2.3 Oceanographic data

Which *water mass* overlies each seamount was determined by reference to the characterisation produced for the New Zealand region by Carter et al. (1998). Remotely sensed data were available to directly measure sea surface temperature and derive data that give temporally and spatially continuous variables that characterise different water masses. Data for *sea surface temperature* (SST) variables 'wintertime SST', 'annual amplitude of SST', 'spatial SST gradient', and 'summertime SST anomaly' were calculated from NIWA archived SST climatology dataset. Procedures for collecting satellite radiometer data, detecting cloud and retrieving SST data were described by Uddstrom & Oien (1999), and the calculation of the specified variables for the New Zealand region (at 1 km resolution) were detailed by Snelder et al. (2006). Patterns in wintertime SST are a proxy for water mass (which is related to nutrient availability); variations in the annual amplitude of SST are due to differences in stratification and wind mixing, that together produce the mixed layer across the region; spatial SST gradient recognises fronts in oceanic water masses (and is expected to correlate with variation in primary productivity); summertime SST anomaly is expected to recognise anomalies in temperature that are due to hydrodynamic forcing, such as upwelling and vigorous mixing due to eddies (areas with high values of this variable are expected to correlate with high primary productivity). All these parameters derived from SST data possibly influence the composition of pelagic and benthic assemblages (Longhurst 1998).

2.4 Biological data

The shortest *distance a seamount is from the continental shelf* was calculated using ArcGIS where seamount distances from the 250 m depth contour (which approximates the continental shelf edge) were calculated at a resolution of ± 1 km, based on an azimuthal equidistant projection (Central Meridian 171° E, Latitude of Origin 41° S, Datum WGS84). The composition of faunal assemblages on seamounts (which are generally features of the slope or deep-sea) is expected to be in part influenced by the degree to which faunal colonisation has been possible from the shallow-water of the shelf (Leal & Bouchett 1991, Gillet & Dauvin 2000). Thus, a measure of the shortest distance from the shelf edge is expected to be a reasonable proxy for the likely extent of seamount colonisation by shallow-water species. To some extent this measure is a proxy for the general degree of biological isolation, and therefore the relative level of likely endemism of a seamount's benthic fauna. Distance from the shelf edge is also a reasonable proxy for the existence of localised, biologically meaningful, hydrodynamic processes. The intensity of the current flow field near a seamount decreases with distance from continental margins (Smith et al. 1989), which concomitantly affects the development of hydrographic features (e.g., localised upwelling, Taylor Caps) that can influence primary productivity overlying seamounts (Comeau et al. 1995).

SeaWiFS 4 km L1A daily radiances for 1998–2002 were processed using the OC4v4 algorithm (Pinkerton et al. 2005) to derive surface chlorophyll a concentrations (mg m^{-3}). The resulting daily chlorophyll products were then further processed using the Fourier decomposition and objective analysis method of Uddstrom & Oien (1999) to generate a temporal *mean chlorophyll a* (and *SD and CV estimates about the mean chlorophyll a* measure) measure for the surface water overlying each seamount. The spatial resolution of these climatologies is about 8 km. Remotely sensed chlorophyll *a* data are generally related to the relative occurrence of phytoplankton in surface waters, and given reasonable assumptions are proxies for phytoplankton biomass in the ocean above the seamount (Martin 2004). The amount of phytoplankton (or rather primary productivity) associated with seamounts is likely to influence the diversity of pelagic, and subsequently the benthic faunal, assemblages (Piepenburg & Müller 2004).

2.5 Fisheries data

Whether or not a seamount has or is subjected to bottom *fishing* is noted. This condition was determined by direct plots of deepwater tow positions (determined from the Ministry of Fisheries Trawl Catch Effort Processing Return data), as well as assignment of trawls with a recorded start position within 3 nautical miles of a summit location, with a trawl duration of less than 30 minutes.

2.6 Descriptive data

Every seamount in the database has been assigned a *registration number*, and where known the official and/or unofficial *name* is indicated. Whether a seamount is located within the New Zealand *Exclusive Economic Zone* is recorded, as is the broad *geographic area* and the *source of the physical data* (e.g., regional bathymetry).

3. THE NEW SEAMOUNT DATABASE (VERSION 2)

An enhancement of the SEAMOUNT (v1) database, via the addition and population of new data fields, was planned as part of NIWA's Seamount programme. With the advent of the present MFish project a meeting was held between NIWA and MFish representatives to discuss the new data fields, to agree on a selection that would facilitate data analysis for management options for the effects of bottom trawling on seamounts. The selection of the additional data fields was subject to the availability of appropriate data, and the resource (time and money) limits of both the MFish project and NIWA's Seamount programme. The names of the 41 additional data fields are italicised in the text below and are listed in Figure 2 and Appendix I.

3.1 Additional oceanographic data

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* (G. Rickard et al., NIWA, unpublished data) - measures of these variables are included in the new version of the database for the position of individual seamounts. These measures are combined with physical variables (already in the SEAMOUNT database) that describe the seamount and its position in the water column to model the likelihood that a seamount could generate closed circulation. Whether a seamount possesses such a hydrographic feature ('Taylor Cap' or 'Cone') is considered important, for nutrient delivery from depth to the surface waters can be enhanced – thereby influencing the primary and secondary/tertiary production associated with the seamount (Rogers 1994). The formation of a Taylor Cap also has implications for recruitment to, and subsequent long-term stability of, seamount communities. Many seamounts are isolated from other seamounts or the nearest shallow water topographies by 100s or 1000s of kilometres, making them difficult for new recruits to reach. The greater the likelihood of a Taylor Cap forming over a seamount the more likely passing larvae are to be entrained in the seamount circulation and to settle there (Mullineaux & Mills 1996). Once populations are established, the strength of this same circulation system may retain larvae that would otherwise disperse away from the seamount and this retention potentially increases the proportion of endemic species found there (see arguments in introduction of Beckman & Mohn (2002)). In contrast, a seamount with a low likelihood of Taylor Cap formation is less likely to entrain passing larvae or retain those that are produced on the same seamount, and may have taxa more representative of the surrounding area. Two measures of the likelihood or probability of Taylor Cap formation have been generated for inclusion in the SEAMOUNT (v2) database; these are *probability of Taylor Cap* *formation in mean flow* and *probability of Taylor Cap formation in tidal flow*. These measures are derived from numerical studies of flow over seamounts, 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. For seamounts where both components are equally significant it is expected that cap formation will still occur, but that the interactions between the forcing flows will result in more complex flow patterns. Further details of how these two measures were calculated are provided in the documentation that accompanies the database (Mackay 2007).

3.2 Additional geological data

The geological origin of a seamount has been further usefully qualified, for volcanic seamounts, by indicating whether a seamount is considered *active* (extinct, dormant, active), and specifically if it is thought or known to posses active *hydrothermal vents*. Submarine volcanic eruptions, though inherently difficult to record, have been interpreted from indirect hydroacoustic *T*-wave data, eruptive manifestations at the sea-surface, and even the emergence of ephemeral island volcanoes. For the New Zealand region, such recordings (although almost certainly under-reported) are restricted to seamounts along the Kermadec Ridge (Kibblewhite 1967, Davey 1980, Latter et al. 1992, Lloyd et al. 1996, Wright et al. 2006). Similarly, the discovery of hydrothermal venting at depths of 500–2000 m below the sea-surface has been difficult. However, more recent and systematic surveys of seamounts along the Kermadec Ridge using towed sensor arrays measuring water chemistry and optical properties have established the incidence of the more significant submarine hydrothermal venting (de Ronde et al. 2001, Baker et al. 2003). Some of these indicative signals of venting have been confirmed by visual observations at the seafloor, using either towed camera arrays, ROVs, or manned submersibles (Rowden et al. 2003).

To date there are no regional studies of seamount substrates within the New Zealand region. The only regional compilation of substrate type is for seafloor sediment composition (Mitchell et al. 1989), which is produced on a scale too coarse to realistically resolve sediment types for a seamount. At smaller spatial scales, modern swath imagery data (typically at an acquisition frequency of about 12 kHz), although restricted to relatively small areas, can provide important information on general substrate compositions at scales of 100–1000 m. Such swath mapping imagery has been acquired from only a few areas where significant numbers of seamounts exist (southern Kermadec/Colville Ridges and Havre Trough, eastern North Island and Chatham Rise; (Coffin et al. 1994, Blackmore & Wright 1995, Lewis et al. 1997, Lewis et al. 1999, Barnes et al. 1998)). These swath imagery data can differentiate broad areas of sediment and rock substrates (Orpin 2004) and the nature of large-scale degradation and mass-wasting of seamounts. More recently, as part of detailed geological investigations of specific seamounts along the southern Kermadec arc (Wright 1994, 1996, 2001, Wright & Gamble 1999) higher frequency and higher resolution multibeam systems (at 30 kHz) have been used (Wright et al. 2006). From these detailed investigations it is possible to describe substrate heterogeneity at scales of 10s to 100s of metres through integrating data from swath mapping backscatter imagery, seafloor photography, and/or seafloor sampling (Wright et al. 2002). Thus, included in the database is a field which indicates whether or not seamount-specific *substrate information is available*, and all available data are located on 'Tsunami', a mass storage device for multibeam data held by NIWA. However, where it is known that particular seamounts (or the areas in which they exist) possess (or can be predicted to possess) *substrates of potential interest for mining*, e.g., ferro-manganese crusts or sulphide rich deposits, this has been recorded in this data field.

An objective morphometric analysis of New Zealand seamounts (morphology) has not been undertaken during the project due to time constraints. Standard hydrographic classifications based on subjective interpretation of seamount morphology and elevation (e.g., seamount, knoll, guyot) could have been applied using the standard International Hydrographic Classification (IHO/IOC 1988). However, while this sort of 'analysis' has already been partly undertaken for submarine features of New Zealand (Eade & Carter 1975, Thompson 1991), such classifications are subjective and time consuming, requiring analysis of each feature, and, therefore, this morphological categorisation was not undertaken. Algorithms and/or GIS based morphometric analysis which could determine a seafloor feature's "footprint area", degree of elongation, elevation, slope, aspect, volume, and corresponding ratios of these parameters, would provide a quantitative and robust analysis of seamount morphology. Morphological measures would provide insight into the possible relationships between, for example, the size of a seamount and the composition of the associated biotic assemblage. However, at present there is a limit to which an objective determination of seamount morphology can progress due to the highly variable quality of the bathymetry data for the New Zealand region. Much of the existing seamount bathymetry is based on limited, poorly navigated, single-beam echo-sounding profiles, though more recent mapping has used modern multi-beam systems to provide 100% coverage of the seafloor. Newly compiled and updated bathymetry datasets could be used for a morphometric analysis of only a small proportion of the region's seamounts.

3.3 Additional biological data

Remotely sensed estimates of chlorophyll *a* are useful proxies for phytoplankton biomass, but chlorophyll *a* is not an ideal proxy for primary productivity. Measures of primary productivity will provide a better indication of the type of communities that a particular seamount environment supports. That is, the composition of faunal communities will in part be determined by the quantity of the potential phytoplankton food source that is in the water above a seamount, be it directly or indirectly available to the seamount associated fauna (Rogers 1994). Algorithms to estimate primary productivity have been developed (Behrenfeld & Falkowski 1997), and recently these global algorithms have been modified to estimate primary productivity for specific areas. Primary productivity estimates have been made for areas of the New Zealand region using two algorithms under development by Behrenfeld and collaborators. These primary productivity measures are derived from a Vertically Generalised Production Model (VGPM) and a Carbon-based Model (Carbon2). Recent work has suggested that the flux of primary production across the seamount (not just the amount of local primary productivity, which itself might be enhanced by the formation of a Taylor Cap – see earlier section) is a more sensitive/pertinent indicator of the type of community that one might expect to develop on a particular seamount (Bulman et al. 2005, Morato & Pitcher 2005). Thus the two estimates of primary production above a seamount have been spatially extended to determine measures of *net primary productivity-VGPM* and *net primary productivity-Carbon2* associated with a particular seamount. It is important to note that due to the lack of published validation results and the substantial differences between the two primary productivity algorithms, these data (and the derived net primary productivity estimates) should be treated as preliminary. Currently it is not possible to decide which of the primary productivity estimates is more meaningful, so both are included in the database. Detailed information of how the values underpinning the algorithms were derived are given in the documentation that accompanies the database (Mackay 2007).

Unfortunately, data for zooplankton (abundance or biomass) directly associated with seamounts in the New Zealand region are very scarce, and it is only recently that plankton data have begun to be systematically collected from above seamounts in the region. Thus it is unlikely that any such data will be added to the database for at least a few years.

Data for the benthic macroinvertebrates of seamounts in the New Zealand region are relatively sparse and generally unstandardised in their collection and taxonomic resolution. Whilst efforts are currently underway to improve data quality it was not possible to complete this exercise within the timeframe of this project. Nonetheless, it is possible to record in the database whether or not biological samples have been taken for a particular seamount (as *biology sampled*). With respect to management considerations, a separate data field has been created to note that records exist for the occurrence of those benthic macroinvertebrates thought particularly vulnerable to the impacts of bottom fishing and important for habitat structuring (e.g., see comments of Probert et al. (1997) for New Zealand context, and Section 5), in this case *structure-forming corals* (the matrix-forming scleractinian corals - *Solenosmilia variabilis, Madrepora oculata, Goniocorella dumosa, Enallopsammia rostrata, Oculina virgosa* (Tracey et al. unpublished data), all *octocorals* (Sanchez & Rowden 2006) and *sponges* (Kelly-Shanks, unpublished data, Rowden & Kelly-Shanks, unpublished data). The records for these taxa are maintained separately in other NIWA marine databases.

Occurrence data for fish fauna sampled from seamounts are more robust than data for benthic macroinvertebrates, and are already stored in the TRAWL database of MFish. Extracts have been made from this database to produce by individual seamount feature, counts of taxa comprising teleost fishes, elasmobranchs (sharks, rays, chimaeras, and ghost sharks), squid, and octopuses. These data (between water depths of 500 to 1700 m) are listed as *number of fish (from research surveys)*, *number of squid and octopus* and *number of research trawls*. This last variable can be used to assess the sampling effort that resulted in the counts.

3.4 Additional fisheries data

Recently, NIWA scientists have developed indices that evaluate the relative importance of seamounts for deepwater fisheries (Clark & O'Driscoll 2003) and intensity of fishing on seamounts (O'Driscoll & Clark 2005) in the New Zealand region. These indices, the *Fishing Importance Index* and *Fishing Effects Index,* are both included in the database. They are calculated from a number of catch and effort variables from Trawl Catch Effort Processing Returns which are stored separately on the MFish database "WAREHOU", but are also included in the SEAMOUNT database in order that the indices can be calculated and updated with relative ease. These variables are: by target species – *number of tows*, *catch* in tonnes, *number of years* in which there were 10 or more tows (all within 10 km of seamount centre); and by seamount – *summed tow length* in km of all tows within 10 km of the seamount centre and of tow length less than 5.6 km, *number of tow directions* (from 1 to 4) for each seamount that had more than five tows. The latter is derived from information for *direction of tow* (north, south, east, west – four separate data fields). In addition, data for the *year first fished* has also been included in the database.

3.5 Additional descriptive data

Whether a seamount is subject to any specific *mining interest* has been indicated with reference to current exploratory mining leases sourced from the Crown Minerals division of the Ministry of Economic Development. This data field refers specifically to mineral exploration and mining permits and does not relate to petroleum or hydrate exploration or production.

The *protection status* of a seamount has been derived from the Department of Conservation report describing all central government area-based restrictions for the New Zealand marine environment (Froude & Smith 2004). For 19 seamounts, there is a prohibition on the use of trawl nets by any commercial fisher to protect the benthic biota from the potentially damaging effects of bottom trawling (Froude & Smith 2004).

Variation in a number of physical and oceanographic parameters across the New Zealand region has been summarised on a spatial basis by the recent Marine Environment Classification or MEC (Snelder et al. 2006). The *environmental class*, according to this classification, to which an individual seamount belongs is noted in the database. The MEC can operate a variety of class 'levels'. The MEC classification strength analysis revealed that below the 15 class level the classification detail was not statistically significant for the benthic invertebrate test data. Between the 20 class level (when statistical significance is achieved for all three test data sets) and the 40–50 class level there was very little difference in classification strength. After the 50 class level there are notable increases in classification strength (with respect to the three test data sets) up to the 60–70 class level, thereafter (above 75 class level) there is little gain in classification strength (up to the maximum of 290 classes). Large bathymetric features such as the Chatham Rise and Challenger Plateau, become aligned with separate MEC classes at the 33 class level. Following the request of MFish, the identity of the class to which a seamount belongs is noted at two classification levels, 20 and 33. These two levels were chosen by MFish because they reflect the low level of spatial detail that can be readily appreciated by managers/stakeholders and easily incorporated into management plans, and, for the latter class level, distinguish between two areas thought to be ecologically distinct.

The classification of about half of the known seamounts in the New Zealand region, also based largely on physical and oceanographic parameters (in addition remotely sensed surface water chl *a*) (Rowden et al. 2005), provides an indication of the degree to which seamounts may provide a similar environment for benthic biota. The *seamount class*, according to this classification (which operates at a 12 class or group level), to which an individual seamount belongs is also noted in the database. Such information will be useful for considering the representative nature of a particular seamount and, because the classifications are designed to be biologically meaningful, also potentially representative of its associated fauna.

3.6 Database structure

The SEAMOUNT (v2) database is currently held as an Empress RDBMS database located in the MFish "snapper" server (managed by NIWA). The SEAMOUNT (v1) database was a spreadsheet and this is reflected in the schema of the second version of the database where there is one large table with many fields but which is now linked to other databases (see above). The overriding factor when designing the schema was the need to transfer data easily between local copy spreadsheets (that individual researchers might have) and the central database. Full details of the structure and content of SEAMOUNT (v2) database are provided in the documentation that accompanies the database (Mackay 2007).

3.7 Interactive capability

The SEAMOUNT (v2) database can be accessed using SQL commands via the dedicated network connection between MFish and NIWA. The data are currently versioned, with editable MS Excel spreadsheet versions held with various NIWA researchers. These editable versions are regularly reconciled and checked-in against the master database. Snapshots of data can be distributed on MS Excel spreadsheets, as they have been to MFish, but these are not reconciled.