Development of seamount risk assessment: application of the ERAEF approach to Chatham Rise seamount features

Malcolm R. Clark[1]
Alan Williams[2]
Ashley A. Rowden[1]
Alistair J. Hobday[2]
Mireille Consalvey[1]

1NIWA
Private Bag 14901
Wellington 6241

[2]CSIRO
GPO Box 1538
Hobart
Tasmania 7000

New Zealand Aquatic Environment and Biodiversity Report No. 74
2011

Published by Ministry of Fisheries
Wellington
2011

ISSN 1176-9440

Clark, M.R.; Williams, A.; Rowden, A.A.; Hobday, A.J.; Consalvey, M. (2011).
Development of seamount risk assessment: application of the ERAEF approach to
Chatham Rise seamount features.
New Zealand Aquatic Environment and Biodiversity Report No. 74.

This series continues the
Marine Biodiversity Biosecurity Report series
which ceased with No. 7 in February 2005.

EXECUTIVE SUMMARY

Clark, M.R.; Williams, A.; Rowden, A.A.; Hobday, A.J.; Consalvey, M. (2011). Development of seamount risk assessment: application of the ERAEF approach to Chatham Rise seamount features.

New Zealand Aquatic Environment and Biodiversity Report No. 74.

Seamounts, knolls, and hills are common features of New Zealand's marine environment. They can host fragile benthic invertebrate communities (e.g., cold-water corals) that are highly vulnerable to human impacts, especially bottom trawling. Commercial fisheries on seamount features for species such as orange roughy are widespread throughout the EEZ, and hence developing a risk assessment for seamount habitat from the effects of bottom trawling has been a focus of research projects supported by both the Ministry of Fisheries and Foundation for Research, Science & Technology.

An approach to ecological risk assessment widely used by the Australian Fisheries Management Authority to assess Australian fisheries is the Ecological Risk Assessment for Effects of Fishing (ERAEF). This is a general assessment framework method that assesses fishing activities in three levels for their effects on five ecological components of the ecosystem: target species, by-product and bycatch (non-target) species, threatened, endangered, and protected species, habitats, and ecological communities. Australian researchers experienced in the application of ERAEF attended a small workshop held in May 2009 to evaluate the suitability of this approach to assess risk of bottom trawling on seamounts. Presentations and discussions included species and communities aspects of the ERAEF and relevant work done in New Zealand, but the focus was on the habitats component of the method, and its application to risk assessment of the orange roughy trawl fishery on seamounts of the Chatham Rise.

A "Level 2.5" assessment was developed at the workshop for a seamount fishery. The list of attributes from the ERAEF Level 2 worksheet was evaluated, and modified to reflect the key variables that were agreed by participants as important for assessing seamount-trawl interactions. There were four main aspects considered: (1) Availability (3 attributes); (2) Encounterability (3 attributes); (3) Selectivity (7 attributes); (4) Productivity (5 attributes). These attributes were applied to seamounts of the Graveyard Seamount Complex on the Chatham Rise to evaluate the utility of the method to assess the risk to seamounts of bottom trawling, and to inform management about which seamounts could be most at risk.

The analysis gave encouraging results, ranking the level of risk to Graveyard seamounts in an order that was consistent with a logical expectation that habitats with little fishing and high biodiversity (e.g., coral-associated assemblages on seamounts) should be at greatest risk from the impacts of bottom trawling. Those characteristics were shared by the four most highly ranked seamounts for risk. The medium ranked seamounts were those moderately or heavily trawled, so they already had a degree of impact and habitat degradation. The two lowest ranked seamounts were both too deep for orange roughy fishing. Results also implied that the closure of Gothic and Pyre in 2001 was an appropriate measure.

1. INTRODUCTION

Seamount fisheries are an important component of the deepwater fishery of New Zealand. Around New Zealand, major deepwater fisheries occur on seamounts for orange roughy (*Hoplostethus atlanticus*), oreos (black oreo *Allocyttus niger* and smooth oreo *Pseudocyttus maculatus*), black cardinalfish (*Epigonus telescopus*), and alfonsino (*Beryx splendens*) (Clark & O'Driscoll 2003). However, bottom trawling can have major impacts on benthic habitat (e.g., Clark & Koslow 2007), and seamounts are generally regarded as fragile habitat (e.g., Probert 1999). Faunal communities can be based on extensive coral growths (particularly in the Southwest Pacific), which are readily impacted by heavy trawl gear (e.g., Hall-Spencer et al. 2002, Koslow et al. 2001, Clark & Rowden 2009). These corals are long-lived and slow growing (e.g., Tracey et al. 2007), meaning their recovery from trawling will be slow (Gass & Roberts 2006, Clark et al. 2010a). Therefore, an important element of fisheries management is to identify and control the effects of fishing.

The Ministry of Fisheries (MFish) is required by the Fisheries Act (1996) "to avoid, remedy, or mitigate any adverse effects of fishing on the aquatic environment". This requirement includes mandates that "associated or dependent species" should be maintained above a level that ensures their long-term viability, that biological diversity of the aquatic environment should be maintained, and that "habitat of particular significance for fisheries management" should be protected. Consequently, understanding the effects of trawling, and the type and nature of trawling impact, have become priorities for MFish.

The potential for fishing to impact ecosystem components (either directly or indirectly) is widely recognised, and appropriate management requires an ecosystem perspective, and clear operational objectives (Fulton et al. 2005). Risk assessment is an integral part of defining objectives, and especially assisting the selection of various management options. The identification of "ecological indicators" is the first step in this process, and in relation to seamount habitat MFish started to address this under project ENV200515 (Rowden et al. 2008).

Risk assessment is a developing concept within New Zealand fisheries management. In the past there have been a number of initiatives to address specific issues that relate to the effects of fishing. Seamounts were closed to trawling as early as 2001 as part of a draft Seamount Management Strategy (Brodie & Clark 2004), and more recently these have been incorporated into the Benthic Protected Areas adopted in 2007 (Helson et al. 2010, Morato et al. 2010).

A key document was produced by MFish in 2005 that proposed an overall strategy specifically aimed at managing the effects of fishing: The Strategy for Managing the Environmental Effects of Fishing (SMEEF) (Ministry of Fisheries 2005). This document covered a wide range of topics and issues, but notably included recommendations for the setting of 'Environmental Standards', and as part of this there would be a requirement for a "risk assessment process by which species and habitats requiring standards as a high priority are identified". Risk assessment objectives have subsequently been included in a number of New Zealand research projects focused on improving understanding of seamount ecology and management of human impacts.

MFish has recently funded two projects which have specific objectives related to assessing the risk of fisheries activities to vulnerable habitats on seamounts. Various methodologies and approaches to risk assessment were reviewed as part of project ENV200515, which recommended that a workshop be held to explore "how to best progress the preliminary development of an appropriate ecological risk assessment method for seamounts" (Rowden et al. 2008). Rowden et al. (2008) summarised several methods and models, including general assessment frameworks, fuzzy logic systems, qualitative modelling, and sensitivity habitat models. They listed a number of advantages of the general assessment framework, noting it was relatively simple, was commensurate with the quality of available data, could incorporate experience of other schemes, and be comparable with them. However, they also warned that the framework involved expert opinion (which can be subjective), is relatively inflexible, and does not incorporate uncertainty.

One approach to ecological risk assessment widely used by the Australian Fisheries Management Authority (AFMA) is the Ecological Risk Assessment for Effects of Fishing (ERAEF) (Hobday et al. 2007). This is a general assessment framework method that assesses fishing activities in three levels for their effects on five ecological components of the ecosystem. The ERAEF has been adopted in Australia as the main method which AFMA uses to assess Australian fisheries. Its use in New Zealand would further a consistent approach between the two countries, as already underlined by the Australian and New Zealand Standard Risk Management (Standards Australia 2004) which was used in a preliminary risk assessment of some New Zealand fisheries by Campbell & Gallagher (2007). In a further seamount-focused project (ENV200516) it was decided in consultation with MFish to hold a workshop to determine the suitability and applicability of the ERAEF method to seamounts in New Zealand, to meet Objective 2 of the project as follows:

Objective 2: To continue development of the risk assessment model to predict the effects of fishing, and provide options for the management of UTF (seamount) ecosystems

The risk assessment developed at this workshop is described in this report.

2. METHODS

2.1 General description of ERAEF

The ERA method has a scoping phase and a three-stage analysis that rates fishing activities for their effects on five ecological components of the ecosystem:

- target species
- by-product and bycatch (non target) species
- threatened, endangered, and protected species (TEP)
- habitats
- ecological communities

The scoping phase describes the activities and management of the fishery and its ecological components, and identifies all available data and information. The subsequent process becomes more complex with each of the three stages. Each level, however, screens out issues of low or lesser concern, so that the focus is on high-risk issues.

1) Level 1 for a fishery scores each fishing activity for its impact on the five ecological components. Each fishery/sub-fishery is assessed using a scale, intensity, and consequence analysis (SICA). If the impact is higher than an agreed standard, an assessment may be required at Level 2. From this scoring process, some aspects of a fishery may be acceptable, requiring no further action, while others go on for more detailed analysis.

2) Level 2 analysis considers the extent of impact on the relevant ecological component due to fishing activity ("susceptibility"), and the potential of the component to recover from the impact ("productivity") for each species or habitat. This stage of analysis considers aspects such as the reproductive capacity of species, and species composition and trophic linkages in communities. This stage has been reached for over 1000 species in Australian waters.

3) Level 3 takes a quantitative approach, using stock assessment or ecosystem models. It has been applied to many bycatch species comparing exploitation rates to overfishing reference points, but is less developed for habitats and communities.

The structure of the assessment framework is shown in Figure 1.

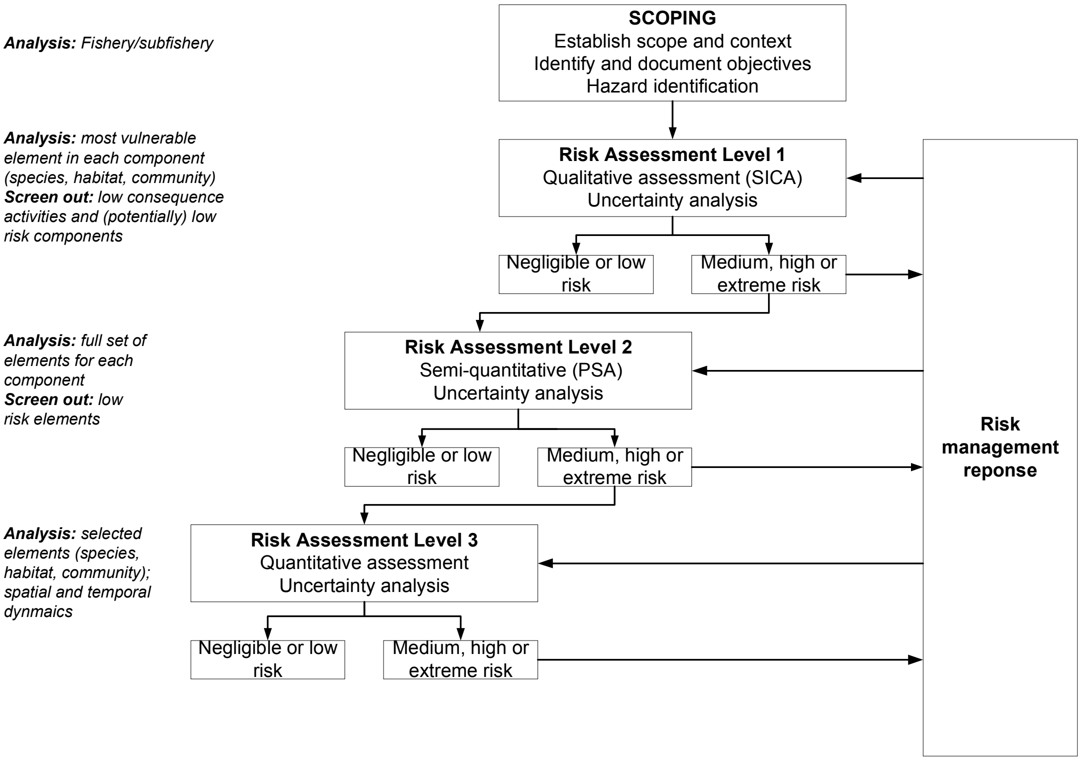

Figure 1. Overview of ERAEF showing focus of analysis for each level at the left in italics (from Hobday et al. 2007).

A key concept of the method at the Level 2 stage is the Productivity and Susceptibility Analysis (PSA). The PSA approach is based on the assumption that the risk of an "adverse impact" to an ecological component will depend on two characteristics of the component units: (1) the extent of the impact due to the fishing activity, which will be determined by the susceptibility of the unit to the fishing activities (Susceptibility) and (2) the productivity of the unit (Productivity), which will determine the rate at which the unit can recover after potential depletion or damage by the fishery. It is presented as a PSA plot (Figure 2).

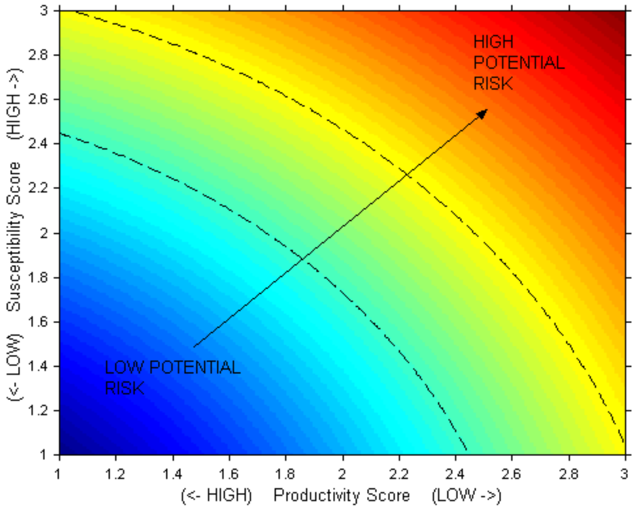

Figure 2. The Productivity-Susceptibility plot, which displays risk to the ecological unit. The contour lines divide regions of equal risk and group units of similar risk levels (from Hobday et al. 2007).

The *x*-axis includes attributes that influence the productivity of a unit, or its ability to recover after impacts from fishing. The *y*-axis includes attributes that influence the susceptibility of the unit to impacts from fishing. The combination of susceptibility and productivity determines the relative risk to a unit, i.e. units with high susceptibility and low productivity are at highest risk, while units with low susceptibility and high productivity are at lowest risk.

2.2 Development of Seamount Risk Assessment ("level 2.5")

The workshop included aspects of the ERAEF for Species (both target and bycatch), Communities, and Habitats. The focus was on the latter, and this report deals only with the Habitats component.

The standard Level 2 Habitat analysis identifies which habitat types are most at risk in a particular fishery. In the case of Chatham Rise seamounts, the starting point is effectively from a Level 2 analysis: seamounts have already been identified as a habitat type that is potentially at high risk from the effects of bottom trawling for deepwater species, in particular orange roughy. This is consistent with an assessment by Campbell & Gallagher (2007) which rated the potential risk to habitats from the orange roughy fishery as "extreme" and with seamounts having high trawl densities and contributing about 50% of the catch of orange roughy (O'Driscoll & Clark 2005).

The objective of this risk assessment is to describe the relative risk within the seamount habitat, and identify which seamounts are most at risk from fishing and may require management input. In moving towards a level 3 assessment, important considerations were:

- a focus on "where" and "how much" rather than "what"
- a procedure that is quantitative and repeatable
- be absolute rather than relative
- incorporate existing management measures

The list of attributes from the Level 2 worksheet was evaluated, and modified to reflect the key variables that were believed by workshop participants to be important for seamount-trawl interactions. There were four main aspects considered:

1) Availability
2) Encounterability
3) Selectivity
4) Productivity

2.2.1 Availability factors

Availability considers overlap of fishing effort with a species distribution (see Table 1 for detail).

The existing ERAEF attribute of Spatial overlap (A1) was retained, and a new one was added which identifies whether the seamount already has some level of protection (A2) (Table 1). The spatial overlap of the sub-fishery with the habitat can be assessed by measuring the geographical and total depth range of the fishery as a proportion of the total known habitat area. In most cases the spatial and depth overlap can be well quantified for seamounts in the New Zealand region. If there is formal protection (e.g., legal closure) the seamount has a low risk, it is medium risk if there is voluntary or partial protection (e.g., a non-binding informal arrangement), and high risk if there is no protection at all.

There was discussion of whether an economic factor was relevant here (A3), in that seamounts close to major ports, or in a cluster, would reduce vessel steaming times and costs to the fishery. The use of this attribute gets complicated by differences and changes in the value of target species, and variable costs such as fuel price. A single seamount well offshore with low value species is likely to be less fished than seamounts closer to land that have high value species.

Table 1: Summary of attributes, concept, and ranking of factors of Availability.

	Aspect	Concept and Rationale		Ranks	
	Attribute (s)		1 (low risk)	2 (medium)	3 (high risk)
	Availability				
A1	Spatial overlap (geographical and depth range)	Spatial overlap of fishery with habitat defined. This seamount is at fishable depth.	No	Partial overlap	Yes
A2	Level of current protection	A variety of spatial closures already operate.	Yes, protected	Interim protection	No protection
A3	Distance to port	Ease and economy of access to fishing grounds makes closer seamounts more attractive.	Distant	Moderate	Close

2.2.2 Encounterability factors

Encounterability considers the likelihood that a species will encounter fishing gear that is deployed within the geographic range of that species (based on adult habitat and depth range) (see Table 2 for details).

The attribute of Depth zone was retained (E1), with expansion through specific depth bands being included, and the expectation of finding commercial concentrations based on the Geographical area where the seamount is located (E2). The rationale for the attribute Ruggedness (E3) was modified, and the ranking definitions altered. An original ERAEF Level of disturbance attribute was removed, although to an extent replaced by a Naturalness attribute under Productivity (see later, Table 4).

Table 2: Summary of attributes, concept, and ranking of factors of Encounterability.

	Aspect	Concept and Rationale		Ranks	
	Attribute (s)		1 (low risk)	2 (medium)	3 (high risk)
	Encounterability				
E1	Depth zone	The seamount is fishable, but depth varies	Deep (1200-1500 m)	Shallow (500-800 m)	Intermediate (800-1200 m)
E2	Geographical area	Encounters driven by expectation of finding target fish species with latitudinal correlation	>50°S	<35, 45-50°S	35-45°S
E3	Ruggedness	Relief, rugosity, hardness and seabed slope influence accessibility to bottom trawling	Predominantly high relief (>1.0 m), rugged surface structure (crevices, overhangs,boulders); > 30° slope.	Predominantly low relief (<1.0 m), rough surface structure (rubble, small boulders); <30° slope.	No relief to impede trawling, smooth simple surface structure; < 30° slope.

The Depth zone (E1) criteria reflect the distribution of orange roughy aggregations on seamounts. Where the seamount summit (or much of its flanks) is at depths between 800 and 1200 m there is greatest likelihood of finding orange roughy, and hence those seamounts have high risk. Shallower summits can still have much of their flanks at suitable depths and so are ranked medium. Where the summit is deeper than 1200 m, there are generally few orange roughy, and these deep features also get harder to trawl successfully.

The Geographical area (E2) has latitudinal divisions, where the likelihood of finding substantial stocks of orange roughy differ. The species is most abundant in the New Zealand region between latitudes 35° and 45° S, where the main commercial fisheries have operated for several decades, and hence seamounts in that zone are at high risk. Further north than this, and slightly further south, there are some fishing grounds (medium risk), and to the south of 50° S orange roughy are rarely found.

Ruggedness (E3) relates to the suitability of the seamount seafloor for bottom trawling. If it is very rugged (boulders, crevices, highly variable relief) or steep (over 30° slope) it is unlikely to be trawled (low risk) whereas medium to high risk have more gradual seamount slope and relief.

2.2.3 Selectivity factors

Selectivity considers the potential of the fishing gear to capture or retain species (see Table 3 for detail).

Three existing attributes (S1, S2, S4) were retained (although all were modified), a third was added (S3), S5 and S6 are probably not applicable to seamounts, and the last (S7) was thought to be a relevant concept, but the definition of ranks needed more consideration.

Table 3: Summary of attributes, concept, and ranking of factors of Selectivity.

	Aspect Attribute (s)	Concept and Rationale	Rank 1 (low risk)	 2 (medium)	 3 (high risk)
	Selectivity				
S1	Removability/ mortality of morphotypes	Erect, large, rugose, inflexible, delicate epifauna and flora, and large or delicate and shallow burrowing infauna (at depths impacted by mobile gears) are preferentially removed or damaged; mortality assumed.	Low, robust or small (<5 cm), smooth or flexible types, OR robust or deep burrowing types. Numerical qualifiers to be decided.	Erect or medium sized (5-30 cm), moderately rugose /inflexible, OR moderately robust or shallow burrowing types. Numerical qualifiers to be decided	Tall, delicate or large (> 30 cm high), rugose or inflexible, OR delicate or shallow burrowing types. Numerical qualifiers to be decided
S2	Reduction of faunal diversity	Potentially higher loss of diversity where diversity/species richness is relatively high.	Diversity low. Numerical qualifiers to be decided	Diversity medium. Numerical qualifiers to be decided	Diversity high. Numerical qualifiers to be decided
S3	Special ecological value	Individual seamount has special role as habitat for community or species (e.g., spawning feature; endemic species, rare species)	No (based on sampling)	Uncertain	Yes (identified by sampling)
S4	Biogenic habitat area	How much of each habitat is present. Larger areal extent means a more significant habitat for maintaining biodiversity and community function.	Rare (<1%) within the seamount.	Moderately common (1-10%) within the seamount.	Common (> 10%) within the seamount.
S5	Removability of substratum (not considered for seamounts)	Intermediate sized clasts (~6 cm to 3 m) that form attachment sites for sessile fauna can be permanently removed.	Immovable (bedrock and boulders >3 m).	< 6 cm (transferable).	6 cm to 3 m (removable).
S6	Substratum hardness	Composition of substrata: harder substratum is intrinsically more resistant.	Hard (igneous or indurated) lithotypes	Soft (sedimentary or weathered) lithotypes	Sediments
S7	Seabed slope (consider in relation to higher density of fauna on steep peaks).	Mobility of substrata once dislodged; e.g., turbidity flows, larger clasts. Higher levels of structural fauna and densities of filter feeding animals found where currents move up and over a seamount summit	1 degree	1-10 degrees	> 10 degrees

Removability of faunal group (S1) is a key attribute, and is assessed assuming there is strong contact of the heavy ground gear used on bottom trawls in seamount fisheries. The size, height, robustness, flexibility and structural complexity of the attached invertebrate fauna will influence whether it will be removed or killed by interaction with fishing gears. Large, erect, rugose, inflexible, and delicate forms living on the seabed (epifauna) are generally most vulnerable, compared to small, low, encrusting, flexible, robust or deep burrowing forms (infauna), which are least vulnerable.

Reduction of faunal diversity (S2) also contributes to risk. High diversity may reflect a patchy distribution of faunal groups on a seamount, and trawling could selectively and severely affect some taxa. Where a seamount has a large number of species the diversity could be at greater risk than if only a few species are distributed widely over the seamount. However, low diversity can also be at risk if it is concentrated in a small area on the seamount, or if the taxa have a localised distribution or special ecological value (S3) (e.g., species are endemic to one or only a few seamounts).

Biogenic habitat (S4) is a well known feature of seamounts in New Zealand, especially the extensive thickets of cold-water coral. Where these thickets cover a large area on the seamount (similar to a reef) they can have a diverse array of species associated with them. This association can provide for increased biodiversity and abundance of some taxa, which is at high risk to damage from trawling. As the areal extent of biogenic habitat decreases, their significance to the overall structure and function of the “seamount ecosystem” decreases, as does overall risk if this is affected by fishing. However, some caution is needed with this attribute, as the relative effect of trawling on the rare patches of habitat will be greater than the larger areas. Hence if there is only limited and geographically confined biogenic habitat on the seamounts being considered, this can qualify as high risk.

The removal of substratum (S5) and hardness of substratum (S6) can be important for whether suitable substrate remains to support certain taxa. For example, whether hard substrate occurs for those fauna that require it, or whether sedimentation from soft sediment being stirred up affects survival of filter feeders or young animals which can be smothered. The size and composition of substrate should be considered when there is information available, but for many seamounts this may be unknown.

Seabed slope (S7) can have a different effect on selectivity of trawl gear on fauna than with encounterability (i.e., how trawlable is a seamount). Where a seamount is relatively steep-sided, there may be enhanced water flow around or over its summit, and a higher biodiversity or species abundance than on shallow-sloping seamounts where there is little oceanographic modification of the faunal assemblage.

2.2.4 Productivity factors

Productivity determines how rapidly a unit can recover from depletion or impact due to fishing (see Table 4 for details).

The ERAEF worksheet has two attributes, Regeneration (P1) and Natural disturbance (P2). The regeneration time scales were modified to account for the high longevity of many deep-sea taxa on seamounts (e.g., corals, see Rogers et al. 2007), but the natural disturbance criteria were unchanged. Three attributes were added: Naturalness (P3), Proximity (P4), and Export production (P5).

Regeneration of fauna (P1) is dependent on a combination of age, growth, recruitment and recolonisation rates. For many sessile invertebrate species these aspects are not known; however, for some of the major taxa data exists and can be applied to a broader range of faunal groups.

Depth can in some cases be a proxy for Natural disturbance (P2). Habitats in deeper waters are unlikely to be subjected to as much natural disturbance as those in shallow waters (under 60 m) which tend to more highly disturbed zones (e.g., from wave generated currents). There are few very shallow seamounts around New Zealand, and none on the Chatham Rise. However, natural disturbance may still be a feature in some areas (e.g., Clark & Koslow 2007) where volcanic activity can cause massive disruption to faunal communities (e.g., active volcanoes on the Kermadec Ridge) or where strong currents/tidal flows exist at depth.

Table 4: Summary of attributes, concept, and ranking of factors of Productivity.

	Aspect	Concept and Rationale		Ranks	
	Attribute (s)		1 (low risk)	2 (medium)	3 (high risk)
	Productivity				
P1	Regeneration of fauna	Accumulation/ recovery of fauna to a mature successional state. Based on intrinsic growth and reproductive rates that are variable in different temperatures, nutrients, productivity.	< Decadal	> Decadal	>100 years
P2	Natural disturbance	Level of natural disturbance affects intrinsic ability to recover.	High (e.g.,volcanism, tidal flow)	Intermediate	No natural disturbance
P3	Naturalness	The historical level of trawl impact determines present status of benthic habitat (this is determined quantitatively by the FEI measure)	High FEI	Medium FEI	Low FEI
P4	Proximity	Proximity is used as a surrogate for the connectedness of seamounts in the context of species recruitment to the seamount	close (<25 km)	(25-100 km)	isolated (>100 km)
P5	Export production to seafloor	Organic material from surface is beneficial to benthic community, especially filter feeders, and is unequally distributed.	High	Medium	Low

Naturalness (P3) can have an effect on productivity, as systems altered by human activities may be less productive. The Fishing Effects Index (FEI, see O'Driscoll & Clark 2005) is a measure of fishing effort on a seamount, and can be used to quantify how much trawling has been conducted. Divisions into High, Medium and Low were subjective, but recent analysis of coral cover on fished and unfished seamounts of the Graveyard Seamount Complex indicates that an FEI of less than 1.0 may constitute lightly impacted (Clark et al. 2010b), and be an appropriate break between low and medium.

Connectivity of fauna between seamounts is important for maintaining the productivity of the system. The dispersal capabilities of benthic invertebrates are not well known, but a review of inshore invertebrate taxa indicated most were able to disperse less than 100 km (Kinlan & Gaines 2003). Hence, using Proximity (P4) as a proxy for connectiveness, we assigned this based on distance between seamounts: there is high risk to seamounts that are separated by more than 100 km, and medium and low with proximity less than this.

In most areas of the ocean, the benthos below about 200 m relies upon the deposition of organic matter to the seafloor from the upper layers of the water column. It is possible to model the flux of organic carbon exported from the surface to be available as food to organisms on the sea floor (P5). The criteria for this attribute were not developed at the workshop.

2.3 Application to the Graveyard Seamount Complex

The Graveyard Seamount Complex was selected to test how appropriate and workable the Level 2.5 attributes and criteria were. The complex consists of about 20 features located 200 km east of New Zealand (Clark et al. 2010c). These seamounts range in depths at their peak from 750 m to 1250 m

(Mackay et al. 2005) and at their base from 1050 m to 1600 m. The seamounts lie in close proximity to one another (distributed over 140 km^2, and between 1.5 and 12.6 km apart) (Figure 3).

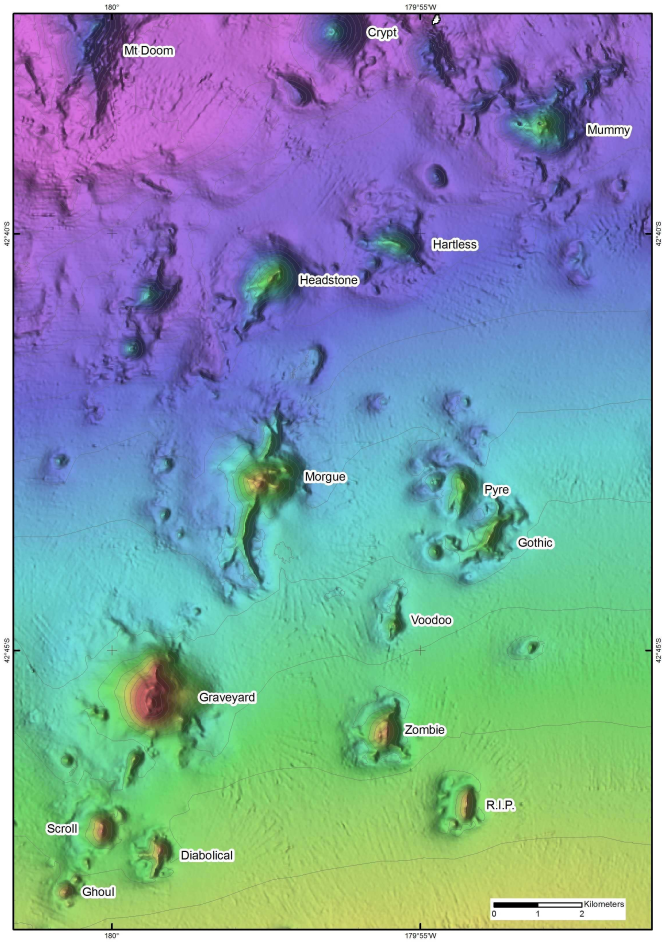

Figure 3: The Graveyard Seamount Complex, including the features considered in the analysis.

Benthic surveys of the area have been conducted in 2001, 2006, and 2009, and the biodiversity is relatively well known (e.g., Rowden et al. 2002, Clark & Rowden 2009, Clark et al. 2010b). Fisheries catch-effort data have been analysed, and FEI levels estimated for the individual seamounts (Clark & Rowden 2009, Clark et al. 2010b).

Ten seamounts were considered, with various characteristics:
Graveyard, Morgue, Zombie, Scroll: all heavily fished, little coral present.
Diabolical: moderately fished, moderate coral.
Pyre, Gothic, Ghoul: unfished, extensive coral.
Doom: unfished, fauna not well known, some coral
Hypothetical-Deep: A "hypothetical" (non-existent) seamount was included to provide contrast (too deep for orange roughy), and used to mimic a deep and distant low risk seamount.

3. RESULTS

3.1 Risk scoring

The seamounts were scored against each of the attributes developed during the workshop, based largely upon information from NIWA surveys in 2001 and 2006. Several attributes were not scored:

A2 because we were evaluating the method assuming no seamounts were yet protected. Attributes S5, S6, S7, and P5 because data were not available or were not at an appropriate scale for individual seamounts. The results of this assessment are summarised in Table 5.

Table 5: Summary of rank values for each of the Level 2.5 Habitat attributes for the 10 Graveyard seamounts. Av=average value of the attributes.

	Availability	Encounterability				Selectivity					Productivity				
Seamount	A1	E1	E2	E3	av	S1	S2	S3	S4	av	P1	P2	P3	P4	av
Graveyard	3	2	3	3	3	1	1	3	1	2	3	3	1	1	2
Morgue	3	3	3	2	3	1	2	3	1	2	3	3	1	1	2
Zombie	3	3	3	3	3	2	2	1	2	2	3	3	1	1	2
Scroll	3	3	3	3	3	1	2	1	1	1	3	3	1	1	2
Gothic	3	3	3	2	3	3	2	1	3	2	3	3	3	1	3
Pyre	3	3	3	2	3	3	2	1	3	2	3	3	3	1	3
Diabolical	3	3	3	3	3	2	2	1	3	2	3	3	2	1	2
Ghoul	3	3	3	3	3	3	2	1	3	2	3	3	3	1	2
Doom	1	1	3	2	2	2	1	1	2	2	2	2	3	2	2
HypotheticalDeep	1	1	3	1	2	1	1	3	1	2	1	1	3	3	2

The scores for the attributes are explained below:

Availability factors:

- For A1 (Spatial overlap with fishery) most of the seamounts are within the geographical distribution of the fishery. Doom and Hypothetical-Deep are to the north of the fishery in this area.

Encounterability factors

- E1 (Depth zone) has a high risk for nine features, with Graveyard being medium (which indicates perhaps that the depth divisions are incorrect as this is the main spawning location for orange roughy on the northwest Chatham Rise), and Doom and Hypothetical-Deep being low as they are deeper than 1200 m.
- E2 (Geographical area) was the same for all seamounts, with a value of 3.
- E3 (Ruggedness) varied, with Graveyard, Zombie, Scroll, Diabolical, and Ghoul classified as reasonably easy to trawl, Morgue, Pyre, Gothic, and Doom being more rugged (medium risk), and Hypothetical-Deep classed as unfishable (low risk).

Selectivity factors

- S1 (Removability of fauna) was ranked high risk for the seamounts with extensive coral thickets identified from research surveys (Gothic, Pyre, Ghoul), medium for seamounts with some coral (Zombie, Diabolical, Doom), and low for the heavily fished seamounts (Graveyard, Morgue, Scroll) as well as Hypothetical-Deep where it is getting too deep for stony coral.
- S2 (Reduction in faunal diversity) was assessed for most seamounts as medium risk (moderate diversity), with a low risk ranking for Graveyard (lower diversity from surveys, heavily fished) and the deeper seamounts (Doom, Hypothetical-Deep) where biodiversity is expected to be lower.
- S3 (Special ecological value) was ranked high risk for Morgue and Graveyard because they are the main seamounts on which orange roughy spawn. For this assessment Hypothetical-Deep was assumed to have a significant ecological value (rare deep species).
- S4 (Biogenic habitat area) ranked high risk for the seamounts where extensive cold-water coral thickets occurred (Gothic, Pyre, Diabolical, Ghoul), medium for those with some (Zombie, Doom), and low for the fished and very deep seamounts.

Productivity factors

- P1 (Regeneration) was ranked high for the eight seamounts which have (or had) ecological communities based on coral, which is likely to be slow growing and may take a long time to recolonise. This high risk value assumes return to a pristine state, rather than to an alternative stable state.
- Natural disturbance (P2) on all these features is unlikely to occur, as they are inactive volcanic cones, so eight of the seamounts scored high risk. Doom and Hypothetical-Deep were ranked lower, as they may be more affected by strong current flows deeper on the northern flanks of the Chatham Rise.
- Naturalness (P3) was ranked high risk for the unfished seamounts, medium for Diabolical, and low for the more heavily trawled Graveyard, Morgue, Scroll, and Zombie.
- Proximity (P4) ranked low risk for the main cluster of eight features, with a medium distance to Doom, and it was assumed Hypothetical-Deep was distant from other seamounts and therefore high risk.

The values from the assessment were input to the ERAEF spreadsheet, and an overall risk level assigned to each seamount (Table 6). Productivity scores were reasonably similar between all seamounts, but susceptibility scores varied. Ghoul, Gothic, Pyre, and Diabolical ranked high risk as they were considered open to greater fishing, yet have extensive coral thickets and associated biodiversity. Doom and Hypothetical-Deep ranked low risk, which is expected as they are deep and beyond the depth range of orange roughy aggregations and effective seamount trawling ability on small seamount features. Zombie, Morgue, Graveyard and Scroll ranked as medium risk, and all were close in value. They are all trawled, but Zombie and Morgue have remnant corals, and hence the rank order is appropriate.

Table 6: Level 2.5 risk assessment summary for the 10 seamounts.

Seamount	Productivity score (Average)	Susceptibility score (Multiplicative)	Overall Risk Value	Overall Risk Ranking
Graveyard	2.00	1.89	2.75	Medium
Morgue	2.00	2.04	2.85	Medium
Zombie	2.00	2.17	2.95	Medium
Scroll	2.00	1.83	2.71	Medium
Gothic	2.50	2.33	3.42	High
Pyre	2.50	2.33	3.42	High
Diabolical	2.25	2.33	3.24	High
Ghoul	2.50	2.50	3.54	High
Doom	2.25	1.22	2.56	Low
HypotheticalDeep	2.00	1.19	2.32	Low

The PSA plot (Figure 4) maps Ghoul, Gothic, and Pyre on the upper right, identifying their high risk status due to both low productivity and high susceptibility. Diabolical had a similarly high susceptibility, but slightly higher productivity ranking. Zombie, Morgue, Graveyard, and Scroll clustered in the medium classification with intermediate rank values of productivity and susceptibility, whereas Doom and Hypothetical-Deep had low values for susceptibility.

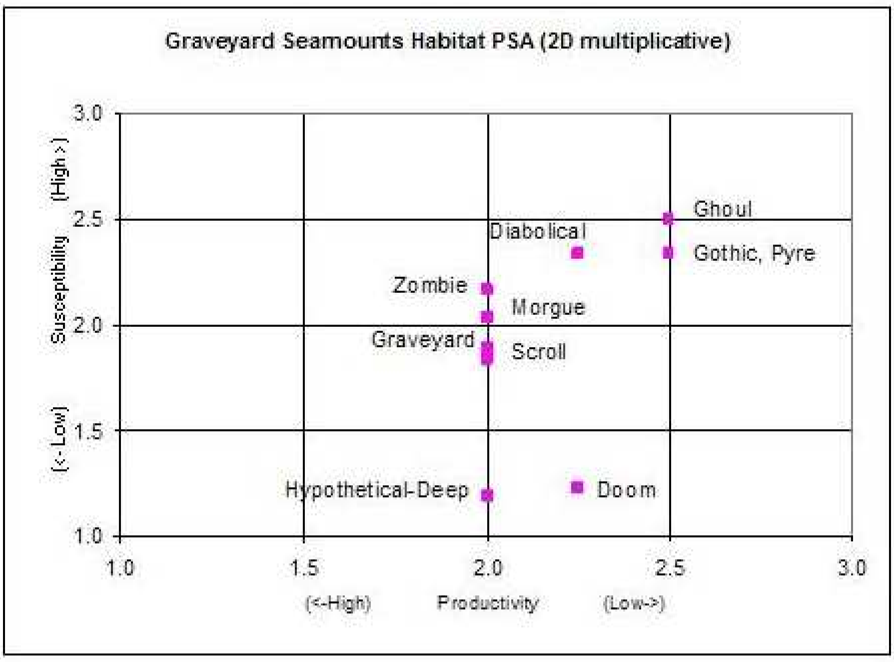

Figure 4: PSA plot of the analysis of risk to the 10 seamounts.

4. DISCUSSION

The Level 2.5 assessment that was developed and carried out in this study is not quantitative in the same way as progressed by CSIRO using the SAFE (Level 3) method (e.g., Zhou & Griffiths 2008). However, it gives the ability to rank different units of habitat, is relatively easy to understand and work through with various levels of data and knowledge, and is transparent. It gave encouraging results ranking seamounts of the Graveyard Seamount Complex in a way that that was consistent with expectations based on ecological principles. There is a logical expectation that habitats with little fishing and high biodiversity (e.g., coral-associated assemblages on seamounts) should rank highly as being at risk from bottom trawling. Those characteristics were shared by the four highly ranked seamounts. The medium ranked seamounts were those moderately or heavily trawled, so they already had a degree of impact and habitat degradation. Results also implied that the closure of Gothic and Pyre in 2001 was an appropriate choice. Ghoul ranked the highest of the 10 seamounts, but Gothic and Pyre were the next two highest ranked seamounts.

The “Level 2.5” approach is still under development and more consideration is needed for defining the attributes and describing the criteria for divisions between high, medium, and low. Nevertheless it is likely that enough information exists within the NIWA “SEAMOUNTS” database (Rowden et al. 2008) to complete an ERAEF at Level 2.5 for most of the 1200 seamounts, knolls, and hills that are known in the New Zealand region (access date August 2009). Over 50 seamounts have been directly sampled for benthic invertebrate species, but where fauna is not known, habitat suitability modelling results are available to evaluate the likelihood of reef-building cold-water coral habitat (based on Tittensor et al. 2009). Fishing information is available for all seamounts in the database (based on Clark & O’Driscoll 2003, O’Driscoll & Clark 2005). This more extensive analysis is suggested as the next step in this process, as it would enable a broader scale regional comparison where there is more variation in ecological characteristics of seamounts, and differences in fishing levels.

A major question to resolve in a more extensive analysis is the treatment of factors for which there is no information. These can either be assigned a precautionary “high risk” value (as recommended by Hobday et al. 2007), or the analysis could be constrained to include only the factors for which all seamounts have equivalent data. There could be an advantage in using equivalent data when the same habitat is being considered (in this case seamounts), whereas if different habitats are being considered, there would be a greater variation in available data, and a greater need to account for uncertainty in how much is known.

5. ACKNOWLEDGEMENTS

The workshop was highly successful in furthering cooperation in risk assessment research between NIWA and CSIRO, and recognised potential for synergies and collaboration to develop the approach further, and apply it to a wider range of fisheries. The participation of MFish helped give the research scientists a better understanding of the management context and environmental fisheries policy within New Zealand. Thanks are due to the other workshop participants for their strong contributions: Jennifer Devine, Matt Dunn, Richard O'Driscoll, Matt Pinkerton, Shona van Zijll de Jong (all NIWA), Martin Cryer, Mary Livingston, Richard Ford, Andrew Penney (all MFish), Ross Daley, Shijie Zhou, Cathy Bulman (unable to attend) (all CSIRO). The willingness and openness of the CSIRO personnel to share their thoughts and experiences with risk assessment and the ERAEF approach was greatly appreciated. MFish provided additional funding to support CSIRO attendance. The risk assessment project was funded by the Ministry of Fisheries (contract ENV200516) and the Foundation for Research Science and Technology (contract CO1X0508).

6. REFERENCES

Brodie, S.; Clark, M.R. (2004). The New Zealand seamount management strategy – steps towards conserving offshore marine habitat. *In*: Beumer, J.P.; Grant, A.; Smith, D.C (Eds). Aquatic Protected Areas: what works best and how do we know? Proceedings of the World Congress on Aquatic Protected Areas, Cairns, 2002. Australian Society for Fish Biology, Australia, pp. 664–673.

Campbell, M.L.; Gallagher, C. (2007). Assessing the relative effects of fishing on the New Zealand marine environment through risk analysis. *ICES Journal of Marine Science 64*: 256–270.

Clark, M.; O'Driscoll, R. (2003). Deepwater fisheries and aspects of their impact on seamount habitat in New Zealand. *Journal of Northwest Atlantic Fishery Science 31*: 441–458

Clark, M.R.; Koslow, J.A. (2007). Impacts of fisheries on seamounts. Chapter 19. *In:* Pitcher, T.J.; Morato, T.; Hart, P.J.B.; Clark, M.R.; Haggan, N.; Santos, R.S. (Eds). *Seamounts: ecology, fisheries, and conservation. Blackwell Fisheries and Aquatic Resources Series 12.* Blackwell Publishing, Oxford.

Clark, M.R.; Rowden, A.A. (2009). Effect of deepwater trawling on the macro-invertebrate assemblages of seamounts on the Chatham Rise, New Zealand. *Deep Sea Research I 56*: 1540–1554.

Clark, M.R.; Rowden, A.A.; Schlacher, T.; Williams, A.; Consalvey, M.; Stocks, K.I.; Rogers, A.D.; O'Hara, T.D.; White, M.; Shank, T.M.; Hall-Spencer, J. (2010a) The ecology of seamounts: structure, function, and human impacts. *Annual Review of Marine Science 2*: 253–278

Clark, M.R.; Bowden, D.A.; Baird, S.J.; Stewart, R. (2010b). Effects of fishing on the benthic biodiversity of seamounts of the "Graveyard" complex, northern Chatham Rise. *New Zealand Aquatic Environment and Biodiversity Report No. 46.* 40 p.

Clark, M.R.; Rowden, A.A.; Wright, I.; Consalvey, M. (2010c). Spotlight: "Graveyard Seamounts". *Oceanography 23(1)*: 146–147

Fulton, E.A.; Smith, A.D.M.; Punt, A.E. (2005). Which ecological indicators can robustly detect effects of fishing? *ICES Journal of Marine Science 62*: 540–551.

Gass, S.E.; Roberts, J.M. (2006). The occurrence of the cold-water coral *Lophelia pertusa* (Scleractinia) on oil and gas platforms in the North Sea: colony growth, recruitment and environmental controls on distribution. *Marine Pollution Bulletin 52*: 549-559

Hall-Spencer, J.; Allain, V.; Fossa, J.H. (2002). Trawling damage to Northeast Atlantic ancient coral reefs. *Proceedings of the Royal Society London B 269*: 507–511.

Helson, J.; Leslie, S.; Clement, G.; Wells, R.; Wood, R. (2010). Private rights, public benefits: Industry-driven seabed protection. *Marine Policy 34*: 557–566.

Hobday, A. J.; Smith, A.; Webb, H.; Daley, R.; Wayte, S.; Bulman, C.; Dowdney, J.; Williams, A.; Sporcic, M.; Dambacher, J.; Fuller, M.; Walker, T. (2007). Ecological Risk Assessment for the Effects of Fishing: Methodology. Report R04/1072 for the Australian Fisheries Management Authority, Canberra.

Kinlan, B.P.; Gaines, S.D. (2003). Propagule dispersal in marine and terrestrial environments: a community perspective. *Ecology 84*: 2007–2020.

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.

Mackay, K.A.; Wood, B.A.; Clark, M.R. (2005). Chatham Rise bathymetry. *NIWA Miscellaneous Chart Series No. 82.* NIWA.

Ministry of Fisheries (2005). Strategy for Managing the Environmental Effects of Fishing. Ministry of Fisheries, Wellington. 20 p.

Morato, T.; Pitcher, T.J.; Clark, M.R.; Menezes, G.; Tempera, F.; Porteiro, F.; Giacomello, E.; Santos, R.S. (2010). Can we protect seamounts for research? A call for conservation. *Oceanography 23*: 190–199.

O'Driscoll, R.L.; Clark, M.R. (2005). Quantifying the relative intensity of fishing on New Zealand seamounts. *New Zealand Journal of Marine and Freshwater Research 39*: 839–850.

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

Rogers, A.D.; Baco, A.; Griffiths, H.; Hart, T.; Hall-Spencer, J.M. (2007). Corals on seamounts. Chapter 8. in: Pitcher, T.J.; Morato, T.; Hart, P.J.B.; Clark, M.R.; Haggan, N.; Santos, R.S. (Eds). *Seamounts: ecology, fisheries, and conservation. Blackwell Fisheries and Aquatic Resources Series 12.* Blackwell Publishing, Oxford, pp. 141-169

Rowden, A.A.; Clark, M.R.; O'Shea, S.; McKnight, D. (2002). Benthic biodiversity of seamounts on the northwest Chatham Rise. *New Zealand Marine Biodiversity Biosecurity Report No. 2*. 21 p.

Rowden, A.A.; Oliver, M.; Clark, M.R.; MacKay, K. (2008). New Zealand's "SEAMOUNT" database: recent updates and its potential use for ecological risk assessment. *New Zealand Aquatic Environment and Biodiversity Report No. 27.* 50 p.

Standards Australia (2004). Australian and New Zealand Standard. Risk Management. Standards Australia, Sydney. 28 pp.

Tittensor, D.P.; Baco-Taylor, A. R.; Brewin, P.; Clark, M.R.; Consalvey, M.; Hall-Spencer, J.; Rowden, A.A.; Schlacher, T.; Stocks, K.; Rogers, A.D. (2009). Predicting global habitat suitability for stony corals on seamounts. *Journal of Biogeography 36*: 1111–1128.

Tracey, D.M.; Neil; H.; Marriott; P.; Andrews, A.H.; Cailliet, G.M.; Sanchez, J.A. (2007). Age, growth, and age validation of two genera of deep-sea bamboo corals (Family Isididae) in New Zealand waters. *Bulletin of Marine Science 81(3)*: 393–408.

Zhou, S.; Griffiths, S.P. (2008). Sustainability Assessment for Fishing Effects (SAFE): a new quantitative ecological risk assessment method and its application to elasmobranch bycatch in an Australian trawl fishery. *Fisheries Research 91*: 56–68.