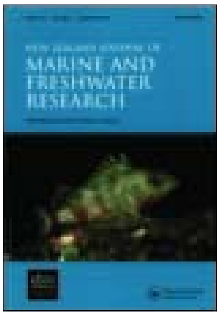

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Physical characterisation and a biologically focused classification of “seamounts” in the New Zealand region

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Physical characterisation and a biologically focused classification of "seamounts" in the New Zealand region

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Abstract The physical, biological, and oceanographic characteristics of seamounts of the New Zealand region of the South Pacific Ocean are poorly known. The aim of this study was to present a synopsis of the physical characteristics of seamounts within the region, and to present a preliminary classification using biologically meaningful variables. Data for up to 16 environmental variables were collated and used to describe the distribution and characteristics of the c. 800 known seamounts in the New Zealand region. Seamounts span a wide range of sizes, depths, elevation, geological associations and origins, and occur over the latitudinal range of the region, lying in different water masses of varying productivity, and both near shore and off shore. As such, it was difficult to generally describe New Zealand seamounts, as there is no "typical" feature. Thirteen environmental variables were included in a multivariate cluster analysis to identify 12 seamount similarity groupings, for a subset of over half the known seamounts. The groupings generally displayed an appreciable geographic distribution throughout the region, and were largely characterised by a combination of four variables (depth at peak, depth at base, elevation, and distance from continental shelf). In the future, the findings of the present study can be tested to determine the validity and usefulness of the approach for directing future biodiversity research and informing management of seamount habitat.

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Keywords characterisation; classification; New Zealand; seamounts

INTRODUCTION

Seamounts have become a high-profile habitat type in recent years, as they have been increasingly recognised as important areas for biodiversity, sites of localised high biological productivity, and are often the focus of commercial fishing for valuable fish species (see review by Rogers 1994). The number of seamounts in the world's oceans is unknown because large areas of sea floor remain unmapped in sufficient detail to identify such features. However, the global number is likely to be very large as more than 30 000 seamounts are thought to exist in the Pacific Ocean alone (Smith & Jordon 1988). An increasingly extensive literature exists on aspects of seamount geology, oceanography, and biology from research carried out mainly on seamounts in the North Pacific Ocean (see reviews by Keating et al. 1987; Rogers 1994). The physical, biological, and oceanographic characteristics of seamounts of the New Zealand region of the South Pacific Ocean are poorly known. The New Zealand region, because of its geological setting and history, has a complex sea-floor relief. Tectonism and volcanism since 300 million years, and crucially within the last 80–100 million years, have formed a sea-floor bathymetry in which isolated submarine rises feature prominently (CANZ 1997). The major physiographic features were known by the early 1970s (e.g., Brodie 1964; Wanoa & Lewis 1972; Thompson 1991), but with the advent of GPS satellite navigation, use of multibeam swath-mapping, and declassification of satellite altimetry data (Sandwell & Smith 1997), the last 10 years have seen a significant increase in knowledge of the distribution of seamounts around New Zealand (Ramillien & Wright 2000). Such data have produced detailed bathymetry of seamounts in some areas (e.g., Lewis et al. 1997; Wright et al. in press), but most have not been mapped in detail. Biological research published in the primary literature on seamounts of the New Zealand region is limited, and reflects the fishery or fishing impact issues (Probert et al. 1997; Clark 1999; Clark & O'Driscoll 2003; Tracey et al. 2004). Only since 1999 has research been focused on assessing the diversity and ecology of seamount benthic macro-invertebrate fauna (Clark et al. 1999a). Determining the identities of species sampled from such previously unexplored habitats is very time-consuming and the results of such research effort have only recently begun to be published in preliminary/interim reports (Clark & O'Shea 2001; Rowden et al. 2002, 2003, 2004). Nonetheless, the importance of conserving seamount habitats (Probert 1999) in the New Zealand region has been recognised with the designation of 19 seamounts with "protected" status (closed to all trawl methods) following a management appraisal (Clark et al. 2000; Brodie & Clark 2004).

The effectiveness of such conservation/management strategies and progress in understanding of the patterns of seamount biodiversity could be improved by a biologically meaningful description/classification scheme for seamounts (Stocks et al. 2004). The aim of this study was to present a synopsis of the physical characteristics of seamounts within the "New Zealand region" (taken here as the area bounded by 24°S, 167°W, 57°S, and 157°E), which extends an earlier characterisation (Wright 1999), and to present an initial classification using biologically meaningful variables (particularly for benthic organisms).

It is important to clarify, in the present context, the term "seamount". Three main types of submarine elevation, as defined by Eade & Carter (1975), are recognised in the New Zealand region: "seamount"—an isolated elevation rising 1000 m or more from the sea floor and of limited extent across the summit (not flat-topped as a "guyot"); "knoll"—an isolated elevation rising less than 1000 m from the sea floor, and of limited extent across the summit; "pinnacle"—a small pillar-like elevation of the sea floor. In recent years, the term seamount has been applied more generally to topographic "hill" elevations regardless of size and relief (e.g., Epp & Smoot 1989; Rogers 1994). Reports on seamounts in the New Zealand region have also used variable definitions, with a vertical extent of 250 m applied by Wright (1999), and 100 m by Clark et al. (1999b) and Clark & O'Driscoll (2003). The New Zealand Ministry of Fisheries (MFish) draft "Seamount Management Strategy" defines seamounts as "protruding irregularities or bottom features that rise greater than 100 m above the sea floor" (MFish 1999). For the purposes of the present study, we have collated data on features with a vertical elevation of 100 m or greater (thus, the term seamount is used here for discrete bathymetric features with ≥100 m of relief) but have presented these data in a way that accounts for differing interpretations of the terminology for undersea features of various sizes (see Clement & Mace 2003 for an example of alternative views on what constitutes a seamount).

METHODS

Data sources and determinations

Physical data on seamounts were collated from existing sources used in the updating of regional bathymetry in 1997 (CANZ 1997), including data held by the National Institute of Water and Atmospheric Research (NIWA), the New Zealand Hydrographic Office, Royal New Zealand Navy, National Geophysical Data Centre (United States), South Pacific Applied Geoscience Commission (Fiji), published scientific papers, and recent multibeam surveys funded by Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER, France). This information was supplemented by detailed data on smaller features from University of Kiel (Germany), Seabed Mapping New Zealand Ltd, and research surveys carried out over the last 20 years by NIWA and MFish (including multibeam surveys in the last 5 years). Many of these surveys were for deep-water fish species such as orange roughy, which often form aggregations over small seamount features on the seabed.

"Position" of a seamount was based on the location of the summit, which was determined from actual bathymetric data wherever possible, or from the central point of the shallowest contour derived from NIWA's regional bathymetric dataset. "Depth at peak" is the shallowest depth record known from the seamount. The "depth at base" of the seamount was generally taken from the deepest most complete depth contour that encircled the entire seamount. In some instances, there was an appreciable difference between sectors of a seamount, where one side is, for example, up-slope of a broader feature like a rise. In these instances the mid-point between the shallow and deep basal depth was taken. "Elevation" was computed as the difference between depth at peak and depth at base. "Area" was estimated from the polygon of the basal depth contour. "Slope" was calculated in two ways. First, actual echo-sounding data from ship tracks over seamounts were analysed and maximum, minimum (usually zero at the peak), and mean slopes computed. For many seamounts, however, data were inadequate for this method, and hence slope was calculated from the seamount trigonometry using elevation and base radius to derive average slope angle. This method tends to underestimate the true slope on the flanks of seamounts, since most seamounts have broadly domed peak regions (i.e., the method tends to average the low gradients near the peak and higher gradients on the flanks).

For the purposes of the present study, the geological "association" of seamounts was broadly categorised as being associated either with the inner New Zealand continental margin (within the enclosing continuous 2000 m isobath) or with various types of ridge and rise systems on the surrounding oceanic sea floor. Most of the known seamounts have received little or no scientific study, and their geological "origin" is not definitive, but over 500 seamounts included in the present study were classified on the basis of geological composition or location, i.e., arc/mid-plate/oceanic plate/hotspot/rifted margin volcanoes, tectonic ridge, rifted continental block, or continental rise. Less than 10 seamounts in the New Zealand region have any form of direct radiometric age dating (e.g., Wright 1994; Mortimer et al. 1998; Wright unpubl. data), thus most "age" determinations for the present study were based on interpretation of magnetic anomaly and plate reconstructions and a regional assessment of sea-floor volcanism (Sutherland 1999). To date there are no regional studies of seamount "substrates" within the New Zealand region. The only regional compilation of substrate type is for sea-floor 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 c. 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, 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. in press). From these detailed investigations it is possible to describe substrate heterogeneity at scales of tens to hundreds of metres through integrating data from swath mapping backscatter imagery, sea-floor photography, and/or sea-floor sampling (e.g., Wright et al. 2002). For the present study the distribution of substrate type on the Kermadec arc seamount Rumble III was assessed by interpolating (using Inverse Distance Weighting in MapInfo) measures of % cover of substrate type determined from seabed images recovered by a photographic survey (see Rowden et al. 2002 for details of camera survey method), combined with a visual interpretation of a multibeam backscatter map. This assessment of physical character for a single seamount was conducted to illustrate the level of substrate heterogeneity that seamounts in the New Zealand region can possess.

Although limited data can be used to indicate substrate type on specific seamounts in the New Zealand region, such a restricted coverage of substrate type and heterogeneity precludes them from the present regional classification of seamount characteristics. Such an omission from the present classification is unfortunate, since substrate type and heterogeneity are known to influence the composition of seamount benthic assemblages (e.g., Raymore 1982; Kaufmann et al. 1989). Even without substrate information the remainder of physical data (13 of the 16 assessed variables; age and position also omitted) compiled for New Zealand region seamounts can be used to produce a biologically meaningful classification. These 13 variables are: association and origin, which effectively represent the geological history of a seamount and thus the potential composition of at least part of the substrate, and other factors that could influence the colonisation of a seamount by benthic fauna (Wilson & Kaufmann 1987); depth at peak, depth at base and elevation, for the position (and extent) of the seamount relative to the water column/surrounding seabed influences the types of organisms which exist in association with the habitat (e.g., Wisher et al. 1990); slope, for slope affects local current regime which in turn can influence the diversity and abundance of suspension-feeding taxa (e.g., Genin et al. 1986); area, because seamounts can be