for that event. Instances of this sort of error, if not already resolved through RDM checks of catches above thresholds, can also be examined by researchers if required.

# 4 Discussion

Errors in recording of coral catch weights can provide misleading data when these are used to characterise species distributions, and especially when attempting to identify areas of high coral abundance. The close examination of historical observer catch records alongside multiple verification methods has allowed a more accurate picture of the spatial distribution of large catches of protected corals than was previously possible. In addition to the assessment of historical catches, we now have a catch weight threshold for each of the 98 current reporting codes that will help to verify future large coral catches and ensure that the *COD* database remains a reliable source of accurate catch information for these protected species.

In setting the new and revised thresholds, the precise level was not highly critical; the aim was to get a balance between ensuring unlikely large values are not recorded in *COD* and limiting the amount of effort required to validate questionable data. A trial period may be necessary to ensure there is not an overwhelming number of records requiring verification by RDM and, if necessary, some threshold values may be revised. Some erroneous data will necessarily remain unflagged in the database, but these will be smaller catches below threshold levels. Of course, erroneous large catch records (above thresholds) can also go undetected even after the application of the verification methods described, but the consequences of this may be less due to the increased likelihood of the occurrence of such a catch at the location concerned.

The relevance of the thresholds used here can be examined to an extent by comparing, where possible, the thresholds used in high seas fisheries management of the South Pacific to signify the potential existence of a Vulnerable Marine Ecosystem (VME) at the site. For example, a catch of Antipatharia (black coral) of 5 kg or more in the area managed by the South Pacific Regional Fisheries Management Organisation (SPRFMO) triggers a VME Encounter Protocol whereby the vessel concerned is required to stop fishing and move away from the site (SPRFMO 2023). The *COD* data loading threshold set here for black corals is similar (4 kg). SPRFMO trigger weights are in place also for gorgonian corals, set at 15 kg compared with the threshold values of 3–10 kg used here. A SPRFMO trigger weight is also set for Scleractinia (stony corals) as a group, 60 kg. This compares with threshold values used here for the various stony coral taxa of 3–202 kg.

The cleaner set of historical coral catch data produced here may be more readily utilised for independent evaluation of species abundance models for protected corals (e.g. Anderson et al. 2023). These models, based on towed video camera data can potentially be tested against catch data, if not in a full statistical manner (due to issues with measuring coral catchability from bottom trawling) at least by correlation or graphical methods.

The availability of verification data layers will be important for any researchers wishing to verify coral catches using the methods described here. Commercial fisheries data, including vessel-reported records and observer trip reports/logbooks/images can be accessed by request to the Fisheries New Zealand Research Data Manager (RDM.SharedRDM@mpi.govt.nz). Coral abundance model outputs (taxon-specific raster layers of estimated abundance) are held by DOC and although not currently publicly available, may be supplied if requested. The SEAMOUNTS database (Clark et al. 2022) is maintained and managed by FNZ and requests for data can be directed to them (through RDM). This PostgreSQL database was designed to be able to link to external datasets and databases (specifically including *COD*) and the PostGIS extension to it allows linkage of spatial geometry data so that the location of seamounts relative to fishing locations can be easily provided.

# 5 Acknowledgements

We are grateful to Darren Stevens from NIWA for his helpful review of a draft of this report, and to Peta Abernethy (Fisheries New Zealand) for her valuable insights and suggestions. We also acknowledge the support of Lyndsey Holland, Conservation Services Programme, Department of Conservation — Te Papa Atawhai, this work being undertaken through Project INT2023-10.

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