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The influence of deepwater coral habitat and fishing on benthic faunal assemblages of seamounts on the Chatham Rise, New Zealand.

Rowden, A.A, Clark M.R. & O'Shea, S.

National Institute of Water & Atmospheric Research, Private Bag 14-901, Kilbirnie, Wellington, New Zealand. Tel: +64 4 386 0300 Fax: +64 4 386 2153 Email: a.rowden@niwa.cri.nz, m.clark@niwa.cri.nz

Abstract

Seamounts are prominent and widely distributed features of the New Zealand marine environment, and also the focus of important commercial fisheries. In 2001 a study was undertaken of eight of the 'Graveyard complex' seamounts on the Chatham Rise, an area that has been heavily trawled for orange roughy since the early 1990s. Half of the study seamounts were considered 'unfished' (total of <10 trawls per seamount) and the other 'fished' (total of 40–1500 trawls per seamount). Benthic macroinvertebrate assemblages of each seamount were sampled using epibenthic sleds, whilst substrate composition, the presence of habitat-forming fauna (i.e. live corals) and indications of trawling (e.g. trawl door marks) were determined using a towed underwater camera that took images a few metres above the seabed. Analyses of resulting data revealed that seabed habitat was heterogenous on all seamounts. However, 'unfished' seamounts possessed a relatively large amount of habitat-forming coral (on average: 33% of seabed images, 17% overall mean cover) comprising live *Solenosmilia variablis* and *Madrepora oculata*, whilst 'fished' seamounts possessed relatively little such habitat (on average: 1.6% of seabed images, 0.04% overall mean cover). Indications of trawling were observed six times more frequently on seabed images from 'fished' as opposed to 'unfished' seamounts (on average: 25% versus 4% of seabed images). Multivariate analyses revealed the assemblage composition of 'fished' and 'unfished' seamounts was significantly different, and that the variability observed in the assemblage composition (not including live coral) between the study seamounts can in-part be explained by the relative occurrence of live coral. The results of the study are discussed with respect to New Zealand's national seamount management strategy, the subsequent protection from fishing of three of the study seamounts, and the need for ongoing monitoring and research to derive conservation practices that allow for appropriate management of seamount fisheries.

Introduction

In the New Zealand marine environment, seamounts are common and widely distributed features (Wright 1999), and some of these features are the focus of important commercial fisheries (Clark 1999). Seamounts are of considerable scientific interest, often hosting unusual or unique assemblages and a biodiversity disproportionate to their size/area (Probert 1999). Seamounts are widely recognised as areas of high productivity, and are also regarded as fragile habitat (Rogers 1994) susceptible to disturbance from fishing (e.g. Koslow et al. 2001) and mining (e.g. Grigg et al. 1987). Within the New Zealand region, very little ecological research has been undertaken on seamounts and only a few studies have addressed the effects that human activities may have on their physical and biological integrity (Probert et al. 1997, Clark & O'Driscoll 2004). A research programme entitled "Seamounts: their importance to fisheries and marine ecosystems" is currently being carried out by the National Institute of Water and Atmospheric Research (NIWA) with funding from the New Zealand Foundation for Research, Science & Technology (FRST) and the Ministry of Fisheries (MFish). This programme aims to describe and build an understanding of the role and dynamics of seamounts (Clark et al. 1999).

As part of this research several "seamounts" (here defined as distinct seabed topography with an elevation of over 100 m) on the Chatham Rise were surveyed to investigate the possible effects of bottom trawling. The 'Graveyard complex' of seamounts on the northwest Chatham Rise has been heavily trawled for orange roughy *(Hoplostethus atlanticus)* since the early 1990s. However, the fishing effort has concentrated on three or four main features. The area therefore presented a number of seamount features close to one another, with various levels of trawling intensity, which would enable quantification of any differences in the habitat and the assemblage composition of benthic macro-invertebrates between 'fished' and 'unfished' seamounts.

Methods

Study site – The 'Graveyard seamount complex' is located on the northern flank of the Chatham Rise. The Chatham Rise is the ridge-like eastern part of the New Zealand Plateau that extends for 1300 km, is generally flat topped at 200–400m and slopes to water depths over 2000 m. The 'unfished' seamounts (total of <10 trawls per seamount) of the complex were Diabolical, Gothic, Pyre and Ghoul, whilst the 'fished' (total of 40-1500 trawls per seamount) seamounts were Graveyard, Morgue, Zombie and Scroll. These seamounts, of different area (0.6–4.1 km^2) and elevation (115–352 m), were distributed over 140 km^2 of seafloor between water depths (at feature base) of 1050–1200 m, with peaks occurring at depths of 748–1004 m. Sampling of the study site seamounts took place between 15th and 21st April 2001, and was undertaken remotely from a ocean-going research vessel.

Benthic habitat – For any sampled seamount, eight photographic transects were arranged in a starburst pattern centred on the seamount peak and extended as far as possible to the base of the seamount. A digital still camera with a wide-angle lens and xenon flash was mounted on the sled frame (fitted 25 cm from and perpendicular to the base of the frame), and in order to achieve good quality pictures, the camera frame was towed down-slope at a target height of 2–3 m off the seabed (at an effective forward tow speed of about 1 knot). The camera was activated remotely at stations at approximately 1 minute intervals along the sample transects. The geographical location of the camera frame (and thereby the position of stills camera stations) was recorded by an attached acoustic device. Only two of each type ('fished'/'unfished') of the study seamounts could be photographically surveyed in the time available.

Macro-invertebrate assemblages – An epibenthic sled (opening: 100 cm wide by 40 cm high, mesh size: 30 mm stretched mesh net), similar in design to a SEBS sled (Lewis 1999), was used for sampling macro-invertebrates on the seamounts of the study site. Sample stations were selected at random by a combination of random direction from the seamount peak and random depth down the slope. Sleds were towed at each seamount station up-slope at 2 knots for a target time of 15 minutes. Sled deployment was maintained as constant as possible between tows to enable robust comparisons of catch per tow. A minimum of four 'good' samples (e.g. no net damage) was required from each seamount. On recovery of each sled, the sample was sorted by hand and all macro-invertebrates recovered were identified (to at least major group), and retained (either fixed in formalin/alcohol or frozen) for further analysis in the laboratory. In the laboratory, macro-invertebrates were identified to species (or putative species) and, when appropriate, species were also enumerated.
Data analysis - Digital images recovered by the photographic survey of seabed habitat were viewed using Corel PHOTO-PAINT and an assessment made by eye of image clarity (good, poor or blank); substrate composition (% cover of soft sediment, cobbles, boulders, bedrock, 'coral rubble'); occurrence of live habitat-forming coral taxa (% cover of the scleractinians *Madrepora oculata*, *Solenosmilia variabilis*); and evidence of the passage of trawl gear (note made of pieces of wire/netting, gouges from trawl doors or bobbins). In practice, photographs of the benthic habitat of the study seamounts were obtained at heights of between <1 m and 11 m off the seabed. In order to allow for reasonable qualitative comparisons of the relative occurrence of substrate type, habitat-forming live coral and evidence of fishing activity, only images taken between 2–5 m off the seabed were selected for frequency analysis. A measure of habitat heterogeneity for each image was also determined using the sample-size independent Simpson's diversity indice, calculated using values of % cover for each substrate types and live coral. Macro-invertebrate data were analysed using PRIMER, a suite of computer programs for multivariate analysis (Clark & Warwick 2001). Macro-invertebrate data were presence/absence transformed prior to analysis. A ranked triangular similarity matrix was constructed using the Bray-Curtis similarity measure. In order to visualise the pattern of assemblage composition for samples taken from the study seamounts, the similarity matrix was subjected to non-metric multidimensional scaling (MDS) to produce an ordination plot. A two-way nested analysis of similarities (ANOSIM) test was carried out to test for statistically significant differences in assemblage composition between 'fished' and 'unfished' seamounts and between seamounts with these groupings. The species contributing to any dissimilarity between samples from 'fished' and 'unfished' seamounts were investigated using the similarity percentages procedure SIMPER. The relationships between multivariate assemblage structure and environmental variables were examined using the BIOENV procedure.

Results

Benthic Habitat - Analysis revealed that the surface of the study seamounts was heterogeneous in nature, with most images revealing the seabed substrate to be a matrix of soft sediment, cobbles, boulders, bedrock and 'coral rubble'. Between seamounts there was little difference in habitat heterogeneity (as measured using Simpsons' index of diversity: 'fished': 0.43, 0.51; 'unfished': 0.39, 0.43), although live habitat-forming coral taxa were more frequently imaged on 'unfished' as opposed to ‘fished’ seamounts. That is, 44% and 21% of images taken on Gothic and Diabolical (respectively) showed colonies of either *Solenosmilia variablis* and/or *Madrepora oculata*, whilst these species could only be seen on 1.4% and 1.8% of images from Graveyard and Morgue (respectively). The overall mean percentage cover for habitat-forming corals was 21% and 12% for ‘unfished’, and 0.03% and 0.04% for ‘fished’ seamounts. The photographic survey also revealed that the habitat-forming coral more frequently occurred in images taken at or near the peak of the ‘unfished’ seamounts. Indications of fishing activity were six times more frequently observed in seabed images from ‘fished’ than ‘unfished’ seamounts. That is, 31% and 18% of images taken on Graveyard and Morgue (respectively) showed seabed with wire or trawl door gouges, whilst such signs were only observed in 7% and 1.6% of images from Diabolical and Gothic (respectively).

Macro-invertebrate assemblages – Multivariate analyses revealed that the macro-invertebrate assemblage composition of ‘fished’ and ‘unfished’ seamounts was significantly different (ANOSIM R= 0.427, P <0.05), and that the composition of assemblages on different seamounts within each of these seamount groupings was also different (though less so) (ANOSIM R = 0.173, P <0.01). Analyses also indicated that the species that best discriminated between the observed assemblage dissimilarity (SIMPER 75%) between ‘fished’ and ‘unfished’ seamounts were two sylasterids (stony corals) (*Calyptopora reticulata, Lepidotheca fascicularis*) and a bryozoan (*Lagenipora* sp.). These species were more frequently present in samples from ‘fished’ seamounts. The multivariate correlation analysis between the macro-invertebrate assemblage composition and environmental variables revealed that depth was the single variable that best explained the pattern of assemblage composition observed (BIOENV ρ_w = 0.163). However, when the occurrence of live habitat-forming coral taxa was included as an environmental variable in a re-analysis of macroinvertebrate data (not including *Solenosmilia variablis* and *Madrepora oculata*), the results indicated that this biotic variable could also in-part explain the pattern of assemblage composition observed between the study seamounts (BIOENV depth: ρ_w = 0.158; habitat-forming coral: ρ_w = 0.144; both variables: ρ_w = 0.225).

Discussion

The results of the present study show that the seamounts of the ‘Graveyard complex’ are comprised of heterogeneous habitat, and that the habitat-forming living colonies of the scleractinian corals *Solenosmilia variablis* and *Madrepora oculata* are more common on ‘unfished’ seamounts than on ‘fished’ seamounts. Conversely, evidence of trawl wire and door gouges is more evident on photographic images of the seabed taken on ‘fished’ seamounts than on ‘unfished’ seamounts. Macro-invertebrate assemblage composition was also revealed to be significantly different between the two groupings of seamounts, and analyses indicated that (as well as water depth) the presence of habitat-forming corals in-part explains the difference in composition observed. The three species (*Calyptopora reticulata, Lepidotheca fascicularis, Lagenipora* sp.) that best contribute to discriminating between the dissimilarity in composition between ‘fished’ and ‘unfished’ are all small in size, have fast growth rates and can be considered so-called opportunistic/’weedy’ species that are able to colonise ‘new’ space i.e. indicators of disturbance. Thus, the results of the study of ‘fished’ and ‘unfished’ seamounts on the Chatham Rise, appear to reveal the physical disturbance of the seabed caused by deep-sea bottom trawling and the associated change in macro-invertebrate assemblage composition, a modification that is likely to be brought about principally by the reduction in the occurrence of two habitat-forming scleractinian corals. However, it should be remembered that the study undertaken was a mensurative experiment, and therefore it is not possible for the results to demonstrate cause and effect.

That seamount fauna, particularly habitat-forming corals that frequently support a diverse fauna themselves (e.g. Morstensen et al. 1995), are vulnerable to the activities of deep-sea bottom trawling has been known for some time (see Rogers 1994). Yet it is only relatively recently that scientific studies have begun to provide evidence that disturbance caused by fishing can be responsible for alterations in the composition of benthic assemblages (e.g. Koslow et al. 2001) that are likely to be relatively persistent and potentially threaten the viability of macro-invertebrate populations, or indeed the survival of seamount endemic species (Richer de Forges et al. 2000). As elsewhere in the world, there is in New Zealand a belief held by non-government and government environmental agencies that measures are required that will protect seamounts and the usually diverse fauna associated with these habitats. Following the initially raised concerns and calls for the conservation of seamounts in New Zealand waters (Probert et al. 1997, Probert 1999), 19 seamounts were recommended as candidates for some form of protection (Clark et al. 2000) - which they duly received from bottom-fishing in May 2001 (Anon. 2001). In addition to the latter act of closure, the New Zealand Ministry of Fisheries has initiated the drafting of a seamount management strategy (Brodie & Clark 2002) which is being developed to provide a management mechanism for the effective conservation of seamounts whilst allowing for a 'sustainable' seamount-based fishery. In order to advance and support the New Zealand seamount management strategy it will be necessary to undertake research relating to a number of unanswered questions that concern the recovery of seamount faunal assemblages from the effects of fishing. Three of the seamounts surveyed during the present study were among those subsequently closed to fishing in 2001. Two of these seamounts (Pyre and Gothic) are 'unfished' whilst one was 'fished' (Morgue), and they and the other seamounts in the 'Graveyard complex' still open to bottom trawling now serve to provide an opportunity to establish a monitoring study. An appropriately design monitoring study would be able to begin to determine the mechanisms and rates of recovery for seamount-associated fauna, population connectivity between proximate seamounts, and further elucidate the relationship between habitat-forming taxa (such as corals) and the diversity and abundance of invertebrates and fish. Such a study, and others that could experimentally control fishing practices (e.g. distribution of effort, gear type and deployment method) on and between seamounts, and effectively record and monitor macro-invertebrate by-catch should now be undertaken (as they have been for the effects of demersal fishing on continental shelves) in order to inform effective management of deep-sea seamounts.

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References

Anonymous (2001). Seamount closures. *Seafood New Zealand 9(5):* 21

Brodie, S.; Clark, M.R. (2002) The New Zealand Seamount Management Strategy – steps towards conserving offshore marine habitat. *Presented at World Congress on Aquatic Protected Areas, Brisbane, August 2002.*

Clark, M.R. (1999) Fisheries for orange roughy (*Hoplostethus atlanticus*) on seamounts in New Zealand. *Oceanologica Acta 22*: 593–602.

Clark, M.R.; O'Driscoll, R.L. (2004). Deepwater fisheries and their impacts on seamount habitat in New Zealand. *Journal of Northwest Atlantic Fishery Science 31:*441-458.

Clark, M.R.; Wright, I.; Wood, B.; O'Shea, S.; McKnight, D. (1999). New research on seamounts. *Seafood New Zealand 7(1)*: 31–34.

Clark, M.R; O'Shea, S.; Wood, B.; Wright, I. (2000). Seamount management: a report on seamounts potentially suitable for consideration under the MFish seamount management strategy. *Unpublished NIWA Client Report WLG 00-33*.

Grigg, R.W.; Malahoff, A.; Chave, E.H.; Landahl, J. (1987). Seamount benthic ecology and potential environmental impact from manganese crust mining in Hawaii. *In*: Keating, B.H.; Fryer, P.; Batiza, R.; Boehlert, G.W. (eds). Seamounts, Islands, and Atolls. *Geophysical Monograph 43*: 379–390.

Koslow, J.A.; Gowlett-Holmes, K.; Lowry, J.K.; O'Hara, T.; Poore, G.C.B.; Williams, A. (2001). Seamount benthic macrofauna off southern Tasmania: community structure and impacts of trawling. *Marine Ecology Progress Series 213*: 111–125.

Lewis, M. (1999). CSIRO-SEBS (Seamount, Epibenthic Sampler), a new epibenthic sled for sampling seamounts and other rough terrain. *Deep-Sea Research I 46*: 1101–1107.

Mortensen, P.B.; Hovland, M.; Brattegard, T.; Frestveit, R.A. (1995). Deep water bioherms of the scleractinian coral *Lophelia pertusa* (L.) at 64° N on the Norwegian shelf: structure and associated megafauna. *Sarsia 80*: 145-158.

Probert, P.K.; McKnight, D.G.; Grove, S.L. (1997). Benthic invertebrate bycatch from a deep-water fishery, Chatham Rise, New Zealand. *Aquatic Conservation*: *Marine and Freshwater Ecosystems 7*: 27–40.

Probert, P.K. (1999). Seamounts, sanctuaries and sustainability: moving towards deep-sea conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems 9*: 601–605.

Richer de Forges, B.; Koslow, J.A.; Poore, G.C.B. (2000). Diversity and endemism of the benthic seamount fauna in the southwest Pacific. *Nature 405*: 944–947.

Rogers, A.D. (1994). The biology of seamounts. *Advances in Marine Biology 30*:

305–350.
Wright, I.C. (1999). New Zealand region "seamounts": a preliminary characterisation of their physical setting. *Unpublished NIWA Client Report WLG99/24.*