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Underwater Topographic Features in the New Zealand region: development of an updated 'SEAMOUNT' database and information on the extent and intensity of deep-sea trawl fisheries on them

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EXECUTIVE SUMMARY

Clark, M.R.[1]; Wood, B.; Mackay, K.; Anderson, O.F.; Hart, A.; Rickard, G.; Rowden, A.A. (2022). Underwater Topographic Features in the New Zealand region: development of an updated 'SEAMOUNT' database and information on the extent and intensity of deep-sea trawl fisheries on them.

New Zealand Aquatic Environment and Biodiversity Report No. 291. **28 p.**

This report documents an update on information for Underwater Topographic Features (UTFs) in the New Zealand region, and the development of a new database to serve this information. UTFs in this report refer to positive elevation features, commonly known as seamounts, knolls, and hills.

An existing 'SEAMOUNT' database was developed between 2000 and 2008 to support ecological risk assessments. This provided the location of 756 UTFs, along with a range of associated geographical, physical, chemical, biological, and fishery parameters for each of the features. Since the initial database development, additional data on features have been collected, and there is now improved bathymetric information throughout much of the New Zealand region. Hence, an update of key environmental characteristics was appropriate, as well as further specification to examine the overlap with commercial deepwater fisheries.

Important changes in the approach and methods included:

- Geographic Information System analysis of recent General Bathymetric Chart of the Oceans (GEBCO) data to add to other data sources used previously.
- A reduction in data fields, excluding those where data could be better extracted from other external databases rather than 'locking in' static values.
- Use of bottom trawl footprint data to allow spatially-explicit analyses of catch and effort.
- Database design utilising functionality of Postgres Structured Query Language (SQL) with other databases and permit greater flexibility in user-defined analyses.

There are 42 fields for each UTF in the new database: these cover descriptors, and physical, oceanographic, geological, biological, and fisheries information.

The updated SEAMOUNT database comprises 2964 UTFs, distributed within the Territorial Sea (89), Exclusive Economic Zone (EEZ) (1907), and outside the EEZ (968). There are 414 seamounts (≥ 1000 m elevation), 1495 knolls (250–999 m), and 1055 hills (100–249 m).

This report provides a range of selected results from various database fields and demonstrates the functionality of PostgresSQL language in linking with external databases. The bottom trawl footprint intersects with 229 UTFs inside the EEZ (including the Territorial Sea). Most fishing effort has occurred on features with summit depths between 400 and 1200 m. An illustration is given of linkages with the trawl footprint area on fished UTFs.

[1] All authors: National Institute of Water and Atmospheric Research (NIWA), New Zealand.

1. INTRODUCTION

1.1 Background

Underwater topographic features (UTFs, in this report seamounts, knolls, and hills defined as features with greater than 100 m elevation from the surrounding seafloor) are widely recognised on a global scale as potentially important sites for biodiversity, localised biological productivity, and commercial fisheries (e.g., Clark et al. 2010, Rogers 2018), although their ecological significance can be variable (e.g., Rowden et al. 2010). They are a prominent habitat type in the New Zealand region (Rowden et al. 2005, Yesson et al. 2011) and are a focus for a number of deepwater commercial fisheries (e.g., alfonsino, black cardinalfish, orange roughy, oreos) (Clark & O'Driscoll 2003, O'Driscoll & Clark 2005, Clark et al. 2014, Roux et al. 2014). However, UTFs are also classified as vulnerable marine ecosystems as they can host fragile and slow-growing benthic communities (Rogers et al. 2007, Tracey et al. 2011) that are readily impacted by bottom trawling (e.g., Clark & Rowden 2009, Clark et al. 2014, 2015, Roux et al. 2014) and are slow to recover from damage (e.g., Williams et al. 2010, Clark et al. 2019, Goode et al. 2020). Hence, conservation efforts have been taken globally (e.g., Morato et al. 2010) as well as around New Zealand with the designation of Seamount Closure Areas (Brodie & Clark 2004) and Benthic Protection Areas (Helson et al. 2010). Nevertheless, the amount of fisheries effort that occurs on UTFs remains important information for management to balance the sustainability of commercial fisheries with ensuring ecosystem integrity (e.g., Marine Stewardship Council 2018).

A SEAMOUNT database was initially developed from a collation of physical and ecological data under research funded from 1999 by the Foundation for Research, Science and Technology (version 1) (Clark et al. 1999) and created as an Empress relational database (version 2) under a 2005 research project for the then Ministry of Fisheries (MFish — now Fisheries New Zealand, used throughout this report for current and previous ministries), Project ENV2005/15). A detailed description of this version 2 database assembly was provided by Rowden et al. (2008), and the database is documented by Mackay (2006). The database provided the location of 756 UTFs within the New Zealand Region (Figure 1), along with a range of associated geographical, physical, chemical, biological, and fishery parameters. In total there were 72 fields associated with each UTF in the SEAMOUNT database, divided into 6 general groups (Figure 2).

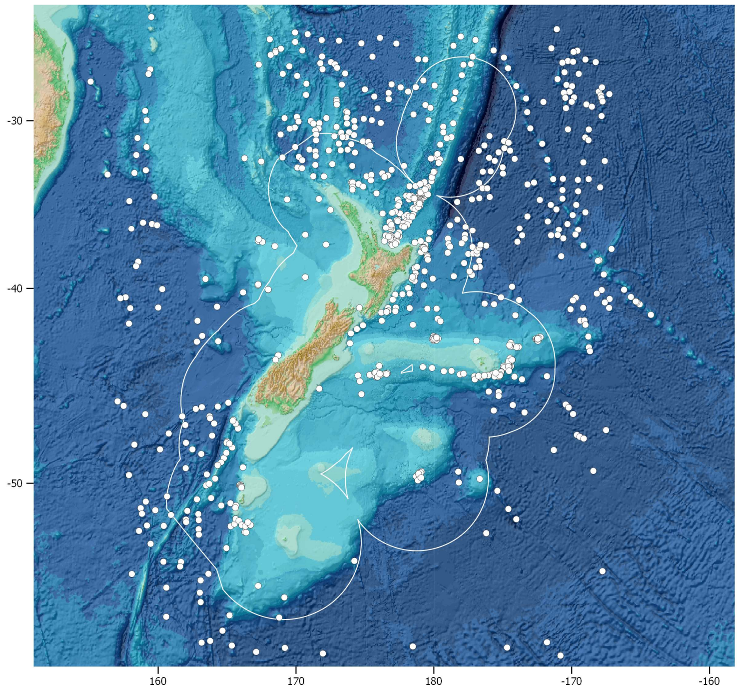

Figure 1: The distribution of UTFs in the SEAMOUNT database (version 2) provided to Fisheries New Zealand in 2008.

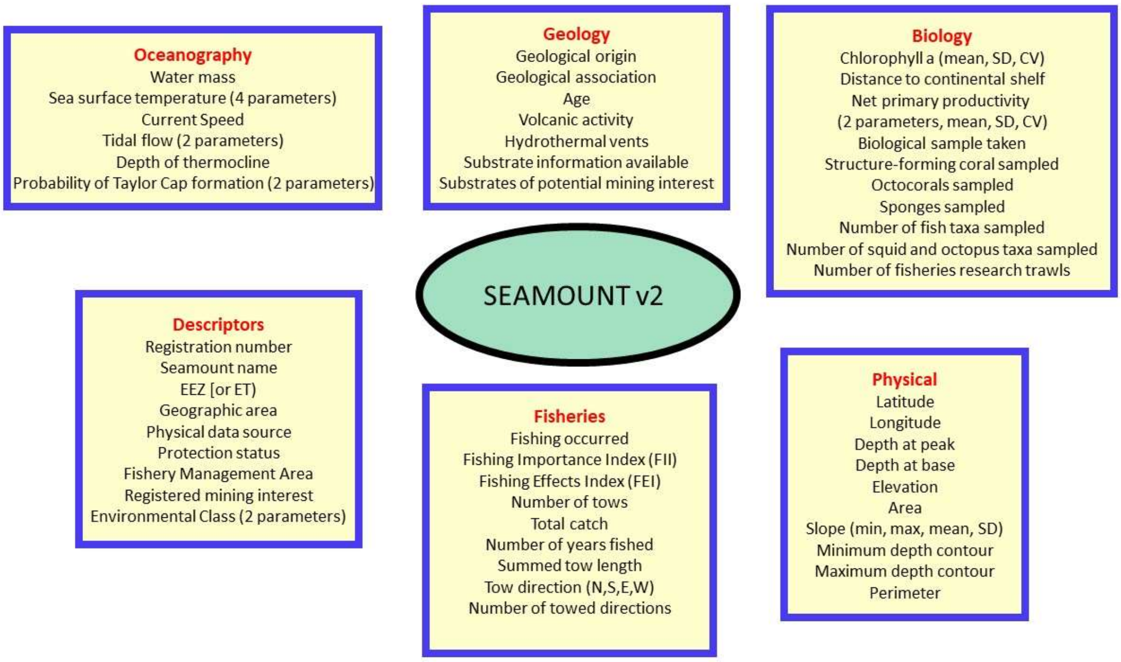

Figure 2: Database fields in the version 2 SEAMOUNT database (from Rowden et al. 2008).

Since the version 2 database for Fisheries New Zealand in 2008, additional data on features have been collected, and there has been improved bathymetric information captured throughout much of the New Zealand region. Hence, an update on the environmental characteristics was appropriate, as well as further investigation into the level of catch and effort of deepwater commercial fisheries taking place on these features.

This work was carried out under Fisheries New Zealand project BEN2020-07: Extent and intensity of trawl effort on or near underwater topographic features in New Zealand’s Exclusive Economic Zone.

1.2 Objectives

1.2.1 Overall objective

Assess the extent to which feature-based fisheries have trawled on or near underwater topographic features (UTFs) in the New Zealand Exclusive Economic Zone (EEZ).

1.2.2 Specific objectives

Objective One: Update the database of all known UTFs with elevations exceeding 100 m in New Zealand’s EEZ and develop a GIS layer delineating all known UTFs.

Objective Two: Estimate the extent and intensity of trawl effort on or near the seafloor of UTFs for each fishing year between 1989–90 and 2019–20

Under the proposal to carry out this work, it was agreed with Fisheries New Zealand that Objective 1 would include UTFs outside the EEZ in the wider New Zealand region, but that Objective 2 would only include trawl effort on UTFs inside the EEZ and Territorial Sea (TS).

2. METHODS

2.1 Database geographical area

The datasets used for this work are consistent with previous versions of the database and cover an area termed 'the New Zealand region' used in NIWA bathymetric charts (CANZ 2008). This region extends from 25° S to 57° S, and 162° E to 167° W.

2.2 Database content

The original database fields were a selection of those that were regarded as potentially useful for supporting ecological risk assessments (Rowden et al. 2008). However, fifteen years on, the context of potential data use has changed. There is now more of a research and management emphasis on the overlap with fisheries, and the core database fields that would be used in risk or vulnerability assessments can be reduced, simplified, or linked to external sources of data managed outside the database. This in turn allows more flexibility for users to retrieve and analyse a wider range of data appropriate for their specific needs.

The revised fields included in the updated database are shown in Figure 3.

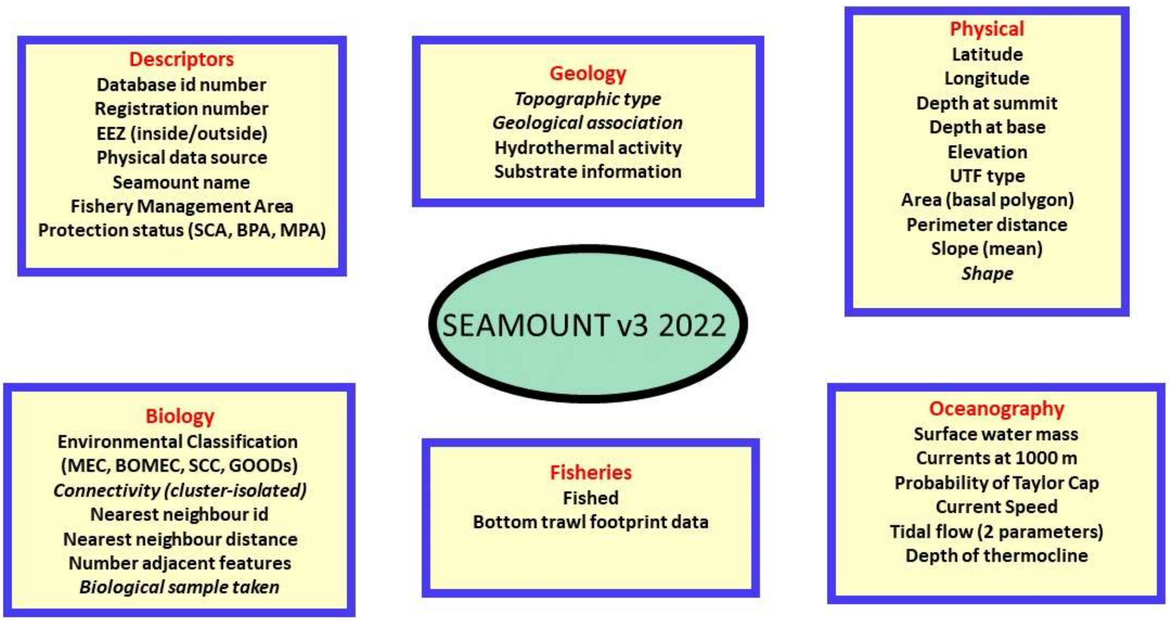

Figure 3: The seamount table fields associated with the 6 general groups used in the SEAMOUNT database (italics signify fields that are not complete for all features).

The fields and data sources that were accessed to populate the new database are described below.

2.2.1 Descriptors

These are descriptive characters of each UTF, comprising a unique database 'identification (id) number'; a 'registration number' (a sequential numbering system based on the NIWA dataset); the location relative to the EEZ (either inside the EEZ, inside an EEZ enclave, in the Territorial Sea (12 nautical mile zone) or outside the EEZ); the Fishery Management Area within which the UTF is located; the UTF name; data source (*see* below); and the protection status of the UTF (if inside a Seamount Closure Area (SCA), a Benthic Protection Area (BPA), or a Marine Protected Area (MPA)—the latter refers to gazetted marine reserves, classified as Type 1 MPAs).

2.2.2 Physical

Descriptive statistics for each UTF includes location (latitude, longitude to the maximum resolution available), depth (metres) (of the summit and the base), elevation from the surrounding seabed, the UTF type (seamount, knoll, hill), overall area (square kilometres), perimeter of the basal shape (kilometres), average slope (degrees), and shape (seamount, guyot, ridge).

Sources for this information are given in Table 1:

Table 1: Description of the six principal data sources for the bathymetric and physical information used to identify UTFs.

Source	Description
NIWA NZ Bathymetry	Regular update of New Zealand-wide bathymetry. Uses all sources, contours at 250 m (regional) down to 100 m (more localised) (see New Zealand bathymetry data set | NIWA)
Vessel SBES	Single beam echo-sounder point data
Vessel MBES	Multibeam echosounder swath data
Science or Industry individuals	Summit location and depth of certain features
Literature	Published bathymetric atlases, gazetteers, reports, and papers
GIS analysis	Interpolated bathymetric surface (using GEBCO 2020 data, Geographic Information System (GIS) algorithm ≥ 150 m

A new analysis carried out for this project was the GIS analysis, using the ArcGIS software “Fill” tool. The fill tool was applied to an inverted seamount topography, searching for sinks (the inverse of peaks), and then filling the sinks to determine the elevation and boundary polygon of the feature from the surrounding bathymetry (Figure 4).

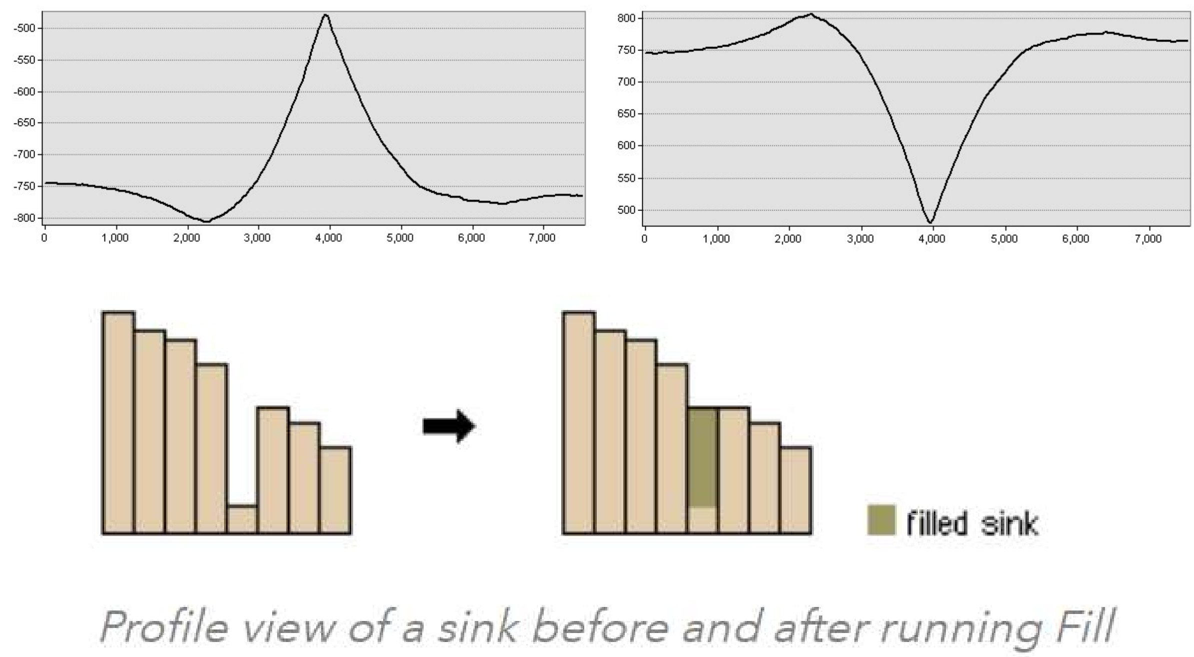

Figure 4: Derivation of features identified by the ‘filled sink’ ArcGIS analysis. Original bathymetry is on the top left, the inverted bathymetry top right, and the histograms at the bottom of the figure show the filling of the sink.

Although the definition of a UTF is based on an elevation of greater than or equal to 100 m, for this analysis a cut-off of 150 m was used (based on advice from bathymetry experts familiar with these sorts of data) given the variability of data sources and resolution of the underlying GEBCO dataset. Setting the threshold higher meant there was a reduced risk of many 'false positives' that would be recorded as UTFs when their actual elevation was likely to be less than 100 m because the data were not sufficiently accurate. Taking a threshold of 150 m is conservative and may underestimate the number of small UTFs (although the analysis resulted in about 40% of its estimated UTFs between 100 and 150 m elevation), but was regarded as a more confident result than if 100 m was taken as the threshold value. Following the analysis, extensive manual checks were done on all the features to confirm their validity and check against the known bathymetry to ensure depths and the derived basal polygon were appropriate. Approximately 100 features were excluded as likely artefacts of the analysis methodology where the bathymetry did not confirm a valid and discrete UTF.

Data for 27 features were regarded as 'sensitive' (provided by individuals and industry sources from whom we do not have permission to make their data public) were excluded.

The latitude and longitude of a UTF were based on the location of the summit. This was determined from bathymetric data wherever possible, or alternatively from the central point of the basal polygon derived from the bathymetric data sources and analyses.

Depth at peak is the shallowest depth record known from the feature. The depth at base of the UTF was generally taken from the deepest most complete depth contour that encircled the entire feature. In some cases, however, there was an appreciable difference between sectors of an UTF, where one side is, for example, up-slope of a broader feature such as a rise. In these cases, the mid-point between the shallow and deep basal depth was taken.

Elevation was calculated as the difference between depth at peak and depth at base. Area is that of the polygon of the basal depth contour. The elevation was used to define the UTF as one of three types:
Seamount: ≥ 1000 m
Knoll: 250–999 m
Hill: 100–249 m

It should be noted that the original definition of 1000 m elevation for a 'seamount' from Menard (1964) is widely acknowledged as an arbitrary elevation with the origin of the feature often regarded as a more important criterion. Many biological and geological studies now use the more ecological term of 'seamount' for all features with an elevation of > 100 m (Pitcher et al. 2007, Staudigel et al. 2010, Wessel et a. 2010). However, where sub-divided, the formal definitions of knolls, hills, and pinnacles are also variable. For knoll, a range of 500–1000 m is used by the United States Board on Geographical Names when naming features, although the New Zealand Geographical Board definitions relate to shape, or origin, and the elevation criterion of a hill and a knoll is the same (< 1000 m). This is also the practice applied by GEBCO and the SCUFN (Sub-Committee on Undersea Features Names) which was established in 1975 under the joint auspices of GEBCO, the Intergovernmental Oceanographic Commission (IOC) (of UNESCO), and the International Hydrographic Organization (IHO). However, when based on elevation, marine geologists at NIWA have tended to use 250 m based on an assessment that the available data can generally support clear identification of a significant feature with that threshold, and hills have a lower elevation. This is a similar rationale to other scientific papers identifying knoll features on a global scale (e.g., Yesson et al. 2011).

A solution for the future is perhaps to combine knolls and hills as a single category. Irrespective of feature name, the data on elevation enable various data ranges to be determined. Most practising ecological researchers in the seamount-UTF space reject broad and generic cut-off points in elevation and naming conventions as not being ecologically relevant. Small features share many of the environmental characteristics of larger features, with similar ecological dynamics, and the size distribution of such elevations are continuous. These factors have been part of the reasoning behind using a single term for all such features.

Slope had previously been estimated using a number of data sources and methods and included maximum and minimum slopes for some features where, for example, multibeam data were available. However, because such detail is not available for the majority of features, it was decided to replace these and present a single and consistent slope parameter for all features: that of mean slope. Mean slope was calculated using the depths of the basal polygon and depth at peak. Eight lines were defined at 45° intervals, and basic trigonometry used to derive the slope (Figure 5). The eight slope estimates were then averaged. Checks against detailed bathymetry showed this to be a reasonable approach, although in general this method could underestimate the true maximum slope because of the assumption that the summit point is the apex of a peak, whereas many features will be more dome- or ridge-shaped.

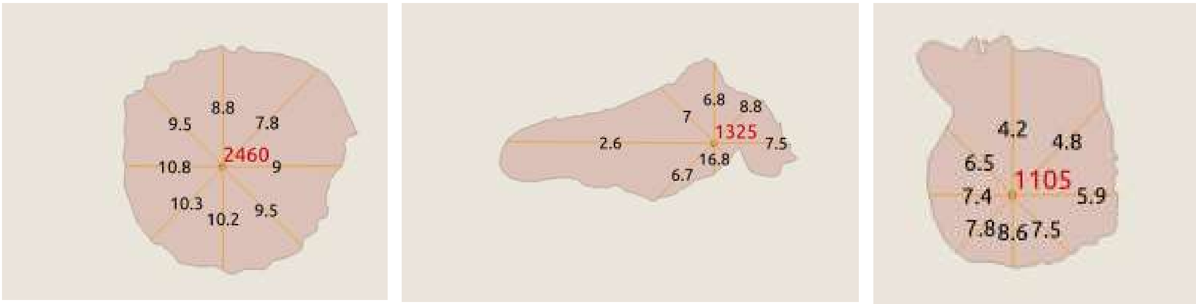

Figure 5: Examples of the calculation of obtaining mean slope information for a feature, based on the average of eight radiating lines from the summit to base. The red text on each image shows the elevation (m), the black text shows the slope of each line

2.2.3 Error checking methods

There were two main stages of error-checking the bathymetric data and database content:

1) Raw data. These checks consisted of comparing summit and base depths against the underlying bathymetric data, to ensure depths and basal polygon areas were sensible. There was also a check against duplicate data derived from different sources at different times, with the deletion of records for the same feature that were less reliable (e.g., using specific MBES derived information instead of generalised bathymetric layers).
2) Once entered into the database, checks were made for completeness (e.g., ensuring each summit point was inside an associated basal polygon), and where multiple peaks or polygons nested within others were sensible data points. An example of this is shown in Figure 6, where there is a small polygon inside a larger one—which in this case is appropriate.

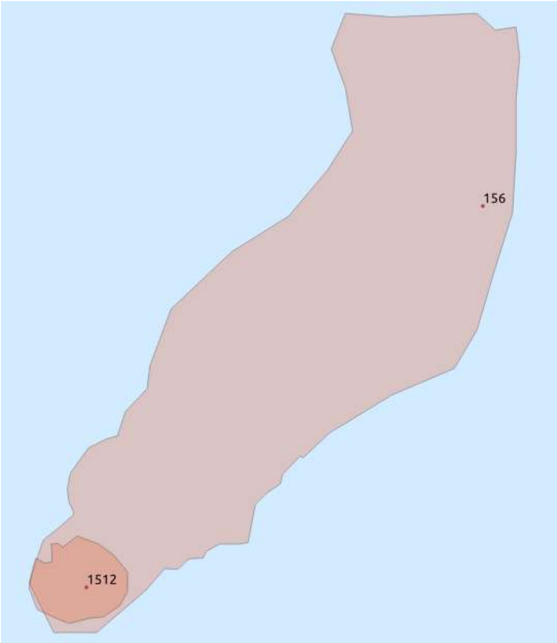

Figure 6: Example plot from a check for nested polygons. This shows an edifice (#156) which has a summit depth of 4690 m, with a deeper secondary peak (#1512). Both are regarded as valid features.

2.2.4 Geology

The large number of new features described in the updated database, constrained the planned update of new information on morphology (geological association, UTF shape, and connectivity). Although the data available from the previous version of the SEAMOUNT database have been retained (with some updates carried out by NIWA since then), only two fields, with high ecological significance, have been updated for all the new UTFs:

- the presence of hydrothermal vent activity based on records from ChEssBase - Ocean Biodiversity Information System (obis.org) (ChEssBase),
- the substrate type information available from sampling gear records in the NIWA *Cruise* database. This is a pointer to where a substrate sample has been taken but does not contain any direct sediment information.

Two of the database fields Geological Association and UTF shape are only partially populated as project resources did not enable these to be completed. For these fields:

- Geological Association of seamounts has been broadly categorised as being associated either with the inner New Zealand continental margin (within the enclosing continuous 2000 m isobath), with various types of ridge systems, or being oceanic. These are populated for 1494 UTFs.
- UTF Shape is defined as a conical seamount, a guyot, or a ridge peak. These are populated for 1435 UTFs.

2.2.5 Oceanography

Current and water mass properties have been re-estimated based on the latest published oceanographic model outputs.

Surface water masses are derived from an updated review of physical oceanography around New Zealand (Chiswell et al. 2015, Figure 7).

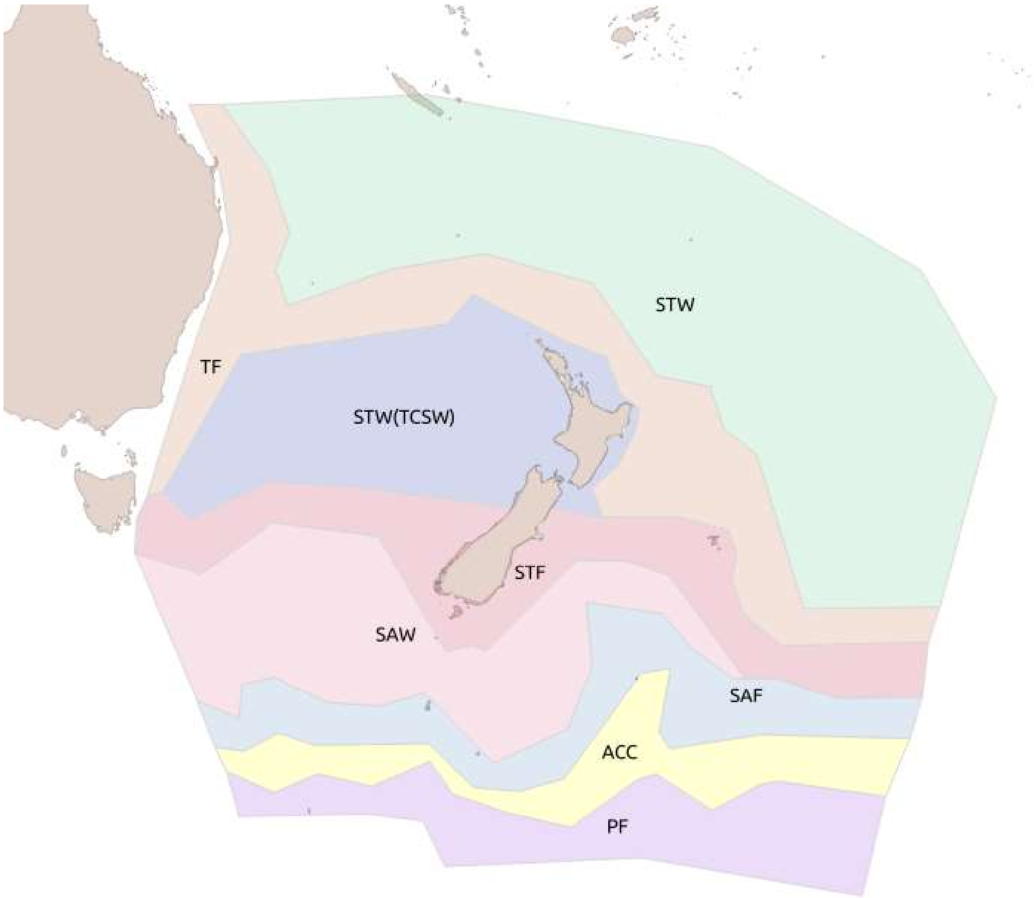

Figure 7: Simplified surface water masses (based on Chiswell et al. 2015).

The categories defined for the surface water masses include:

- Subtropical Water (STW and TCSW))
- Subtropical Front (STF)
- Tasman Front (TF)
- Subantarctic Water (SAW)
- Subantarctic Front (SAF)
- Antarctic Circumpolar Current (ACC)
- Polar Front (PF)

Although the characteristics of bottom water near the seabed can influence biological community structure and abundance more directly than surface waters, the latter enable a simple understanding of how the summit communities may vary, given the differences between, in particular, Subtropical water, Subantarctic water, and the fronts (zones of mixing) between them.

Current direction and speed at depth are new fields derived from ARGO float data at 1000 m (see Chiswell & Sutton 2015) (Figure 8). These vectors were calculated from 1 degree mean velocities. They provide a useful metric relevant to potential connectivity between seamounts through dispersal of nekton or eggs and larvae from benthic invertebrates, and for where flows at depth are more relevant than surface currents for deep-sea species and potentially concentrating food and nutrients around UTFs.

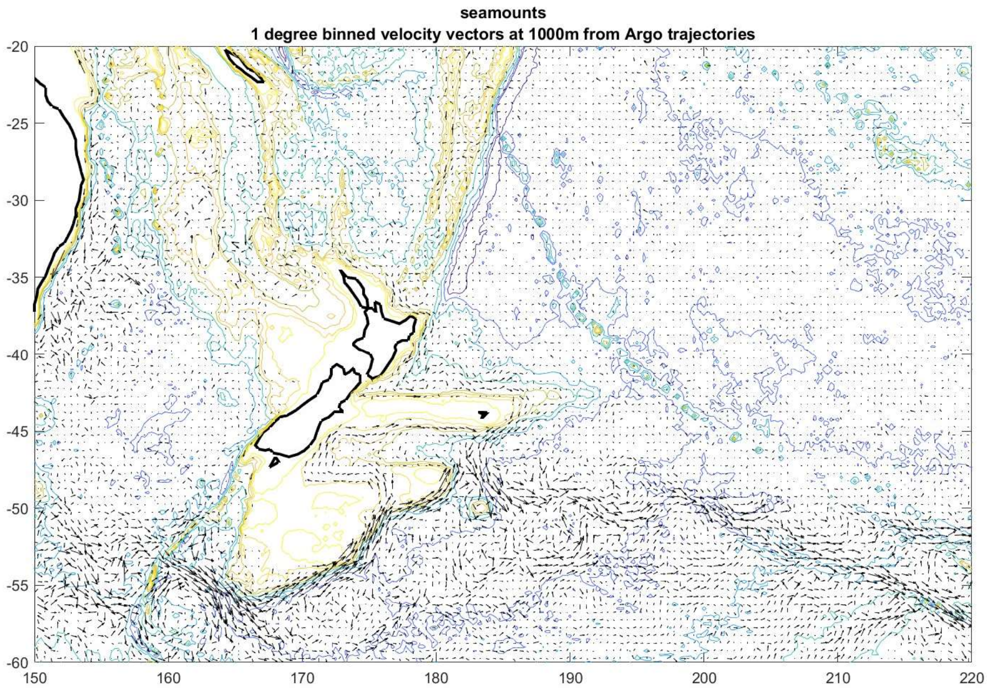

Figure 8: Velocity vectors at 1000 m depth based on ARGO float data.

The bathymetry of a UTF structure has the capacity to alter the current flow around and over the feature and can generate closed circulation (known as Taylor caps or cones) which can affect primary and secondary productivity associated with a feature, as well as affect recruitment of larvae and hence stability of seamount communities. NIWA has developed regional climatologies (at 1 km^2 resolution) for current speed, mean diurnal tidal flow and annual mean semi-diurnal tidal flow, and depth of thermocline (e.g., Rickard et al. 2005) which when combined with UTF location and depth data can model the likelihood that a seamount could generate such closed circulation. Two measures of the likelihood or probability of Taylor Cap formation were generated for inclusion in the SEAMOUNT (v2) database (Rowden et al. 2008): the probability of Taylor Cap formation in a mean flow and in a tidal flow. These measures are derived from numerical studies of flow over seamounts (Chapman & Haidvogel 1992, Beckmann 1995) and have been adapted for the variables available in the present database. If either the mean flow or the tidal flow dominates then the likelihood is that the nature of the Taylor cap formation will be consistent with the dominant component. There will be UTFs where both components will be equally significant; for those UTFs it is expected that cap formation will still occur, but that the interactions between the forcing flows will result in more complex flow patterns.

In the previous and earlier study datasets, a number of remotely sensed data related to sea surface temperature (SST) and primary productivity (chlorophyll a) had been included. There are several models and datasets available for these parameters, and it was decided that they would not be updated as static fields in the database, but be accessed externally as required by the user (e.g., Online services | NIWA Sea Surface Temperature - MetService New Zealand; oceaneyeq.com; FishTrack).

2.2.6 Biology

Collection records from museums and environmental institutes (e.g., NIWA Invertebrate Collection Specify database *niwainvert*, Te Papa Tongarewa Museum of New Zealand, Auckland Museum Tāmaki Paenga Hira) and other relevant databases (e.g., Ocean Biodiversity Information System (OBIS), Fisheries New Zealand *trawl*, NIWA *biods*) can be linked with the SEAMOUNT database. The original proposal was to search these various databases and incorporate a presence/absence record for sampling and various selected taxa on each UTF (such as protected coral species, sensitive environment indicator species, VME indicator species). However, this is a cumbersome process and locks in fields that may not be relevant to certain users. Therefore, in discussion with Fisheries New Zealand, the approach was changed to one whereby the database can include links to other accessible databases and enable users to undertake their own selection, extracts, and analyses, rather than relying upon taxonomic and biodiversity data that can quickly be outdated or changed (see Section 2.3 on database design).

Links have been successfully trialled with:

- *niwainvert* database (based on records held in the NIWA Invertebrate Collection)
- *trawl* database (records of fish and invertebrate catch data from Fisheries New Zealand trawl surveys and other fisheries surveys).

The database schema in Figure 3 indicates a 'Biological sample taken' field. This has not been finalised, pending an intention to make the database operational for identifying which database can be accessed to find certain biological records for a particular UTF.

Connectivity is a subjective categorisation of being isolated as a separate single feature, as a 'cluster' if there is a group of features together, or as a 'chain' where there is a line of features. These are populated for 1365 UTFs. Nevertheless, connectivity is to an extent addressed by separate physical-distance metrics calculated for all features, specifically:

- Nearest neighbour (the actual seamount reg_no).
- Distance to nearest neighbour (km)
- Number in 100 km: the number of other UTFs within a 100 km radius. This radius is regarded as being within potential larval drift ranges of many fish and benthic invertebrates.

2.2.7 Environmental Class

Along with the New Zealand Marine Environment Classification (MEC) classes (Leathwick et al. 2008) included in the previous SEAMOUNT database version (20 and 33 class results), the benthic optimised version (BOMEC) (Leathwick et al. 2012), the New Zealand Seafloor Community Classification (NZSCC) (Stephenson et al. 2022), and the revised Global Open Oceans and Deep Seabed (GOODS) seafloor biogeographic provinces for lower bathyal and abyssal plains (Watling et al. 2013) have been added to the database. GIS layers for these sorts of data can be included as polygons linked to the database and incorporated into spatial analyses as appropriate rather than being locked into static fields. An example is given of the NZSCC layer in Figure 9.

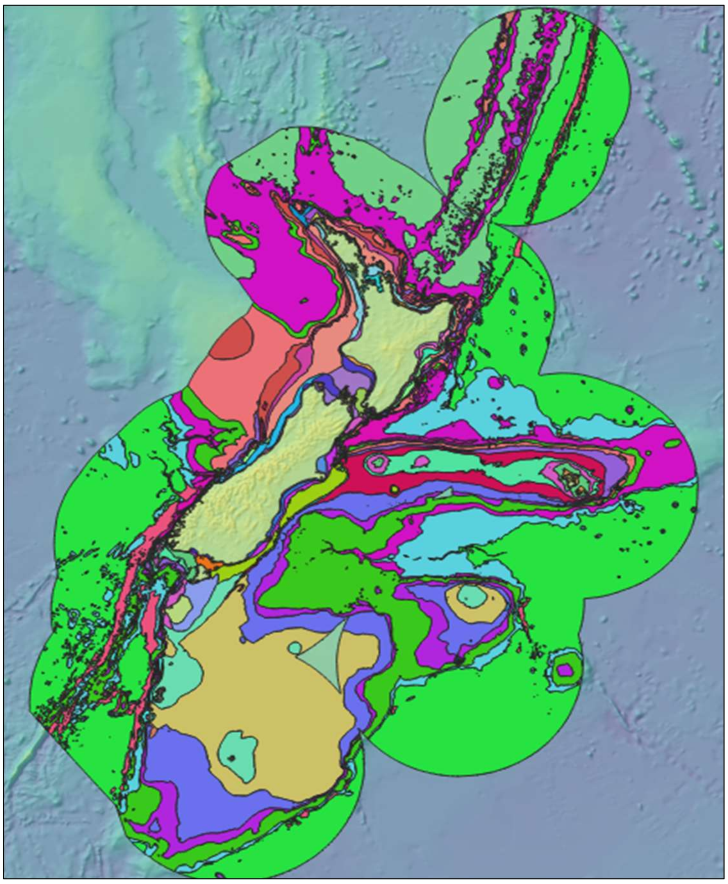

Figure 9: Example of the Seafloor Community Classification (SCC) environmental classification layer for the New Zealand Exclusive Economic Zone (EEZ) included in the database.

2.3 Database design

Relational databases incorporate data in well-defined structures that manage data about entities but also about the relationships between different entities. Object relational databases, fully support all the relational concepts, add support for object-oriented capabilities (more user defined data types), and are generally more expandable. The Empress database system used for the original SEAMOUNT database is not a spatially 'aware' Relational Database Management System (RDBMS) and is no longer supported by NIWA or Fisheries New Zealand. Most fisheries databases now operate under the open-source PostgreSQL Object-Relational Database Management System (ORDBMS).

The Postgres information software was used as the basis for the production of the new SEAMOUNT database (v.3) and, in addition, has been enhanced to enable links to external datasets which are implemented as (virtual) local tables. This approach was taken to simplify access to, and repeated use of, a wide range of data managed in separate databases or only accessible as disconnected datasets. The new approach allows much greater flexibility in user-defined dynamic queries and analyses, rather than attempting to load into a static database a large number of fields and parameters which may, or may not, suit the needs of government (e.g., Fisheries New Zealand), and other stakeholders and users. It also means that current versions of external data can be used interactively, rather than having to regularly update external data snapshots stored in the SEAMOUNT database.

Another advantage is that the PostgreSQL database supports the Postgis extension. This spatially enables the database with geometry datatypes such as points, lines, and polygons and operators and functions to work with these data

Other extensions that are employed to improve the functionality of the database include:

- FDW: Foreign Data Wrapper used to create virtual tables which are links to external data
- postgres_fdw: To create links to tables in other postgres databases (e.g.: *trawl, COD, Biods*)
- ogr_fdw: To create links to ogr data sources (e.g.: NIWA's invertebrate database *niwainvert*, WFS services).

Basic SQL commands can be used to extract UTF data along with associated data from 'foreign' tables and databases. In addition to command line SQL, graphical clients (e.g., RazorSQL, SquirrelSQL, DBeaver), can be used.

NIWA has a PostgreSQL/PostGIS database server and infrastructure available specifically to manage project data during the lifetime of a project (wellpgdev01), provided and supported by NIWA's Information Technology (IT) Group. This has been used in the initial stages of developing this database. However, maintenance and management of the database will be discussed with Fisheries New Zealand as the database content and functionality becomes finalised.

2.4 Fisheries data

Trawl footprint data compiled under Fisheries New Zealand project BEN2019-01 (Baird & Mules 2021) was the basis for building a dataset of trawl polygons representing all inshore bottom trawl fisheries from 2007–08 to 2018–19 and all deep-sea bottom contacting trawls from 1989–90 to 2018–19. Commercial bottom trawl positions were obtained from data archived from this project at their native resolution (tow-by-tow) rather than as the published outputs of the project (i.e., assembled into broad grids of trawl footprints), so that we were not limited to a cell/grid-based analysis. The dataset included bottom trawls as well as all midwater trawls towed within 1 m of the seafloor. Trawl widths were assigned to each tow based on a combination of several criteria, including vessel size, nationality, target species, and number of nets (after Baird & Mules 2021). Polygons representing the estimated swept-area for each trawl have been included in the database.

Latitude and longitude data for 15% of the trawl footprint records were reported at a resolution finer than 1 minute. The start and finish positions of the remaining data were randomly jittered under Fisheries New Zealand Project BEN2019-01, using an offset of ± 0.5 minute. This was carried out to provide a more realistic spread of effort (see Black et al. 2013), although it is uncertain how appropriate this is for UTF fisheries.

For much of the inshore data (Trawl Catch Effort Return forms) there is no information identifying the finish location of the trawl, hence methods described by Baird et al. (2015) were used to estimate these positions. Within each trip, a tow direction was generated from the bearing between the start position of a tow and the start of the following tow. A distance measure (in kilometres) was then estimated from the tow speed and tow duration data and used with the estimated bearing to generate finish co-ordinates. For all tow by tow data, the following methods were applied:

- Positions were adjusted for the gear/vessel offset based on the direction of travel, i.e., moving the start and end positions back by a value calculated from the start depth and approximating the warp length as 2x depth.
- Values for missing depths were estimated using a 1-km resolution depth raster for the region.
- Only fishing associated with UTF fisheries were retained, defined for this analysis as those targeting the following species and their respective 3-letter fisheries code(s): orange roughy (ORH), oreos (OEO, SSO, BOE, SOR), alfonsino (BYX, BYS), or cardinalfish (CDL, EPT).
- Only short tows (less than 30 minutes), and tows recorded as bottom trawl methods were retained as these help correctly assign tows to UTF features rather than on the slope or in midwater.
- A standard trawl width (door-spread) of 110 m was assigned to each tow after values agreed on at an expert workshop in 2017, then further adjusted by a factor of 0.25136 to account for sweeps

and bridles not being in contact with the seafloor for the entire trawl on UTF tows (Mormede et al. 2017). The final trawl width assigned to each event was therefore 0.25136*110 = 27.65 m.

The tows that were selected were then overlaid as spatial polygons (formed from the adjusted start/finish positions and effective trawl width) on the updated set of basal polygons for the set of UTFs.

3. RESULTS

3.1 Database content

The final SEAMOUNT table comprises 42 fields and is summarised in Appendix 1, which includes the various data fields, their description, and unit measures.

A total of 2964 UTFs are included in the new dataset.

The primary sources of information are described in Table 2, with most features identified from the GIS analysis carried out as part of this project. Many of the features are now based on high quality multibeam data, or from local New Zealand regional bathymetry for which we have good confidence.

Table 2: Source of data to identify features in the database. MBES (Multibeam echosounder swath data); SBES (Single beam echo-sounder point data); GEBCO2008 (General Bathymetric Chart of the Oceans 2008) (see Table 1).

Source of information	Number of UTFs	Percentage of UTFs
GIS 2021 analysis	1 456	49.1
MBES (multibeam)	760	25.6
SBES (single beam)	157	5.3
NIWA bathymetry	503	17.0
GEBCO 2008	9	0.3
Literature	30	1.0
Individuals	49	1.7
TOTAL	2 964	

Of the features included in the final dataset, 89 are within the Territorial Sea (TS), 1886 within the EEZ, and 989 outside the EEZ (Table 3).

Table 3: Number of UTFs by type and location (TS = 12 n.mi Territorial Sea; EEZ = beyond TS inside the 200 n.mi Exclusive Economic Zone; Outside EEZ = areas beyond the EEZ, or in enclaves within the outer limits of the EEZ).

UTF type	TS	EEZ	Outside EEZ	Total
Seamount	2	144	268	414
Knoll	30	926	539	1 495
Hill	57	837	161	1 055
Total	89	1 907	968	2 964

The distribution of these features by UTF type (seamount, knoll, hill) is plotted in Figure 10.

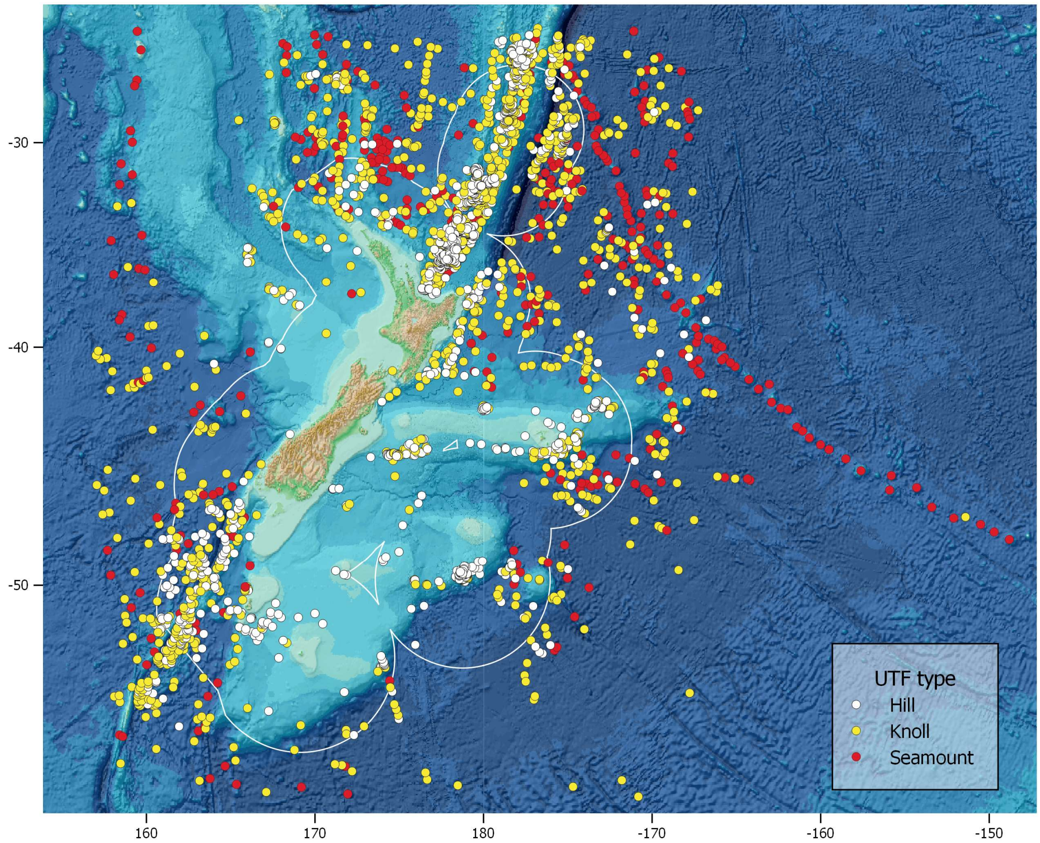

Figure 10: Distribution of Underwater Topographic Features (UTFs) in the New Zealand region.

Summit depths range from 10 to 8790 m and span epipelagic to hadal depths (Table 4). These distributions are plotted as a histogram in Figure 11.

Table 4: Summit depth distribution by bathymetric zone of all UTFs.

Bathymetric zone	Depth range	No. UTFs
Epipelagic	0–200 m	39
Mesopelagic	200–1000 m	638
Bathypelagic	1000–3500 m	1 626
Abyssal	3500–6000 m	636
Hadal	> 6000 m	25

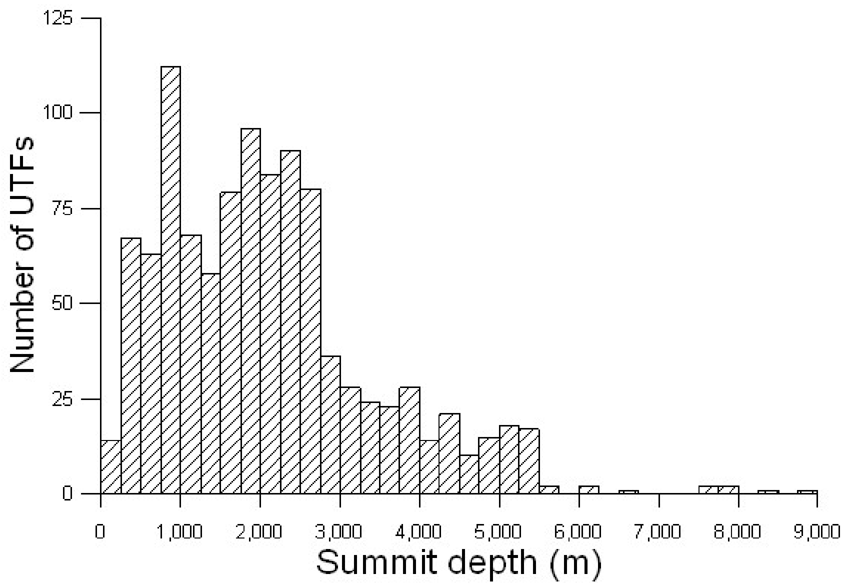

Figure 11: Summit depth distribution by 250 m intervals of all UTFs in the SEAMOUNT database.

3.1.1 Protected status:

A total of 916 UTFs are currently protected from bottom trawling as they are within either a Benthic Protection Area (BPA) or a Seamount Closure Area **(**SCA). Table 5 summarises the numbers of UTF types in the BPAs as a whole, those considered in the original SCA designations, and those from the full dataset available now.

Although it was known that there were multiple features within the area defined by the SCA boundaries (e.g., Pyre and Gothic being two features inside a single SCA in the Graveyard area, Diamond Head peaks A, B, and C in the eastern Chatham Rise), there are numerous new features identified in the expanded dataset. Bollons Seamount to the east of the Bounty Plateau is notable here. The core seamount is a very large edifice with complex topography surrounding it within the SCA boundaries. Within this feature are 7 seamount, 16 knoll, and 8 hill features.

Table 5: Numbers of UTFs by topographic type that are protected within SCAs or BPAs. Numbers in parentheses indicate where summit depth < 1600 m. A number of additional UTFs have been identified within SCAs since they were initially designated (SCA-new inside area).

	Seamount	Knoll	Hill	Total
BPA	64 (32)	425 (171)	364 (108)	855 (311)
SCA (original)	12 (8)	10 (8)	3 (3)	25 (19)
SCA (new inside area)	4 (1)	19 (6)	13 (1)	36 (26)
Total	80 (41)	456 (185)	380 (112)	916 (356)

A total of 68 features are protected within the Territorial Sea inside marine reserves (primarily the Kermadec and Subantarctic islands) which are also included within BPA boundaries.

3.1.2 Database functionality

An example of the database functionality is given below, where the SQL extracts linked catch data from a research trawl held in the external *trawl* database specifically where the trawl track intersects a UTF polygon:

```
Select  s.reg_no,
        s.name,
        st.trip_code,
        st.station_no,
        c.species,
        coalesce(c.weight, 0.100) as weight
from    fdw.t_station st,
        fdw.t_catch c,
        seamount_raw s,
        polygons_2021 p
where ST_Intersects(ST_Transform(st.track, 3994),p.poly)
        and p.seamount = s.reg_no
        and st.trip_code||'_'||st.station_no = c.trip_code||'_'||c.station_no;
```

Returning:

Reg_no	UTF name	Trip_code	Station_no	Species	Weight (kg)
654	Pimple	AEX0101	19	CKA	0.50
654	Pimple	AEX0101	19	CSU	0.10
654	Pimple	AEX0101	19	SSO	11 263.30
657	Hegerville	AEX0101	27	BYS	1.30
657	Hegerville	AEX0101	27	BOE	2 000.00
657	Hegerville	AEX0101	27	BJA	73.80

The SEAMOUNT database also stores copies of datasets that are relevant to, but not directly part of, the UTF data. These are either local copies of GIS layers or linked to foreign tables. Other datasets can generally be added if required. Examples include:

- New Zealand coastline (including offshore islands)
- New Zealand EEZ (200 n.mi Exclusive Economic Zone)
- New Zealand Fisheries Management Areas (FMA)
- Marine Environment Classification (MEC) 20 and 33 class polygons
- Seafloor Community Classification (SCC) polygons
- Trawl footprint polygons

Examples of several layer types are given below in Figure 12, where the database links with GIS layers of the trawl footprint and research trawls.

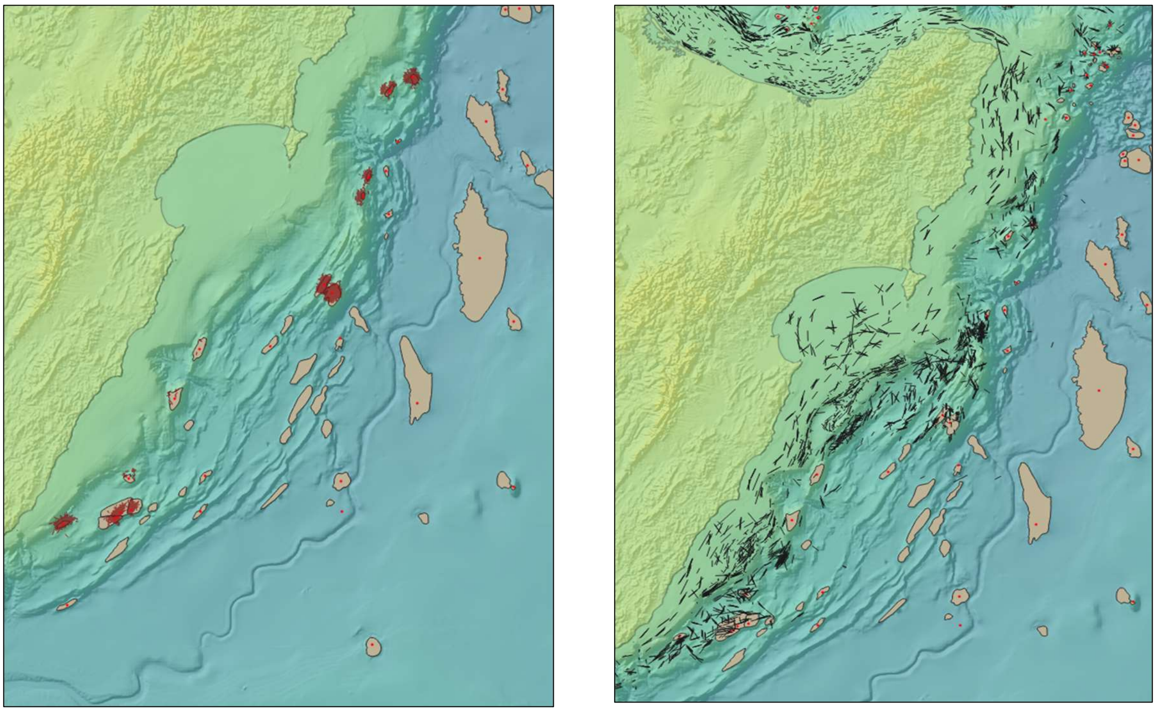

Figure 12: Trawl footprint polygons (left panel) and research trawl tracks (right panel) overlain on Underwater Topographic Feature (UTF) polygons. The research trawl tracks are accessed directly from the research trawl database using a linked virtual table in the seamount database.

3.2 Fisheries on UTFs

A total of 229 UTFs had overlapping bottom trawl footprints within the EEZ (and TS). By UTF type these were:

- Seamount: 21
- Knoll: 128
- Hill: 80.

The database is designed to be able to support user-defined analyses of footprint by UTF. In this report we do not describe a large array of results, but instead provide an indication of some of the kinds of queries, aggregated reports, and analyses that are possible. We show some specific results that were discussed with Fisheries New Zealand. We emphasise that the power and flexibility of the spatially enabled Postgres/PostGIS ORDBMS with direct links to externally managed datasets provides not just a datastore, but also powerful analytical tool.

Below we demonstrate a number of example outputs:

1. **Numbers of UTFs fished by time period**

Table 6 shows the number of UTFs by type that have never been trawled, numbers that have been trawled (since 1989/90 and for the last 10 years), and numbers previously fished but now closed due to being inside BPAs or SCAs.

Table 6: Summary of trawled and untrawled features in the EEZ and TS.

	Total number (total < 1600m summit depth)	Never fished	Fished	Fished in the last ten years	Fished and now closed to fishing
All UTFs	1 996 (613)	1 767	229	198	3
UTFs 100–250m	894 (270)	814	80	52	0
UTFs 250–1000m	956 (291)	828	128	126	3
UTFs > 1000m	146 (52)	125	21	20	0

2. Fished footprint area by UTF

The 229 UTFs that have been fished all have a basal depth of less than 1600 m. Hence, the fishable depth is effectively the entire feature. Table 7 shows an extract of the number of tows on each feature and the area and percentage of the trawl footprint and aggregated area relative to the estimated area of the feature. A full extract is not provided given uncertainties around the accuracy of the footprint estimates on UTFs (see Discussion). However, the UTFs with most effort (expressed as relative % footprint) are on the Chatham Rise, east coast of the North Island, Challenger Plateau, and several UTF complexes in southern waters (Figure 13).

Table 7: An example of an extract showing effort (number of tows) and footprint data for each fished UTF. See Appendix 2 for full results.

reg_no	no_tows	footprint_area (km^2)	footprint_area (%)	agg_area (km^2)	agg_area (%)	UTF_area (km^2)
181	1	0.02	0.02	0.02	0.02	131.32
198	1	0.02	0.03	0.02	0.03	70.65
202	1	0.01	0.01	0.01	0.01	127.90
213	635	11.10	12.44	15.24	17.09	89.16
226	67	2.06	0.79	2.22	0.85	262.23
228	30	0.83	0.26	0.86	0.27	323.66
230	3 856	23.32	27.26	91.66	107.16	85.54
243	17	0.50	3.61	0.52	3.76	13.82
244	3	0.09	0.27	0.09	0.28	31.20
248	3	0.11	0.21	0.11	0.21	51.53
257	2 012	22.97	67.39	55.72	163.47	34.08

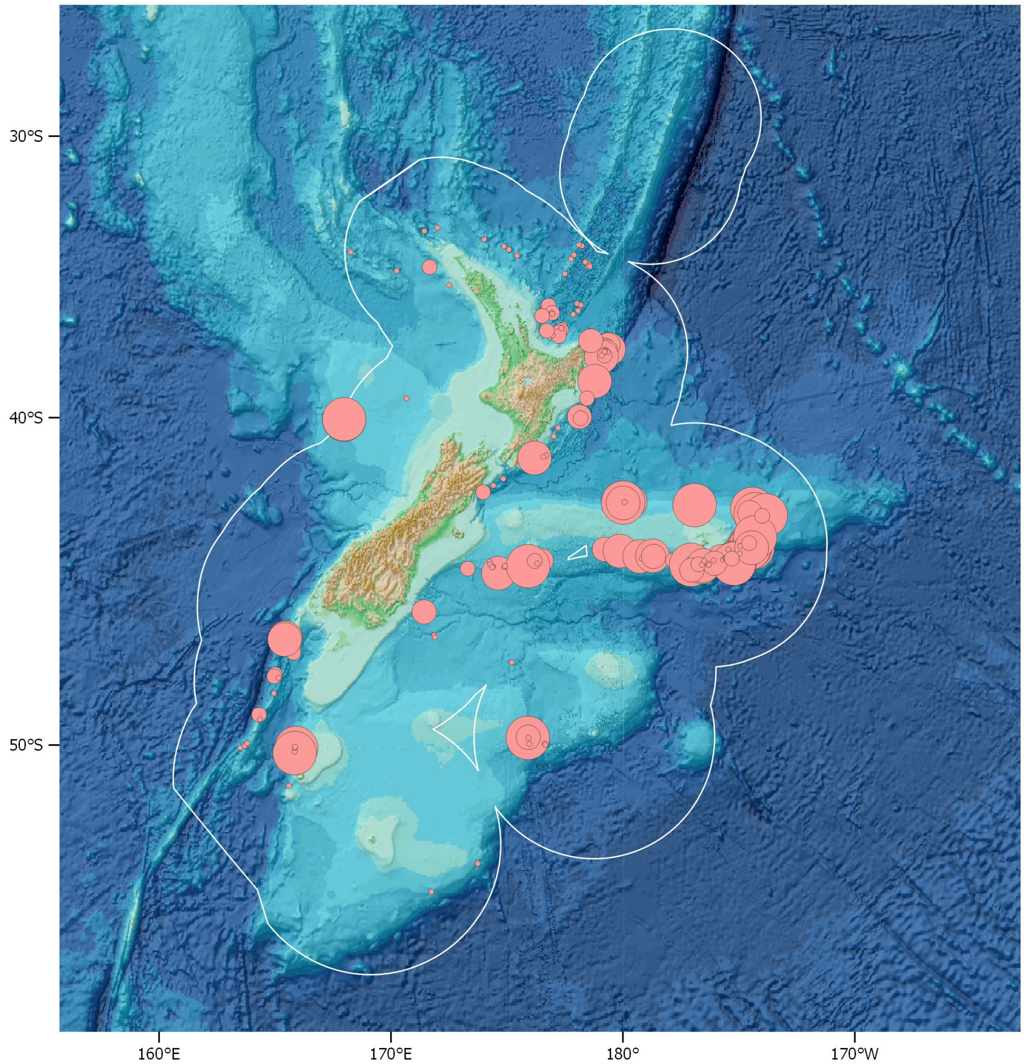

Figure 13: The distribution of fished UTFs, showing the relative proportion of the area of the feature covered by the estimated footprint from Appendix 2.

This footprint area summary has taken the trawl footprint and cropped the tow polygons at the base of the UTF. Hence it reflects the area estimated to be trawled that is physically on the UTF. An alternative analysis can be done where the full polygons are used to estimate the area metrics of the UTF fishery footprint. The distinction between these approaches is shown in Figure 14.

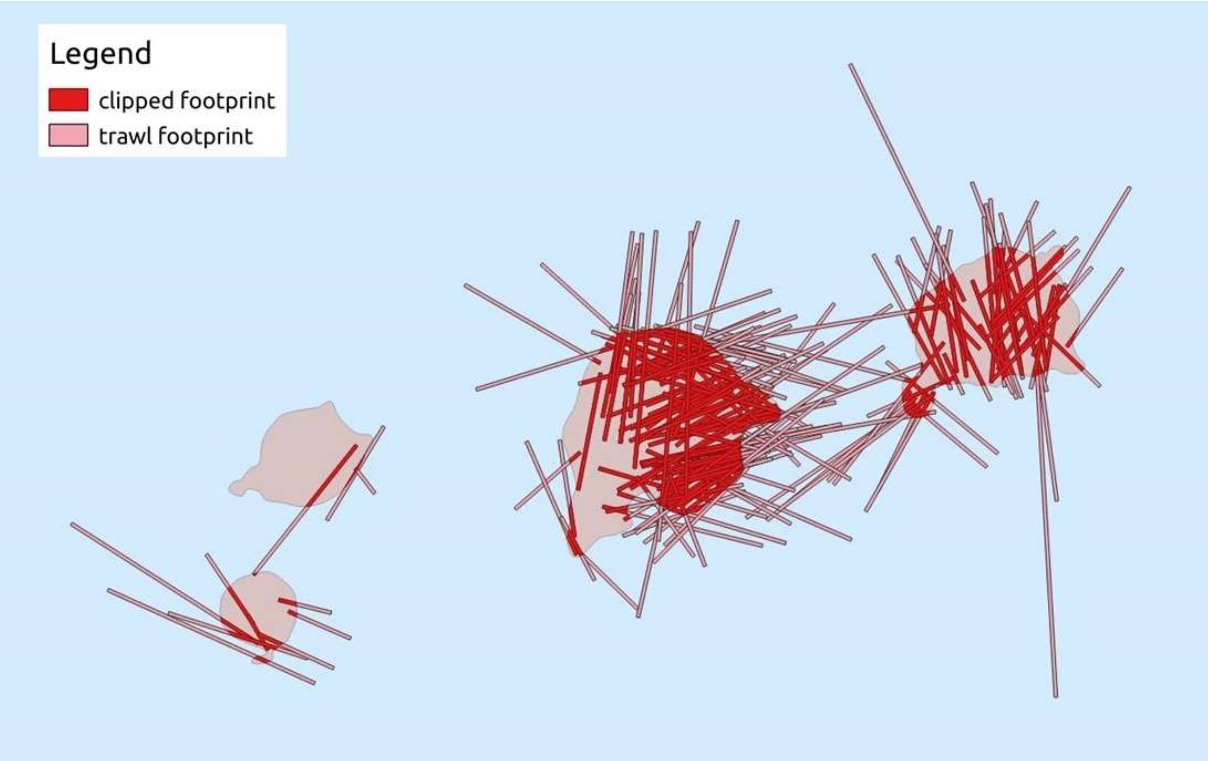

Figure 14: Plot showing the difference in trawl footprints between those clipped to the base of the UTF representing physical effort on the feature itself, and those extending beyond the base, representing the extent of the footprint resulting in the catch from on and nearby the feature. This dataset was created using a spatial query on the seamount data.

3) Fishing effort and footprint by depth

The majority of fishing effort has occurred on UTFs with summit depths between 400 m and 1200 m (Table 8).

Table 8: UTF and effort metrics grouped by 200 m summit depth intervals.

depth_class (summit_depth)	No_ UTF unfished	no_UTF fished	no_trawls
0–200	21	6	26
200–400	75	9	715
400–600	74	23	8 207
600–800	98	60	27 474
800–1000	79	91	16 776
1000–1200	64	32	2 010
1200–1400	97	5	549
1400–1600	126	3	8
1600–1800	147	0	0
1800–2000	123	0	0

4) Changes over time

The fishing effort and catch has varied considerably over time on many features. The database can be queried to produce data that can be plotted to show changes over time. The SQL is:

```
Select   p.poly as seamount_polygon,
         p.seamount as reg_no,
         p.name as seamount_name,
         f.fyear as fishing_year,
         sum(ST_Area(ST_Transform(f.poly,3994)))::geometry as footprint_area,
         ST_Union(f.poly)::geometry as seamount_footprint
from footprint_polygons f,
         polygons_2021 p
where ST_Intersects(ST_Transform(f.poly,3994),ST_Transform(p.poly,3994))
group by p.poly,
         p.seamount,
         p.name,
         f.fyear;
```

This SQL generates a new polygon, for each year and each UTF, and which comprises the geometric union of the footprint polygons. Note: this example uses a version of the trawl footprint which is not cropped at the basal UTF polygon (Figure 15).

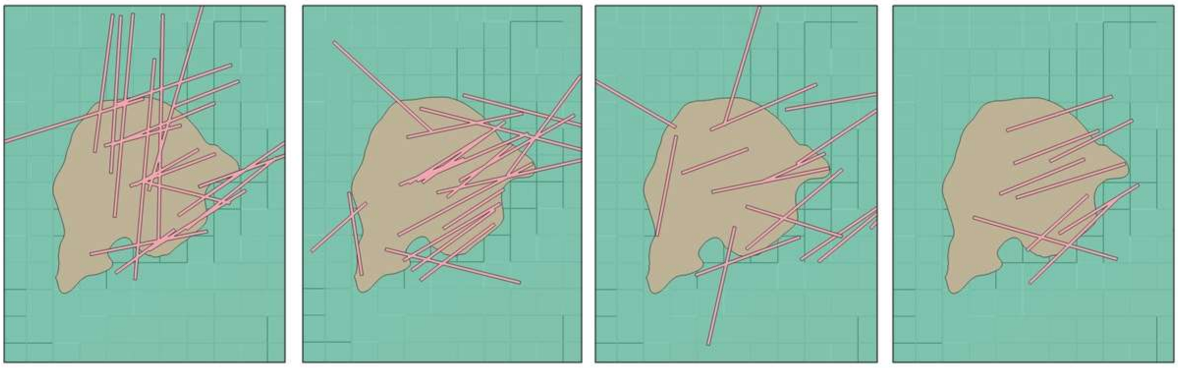

Figure 15: The trawl footprint (not clipped to seamount base) over four consecutive years on a knoll.

4. DISCUSSION

The work undertaken in this project represents considerable advances in both identifying and describing UTF 'seamount feature' habitat throughout the New Zealand region as well as showing how the information is served through the new database structure and functionality.

Extensive efforts were made as part of this project to check and groom the information. This included reconciling duplicates from different sources, manually examining the automated GIS analysis to ensure that it was producing sensible results and that the bathymetric data were realistic. Nevertheless, there are still some issues that may need to be updated in future. The basal polygons are at times complex, particularly in instances where they reflect a ridge-type structure. Ultimately these may need some modification and ground-truthing that will potentially change the details for a number of features. However, the improvement in multibeam echosounder coverage, and the combination of a variety of bathymetric datasets into the underlying source bathymetry, gives us confidence that the overall dataset is generally reliable.

At the start of this project, it was proposed to use the existing trawl footprint results in order to have a consistent approach to the use of such bottom-contact effort data between Fisheries New Zealand projects. It also adopts a standard methodology whereas in past UTF fishery analyses the assignment of tows to UTFs has varied (e.g., Clark & O'Driscoll 2003, O'Driscoll & Clark 2005, Clark et al. 2016). However, it is acknowledged that the footprint data have been extracted from analyses directed at describing the distribution of fishing effort at large spatial scales. Although we have adjusted data from the vessel position to the estimated gear position (by applying a correction based on trawl-depth-direction geometry), the accuracy of the gear position data on small features still suffers from two key aspects: firstly the underlying resolution of the older reported data to the nearest nautical mile can be a major offset on small UTFs; and secondly a jittering process applied in the footprint analysis to separate tows that otherwise all appear as being exactly the same line might shift tows off a feature or affect the estimated extent of overlap. This potential under-estimating the trawl footprint is shown in Figure 16, where tow lines are often very close to a UTF position, but do not intersect it. Many of these seem likely to be UTF-targeted tows, although some may legitimately occur on drop-off terrain or in the 'moat' topography often common just beyond the base of a feature. Most tows on a UTF will start on or near the summit, but direction can vary appreciably, given weather, currents, and fish location. Hence whether the existing method over-estimates or under-estimates the actual trawl footprint is uncertain. These aspects warrant further investigation given the small size of many fished UTFs, in particular on the knoll and hill features. A method correcting for depth has been developed and could be a useful approach to examine in more detail in discussion with Fisheries New Zealand staff and consultation with the Aquatic Environment Working Group.

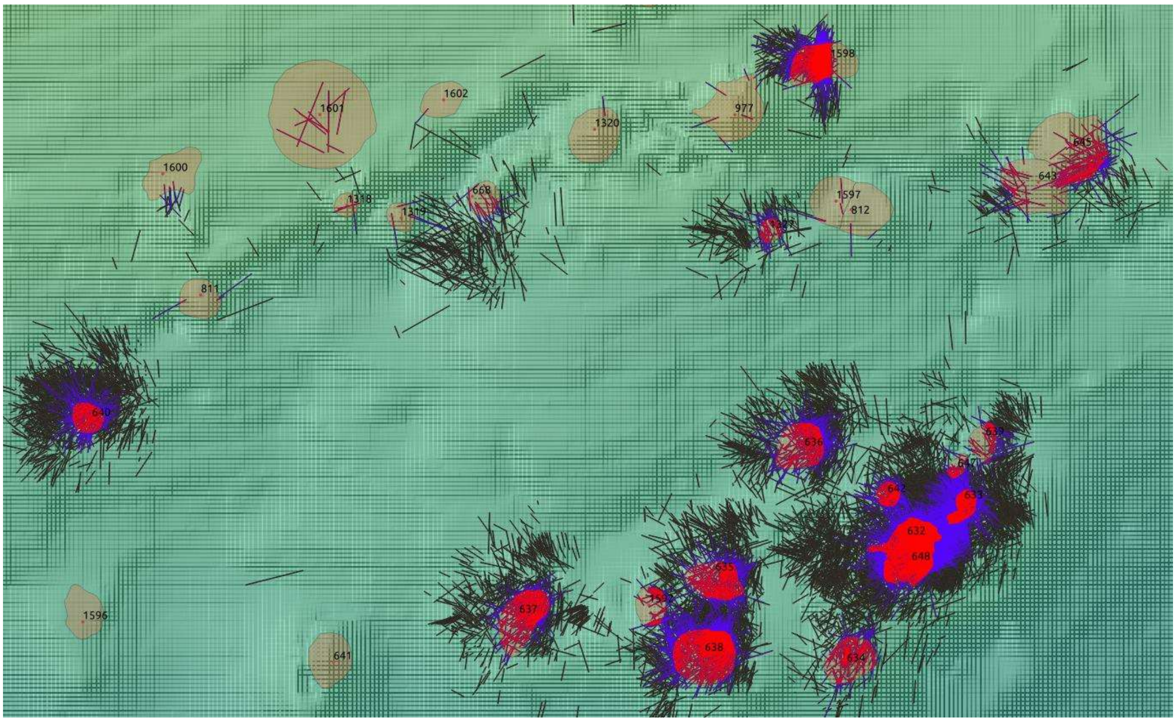

Figure 16: Bottom trawl tows (lines) overlain on UTFs (brown filled polygons). The red tows are those that intersect the basal polygon, blue show parts of tows that intersect but are clipped off beyond the polygon, and black lines are tows that do not intersect a UTF.

The approach taken in this project to design the database to be less a static repository of data and more a tool supporting user-defined analyses is a considerable step forward from previous versions. External datasets or GIS shape files can now be linked directly to the database and can be joined and extracted with local data stored within the seamount database While trials have provided a successful proof of concept, (with example extracts from *trawl* and *niwainvert* databases), there remain issues with compatibility of computer platforms, data confidentiality, and IT security requirements that should be resolved for the final SEAMOUNT database system.

5. MANAGEMENT IMPLICATIONS

There are no direct management implications at this stage. The database is a resource to enable Fisheries New Zealand (and potentially a wider array of stakeholders), to more easily access a range of relevant data for a variety of analyses related to improving our scientific understanding of the distribution of UTFs, their environmental characteristics, and their fisheries within the New Zealand region. In turn this information will help to support the evaluation of management planning options for both fisheries and conservation. The underlying UTF data can also be relevant to assessments outside the EEZ by the South Pacific Regional Fisheries Management Organisation.

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APPENDIX 1

SEAMOUNT database field descriptions

Data field	Description	Units	Database/Linked layer
id	Database identifier	Number	
reg_no	Unique NIWA data identifier	Number	
EEZ	Inside/outside EEZ/territorial sea	Yes/No	
FMA	Fisheries Management Area	FMA Number	
latitude	Latitude	Decimal degree	
longitude	Longitude	Decimal degree (both 180 and 360 format)	
depth_top	Depth at summit	m from sea surface	
depth_base	Depth at base	m from sea surface	
elevation	Elevation of seamount (base to summit)	m	
UTF type	Feature type	Seamount/Knoll/Hill	
name	Seamount name	Name where known	
Source type	Source of locality data	Source categories with no specific details	
area_km2	Estimated area of basal polygon	sq.km	
assoc	Geological association	Margin, oceanic etc	
shape	General topographic form	Conical UTF, guyot	
Connectivity	Topographic discreteness (based on manual definition)	Chain, cluster, isolated	
hydrothermal_activity	Active hydrothermal activity	Yes/No	
substrate	Substrate information available	Yes (based on NIWA sampling information	NIWA cruise_db
surf_water	Surface water mass	Subtropical, Subantarctic etc	
1000m current	ARGO float vector at 1000m	Flow direction and speed	
biol_samp	Biology sampled	Links to associated tables or databases	NIWAinvert, Trawl_db, Biods
MEC_20	Marine Environmental Classification	20 class	
MEC_33	Marine Environmental Classification	33 class	
BOMEC	Biologically-Optimised Marine Environmental Classification		
SCC	Seabed Community Classification		
GOODS	The GOODS biogeography (updated by Watling et al 2013)	Bathyal and Abyssal classes	
curr_speed	Mean current speed (used for Taylor Cap)	m/second	
depth_thermocline	Depth of thermocline (used for Taylor Cap)	m	
ann_mean_semi_diur_tide	Mean semi-diurnal tidal flow (used for Taylor Cap)	m	

diurnal_tide	Mean diurnal tidal flow (used for Taylor Cap)	m
prob_cap_diurnal	Probability of Taylor Cap formation in mean tidal flow	Decimal
prob_cap_meanflow	Probability of Taylor Cap formation in mean current flow	Decimal
mean_slope	Mean slope	degrees
perimeter	Perimeter distance of base	km
Nearest_neighbour	Identity of closest adjacent UTF	Reg_no
Distance_nn	Distance to nearest adjacent UTF	Summit to summit, km
Num_in_100km	Number of UTFs within a 100 km radius	Number
BPA	Inside Benthic Protection Area	Yes/No
SCA	Inside Seamount Closure Area	Yes/No
MPA	Inside Marine Protected Area	Yes/No
UTF type	Terminology based on elevation	Seamount, Knoll, Hill
geom	Postgis point geometry with longitude/latitude coordinates	
fished	Intersection of trawl footprint and basal polygon	Yes/No