Expert Risk Assessment of Activities in the New Zealand Exclusive Economic Zone and Extended Continental Shelf

Prepared for the Ministry for the Environment

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Contents

Executive summary **7**

1 Introduction **13**

- 1.1 Background 13
- 1.2 Approach 13

2 Methods **18**

3 Classification of activities and environmental risk **24**

4 Results **26**

- 4.1 Oil and gas 26
- 4.2 Carbon sequestration 36
- 4.3 Gas (methane) hydrates 41
- 4.4 Ironsand mining 50
- 4.5 Placer gold 58
- 4.6 Phosphorite nodules 65
- 4.7 Massive sulphides 73
- 4.8 Polymetalic crusts 82
- 4.9 Polymetalic nodules 90
- 4.10 Ocean basin telecommunications cabling 97
- 4.11 Offshore renewable marine energy extraction 103
- 4.12 Offshore Aquaculture 109
- 4.13 Offshore ecotourism 115
- 4.14 Scientific Exploration and Sampling 119

5 Summary and Conclusions **126**

6 Acknowledgements **135**

7 References **135**

Tables

Table 2-1: Expert panellists, observers and advisors. [1]Advisor; [2]Observer. 21

Table 2-2: Consequence levels. Summary descriptions of the six sets of consequence levels covering five environmental categories. Adapted from Fletcher (2005). 22

Table 2-3: Consequence likelihood categories. Levels and descriptions for each likelihood category (used for all environmental components). Adapted from Fletcher (2005). 23

Table 2-4: Confidence. Confidence rating, score and description. 23

Table 3-1: Risk levels and categories. 25

Table 4-1: Expert Panel Assessment: Oil & Gas Extraction. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. 34

Table 4-2: Expert Panel Assessment: Carbon sequestration. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. 40

Table 4-3: Expert Panel Assessment: Gas hydrate extraction. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. 48

Table 4-4: Expert Panel Assessment: Ironsand mining. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. 56

Table 4-5: Expert Panel Assessment: Placer gold mining. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. 63

Table 4-6: Expert Panel Assessment: Phosphorite nodule mining. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. 71

Table 4-7: Expert Panel Assessment: Massive sulphide deposit mining. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. 80

Table 4-8: Expert Panel Assessment: Polymetalic crust mining. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. 88

Table 4-9: Expert Panel Assessment: Polymetalic nodule mining. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. 95

Table 4-10: Expert Panel Assessment: Ocean basin telecommunications cabling. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. 101

Table 4-11: Expert Panel Assessment: Offshore renewable energy extraction. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. 107

Table 4-12: Expert Panel Assessment: Offshore aquaculture. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. 113

Table 4-13: Expert Panel Assessment: Offshore ecotourism. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. 118

Table 4-14: Expert Panel Assessment: Scientific exploration and sampling. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. 124

Table 5-1: Summary of categorisation of activities as having extreme, high, moderate or low environmental risk. At the bottom of the table we summarise the total number of risks of each category for each industry and for scientific exploration and sampling. 129

Figures

Figure 1-1: New Zealand's marine area. 15
Figure 1-2: Distribution of sedimentary basins and some mineral resources in the EEZ and ECS 16
Figure 1-3: Spatial extent of relevant legislation and regulations (courtesy MfE). 17
Figure 4-1: Distribution of sedimentary basins and mineral resources in the EEZ and ECS. 26
Figure 4-2: Phosphorites nodules. Dark, gavel-sized nodules exposed on the Chatham Rise seafloor, with feathery starfish, deepwater corals and small clumps of brachiopods. 65
Figure 4-3: Black smoker chimney and massive sulphide deposit on the Kermadec Ridge. 73
Figure 4-4: New Zealand EEZ distribution of mineral crusts and nodules. 82
Figure 4-5: A dense field of Polymetalic (manganese) nodules from the Campbell plateau slope. 90
Figure 4-6: Telecommunication routes in the New Zealand region. 97

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Executive summary

- The Ministry for the Environment (the Ministry) is leading the development of the Exclusive Economic Zone and Extended Continental Shelf (Environmental Effects) Bill.
- The Bill will be underpinned by regulations that will set out, among other matters, how activities undertaken within the Exclusive Economic Zone (EEZ) and the Extended Continental Shelf (ECS) will be regulated taking into account existing legislation.
- NIWA was contracted by the Ministry to undertake a study and prepare a report that identifies current and potential activities in the EEZ and provides scientific advice on how activities in the EEZ and ECS might be classified (prohibited, discretionary, or permitted), based on the level of environmental risk involved.
- Our recommendations for classifications are based only on the level of environmental risk from activities. Other criteria will need to be considered when deciding on regulations.
- Levels of risk were established using a precautionary approach, taking into account the worst case scenario for environmental risks. We have also not taken into account how any mitigation measures might reduce environmental risk when recommending classifications. These recommendations should not be taken as a comprehensive assessment of how activities should be finally regulated. They serve primarily as an indication of the activities that might require special conditions and close monitoring, regardless of how they are ultimately classified.
- The approach taken by NIWA has been to carry out an expert Ecological Risk Assessment (ERA), which is a “Level 1” assessment in line with accepted New Zealand and Australian risk assessment standards.
- An ERA panel of NIWA experts progressed through 3 main steps:
    - the examination of sources of risk, their magnitudes, frequencies and intensities;
    - an assessment of the potential consequences of those risks; and
    - the likelihood of a particular level of consequence occurring from the various activities.
- Scores were given to the potential consequence (6 levels from negligible to catastrophic) and to the likelihood of that consequence (remote to likely) of an activity using a set of standard tables that described each level.
- Risk for each activity was then calculated as the product of consequence and likelihood. This approach is commonly referred to as the exposure – consequence risk assessment method. This process was repeated for each identified activity likely to occur in the EEZ and ECS.
- Using the tables of defined levels and scores of environmental consequences (Table 2-2) and likelihoods (Table 2-3) ecological risk can range from a minimum of 0 to a maximum of 30.

- Although we arrived at numerical scores of risk, the assessments underpinning the scores were made on qualitative assessments of likelihood and consequence.
- We considered that if environmental risk is the only criteria for classification activities with low risk levels of 6 or less across all five environmental categories should be categorised as permitted – these arise from the lowest two levels of consequence (0 - negligible and 1- minor) at all levels of likelihood (including 6, likely), from moderate levels of consequence (2) at unlikely (3) or lower levels of likelihood, from severe levels of consequence (3) at rare (2) or remote (1) levels of likelihood, or from major and catastrophic levels of consequence at remote levels of likelihood (see Table 3-1 for a summary of risk scores, their derivation and categorisation).
- From an ecological perspective we considered that if environmental risk is the only criteria for classification then activities with extreme risk levels (of 24 or more) for one or more of the 5 environmental categories should be provisionally classified as prohibited (Table 3-1) unless some means of avoiding or reducing the ecological consequences can be found. These levels of risk arise only from those activities judged to have major consequences (4) at the highest level of likelihood (6) and catastrophic consequences (5) at the two highest levels of likelihood (5 and 6).
- Activities over a broad range of moderate (7-12) and high (15-20) risk values for all of the five environmental categories, we considered, should be provisionally categorised as discretionary, if environmental risk is the only criteria for classification, (Table 3-1) and conditions applied that monitor and reduce the associated ecological risks.In this report we summarise the findings of the expert panel from their assessment of activities associated with13 present or potential industries as well as scientific exploration and sampling in the EEZ and ECS. These industries are:
    - Petroleum oil and gas exploration and production
    - Carbon sequestration
    - Gas hydrate extraction
    - Ironsand mining
    - Placer gold mining
    - Phosphorite nodule mining
    - Massive sulphide deposit mining
    - Polymetalic crust mining
    - Polymetalic nodule mining
    - Ocean basin telecommunications cabling
    - Offshore energy harvesting
    - Offshore aquaculture
    - Deep-sea ecotourism
    - Scientific exploration and sampling

- A total of 207 assessments were made of 42 identified activities across the industries. Of these 19 (9.2%) were assessed as having extreme risks to the environment and should be provisionally classified as prohibited unless there are conditions which avoid, mitigate or remedy their effects.
- A further 48 assessments (23.2%) identified high risk activities that should provisionally be classified as discretionary. Another 75 assessments (36.2%) identified moderate risk activities which should also be provisionally classified as discretionary. The ecological risks from both groups of discretionary activities could be reduced through imposition of conditions which avoid, mitigate or remedy their effects.
- Sixty-four assessments (30.1%) identified low risk activities which could be classified as permitted and standard conditions applied.
- A summary of categorisation of activities as extreme, high, moderate or low is provided in Table 5-1.
- The number of activities assessed for an industry ranged from 7 for offshore ecotourism to 17 for mining of massive sulphide deposits, polymetalic crusts and polymetalic nodules and renewable marine energy.
- Four industries had between 3 and 7 activities classified as posing an extreme risk to the environment. These industries were mining for phosphorite nodules, massive sulphides, polymetalic crusts, and polymetalic nodules.
- All industries had one or more activities that pose a high risk to the environment and 2-10 activities that pose a moderate risk.
- The industry with the highest percentage of activities in the low risk range was offshore aquaculture though there is a high risk in this industry to marine mammals from surface and sub-surface buoys, ropes and structures.
- There are often ways of avoiding, remedying or mitigating the effects of activities that would otherwise put marine species or ecosystems at extreme, high or moderate risk. In each section we discuss some useful mitigation strategies and some of the common strategies include:
    - Following non-mandatory Department of Conservation guidelines (2006 and 2011) to avoid or mitigate acoustic impacts on marine mammals.
    - Limiting unnecessary use of platform and vessel flood lights at night and ensuring that those that are required are directed approximately vertically onto work surfaces to avoid or mitigate seabird strikes. Visual checks of the super-structure at first light each day for the presence of dazed or injured birds and the provision of appropriate care may help to remedy this impact.
    - Avoidance or mitigation of vessels and underwater equipment as vectors for non-indigenous species is possible by appropriate checking, cleaning, and application of antifouling paints. We understand that Biosecurity New Zealand (MAF-BNZ) is developing an import health standard and legislation and relevant regulations may be put in place in next 2-3 years.

  - Pressure on fish stocks caused by the declaration of an exclusion zone around a drilling or mining site, pipeline or cable route, forcing fishing activities into the remainder of the quota management area can be reduced or eliminated by purchase and retirement of appropriate commercial fish quota for the duration of the production phase.
  - Avoidance or mitigation of seals hauling out on platform structures is possible by reducing access to potential haul-out areas but modifications to exploration platforms is unlikely given that they invariably come to NZ from overseas for a relatively short period of intense exploration activity.
  - Efforts should be made to avoid areas of protected deepwater corals within the footprint of the drilling, mining, energy, or aquaculture operation. Pipelines and cables should also be routed to avoid reef habitat and any other vulnerable benthic habitat.
  - Risks to seep communities during the exploratory drilling process or through methane extraction altering fluid flow at seep sites and/or direct damage from rig or production facilities can be avoided or minimised through careful selection of drilling sites.
  - Assuming that iron sands and placer gold deposits occur to depths of 20-30m below the seafloor, impacts on benthic fauna will be minimised if fewer deeper pits are dug to extract a prescribed tonnage of ore. This is because most fauna is restricted to the upper 10-15 cm of sediment. A wide shallow pit will cause the maximum ecological damage for the least gain in ore extraction.
  - Actions that increase the rate of recovery of benthic fauna from the impacts of mining will greatly reduce the risks associated with these industries. Recolonisation by larval settlement from adjacent populations may be increased by mining in a chequerboard or strip pattern or by leaving up current populations intact. So little is known about larval connectivity in these populations that the optimal size or placement of these mining patterns is unknown.
  - Impacts of tourism activities on vulnerable benthic species can be minimised by rotating visits around a number of sites. The appropriate rotation interval should be guided by the likely recovery time of the species concerned.

- For many of the activities associated with new or yet to be established industries there are insufficient details available to determine the best conditions to apply to avoid, remedy or mitigate their effects. These need to be determined during the consenting process.
- We have not assessed the environmental risks from oil spills in this report. Oil spill risk and response is managed under the Health and Safety in Employment Act 1992 and the Maritime Transport Act 1994. We have assessed the potential risk from other oil and gas extraction activities that are not already covered by existing legislation.
- We have not assessed the environmental risks from dumping of dredged sediments, explosives, old ships etc. The risks and responses to these activities are managed under the Maritime Transport Act 1994 and the London Convention on Dumping to which New Zealand is a signatory.

- We have not assessed the effects of fishing in the EEZ or ECS. Effects of fishing are managed under the Fisheries Act 1996.
- In our view the most effective way to manage ecological risk is to regulate the individual activities that together make up a marine industry taking place within defined marine habitats.

1 Introduction

1.1 Background

New Zealand has a large Exclusive Economic Zone (EEZ) and Extended Continental Shelf (ECS) (Figure1-1) that contains oil, gas, mineral and biological resources attractive for development (Figure 1-2).

The Ministry for the Environment (the Ministry or MfE) is developing the Exclusive Economic Zone and Extended Continental Shelf (Environmental Effects) Bill. The Minister for the Environment, The Hon. Dr Nick Smith, announced in June 2011 his intention to introduce this Bill to Parliament this year (2011), with the intention that the Bill will be passed on 1 July 2012.

This Bill will be underpinned by regulations that will set out, along with other matters, how activities undertaken within New Zealand's EEZ and ECS (Figure 1-1) will be regulated, taking into account existing legislation (see Figure 1-3 for a summary of the spatial extent of existing legislation in the EEZ). One aspect that will affect how activities in the EEZ should be classified is the potential environmental risk and opportunities for risk mitigation.

In August 2011, NIWA was contracted by MfE to undertake a study and prepare a report that provides scientific advice on how activities could be classified according to the level of environmental risk. The environmental effects are only one strand of evidence to be weighed in setting policy. Other criteria must also be considered before classifications are confirmed, including, among other things, the practicability and effectiveness of different regulatory approaches.

In line with legislation, such as the 1991 Resource Management Act (RMA) and also given the nature and extent of many of the activities, it is most appropriate to manage the environment based on the effects of activities in certain environments, rather than regulate the activities themselves. The acceptability of environmental effects depends upon a balanced combination of management objectives and the characteristics of the habitats in which the activities are proposed, so that highly valued or sensitive environments may require higher degrees of protection to prevent them from harm.

1.2 Approach

NIWA's approach to the work has been to first determine the activities likely to occur within the EEZ and ECS, and their nature and extent. This has highlighted the probable locations of activities and the habitats most likely to be affected since many of the activities are likely to be site-specific, targeting sea surface, seabed and/or subsurface resources that, because of biogeochemical and physical factors, are found only in particular locations. Likely environmental threats arising from these activities to the local habitats were identified. To assess the possible environmental consequences of these activities we adopted an Ecological Risk Assessment Framework, which is a means to formalise risk assessment as part of an integrated strategy of Ecological Risk Management. We undertook what is commonly referred to as a "Level 1" assessment in line with accepted New Zealand and Australian risk assessment standards (AS/NZ4360 standard 2004). An expert Ecological Risk Assessment (ERA) Panel progressed through 3 main steps:

(i) examination of sources of risk, their magnitudes, frequencies and intensities;

(ii) assessment of the potential consequences of those risks; and

(iii) likelihood of a particular level of consequence occurring from the various activities.

Scores were given to the potential consequence (6 levels from negligible to catastrophic, level 0 representing the lowest risk) and to the likelihood of that consequence (remote to likely) using a set of standard tables that described each level. Risk was then calculated as the product of consequence and likelihood. This is commonly referred to as the exposure – consequence risk assessment method (Fletcher 2005). This process was repeated for each identified activity likely to occur in the EEZ and ECS.

The approach we adopted for this study identified and ranked activities with a certain level of risk. The step-wise procedures under a general risk assessment framework will then allow high-risk activities to be investigated further under a “Level 2” assessment if required by MfE in the future. Activities classified as low risk will probably not require further consideration.

To assist the expert panel two industry representatives attended parts of its deliberations. Mr John Pfahlert of the Petroleum Exploration and Production Association of New Zealand (PEPANZ) sat in the session discussing petroleum oil and gas exploration and production and the session on carbon sequestration via deep well injection. Deep well injection of carbon may possibly use existing oil production platforms and infrastructure and oil or gas bearing structures once reserves are exhausted so Mr Pfahlert’s knowledge of plans for the fate of existing production platforms off Taranaki was useful.

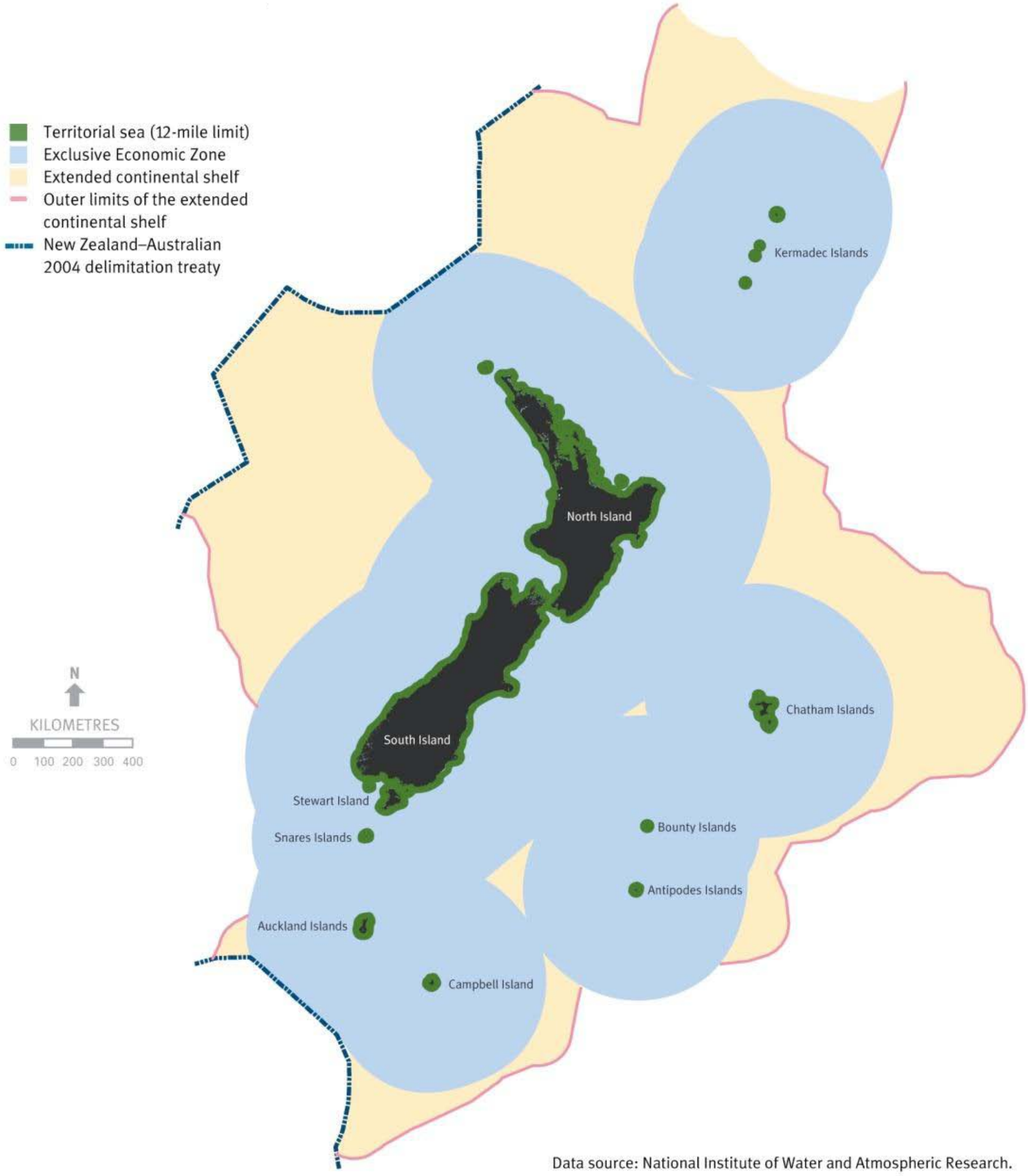
Mr Bernie Napp, a senior policy analyst of Straterra, an industry group representing New Zealand mining, attended sessions on mining of deposits of massive sulphides, iron sands, placer gold and gas hydrates.

These two industry representatives did not sit on the panel to offer expert input. Rather, their role was to assist the panel by reviewing an initial list of activities associated with their industries that NIWA had drawn together, to ensure the list was full and complete. While the expert panel was deliberating, the role of the industry representatives was to provide detailed advice and context for the likely magnitude, frequency and extent of commercial activities, with the likely environmental consequences considered by the NIWA panellists.

We have not assessed the risks from oil spills in this report. Oil spill risk and response is managed under the Health and Safety in Employment Act 1992 and the Maritime Transport Act 1994. We have assessed the potential risk from other oil and gas extraction activities that are not already covered by existing legislation.

We have not assessed the environmental risks from dumping of dredged sediments, explosives, old ships etc. The risks and responses to these activities are managed under the Maritime Transport Act 1994 and the London Convention on Dumping to which New Zealand is a signatory.

We have not assessed the effects of fishing in the EEZ or ECS. Effects of fishing are managed under the Fisheries Act (1996).



Data source: National Institute of Water and Atmospheric Research.

Figure 1-1: New Zealand's marine area.

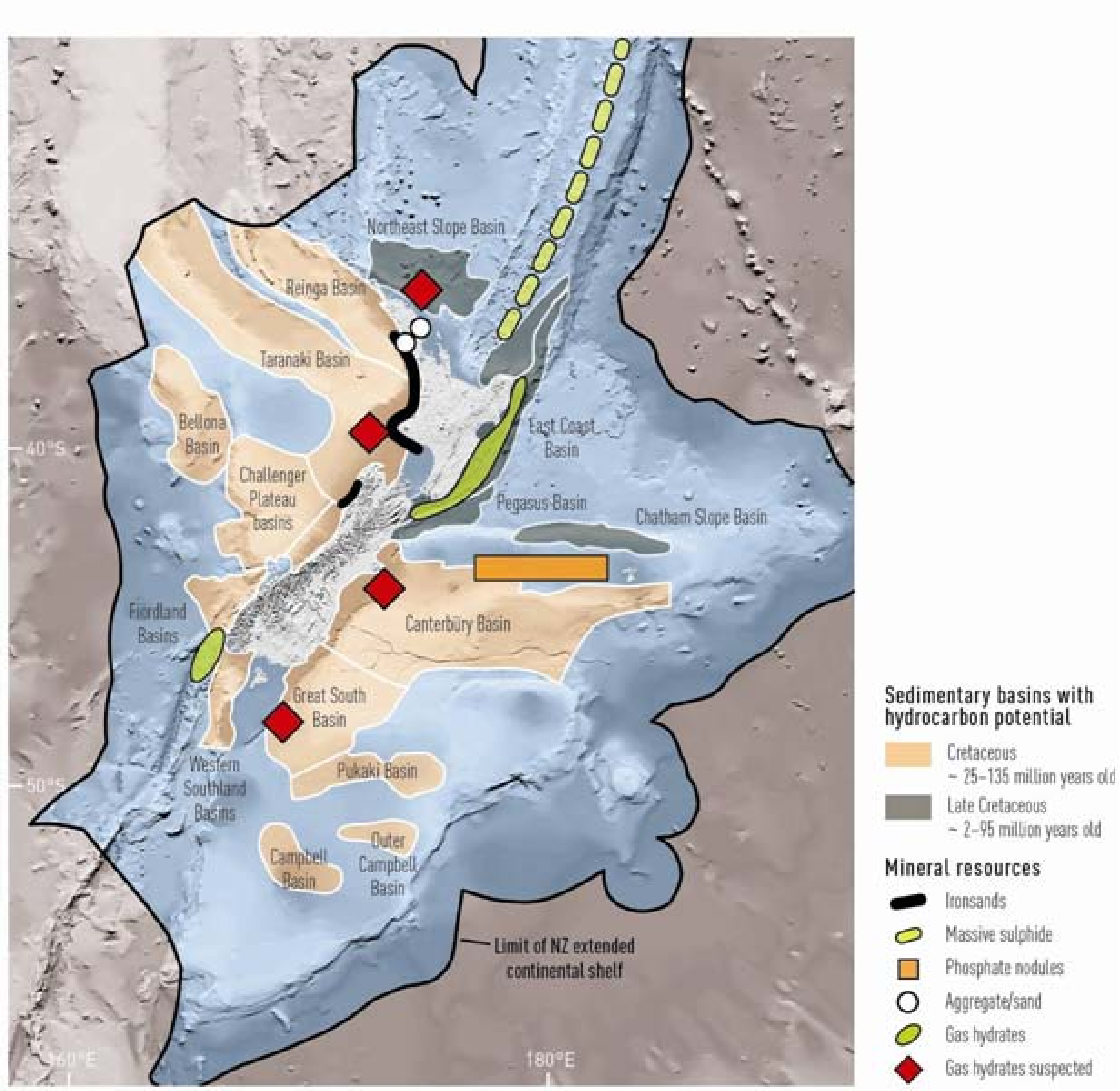


Figure 1-2: Distribution of sedimentary basins and some mineral resources in the EEZ and ECS

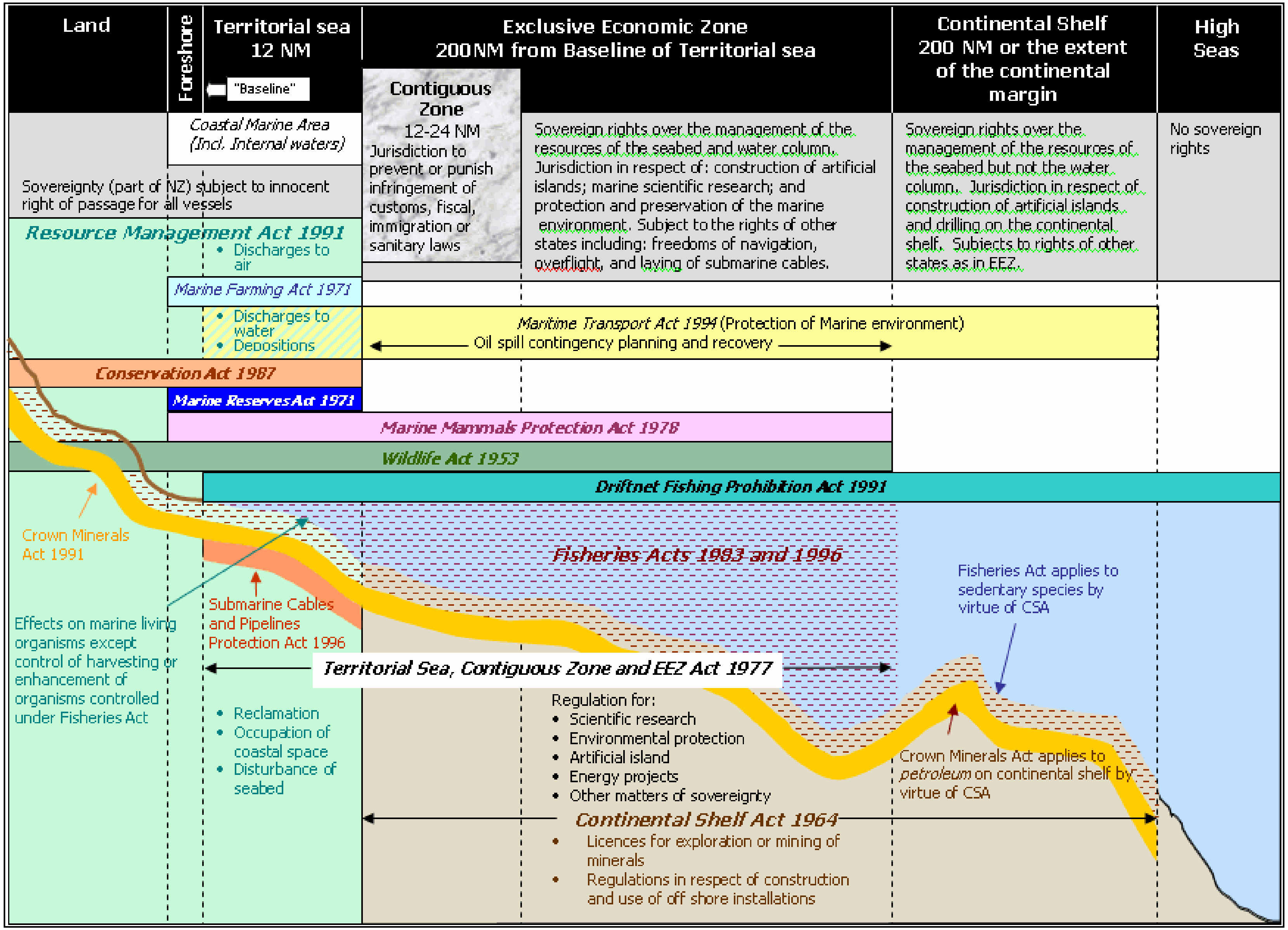


Figure 1-3: Spatial extent of relevant legislation and regulations (courtesy MfE).

2 Methods

The methodology included the following stages:

1) **Determination of the likely activities in the EEZ and ECS:** We drew up a list of present and potential industries, such as aquaculture, power generation, gas and oil activities, and minerals exploration and mining, likely to be carried out in the EEZ and ECS over a 20-30 year horizon. We subdivided these into their component phases and activities over the lifetime of an industrial operation to ensure that all relevant components were assessed.

   Early in the project an initial list of activities was circulated to the expert panellists as well as to the industry representatives and to MfE. An updated list of activities, incorporating feedback from the above group, was circulated again before the panel met. The activities were then discussed and updated as necessary during the panel deliberations.

2) **Determination of the probable locations of these activities**: We determined the probable location of activities, the methods likely to be used carrying out such activities, and thus the habitats likely to be influenced by them. This stage was informed by collation of available published and unpublished material identifying probable locations of these activities supplemented by the input of experts and stakeholders in the relevant industries. Probable locations of activities were further discussed during the workshop.

3) **Establishment of likely environmental threats arising from activities:** Given the tight timeframe for this work (i.e., one month), there was no scope for new research to better understand the environmental threats stemming from activities presently or likely to occur within New Zealand's EEZ and ECS, or capacity for significant desktop discovery via exhaustive literature searches for a wide range of international examples that may be directly translatable to New Zealand conditions. Instead we were limited to a brief literature review from two main sources: a) existing New Zealand environmental assessment studies and b) widely available international studies and policy. The panellist's expert knowledge supported by the limited literature review, provided the information to enable us to determine a broad-scale definition of the likely magnitude and frequency of environmental effects of certain activities, and their lifecycle components, on the ocean environment. Much of the literature was already familiar to NIWA staff from previous research and environmental studies.

   An initial list of activities and threats deriving from them was circulated to the expert panellists, as well as to the industry representatives and to MfE, for their feedback and input at an early stage of the project. An updated list of activities and threats incorporating feedback from the panellists was circulated again before the panel met. The activities and threats were then discussed and updated as necessary during the panel deliberations.

4) **Expert Panel:** We convened an Ecological Risk Assessment (ERA) panel of experts (the Panel), made up of available NIWA staff based at Wellington , including MfE staff as observers and industry representatives as advisors, to help assess the ecological consequences of threats arising from various activities in the EEZ and ECS as well as the likelihood of these threats occurring.

ERA panellists included those with a good level of knowledge of the activity as well as those with knowledge of consequences to particular aspects of the ecosystem. A core number of panellists assessed all activities while others were present for only those activities for which they had specific technical expertise. A list of experts, observers and advisors present for the assessment of each activity is provided in Table 2-1. The assessments were based on the expert judgement of the ERA Panel members and therefore were qualitative rather than quantitative.

5) **Threats, consequences and likelihood:** The method sequentially progressed through three main steps: (i) re-examination of activities and threats arising from them; (ii) an assessment of the potential consequences of those threats to five aspects of the environment and; (iii) the likelihood of a particular level of consequence occurring from the various activities. It is important that subsequent use of these ratings reflect all three of these steps to maintain the integrity and context within which risks were assessed.

The panel considered consequences and likelihoods with regard to five aspects of the environment (adapted from Fletcher 1995): the time to recover if the threat stopped, impacts on key species, impacts on protected species, ecosystem functional impact, and the proportion of habitat affected by a threat. These are all key indicators of ecological response at a range of scales. The proportion of a habitat affected by an activity is critical to assessing the spatial extent of any impact. The ecological functional impact is likewise a broad indicator of the ecological significance of a disturbance. The impacts on protected and key species are more specific indicators highlighting socially and ecologically important species in the affected environment. Lastly recovery period provides an indication of the affected species and habitat ability to recover from the threat taking into account knowledge of the biology and ecology.

The Panel discussed, evaluated and scored the consequences of the activities on a scale of 0 to 5, using a set of 6 prepared consequence descriptions ranging from negligible to catastrophic. Table 2-2 provides the descriptions of the consequence levels and scores for the five environmental categories. Since the nature of the potential consequences of exposure to the identified activities in the EEZ and ECS depends on the particular environmental component being considered, there are different sets of descriptions of consequence levels for each of the environmental categories. These descriptions were reviewed by the Panel prior to the workshop and some adjustments were made during the workshop when the original wording was found to be ambiguous. The consequence scores and the reasons for them were recorded by the workshop convener.

Where data or information did not exist, a precautionary approach was necessarily adopted to reflect the uncertainty in the likely effects of the activity. For example, where the distribution of a particular relevant activity was known but the distribution of the environmental component was uncertain, there was an assumption that the potential risk was high because the ecological component under consideration may be exposed to the activity. This is likely to occur, for example, in relation to migratory species.

Following the scoring of the consequence, the ERA Panel discussed, assessed and then scored the likelihood of that consequence occurring. Likelihood scores ranged from 1 to 6, from remote to likely. The likelihood descriptions (Table 2-3) were reviewed by the ERA Panel prior to the workshop. The likelihood scores and the reasons for them were recorded by the workshop convener.

The assessments were based on the expert judgement of the ERA Panel members and therefore were qualitative rather than quantitative. However, quantitative data, scientific reports and other information collated during Stage 3 above were used to support and inform the risk assessments.

This process was repeated for each identified activity likely to occur in the EEZ or ECS.

6) **Confidence:** When it had completed the evaluation of each environmental component, the Panel rated its confidence in its assessment (high or low). Table 2-4 provides the confidence ratings together with a set of prepared rationales. These were reviewed by the Panel prior to the workshop. Note that within each confidence rating (low and high) confidence levels are not listed in rank order.

7) **Risk:** Risk was then calculated as the product of consequence and likelihood. This calculation is commonly referred to as the exposure – consequence risk assessment method. This process was repeated for each identified activity likely to occur in the EEZ or ECS. Risk scores ranged from 0 (negligible) to 30 (extreme).

Table 2-1: Expert panellists, observers and advisors. [1]Advisor; [2]Observer.

Oil and Gas & Carbon Sequestration
Dr Alison MacDiarmid – Convener
Dr Geoffroy Lamarche - Geologist
Dr Helen Bostock - Geochemist
Dr David Thompson – Seabirds
Dr Leigh Torres – Marine mammals
[1]Mr John Pfahlert – PEPANZ
[2]Mr Joshua McLennan-Deans – MfE

Scientific exploration and sampling
Dr Alison MacDiarmid – Convener
Dr Helen Bostock – Geochemist
Dr Malcolm Clark – Deep-sea biologist
Dr David Bowden – Benthic ecologist
Dr David Thompson – Seabirds
Dr Craig Stevens – Ocean physicist
Dr Leigh Torres – Marine mammals

Iron Sands & Placer Gold
Dr Alison MacDiarmid – Convener
Dr Alan Orpin – Geologist
Dr David Thompson – Seabirds
Dr Leigh Torres –Marine mammals
Dr Jenny Beaumont – Benthic ecologist
Dr Mark Hadfield – Sediment modeller
[1]Mr Bernie Napp – Snr Policy Analyst, Straterra

Offshore aquaculture & Ecotourism
Dr Alison MacDiarmid – Convener
Dr Phil Heath – Aquaculture biologist
Dr Craig Stevens – Ocean physicist
Dr David Thompson – Seabirds
Dr Leigh Torres – Marine mammals
Dr David Bowden – Benthic ecologist
Dr Scott Nodder – Sedimentologist

Massive Sulphides
Dr Alison MacDiarmid – Convener
Dr Malcolm Clark – Deep sea biologist
Dr David Thompson – Seabirds
Dr Leigh Torres – Marine mammals
Dr Richard Wysoczanski – Vulcanologist
Dr Jenny Beaumont – Benthic ecologist
Dr Mark Hadfield – Hydrographic modeller
[1]Mr Bernie Napp – Snr Policy Analyst, Straterra

Polymetalic crusts & nodules
Dr Alison MacDiarmid – Convener
Dr Scott Nodder – Sedimentologist
Dr Malcolm Clark – Deep-sea biologist
Dr David Thompson – Seabirds
Dr Helen Bostock – Geochemist
Dr David Bowden – Benthic ecologist
Dr Leigh Torres – Marine mammals
Dr Mark Hadfield – Sediment modeller

Gas (methane) hydrates
Dr Alison MacDiarmid – Convener
Dr David Bowden – Benthic ecologist
Dr David Thompson – Seabirds
Dr Leigh Torres – Marine mammals
Dr Mark Hadfield – Sediment modeller
[1]Mr Bernie Napp – Snr Policy Analyst, Straterra

Phosphorite Nodules
Dr Alison MacDiarmid – Convener
Dr Scott Nodder – Sedimentologist
Dr Jenny Beaumont – Benthic ecologist
Dr David Thompson – Seabirds
Dr Leigh Torres –Marine mammals
Dr Mark Hadfield – Sediment modeller

Telecommunications
Dr Alison MacDiarmid – Convener
Dr David Thompson – Seabirds
Dr Leigh Torres – Marine mammals
Dr David Bowden – Benthic ecologist
Dr Craig Stevens – Ocean physicist

Deep-sea energy
Dr Alison MacDiarmid – Convener
Dr Craig Stevens – Ocean physicist
Dr David Thompson – Seabirds
Dr Leigh Torres – Marine mammals
Dr David Bowden – Benthic ecologist

Table 2-2: Consequence levels. Summary descriptions of the six sets of consequence levels covering five environmental categories. Adapted from Fletcher (2005).

Consequence level	Recovery Period	Key species	Protected species	Ecosystem functional impact	Proportion of habitat affected
0 - Negligible	No recovery time needed	Undetectable for populations of these species	Almost none are impacted	Interactions may be occurring but it is unlikely that there would be any change outside of natural variation	Affecting <<1% of area of original habitat area
1 - Minor	Rapid recovery would occur if stopped - measured in weeks to months	Possibly detectable but little impact on population size and none on their dynamics	Some individuals impacted but no impact on population.	Affected species do not play a keystone role - only minor changes in relative abundance of other constituents	Measurable but localized; affects <1-5% of total habitat area
2 - Moderate	Recovery probably measured in months - years if activity stopped	Affected but long-term recruitment/ dynamics not adversely impacted	Level of interaction/ impact moderately affects population	Measurable changes to the ecosystem components without there being a major change in function (i.e. no loss of components)	Impacts more widespread; 5-20% of habitat area is affected
3 - Severe	Recovery measured in years if stopped	Affecting recruitment levels of populations or their capacity to increase	Level of impact severely affects population levels	Ecosystem function altered measurably and some function or components are missing/ declining/ increasing well outside historical acceptable range and/or allowed/ facilitated new species to appear.	Impacts very widespread; 20-60% of habitat is affected/ removed
4 - Major	Recovery period measured in years to decades if stopped	Likely to cause local extinctions if continues	Likely to cause local extinctions if continues	A major change to ecosystem structure and function. Different dynamics now occur with different species or groups now affected.	Activity may result in major changes to ecosystem; 60-90% affected
5 - Catastrophic	Long term recovery to former levels will be greater than decades or never, even if stopped	Local extinctions are imminent/immediate	Local extinctions are imminent/immediate	Total collapse of ecosystem processes. The diversity of most groups is drastically reduced and most ecological functional groups (primary producers, grazers etc.) have disappeared. Most ecosystem functions such as carbon cycling, nutrient cycling, flushing and uptake have declined to very low levels.	Entire habitat in region is in danger of being affected; >90% affected/ removed

Table 2-3: Consequence likelihood categories. Levels and descriptions for each likelihood category (used for all environmental components). Adapted from Fletcher (2005).

Level/score	Descriptor	Likelihood of exposure
1	Remote	Highly unlikely but theoretically possible
2	Rare	May occur in exceptional circumstances
3	Unlikely	Uncommon, but has been known to occur elsewhere
4	Possible	Some evidence to suggest this is possible.
5	Occasional	May occur occasionally
6	Likely	It is expected to occur

Table 2-4: Confidence. Confidence rating, score and description.

Confidence rating	Score	Rationale for confidence score
Low	1a	Data exists, but is considered poor or conflicting.
	1b	No data exists.
	1c	Agreement between experts, but with low confidence
	1d	Disagreement between experts
High	2a	Data exists and is considered sound.
	2b	Consensus between experts even though data may be lacking
	2c	High confidence - exposure to impact cannot occur (e.g. no spatial overlap of activity and species distribution)

3 Classification of activities and environmental risk

There are often ways of avoiding, remedying or mitigating the effects of activities that would otherwise put marine species or ecosystems at risk. If risks are high and there are no ways to avoid, remedy or mitigate the effects of an activity it should be prohibited.

Using the exposure – consequence risk assessment framework adopted in this study, ecological risk is defined as the product of consequence and likelihood. Using the tables of defined levels and scores of environmental consequences (Table 2-2) and likelihoods (Table 2-3) ecological risk can range from a minimum of 0 to a maximum of 30.

We consider that activities with low risk levels of 6 or less across all five environmental categories should be categorised as permitted – these arise from the lowest two levels of consequence (0 -negligible and 1- minor) (see Table 3-1) at all levels of likelihood (including 6, likely), from moderate levels of consequence (2) at unlikely (3) or lower levels of likelihood, from severe levels of consequence (3) at rare (2) or remote (1) levels of likelihood, or from major and catastrophic levels of consequence at remote levels of likelihood.

From an ecological perspective we consider that if environmental risk is the only criteria for classification activities with extreme risk levels of 24 or more for one or more of the 5 environmental categories should be provisionally classified as prohibited (Table 3-1) unless some means of avoiding or reducing the ecological consequences can be found. These levels of risk arise only from those activities judged to have major (4) consequences at the highest level of likelihood (6) and catastrophic consequences (5) at the two highest levels of likelihood (5 and 6)

If environmental risk is the only criteria for classification activities over a broad range of moderate (7-14) and high (15-20) risk values for all of the five environmental categories, we consider, should be categorised as discretionary (Table 3-1).. This classification does not take into account potential mitigation measures. If mitigation measures are taken into account and required as conditions it may be appropriate to downgrade the classification of some activities to permitted. We do not have full information to assess the degree to which mitigation measures might reduce the risk scores of the activities.

The recommended classifications should not be translated into firm recommendations about how the activities should be ultimately regulated. They are based purely on an assessment of environmental risk, with increased risk meaning the activity will need to be more closely controlled. Our recommendations do not take into account other criteria that policy makers are likely to use in deciding final classification of activities.

Table 3-1: Risk levels and categories.

Risk Level	**Risk score range**	**Risk score derivation**		**Category**
		Consequence level	**Likelihood levels**	
Low	0-6	0 – negligible 1 – minor 2 – moderate 3 – severe 4 – major 5 – catastrophic	1-6 (remote to likely) 1-6 (remote to likely) 1-3 (remote, rare or unlikely) 1-2 (remote or rare) 1 (remote) 1 (remote)	Permitted, with appropriate conditions.
Moderate	8-12	2 – moderate 3 – severe 4 – major 5 – catastrophic	4-6 (possible, occasional, likely) 3-4 (unlikely, possible) 2-3 (rare, unlikely) 2 (rare)	Discretionary (pending possible mitigation measures)
High	15-20	3 – severe 4 – major 5 – catastrophic	5-6 (occasional, likely) 4-5 (possible, occasional) 3-4 (unlikely, possible)	
Extreme	24-30	4 - major 5 – catastrophic	6 (likely) 5-6 (occasional or likely)	Prohibited

4 Results

4.1 Oil and gas

4.1.1 Background

New Zealand has at least 14 sedimentary basins of various ages with hydrocarbon potential (Figure 4-1). The Taranaki Basin is currently the only producing basin in New Zealand with over 400 onshore and offshore exploration and production wells have been drilled to date. No production wells have been drilled beyond the Taranaki shelf edge. The basin remains under-explored compared to many comparable rift complex basins of its size and there remains considerable potential for further discoveries, especially in deep parts of the basin.

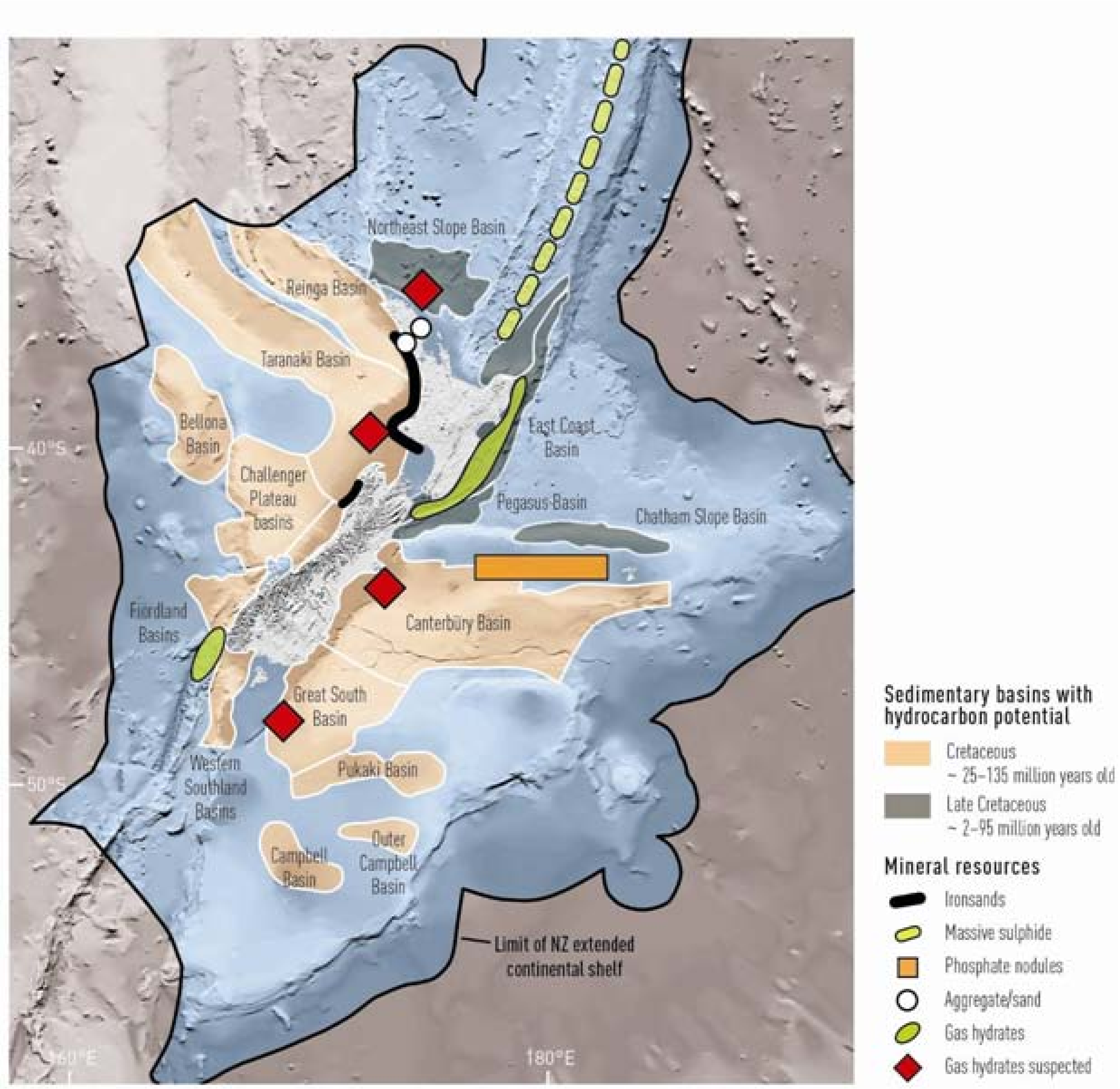


Figure 4-1: Distribution of sedimentary basins in the EEZ and ECS.

In 2010, New Zealand produced ~21 million barrels (mmbbls) of oil and LPG Production and 157 billion cubic feet (Bcf) of gas essentially originating from the Taranaki Basin. The ultimate proved reserves are estimated at ~560 mmbbls of oil and 6400 Bcf of gas (see www.nzpam.govt.nz/cms/petroleum).

The rest of New Zealand is severely under-explored; nevertheless, frontier basins drilled to date have all yielded discoveries confirming viable petroleum systems, such as in the Great South Basin off SE South Island. Given many untested structures mapped have closures bigger than the Maui field (New Zealand's largest field); there is considerable potential for commercial hydrocarbon discoveries under New Zealand's largely untouched seabed (Crown Minerals (2004).

Presently there are just over 30 offshore exploration permits delivered by New Zealand Petroleum and Mineral in Taranaki and west coast North Island, East Coast North Island, Raukumara Basin and SE South Island, with an additional five applications pending (Crown Minerals 2004, www.nzpam.govt.nz/cms/petroleum).

4.1.2 Assessment

We assessed four phases of New Zealand's marine oil and gas industry: prospecting, exploration, production and abandonment / decommissioning. For each phase we identified and assessed the ecological impact of several distinct activities (Table 4-1). Below we present the main results for each phase.

Prospecting

Surveying for likely oil or gas bearing geological structures using surface ships is the main activity in the EEZ during this phase.

The survey ship acquires bathymetric data using a multi-beam echo-sounder, and data about geological structures beneath the seafloor using a seismic source and a streamer comprising multiple hydrophones that may be up to 15 km long (usually 6-8 km). The streamer is typically deployed at ~2 knots and acquisition of data occurs at 5 knots. A very large area, perhaps approaching 100% of the prospecting licence area, may be surveyed during this phase though sequentially over a period of several weeks to a few months. We assume the habitat area under consideration is a particular sedimentary basin.

The acoustic impact of seismic surveys on marine mammals, in particular, is well documented (Gordon & Moscrop 1996, Cox et al. 2006, Brandon et al. 2008, Di Iorio and Clark 2010) but may also affect a range of marine reptiles, fish and invertebrates (e.g. Luyeye 2005). The consequences for marine mammals will vary from none to behavioural (may leave area) to acute injury (ear drum damage) to serious (death) depending on noise level encountered, species and habitat (Gordon & Moscrop 1996). Beaked whales are thought to be particularly at risk (Cox et al. 2006). There may also be cumulative effects from repeated exposure. Noise travels great distances underwater and so the footprint of this activity may be very broad though fatal impacts will be much more restricted in area as sound intensity typically falls as the square of the distance from the source. Acoustic depth sounders and multibeam echo-sounders used for swath mapping pose little risk but high energy seismic devices such as air guns used for mapping sub seafloor geological structures pose a much greater risk (Brandon et al. 2008). Using a precautionary approach our assessment assumed that air guns were used and the species affected was a nationally critical species such as southern right whales as these may occur throughout the EEZ though they occur in different areas at different times of the year. The risk from this activity was assessed to reach a score of 18 with a high level of confidence (Table 4-1).

Fur seals and sea lions may be attracted to the seismic streamer during deployment and retrieval and could become entangled and injured or drown (G. Lamarche personal observation). The number of individuals affected is likely to be small given the one-off nature of a seismic survey and impacts will be largely restricted to locations where deployment and retrieval takes place at slow speeds. Using a precautionary approach our assessment assumed that the species affected was the New Zealand sea lion though few occur north of about 45° S. The risk to sea lions during seismic streamer deployment and retrieval was assessed to reach a score of 3 but with a low level of confidence (Table 4-1) because few data exist about this effect. Populations are unlikely to be affected and ecosystem effects will be negligible.

Lights on survey ships at night typically attract and disturb seabirds and may cause them to collide with the ship (Black 2005). These effects are covered under the Maritime Transport Act (1994) and the Wildlife Act (1953).

Ship strikes on marine mammals, fish, and reptiles may occur during the survey and during transits to and from the survey area. These effects are covered under the Maritime Transport Act (1994) and the Marine Mammal Protection Act (1978) and although these threats were assessed (Table 4-1) the risks will not be considered further here.

We have not assessed the potential for survey ships to act as vectors for the introduction of non-indigenous species as this is already managed under existing legislation.

Exploration

A wider range of activities occur during this phase albeit over a much smaller area than during the prospecting phase (Table 4-1). Typically a drill ship or platform is used to assess the oil and/or gas reserves of specific rock strata. A single drill hole may take weeks to a few months to reach its target depth depending on the rock type encountered. One or more holes may be drilled on single exploration permit.

Lights on a drilling platform at night typically attract and disturb seabirds and may cause them to collide with the above sea surface structure (Black 2005). Although these frequently cause some seabird deaths, on average there will be little impact on most seabird populations as the duration of this phase in any one place is short (months), but even a few deaths could affect the recovery of populations of some nationally critical species. Only seabirds in the area at night will be affected. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk from this activity was assessed to reach a score of 10 with a high level of confidence (Table 4-1) indicating the need for this to be a discretionary activity.

Marine mammals potentially may interact with a drilling platform, or be affected by surface or subsurface activity and lights. Rigs also attract prey species. Seal haul-outs are possible on the leg bracing struts on some platforms (John Pfahlert personal comment). If the interaction is with a threatened species then the impact potentially may be more severe. In deeper parts of basins, species such as sperm whales and beaked whales may be affected. In southern oil basins sea lions and elephant seals may be affected. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk to marine mammals from this activity was assessed to reach a score of 5 with a high level of confidence (Table 4-1) indicating that this activity could be classified as permitted.

The benthic ecosystem on the seafloor will be impacted by exploratory drilling but the affected proportion of the benthic habitat in the licence area and the oil basin is likely to be very small. At the drill site itself the legs of the drill platform may directly impact the seafloor, as will the drill head of ~5-10 m^2 and any mooring chain used that may be up to 1-2 km long with or without an anchor. When new oil or gas wells are drilled, the lubricant used is of three types: oil-based, synthetic, or water-based (in order of decreasing severity of impact on the environment). The type of drilling lubricant used has a large bearing on the toxicity of drill cuttings that were formerly dumped on the seabed and the time for the benthos to recover (Addy et al. 1984, Olsgard & Grey 1995, Patin 1999). Cuttings from new wells will likely be collected and stored during exploratory phase and ultimately be disposed of on land (John Pfahlert personal comment) but this is not yet 100% certain. Discharges from the drilling platform or ship are already managed under existing legislation and so are not evaluated here. The level of benthic impact will be low for most areas but impacts could be higher in some areas if they contain protected species of deep-water corals or vulnerable benthic species. Risk levels for recovery of the benthos, impacts on key species, protected benthic species such as deepwater corals, and the functioning of the ecosystem were 15, 12, 12 and 12 respectively. The speed of recovery of the benthos after completion of drilling will depend on the type of lubricant used in the drilling process but is likely to take years (Olsgard & Grey 1995, Daan & Mulder 1996, Patin 1999).

Drilling activities will produce some level of underwater noise from the drill itself, and any submersed cutters, pumps or other machinery that could affect marine mammals but probably at the lower end of the impact range (Gordon & Moscrop 1996).

Exploratory drilling platforms brought in to New Zealand from Australia or further afield may act as vectors for non-indigenous species. The functional impacts on the ecosystem surrounding the rig is probably minor as vectored species are unlikely to survive independently of the rig in deep offshore waters. The rig may act as a stepping stone for non-indigenous species to invade shallow coastal habitats.

Production

The production phase for oil and gas may or may not involve a surface production platform and a pipeline to shore. It is possible that a seabed facility could be put in place leading directly to a pipeline to shore or to a surface mooring for transfer of oil or gas to tankers.

If a production platform is used, then as during the exploratory drilling phase, lights on the platform at night will typically attract and disturb seabirds and may cause them to collide with the above sea-surface structure. Although these frequently cause some seabird deaths, on average there will be little impact on most seabird populations, but even a few deaths could affect the recovery of populations of some nationally critical species. Only seabirds in the area at night will be affected but the production platform may be in place for decades. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk from this activity was assessed to reach a score of 15 with a high level of confidence (Table 4-1) indicating the need for this to be a discretionary activity.

Marine mammals may interact with a production platform. Seal haul-outs are possible on the leg bracing struts on some platforms. Rigs attract fish and marine predators. Mitigation is possible by reducing access to potential haul-out areas and this is recommended for production platforms that may be in place for decades. If the interaction is with a threatened species then the impact potentially may be more severe. In deeper parts of basins, species such as sperm whales and beaked whales may be affected. In southern oil basins, sea lions and elephant seals may be affected. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk to protected marine mammals from this activity was assessed to reach a score of 5 with a high level of confidence (Table 4-1). Recovery once the platform was removed may take months to years.

Production platforms are likely to be purpose built in New Zealand or overseas. New Zealand built platforms should pose little risk. Platforms brought in to New Zealand from Australia or further afield may act as vectors for non-indigenous species but the likelihood is low for a new platform with fresh antifouling. The functional impacts on the ecosystem surrounding the platform is probably minor as vectored species are unlikely to survive independently of the rig in deep offshore waters. However, the platform may act as a stepping stone for non-indigenous species to invade shallow coastal habitats.

The benthic ecosystem on the seafloor will be impacted by a single platform during the long production phase but the affected proportion of the benthic habitat in the licence area and the oil basin is likely to be very small. Regulators need to be mindful, however, of the possibility for multiple production facilities and pipelines to occur in a single region and benthic impacts to increase accordingly. This is a serious issue in some regions (Kingston 1992). At the well site itself the legs of the production platform may directly impact the seafloor, as will the well head of ~5-10 m^2 and any mooring chain used that may be up to 1-2 km long with or without an anchor. If a submerged pipeline is built to bring the oil or gas onshore then the seabed will be impacted during construction and trenching. Discharges from the platform are already managed under existing legislation. The level of benthic impact will be low for most areas but impacts could be higher in some areas if they contain protected species of deepwater corals. Risk levels for recovery of the benthos, impacts on key species, protected benthic species such as deepwater corals, and the functioning of the ecosystem were 6, 6, 12 and 12 respectively.

Installation of the production platform, pipeline construction and trenching, underwater inspection using ROVs or submersibles as well as routine maintenance and pumping will regularly produce some level of underwater noise in the vicinity of the production platform and more intermittently along the pipeline route. This underwater noise may affect marine mammals, mainly causing then to avoid the area (Gordon & Moscrop 1996), but we assessed this to pose low risk (6) and that recovery would occur almost immediately after the noise stopped.

Oil and gas production may affect stocks of fished species in two ways. There may be some direct effects during the construction of the well head, installation and anchoring of a platform and construction and trenching of a pipeline. These structures will also alienate an area (albeit small) of seafloor so that it no longer provides foraging habitat for demersal fishes. These same structures may also provide a new artificial reef-like surfaces and increase reef habitat in the area for reef associated fishes (Dauterive 2000). Production platforms and pipelines invariably have a zone of restricted access around them that restricts fishing access to these areas. Unless commercial fish quota is purposefully bought by the production company and retired for the duration of the production phase then commercial fishing will be displaced into the remainder of the quota management area (QMA). The resulting fishing pressure has the potentail to affects some fish stocks, especially sedentary species with limited migrations. However, the area of a QMA likely affected by a single production platform will be small and we assessed there to be low risk (5) from this threat. Regulators need to be mindful, however, of the possibility for multiple production facilities and pipelines to occur in a single region and for fishing to be forced into an ever decreasing proportion of a QMA. The region most likely to be affected in this way over the next 20-30 years is off Taranaki.

Abandonment / Decommissioning

The ecological risks associated with this phase will depend on whether the production platform and equipment is dismantled and removed, sunk to the seafloor and abandoned, or left intact for another use such as carbon sequestration (see section 4.2). Active discussion of these alternatives is underway within New Zealand's oil and gas production community as the Maui platforms off Taranaki are now nearing the end of production. If left intact for another use then the ecological risks will be largely the same as during the production phase and are not considered further here. The impacts of platform dismantlement and abandonment are considered below. We assumed that any buried pipeline and anchor chains will be left in place as the cost of recovery would be high and the ecological impacts of removal would be equivalent to their initial installation.

Regardless of whether the production platform is dismantled and removed or sunk and abandoned there will be a great deal of preparatory work on the platform to prepare it for either fate. Cleaning the structure of oils and toxic substances in preparation for planned sinking in the EEZ is mandatory under the Maritime Transport Act (1994). Preparatory work is likely over a period of months and may require the use of lights on the platform at night. These typically attract and disturb seabirds and may cause them to collide with the remaining super-structure. Although these frequently cause some seabird deaths, on average there will be little impact on most seabird populations, but even a few deaths could affect the recovery of populations of some nationally critical species. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk from this activity was assessed to reach a score of 10 with a high level of confidence (Table 4-1). Marine mammals may also be affected during this phase by the increased activity around the platform for a period of months to remove it or abandon it. We assumed no underwater explosions would be used for either scenario. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk to protected marine mammals from this activity was assessed as low (5) with a high level of confidence (Table 4-1). Recovery once the platform is removed may take months to years.

We assessed the risks to seafloor ecosystem of removal of the platform to be minor (6) and that recovery of benthic organisms would take on the order of months to years.

Sinking of a steel platform will have lasting impacts on the local benthic ecosystem as the platform slowly rusts and disintegrates over a period of ~100 years and so recovery is likely to be very long-term taking many decades. However, the overall area impacted is very likely to be only a small proportion of the benthic ecosystem in the licence area or the oil basin so the overall risk to ecosystem functioning, protected benthic species and key species is low (6).

Risk summary for oil & gas extraction

There were no activities associated with oil and gas extraction considered to represent an extreme environmental risk provisionally indicating prohibited status.

The following activities were considered to be of high environmental risk (15-20) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Surface flood lights at night
- Operation of airguns and streamers during seismic surveys

- Survey vessel activity causing strikes on marine mammals (regulated under the Maritime Transport Act (1994) and the Marine Mammal Protection Act (1978)).
- Drilling activities

The following activities were considered to be of moderate environmental risk (7-12) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Presence of seafloor structures and anchors
- Boomer surveys
- Provision of biofouling surfaces
- Presence of platform structure
- Underwater pipeline laying and trenching
- Well capping
- Recovery of underwater equipment, plant and machinery
- Underwater lights
- Incidental underwater noise
- Abandonment, sinking of platform and equipment
- Material degradation

The following activities were considered to be of low environmental risk (0-6) and should be categorised as permitted:

- Single and multibeam echo sounding
- Declaration of exclusion zone

4.1.3 Avoidance, mitigation, remediation

There are often ways of avoiding, remedying or mitigating the effects of activities that would otherwise put marine species or ecosystems at risk. Below we briefly discuss those relevant to oil and gas exploration and exploitation.

Non-mandatory Department of Conservation guidelines (2006 and 2011) should be followed to avoid or mitigate acoustic impacts on marine mammals.

Avoidance or mitigation of seabird strikes on drilling platforms is possible by limiting unnecessary use of platform lights at night and ensuring that those that are required are directed approximately vertically onto work surfaces. Visual checks of the platform structure at first light each day for the presence of dazed or injured birds and the provision of appropriate care may help to remedy this impact.

Avoidance or mitigation of seals hauling out on platform structures is possible by reducing access to potential haul-out areas but modifications to exploitation platforms is unlikely given that they invariably come to NZ from overseas for a relatively short period of intense exploration activity.

Efforts should be made to avoid areas of vulnerable benthic fauna such as protected deepwater corals within the footprint of the production platform and its anchors. Pipelines should also be routed to avoid reef habitat and any other vulnerable benthic habitat.

Avoidance or mitigation of exploratory or production platforms acting as vectors for non-indigenous species is possible by appropriate checking, cleaning, and application of antifouling paints. We understand that Biosecurity New Zealand (MAF-BNZ) is developing an import health standard to cover the import of drilling rigs and legislation and relevant regulations may be put in place in next 2-3 years.

Table 4-1: Expert Panel Assessment: Oil & Gas Extraction. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. Activities are listed (a, b, c, etc) after each threat to which they contribute. The maximum possible level of environmental risk is 30. Extreme environmental risks are highlighted in red, high in yellow, and moderate in green. Low risk activities are not highlighted. *Threats managed under the Maritime Transport Act (1994). NA = not applicable as species assessed are all protected.

Expert Panel Assessment: Oil and Gas		Recovery period				Key species				Protected species				Ecosystem functional impact				Proportion of habitat affected			
Activity	**Threat**	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence
Acoustic prospecting / Seismic surveying a) Surface flood lights & noise b) Single and multi-beam echo sounder c) Air gun & streamers d) Ship activities	*Seabird attraction, disturbance, collision with survey ship (a)	1	6	6	2b	NA	NA	NA	NA	3	5	15	2b	0	6	0	2b	1	6	6	2b
	Acoustic impact from multi-beam echo sounders on marine mammals, reptiles, fish and invertebrates (b)	0	5	0	2a	0	6	0	2a	1	5	0	2a	0	6	0	2a	0	6	0	2a
	Acoustic impact of air gun on marine mammals, reptiles, fish and invertebrates (c)	3	6	18	2a	3	6	18	1c	3	6	18	2a	0	6	0	2a	3	6	18	2a
	Fur seal and sea lion attraction during streamer deployment and retrieval (c)	1	6	6	2b	NA	NA	NA	NA	1	3	3	1c	0	6	0	2b	0	6	0	2b
	*Ship strikes on marine mammals, fish, and reptiles (d)	3	6	18	2a	2	2	4	2b	2	2	4	1c	0	6	0	2b	0	6	0	2b
Exploratory drilling e) Platform flood lights and noise f) Drilling activities g) Platform structure h) Provision of biofouling surfaces i) Sea floor structures including anchors & moorings j) Site surveys using swath mapping k) Underwater lights l) Boomer surveys m) Support vessel activity	Seabird attraction, disturbance, collision with platform (e)	0	6	0	2b	NA	NA	NA	NA	2	5	10	2b	0	6	0	2b	0	6	0	2b
	Marine mammal interaction (g, i)	1	6	6	2a	NA	NA	NA	NA	1	5	5	2a	0	6	0	2b	0	6	0	2b
	Impact on benthos (f, i)	3	5	15	2b	2	6	12	2b	2	6	12	2b	2	6	12	2b	0	6	0	2b
	Acoustic impact from boomer surveys (l)	1	4	4	2a	0	2	0	1c	2	4	8	2a	0	6	0	2a	1	6	6	1b
	Acoustic impact from multibeam echo sounders (j)	1	6	6	2b	1	6	6	2b	1	6	6	2b	0	6	0	2b	0	6	0	2b

	Vector for non-indigenous species (h)	3	4	12	2b	1	4	4	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b
	*****Ship strikes on marine mammals, fish, and reptiles from support vessels (m)	3	6	18	2a	2	2	4	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b
Oil or gas production n) Platform flood lights and noise o) Platform structure p) Import and provision of biofouling surfaces q) Seabed structures r) Support vessel activity s) Underwater pipeline laying, trenching, inspection and maintenance t) Underwater lights u) Underwater noise v) Platform and pipeline exclusion zone	Seabird attraction, disturbance, collision (n)	0	6	0	2b	NA	NA	NA	NA	3	5	15	2b	0	6	0	2b	0	6	0	2b
	Marine mammal interaction (o, q, r, s, t, u)	2	6	12	2b	NA	NA	NA	NA	1	5	5	2a	0	6	0	2b	0	6	0	2b
	Vector for non-indigenous species (p)	3	4	12	2b	1	4	4	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b
	Impact on benthos (q, s)	1	6	6	2b	1	6	6	2b	2	6	12	2b	2	6	12	2b	1	6	6	2b
	Acoustic impact (u)	0	6	0	2b	0	6	0	1c	1	6	6	1c	0	6	0	2b	1	6	6	2b
	Impact on fished species (o, q, s)	0	6	0	2b	0	6	0	2b	0	6	0	2b	0	6	0	2b	0	6	0	2b
	Effects of spatial displacement of fishing on commercial fish stocks (v)	1	5	5	2b	1	5	5	2b	NA	NA	NA	NA	0	4	0	2b	1	5	5	2b
	*****Ship strikes on marine mammals, fish, and reptiles (r)	3	6	18	2a	2	2	4	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b
Abandonment/ decommissioning w) Surface flood lights and noise x) Well capping y) Recovery of all equipment, plant & machinery z) Abandonment, sinking of platform and equipment aa) Underwater lights bb) Underwater cc) noise dd) Material degradation ee) Support vessel activity	Seabird attraction, disturbance, collision (w)	0	6	0	2b	NA	NA	NA	NA	2	5	10	2b	0	6	0	2b	0	6	0	2b
	Marine mammal interaction (y, z, aa, bb)	2	6	12	2b	NA	NA	NA	NA	1	5	5	2b	0	6	0	2b	0	6	0	2b
	Impact on benthos of removal of platform etc. (x,y)	2	6	12	2b	1	6	6	2b	1	6	6	2b	1	6	6	2b	0	6	0	2b
	Impact on benthos of sinking and abandonment of platform etc. (x, z, dd)	2	6	12	2b	1	6	6	2b	1	6	6	2b	1	6	6	2b	1	6	6	2b
	*****Ship strikes on marine mammals, fish, and reptiles (ee)	3	6	18	2a	1	2	2	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b

4.2 Carbon sequestration

4.2.1 Background

Carbon capture and sequestration (CCS) is the process of capturing carbon dioxide (CO_2) and then storing it as a means of mitigating the contribution of fossil fuel emissions to global warming. CCS usually involves injecting CO_2, generally in supercritical form, directly into underground geological formations, such as oil fields, gas fields, saline formations, un-mineable coal seams (Herzog and Golomb 2004, Zenz House et al. 2006). CO_2 has also been injected into declining oil fields to increase the pressure in the field and improve oil recovery (Moritis 2006). A major concern of CCS is the leakage of stored CO_2 (Benson 2005). For this reason abandoned oil and gas fields are considered good candidates as they have stored hydrocarbons for millions of years, and there is often good geological information about the size of the reservoir, and cap rock sealing the reservoir. A number of successful pilot projects have been undertaken over the past decade, including the monitoring of the CO_2 movement within the reservoir using seismic surveys. For example, Sleipner Oil Field, Statoil, Norway, has injected 1 Mt CO_2/yr since 1996 (Solomon 2006).

In New Zealand the oil and gas fields off Taranaki are potential candidates for CCS over the next 20-30 years especially as some of the fields are nearing the end of their production and have suitable infrastructure already in place.

4.2.2 Assessment

Our assessment of the ecological risks associated with CCS in New Zealand's EEZ assumed that existing oil and gas facilities and geological structures off Taranaki will be utilised and that little in the way of new infrastructure will be required. Thus there may be two phases to this industry – injection and final decommissioning once the reservoir is full of carbon.

Injection

As in the oil and gas production phase, lights on the injection platform at night will typically attract and disturb seabirds and may cause them to collide with the above sea-surface structure (Black 2005). Although these frequently cause some seabird deaths, on average there will be little impact on most seabird populations, but even a few deaths could affect the recovery of populations of some nationally critical species. Only seabirds in the area at night will be affected but the injection platform may be in place for decades. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk from this activity was assessed to reach a score of 15 with a high level of confidence (Table 4-2).

Marine mammals may interact with an injection platform, or be affected by surface or subsurface activity and lights. Rigs also attract prey species. Seal haul-outs are possible on the leg bracing struts on some platforms. If the interaction is with a threatened species then the impact potentially may be more severe. In deeper parts of the Taranaki basin, species such as sperm whales and beaked whales may be affected. Sea lions and elephant seals are unlikely to be affected in this region. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk to protected marine mammals from this activity was assessed to reach a score of 5 with a high level of confidence (Table 4-2). Recovery was assessed to be in the range of months to years.

If existing infrastructure is utilised then there is little risk of the injection platform being a vector for entry on non-indigenous fauna to New Zealand waters. However, in exceptional circumstances this may occur, perhaps by transfer from and to other vessels and recovery may take years.

Impacts on the benthic community during the carbon injection phase were assessed as minor to moderate (Table 4-2) as the footprint of the facilities will be small as a proportion of the licence area or areas of similar habitat.

Underwater inspection using ROVs or submersibles as well as routine maintenance and pumping will regularly produce some level of underwater noise in the vicinity of the injection platform and more intermittently along the pipeline route. This underwater noise may affect marine mammals, mainly causing then to avoid the area, but we assessed this to pose low risk (6) and that recovery would occur almost immediately after the noise stopped.

CCS may affect stocks of fished species in two ways. Seafloor infrastructure will alienate an area (albeit small) of seafloor so that it no longer provides foraging habitat for demersal fishes. These same structures may also provide a new artificial reef-like surfaces and increase reef habitat in the area for reef associated fishes. Sea platforms and pipelines invariably have a zone of restricted access around them that prevent fishing access to these areas. Unless commercial fish quota is purposefully bought by the CCS company and retired for the duration of the injection phase then commercial fishing will be displaced into the remainder of the quota management area (QMA). The resulting increased fishing pressure has the potential to affect some commercial fish stocks, especially sedentary species with limited migrations.The resulting fishing pressure has the potentail to affects some fish stocks, especially sedentary species with limited migrations. However, the area of a QMA likely affected by a single injection platform will be small and we assessed there to be low risk (5) from this threat.

Abandonment / Decommissioning

The ecological risks associated with this phase will depend on whether the injection platform and equipment is dismantled and removed or sunk to the seafloor and abandoned. The impacts of platform dismantlement and abandonment are considered below. We assumed that any buried pipeline and anchor chains will be left in place as the cost of recovery would be high and the ecological impacts of removal would be equivalent to their initial installation.

Regardless of whether the injection platform is dismantled and removed or sunk and abandoned there will be a great deal of preparatory work on the platform to prepare it for either fate. This is likely over a period of months to require the use of lights at night. These typically attract and disturb seabirds and may cause them to collide with the remaining super-structure. Although these frequently cause some seabird deaths, on average there will be little impact on most seabird populations, but even a few deaths could affect the recovery of populations of some nationally critical species. Using a precautionary approach our assessment assumed that the species affected will be a nationally critical species as these may occur throughout the EEZ. The risk from this activity was assessed to reach a score of 10 with a high level of confidence (Table 4-2). Marine mammals may also be affected during this phase by the increased activity around the platform for a period of months to remove it or abandon it. We assumed no underwater explosions would be used for either scenario. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk to protected marine mammals from this activity was assessed as low (5) with a high level of confidence (Table 4-2). Recovery once the platform is removed may take months to years.

We assessed the risks to seafloor ecosystem of removal of the platform to be minor (6) and that recovery of benthic organisms would take on the order of months to years.

Sinking of a steel platform would have lasting impacts on the local benthic ecosystem as it slowly disintegrated over a period of 50-100 years and so recovery would be very long-term taking many decades with a high level of risk (20). However, the overall area impacted is very likely to be only a small proportion of the benthic ecosystem in the licence area or broadly similar habitats so the overall risk to ecosystem functioning, protected benthic species and key species is low (6).

Risk summary for carbon sequestration

There were no activities associated with carbon sequestration that were considered to represent an extreme environmental risk provisionally indicating prohibited status.

The following activities were considered to be of high environmental risk (15-20) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Support vessel activity causing strikes on marine mammals, fish and reptiles
- Surface lights at night

The following activities were considered to be of moderate environmental risk (7-12) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Underwater pipelines
- Presence of seafloor structures and anchors
- Presence of platform structure
- Well capping
- Recovery of underwater equipment, plant and machinery
- Abandonment sinking of platform and equipment
- Underwater noise

The following activities were considered to be of low environmental risk (0-6) and should be categorised as permitted:

- Vector for non-indigenous species
- Underwater lights
- Declaration of exclusion zone

4.2.3 Avoidance, mitigation, remediation

There are often ways of avoiding, remedying or mitigating the effects of activities that would otherwise put marine species or ecosystems at risk. Below we briefly discuss those relevant to carbon sequestration by deep well injection.

Non-mandatory Department of Conservation guidelines (2006 and 2011) should be followed to avoid or mitigate acoustic impacts on marine mammals.

Avoidance or mitigation of seabird strikes on platforms is possible by limiting unnecessary use of platform lights at night and ensuring that those that are required are directed approximately vertically onto work surfaces. Visual checks of the platform structure at first light each day for the presence of dazed or injured birds and the provision of appropriate care may help to remedy this impact.

Avoidance or mitigation of seals hauling out on platform structures is possible by reducing access to potential haul-out areas. This is recommended for injection platforms that may be in place for decades

Efforts should be made to avoid areas of protected deepwater corals within the footprint of the injection platform and its anchors. Pipelines should also be routed to avoid reef habitat and any other vulnerable benthic habitat.

Avoidance or mitigation of platforms acting as vectors for non-indigenous species is possible by appropriate checking, cleaning, and application of antifouling paint. We understand that Biosecurity New Zealand (MAF-BNZ) is developing an import health standard to cover the import of drilling rigs and legislation and relevant regulations may be put in place in next 2-3 years.

Table 4-2: Expert Panel Assessment: Carbon sequestration. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. Activities are listed (a, b, c, etc) after each threat to which they contribute. The maximum possible level of environmental risk is 30. Extreme environmental risks are highlighted in red, high in yellow, and moderate in green. Low risk activities are not highlighted. *Threats managed under the Maritime Transport Act (1994). NA = not applicable as species assessed are all protected.

Expert Panel Assessment: Carbon Sequestration		Recovery period				Key species				Protected species				Ecosystem functional impact				Proportion of habitat affected			
Activity	**Threat**	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence
Injection a) Platform flood lights and noise b) Platform structure c) Provision of biofouling surfaces d) Seabed structures e) Anchors/moorings f) Pipeline inspection and maintenance g) Underwater noise h) Support vessel activity i) Platform and pipeline exclusion zone	*Seabird attraction, disturbance, collision (a)	0	6	0	2b	NA	NA	NA	NA	3	5	15	2b	0	6	0	2b	0	6	0	2b
	Marine mammal interaction (b, d, e, f, h)	1	6	6	2a	NA	NA	NA	NA	1	5	5	2a	0	6	0	2a	0	6	0	2a
	Vector for non-indigenous species (c)	3	2	6	2b	1	4	4	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b
	Impact on benthos (b, d, e, f)	2	6	12	2b	1	6	6	2b	2	6	12	2b	2	6	12	2b	1	6	6	2b
	Acoustic impact (g)	0	6	0	2b	0	6	0	1c	1	6	6	1c	0	6	0	2b	1	6	6	2b
	Impact on fished species (b, c, d, e)	0	6	0	2b	0	6	0	2b	0	6	0	2b	0	6	0	2b	0	6	0	2b
	Effects of spatial displacement of fishing on commercial fish stocks (i)	1	5	5	2b	1	5	5	2b	NA	NA	NA	NA	0	4	0	2b	1	5	5	2b
	*Ship strikes on marine mammals, fish and reptiles from support vessels (h)	3	6	18	2a	2	2	4	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b
Abandonment/decommissioning j) Surface flood lights & noise k) Well capping l) Recovery of equipment, plant and machinery m) Abandonment, sinking of platform, equipment n) Underwater lights o) Underwater noise p) Material degradation q) Support vessel activity	*Seabird attraction, disturbance, collision (j)	0	6	0	2b	NA	NA	NA	NA	2	5	10	2b	0	6	0	2b	0	6	0	2b
	Marine mammal interaction (k, l, m, n, o)	1	6	6	2b	1	5	5	2b	1	5	5	2b	0	6	0	2b	0	6	0	2b
	Impact on benthos of removal of platform etc (l, m)	2	6	12	2b	1	6	6	2b	1	6	6	2b	1	6	6	2b	0	6	0	2b
	Impact on benthos of sinking and abandonment of platform etc (m, p)	4	5	20	2b	1	6	6	2b	1	6	6	2b	1	6	6	2b	1	6	6	2b
	*Ship strikes on mammals, fish and reptiles (q)	3	6	18	2a	1	2	2	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b

4.3 Gas (methane) hydrates

4.3.1 Background

Gas hydrate is a frozen crystalline solid consisting of “cages” of water molecules that surround and hold gas molecules (essentially methane) inside. New Zealand has one of the largest single offshore gas hydrate provinces in the world, along the east coast of the North Island (Hikurangi Margin) and the south-west coast of the South Island (Fiordland Margin) (CAENZ. 2009, Pecher and Henrys 2003). Other deposits are suspected from at least four areas (Figure 4-1). Gas hydrates occur in specific pressure-temperature conditions. Offshore, these conditions are met within the upper 500 m of sediments beneath the seafloor and in water depths of at least 500 m. Most usually the free gas is contained within a stability zone well beneath the seafloor by the layer of solid gas hydrates which acts as a "seal" (Pecher and Henrys 2003). Rupture of the gas hydrate stability zone, by e.g. geological faulting or large landslides may however result in gas hydrates and free gas reaching the seafloor forming cold (methane) seeps with associated specialised fauna.

Initial estimates indicate a potential immense source of natural gas with 820 trillion cubic feet of natural equivalent for the Hikurangi Margin alone (Pecher and Henrys 2003). For comparison, New Zealand energy consumption from natural gas in 2008 was 0.18 tcf equivalent (www.med.govt.nz).

Current research on methane hydrate is focusing on: (1) quantifying the resource potential; (2) understanding gas formation to improve operational safety and avoid hazards (e.g., placement of infrastructure on seafloor, drilling and production scenarios); and (3) develop environmentally and economically sound exploitation protocols (Pecher and Henrys 2003).

Exploitation remains a great challenge because of the offshore location and most remarkably because about 160 times the volume of gas is released from hydrate when it is brought to the surface. Exploitation requires drilling infrastructure, such as rigs, production platforms and pipelines, capable of resisting extreme environmental and pressure conditions and at present these are only at the experimental stages in Japan and the USA (CAENZ 2009).

In addition to their energy potential, gas hydrates are of interest because they may affect seafloor instability and therefore represent a hazard. Because methane is a greenhouse gas, release in the atmosphere may potentially have an adverse effect on global climate.

4.3.2 Assessment

Similar to the petroleum oil and gas industry there are likely to be four phases to the exploitation of gas hydrates; prospecting, exploration, production and abandonment / decommissioning. For each phase we identified and assessed the ecological impact of several distinct activities (Table 4-3). Below we present the main results for each phase.

Prospecting

Seismic prospecting using surface ships is the main activity in the EEZ during this phase. The survey ship acquires bathymetric information using a multi-beam echo-sounder, and information about underlying geological structures using seismic air guns and a streamer comprising multiple hydrophones that may be up to 15km long. The streamer is typically deployed at ~2 knots and acquisition of data occurs at 5 knots. A very large area, perhaps approaching 100% of the prospecting licence area, may be surveyed during this phase though sequentially over a period of several weeks to a few months. We assume the habitat area under consideration will be either the Hikurangi Margin or the Fiordland margin (see Figure 4-1).

The acoustic impact of seismic surveys on marine mammals, in particular, is well documented (Gordon & Moscrop 1996, Cox et al. 2006, Brandon et al. 2008, Di Iorio and Clark 2010) but may also affect a range of marine reptiles, fish and invertebrates. The consequences for marine mammals will vary from none to behavioural (may leave area) to acute injury (ear drum damage) to serious (death) depending on noise level encountered, species and habitat. Beaked whales are thought to be particularly at risk. There may also be cumulative effects from repeated exposure. Noise travels great distances underwater and so the footprint of this activity may be very broad though fatal impacts will be much more restricted in area as sound intensity typically falls as the square of the distance from the source. Acoustic depth sounders and multibeam echo-sounders used for swath mapping pose little risk but high energy seismic devices such as air guns used for mapping sub seafloor geological structures pose a much greater risk. Using a precautionary approach our assessment assumed that air guns were used and the species affected was a nationally critical species such as southern right whales as these may occur throughout the EEZ though they occur in different areas at different times of the year. The risk from this activity was assessed to reach a score of 18 with a high level of confidence (Table 4-3) indicating the need for this to be a discretionary activity.

Fur seals and sea lions may be attracted to the seismic streamer during deployment and retrieval and could become entangled and injured or drown. The number of individuals affected is likely to be small given the one-off nature of a seismic survey and impacts will be largely restricted to locations where deployment and retrieval takes place at slow speeds. Using a precautionary approach our assessment assumed that the species affected was the New Zealand sea lion though few occur north of about 45^{o} S. The risk from this activity was assessed to reach a score of 12 principally because the recovery of any affected population will be slow (Table 4-3). However, ecosystem effects will be negligible.

Lights on survey ships at night typically attract and disturb seabirds and may cause them to collide with the ship (Black 2005). These effects are covered under the Maritime Transport Act (1994) and the Wildlife Act (1953).

Ship strikes on marine mammals, fish, and reptiles may occur during the survey and during transits to and from the survey area. These effects are covered under the Maritime Transport Act (1994) and the Marine Mammal Protection Act (1978).

We have not assessed the potential for survey ships to act as vectors for the introduction of non-indigenous species as this is already managed under existing legislation.

Exploration

A wider range of activities occur during this phase albeit over a much smaller area than during the prospecting phase (Table 4-3). Typically a drill ship or platform is used to assess the reserves of specific rock strata. A single drill hole may take weeks to a few months to reach its target depth depending on the rock type encountered. A number of holes may be drilled on single exploration permit.

Lights on a drilling platform at night typically attract and disturb seabirds and may cause them to collide with the above sea surface structure (Black 2005). Although these frequently cause some seabird deaths, on average there will be little impact on most seabird populations as the duration of this phase in any one place is short (months), but even a few deaths could affect the recovery of populations of some nationally critical species. Only seabirds in the area at night will be affected. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk from this activity was assessed to reach a score of 10 with a high level of confidence (Table 4-3) indicating the need for this to be a discretionary activity.

Marine mammals may interact with a drilling platform, or be affected by surface or subsurface activity and lights. Rigs also attract prey species. Seal haul-outs are possible on the leg bracing struts on some platforms. If the interaction is with a threatened species then the impact potentially may be more severe. Along slope margins species such as sperm whales and beaked whales may be affected. In southern areas sea lions and elephant seals may be affected. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk to marine mammals from this activity was assessed to reach a score of 6 with a high level of confidence (Table 4-3) indicating that this activity could be classified as permitted.

The benthic ecosystem on the seafloor will be impacted by exploratory drilling (assuming drilling activity is similar to that for oil & gas, Patin 1999) but the affected proportion of the benthic habitat in the licence area and the slope margin is likely to be very small (<1-5%). At the drill site itself the legs of the drill platform may directly impact the seafloor, as will the drill head of ~5-10 m^2 and any mooring chain used that may be up to 1-2 km long with or without an anchor. When a well is drilled, the lubricant used is of three types: oil-based, synthetic, or water-based (in order of decreasing severity of impact on the environment). The type of drilling lubricant used has a large bearing on the toxicity of drill cuttings (Addy et al. 1984, Olsgard & Grey 1995, Patin 1999). In the oil and gas industry these were formerly dumped on the seabed and it is likely in this industry drill cuttings will be collected and stored during exploratory phase and ultimately disposed of on land (John Pfahlert personal comment). It is strongly recommended that drill cuttings in the gas hydrate industry are collected, processed and disposed of in a similar fasion. Discharges from the drilling platform or ship are already managed under existing legislation. The level of benthic impact will be low for most areas but impacts could be higher in some areas if they contain protected species of deepwater corals or specialised cold (methane) seep communities (which include a nationally critical clam species that is among the marine invertebrate species most at risk from extinction in NZ, Freeman et al 2010). Our functional impact assessment is contingent upon seep communities being affected during the exploratory drilling process and through methane extraction altering fluid flow at seep sites and/or direct damage from rig or production facilities. Clearly, careful placement of drilling sites to avoid this occurring would greatly reduce the risk. Under this assumption, risk levels for recovery of the benthos, and impacts on key species, protected benthic species such as deepwater corals, and the functioning of the ecosystem were all high (Table 4-3). Recovery of affected benthos after completion of exploratory drilling is likely to take years to decades as some potentially affected species such as seep tube worms are thought to be very long-lived and slow growing (Fisher et al 2007).

Drilling activities will produce some level of underwater noise from the drill itself, and any submersed cutters, pumps or other machinery. This underwater noise may affect marine mammals, mainly causing then to avoid the area, but we assessed this to pose low risk (6) and that recovery would be rapid after the noise stopped.

Exploratory drilling platforms brought in to New Zealand from Australia or further afield may act as vectors for non-indigenous species. The functional impacts on the ecosystem surrounding the rig is probably minor as vectored species are unlikely to survive independently of the rig in deep offshore waters. The rig may act as a stepping stone for non-indigenous species to invade shallow coastal habitats.

Production

The production phase for gas hydrates may or may not involve a surface production platform and a pipeline to shore. It is possible that a seabed facility could be put in place leading directly to a pipeline to shore or to a surface mooring for transfer of oil or gas to tankers. This technology is still under development and so there is a high degree of uncertainty in assessing potential effects.

If a production platform is used, then as during the exploratory drilling phase, lights on the platform at night will typically attract and disturb seabirds and may cause them to collide with the above sea-surface structure. Although these frequently cause some seabird deaths, on average there will be little impact on most seabird populations, but even a few deaths could affect the recovery of populations of some nationally critical species. Only seabirds in the area at night will be affected but the production platform may be in place for decades. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk from this activity was assessed to reach a score of 15 with a high level of confidence (Table 4-3). Marine mammals may interact with a production platform. Seal haul-outs are possible on the leg bracing struts on some platforms. Rigs attract prey species. If the interaction is with a threatened species then the impact potentially may be more severe. Along deep slope margins species such as sperm whales and beaked whales may be affected. In southern areas sea lions and elephant seals may be affected. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk to protected marine mammals from this activity was assessed to reach a score of 5 with a high level of confidence (Table 3-3). Recovery once the platform was removed may take months.

Production platforms are likely to be purpose built in New Zealand or overseas. Platforms brought in to New Zealand from Australia or further afield may act as vectors for non-indigenous species but the likelihood is low for a new platform with fresh antifouling. New Zealand built platforms should pose little risk. The functional impacts on the ecosystem surrounding the platform is probably minor as vectored species are unlikely to survive independently of the rig in deep offshore waters. However, the platform may act as a stepping stone for non-indigenous species to invade shallow coastal habitats.

The benthic ecosystem on the seafloor will be impacted during the long production phase (Fisher et al 2007) but the affected proportion of the benthic habitat in the licence area is likely to be very small. At the production site itself the legs of the production platform may directly impact the seafloor, as will the well head of ~5-10 m^2 and any mooring chain used that may be up to 1-2 km long with or without an anchor. If a submerged pipeline is built to bring the gas onshore then the seabed will be impacted during construction and trenching. Discharges from the platform are already managed under existing legislation. The level of benthic impact will be low for most areas but impacts could be higher in some areas if they contain protected species of deepwater corals or specialised cold (methane) seep communities. We have taken a precautionary approach and assumed that the production well, production platform and any pipelines are sited near or among seep communities and deep reef communities which will recieve direct damage. Moreover, methane extraction may alter fluid flow at seep sites and as the associated fauna is very long lived (in excess of 100 years); recovery of this fauna will be very long term (many decades) or may never occur. Away from seep sites the benthic fauna on soft sediments is probably broadly similar over a wide area. Under the above sceanrio, during the production phase of gas hydrate extraction risk levels for recovery of the benthos, and impacts on key species, protected benthic species such as deepwater corals, and the functioning of the ecosystem is high (Table 4-3).

Installation of the production platform, pipeline construction and trenching, underwater inspection using ROVs or submersibles as well as routine maintenance and pumping will regularly produce some level of underwater noise in the vicinity of the production platform and more intermittently along the pipeline route. This underwater noise may affect marine mammals, mainly causing then to avoid the area, but we assessed this to pose low risk (6) and that recovery would occur almost immediately after the noise stopped (Table 4-3).

Gas hydrate production may affect stocks of fished species in two ways. There may be some direct effects during the construction of the well head, installation and anchoring of a platform and construction and trenching of a pipeline. These structures will also alienate an area (albeit small) of seafloor so that it no longer provides foraging habitat for demersal fishes. These same structures may also provide a new artificial reef-like surfaces and increase reef habitat in the area for reef associated fishes. Production platforms and pipelines invariably have a zone of restricted access around them that restricts fishing access to these areas. Unless commercial fish quota is purposefully bought by the production company and retired for the duration of the production phase then commercial fishing may be displaced into the remainder of the quota management area (QMA). The resulting increased fishing pressure has the potential to affect some commercial fish stocks, especially sedentary species with limited migrations. However, the area of a QMA likely affected by a single production platform will be small and we assessed there to be low risk (5) from this threat (Table 4-3). Regulators need to be mindful, however, of the possibility for multiple production facilities and pipelines to occur in a single region and for fishing to be forced into an ever decreasing proportion of a QMA.

Abandonment / Decommissioning

The ecological risks associated with this phase will depend on whether the production platform and equipment is dismantled and removed, sunk to the seafloor and abandoned, or left intact for another use such as carbon sequestration (see section 4.2). If left intact for another use then the ecological risks will be largely the same as during the production phase and are not considered further here. The impacts of platform dismantlement and abandonment are considered below. We assumed that any buried pipeline and anchor chains will be left in place as the cost of recovery would be high and the ecological impacts of removal would be equivalent to their initial installation.

Regardless of whether the production platform is dismantled and removed or sunk and abandoned there will be a great deal of preparatory work on the platform to prepare it for either fate. This is likely over a period of months to require the use of lights at night. These typically attract and disturb seabirds and may cause them to collide with the remaining super-structure. Although these frequently cause some seabird deaths, on average there will be little impact on most seabird populations, but even a few deaths could affect the recovery of populations of some nationally critical species. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk from this activity was assessed to reach a score of 10 with a high level of confidence (Table 4-3). Marine mammals may also be affected during this phase by the increased activity around the platform for a period of months to remove it or abandon it. We assumed no underwater explosions would be used for either scenario. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk to protected marine mammals from this activity was assessed as low (5) with a high level of confidence (Table 4-3). Recovery, once the platform is removed, may take months to years.

We assessed the risks to seafloor ecosystem of removal of the platform to be minor (6) and that recovery of benthic organisms from this activity would take on the order of months to years.

Sinking of a steel platform would have lasting impacts on the local benthic ecosystem as it slowly disintegrated over a period of 50-100 years and so recovery would be very long-term taking many decades with a moderately high level of risk (20). However, the overall area impacted is very likely to be only a small proportion of the benthic ecosystem in the licence area or broadly similar habitats along the slope margin so the overall risk to ecosystem functioning, protected benthic species and key species is low (6).

Risk summary for gas hydrate extraction

There were no activities associated with gas hydrate extraction that were considered to represent an extreme environmental risk provisionally indicating prohibited status.

The following activities were considered to be of high environmental risk (15-20) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Deployment of airguns and streamers during seismic surveys
- Surface flood lights at night
- Support vessel activity causing strikes on marine mammals, fish and reptiles
- Sea floor structures
- Installation of pipelines
- Drilling activities
- Gas hydrate extraction
- Well capping
- Platform abandonment

The following activities were considered to be of moderate environmental risk (7-12) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Vector for non-indigenous species
- Recovery of underwater equipment, plant and machinery
- Use of underwater lights

- Production of incidental underwater noise
- Material degradation

The following activities were considered to be of low environmental risk (0-6) and should be categorised as permitted:

- Single and multibeam echo sounding
- Declaration of exclusion zone

4.3.3 Avoidance, mitigation, remediation

There are often ways of avoiding, remedying or mitigating the effects of activities that would otherwise put marine species or ecosystems at risk. Below we briefly discuss those relevant to gas hydrate exploitation.

Non-mandatory Department of Conservation guidelines (2006 and 2011) should be followed to avoid or mitigate acoustic impacts on marine mammals.

Entanglement of fur seals and sea lions during deployment and retrieval of the seismic streamer can be minimised by keeping a close watch for them around the stern of the vessel and halting operations if seals are in danger.

Avoidance or mitigation of seabird strikes on drilling and production platforms is possible by limiting unnecessary use of platform lights at night and ensuring that those that are required are directed approximately vertically onto work surfaces. Visual checks of the platform structure at first light each day for the presence of dazed or injured birds and the provision of appropriate care may help to remedy this impact.

Avoidance or mitigation of seals hauling out on platform structures is possible by reducing access to potential haul-out areas but modifications to exploration platforms is unlikely given that they invariably come to NZ from overseas for a relatively short period of intense activity.

Risks to seep communities during the exploratory drilling process or through methane extraction altering fluid flow at seep sites and/or direct damage from rig or production facilities can be avoided or minimised through selection of drilling sites and production wells least likely to cause damage to these vulnerable communities.

Efforts should be made to avoid areas of protected deepwater corals and other vulnerable species within the footprint of the production platform and its anchors. Pipelines should also be routed to avoid reef habitat and any other vulnerable benthic habitat.

Avoidance or mitigation of exploratory or production platforms acting as vectors for non-indigenous species is possible by appropriate checking, cleaning, and application of antifouling paints. We understand that Biosecurity New Zealand (MAF-BNZ) is developing an import health standard to cover the import of drilling rigs and legislation and relevant regulations may be put in place in next 2-3 years.

Table 4-3: Expert Panel Assessment: Gas hydrate extraction. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. Activities are listed (a, b, c, etc) after each threat to which they contribute. The maximum possible level of environmental risk is 30. Extreme environmental risks are highlighted in red, high in yellow, and moderate in green. Low risk activities are not highlighted. *Threats managed under the Maritime Transport Act (1994). NA = not applicable as species assessed are all protected.

Expert Panel Assessment: Gas (methane) hydrates		Recovery period				Key species				Protected species				Ecosystem functional impact				Proportion of habitat affected			
Activity	**Threat**	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence
Acoustic prospecting / Seismic surveying a) Surface flood lights and noise b) Acoustic sounder c) Multibeam echo sounder d) Air gun & streamers e) Ship activities	*Seabird attraction, disturbance, collision (a)	1	6	6	2b	NA	NA	NA	NA	3	5	15	2b	0	6	0	2b	1	6	6	2b
	Acoustic impact from multi-beam echo sounders on marine mammals, reptiles, fish and invertebrates (b, c)	0	5	0	2a	0	6	0	2a	1	5	0	2a	0	6	0	2a	0	6	0	2a
	Acoustic impact from air guns on marine mammals, reptiles, fish and invertebrates (d)	3	6	18	2a	3	6	18	1c	3	6	18	2a	0	6	0	2a	3	6	18	2a
	Fur seal and sea lion attraction during streamer deployment and retrieval (d)	2	6	12	2b	NA	NA	NA	NA	1	3	3	1c	0	6	0	2b	0	6	0	2b
	*Ship strikes on marine mammals, fish, and reptiles (e)	2	6	12	2b	2	2	4	2b	2	2	4	1c	0	6	0	2b	0	6	0	2b
Exploratory drilling f) Platform flood lights and noise g) Platform structure h) Sea floor structures including anchors & moorings i) Site surveys using swath mapping j) Underwater lights & noise k) Support vessel activities l) Drilling activities	*Seabird attraction, disturbance, collision (f)	0	6	0	2b	NA	NA	NA	NA	2	5	10	2b	0	6	0	2b	0	6	0	2b
	Marine mammal interaction (g, h, j)	1	6	6	2a	NA	NA	NA	NA	1	5	5	2a	0	6	0	2b	0	6	0	2b
	Acoustic impact from multi-beam echo sounders on marine mammals, reptiles, fish and invertebrates (i)	0	5	0	2a	0	6	0	2a	1	5	0	2a	0	6	0	2a	0	6	0	2a
	Impact on benthos (h, l)	4	5	20	2b	4	4	16	1c	4	4	16	1c	4	4	16	1c	1	5	5	1c
	Vector for non-indigenous species (g)	3	4	12	2b	1	4	4	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b

	*Ship strikes on marine mammals, fish, and reptiles from support vessels (k)	3	6	18	2a	2	2	4	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b
Gas hydrate production m) Platform flood lights and noise n) Platform structure o) Seabed structures p) Anchors/moorings q) Pipeline laying, trenching r) Underwater lights s) Underwater noise t) Support vessel activities u) Platform and pipeline exclusion zone v) Gas hydrate extraction	*Seabird attraction, disturbance, collision (l)	0	6	0	2b	NA	NA	NA	NA	3	5	15	2b	0	6	0	2b	0	6	0	2b
	Marine mammal interaction (n, o, p, q,r)	1	6	6	2a	NA	NA	NA	NA	1	5	5	2a	0	6	0	2b	0	6	0	2b
	Vector for non-indigenous species (n)	3	4	12	2b	1	4	4	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b
	Impact on benthos (o, p, q v)	5	4	20	1c	4	4	16	1c	4	4	16	1c	4	4	16	1c	1	5	5	1c
	Acoustic impact (s)	0	6	0	2b	0	6	0	1c	1	6	6	1c	0	6	0	2b	1	6	6	2b
	Spatial displacement of fishing activities (u)	0	6	0	2b	0	6	0	2b	0	6	0	2b	0	6	0	2b	0	6	0	2b
	*Ship strikes on marine mammals, fish, and reptiles from support vessels (t)	3	6	18	2a	2	2	4	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b
Abandonment/ decommissioning w) Surface flood lights and noise x) Well capping y) Recovery of all equipment, plant & machinery z) Abandonment, sinking of platform and equipment aa) Underwater lights and noise bb) Material degradation cc) Support vessel activities	*Seabird attraction, disturbance, collision (w)	0	6	0	2b	NA	NA	NA	NA	2	5	10	2b	0	6	0	2b	0	6	0	2b
	Marine mammal interaction (x, z, aa)	1	6	6	2b	NA	NA	NA	NA	1	5	5	2b	0	6	0	2b	0	6	0	2b
	Impact on benthos of removal of platform etc (x, y)	2	6	12	2b	1	6	6	2b	1	6	6	2b	1	6	6	2b	0	6	0	2b
	Impact on benthos of sinking and abandonment of platform etc (x,z)	4	5	20	2b	1	6	6	2b	1	6	6	2b	1	6	6	2b	1	6	6	2b
	*Ship strikes on marine mammals, fish, and reptiles (cc)	3	6	18	2a	1	2	2	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b

4.4 Ironsand mining

4.4.1 Background

Ironsands are the largest known reserve of metalliferous ore in New Zealand. Ironsand is a general term for sand-sized grains of heavy iron-rich minerals, principally magnetite (Fe_3O_4), titanomagnetite (Fe_2TiO_3), and ilmenite ($FeTiO_3$). New Zealand's iron sands occur extensively in coastal dunes and the adjacent continental shelf of the western North Island (see Figure 4-1), and have been successfully mined onshore for over 35 years.

Offshore surficial deposits of ironsand have been known since the early 1960's, but estimates of their reserves are poorly constrained and to date remain largely unexploited. The coastal ironsands of the central North Island west coast are primarily derived from erosion of the Taranaki volcanics, but local fluxes of ironsand, for example off the Mokau River, suggest input from other sources, such as recycling of older, onshore dunes. The geometry of the ironsand deposits is locally influenced by paleo-topographic features on the shelf from the post-last glacial sea level rise. Underlying ironsand-rich deposits might also occur, reflecting older Quaternary shorelines and changes in sea level. The continental shelf of the North Is west coast is subject to a vigorous wave climate driven by the prevailing westerly winds and southerly storms, and accordingly, the seabed of the inner and mid-shelf is naturally subjected to frequent resuspension and energetic near-bed currents, as evidenced by the extensive occurrence of sand sheets, gravels, and sediment bedforms (e.g. dunes and ripples).

The marine iron sand industry is still at an early stage. Prospecting and Exploration licences have been granted for large areas off the west coast of the North Island to a number of different companies but none have yet progressed to the production phase. To date, extraction methods will likely utilise well established suction-cutter dredge technology, removing or disturbing significant quantities of the top few to tens of metres of seabed sediment. Other technologies are developing in response to international demand. Extraction methods will be guided by the depth and three-dimensional distribution of the resource, in combination with logistical practicalities and environmental considerations. Mining targets currently constitute only of a small fraction of the total permit areas.

4.4.2 Assessment

We assessed three phases of New Zealand's fledgling iron sand mining industry; prospecting, exploration, and production. Compared to the oil industry where the production facilities may be largely static for decades, decommissioning in the iron sand mining industry is likely to be a relatively routine part of on-going production as equipment is moved around the mining site once ore-bearing sands in one part have been exhausted and any pit created in the process has been backfilled with de-ored sediments. Thus we have not considered decommissioning as a separate phase in this industry. For each phase we identified and assessed the ecological impact of several distinct activities (Table 4-4). Below we present the main results for each phase.

Prospecting

This phase is likely to involve aerial or towed magnetometer surveys over a large proportion of the prospecting licence areas. Ship strikes on marine mammals, fish, and reptiles may occur during the survey and during transits to and from the survey area. These effects are covered under the Maritime Transport Act (1994) and the Marine Mammal Protection Act (1978).

Lights on survey ships at night typically attract and disturb seabirds and may cause them to collide with the ship (Black 2005). These effects are covered under the Maritime Transport Act (1994).

The magnetometer device is passive; merely recording variations in the local magnetic field so poses no threat to any part of the marine ecosystem.

Acoustic swath mapping may be used to define the bathymetry of promising areas and high resolution seismic (e.g. Boomer, CHIRP) may be used to define the sub-seafloor geological strata. Use of air guns to obtain deeper seismic information in these surveys is unlikely. The acoustic impact of seismic surveys on marine mammals, in particular, is well documented (Gordon & Moscrop 1996, Cox et al. 2006, Brandon et al. 2008, Di Iorio and Clark 2010) but may also affect a range of marine reptiles, fish and invertebrates. The consequences for marine mammals from the seismic gear likely to be used for these surveys will vary from none to behavioural (may leave area) perhaps to acute injury (ear drum damage) depending on noise level encountered, species and habitat. Beaked whales are thought to be particularly at risk. There may also be cumulative effects from repeated exposure.

Noise travels great distances underwater and so the footprint of this activity may be very broad though the greatest impacts will be much more restricted in area as sound intensity typically falls as the square of the distance from the source. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species such as southern right whales as these may occur throughout the EEZ though they occur in different areas at different times of the year. The risk from this activity was assessed to reach a moderate score of 8 with a high level of confidence (Table 4-4). Use of air guns, though inappropriate for defining these near seabed surface deposits, would considerably increase this risk.

Obtaining cores of sediment through the ore bearing strata to quantify ore concentrations at various depths is likely to occur over a wide area during this phase. Cores are likely to be about 12-15cm in diameter and affect a very small proportion of the sediment habitats in the area. The risk to benthic habitats and organisms from this activity is likely to be negligible (Table 4-4).

Exploration

In this phase more intensive evaluation of potential mining sites will take place. The focus is likely to be on areas of 30-50 km^2 capable of sustaining mining for a decade or more.

Within the more promising areas multi-beam echo-sounders are likely to be used to define the bathymetry and high resolution seismic (e.g. Boomer, CHIRP) may be used to better define the sub-seafloor geological strata. The area affected is likely to be a small proportion (<1-5%) of the licence area or the area of broadly similar habitat. The risk to marine mammals and other organisms from this activity was assessed to reach a score of 8 with a high level of confidence (Table 4-4). Use of air guns, though inappropriate for defining near seabed surface deposits, would considerably increase this risk.

Obtaining sediment core/drill logs to better quantify ore concentrations at various depths is likely to continue during this phase but will probably be most concentrated over a small proportion (<1-5%) of the licence area, or areas of broadly similar habitat. The risk to benthic habitats and organisms from this activity is likely to be minor (Table 4-4).

Production

The extraction methods for deeper areas in the EEZ are still unclear in detail but may involve some form of seabed suction-dredge that pumps a slurry of sandy sediment and seawater to a surface vessel that extracts and concentrates the ore, and via a second pipeline returns the unwanted sediment back to the seafloor for stock-piling or back filling of the excavation pit that may be up to 10 m deep (Bernie Napp pers. com.). This activity will require large ships, which may moor to ‘permanent’ anchors blocks or anchor moorings. There is likely to be a sediment plume originating from the active mine face as well as from the slurry pipe depositing deored sediments. This arrangement is more probable than mining of ironsands in the shallower territorial sea where a variety of standard dredges could be used. Where iron sands lie well below the surface sediments it is possible that “keyhole” technologies are available or may develop where resources could be removed from within the ore bearing sediment thereby minimising disruption at the seabed containing the majority of benthic organisms, but some slumping may still occur.

To be profitable many millions of tons of ore bearing sands will need to be extracted each year by a mining operation. Mr Bernie Napp of Straterra noted during the workshop that some industry estimates of 100 million tonnes per year (Mt/y) were perhaps overly optimistic, and suggested that 30-50 Mt/y were likely achievable. This equates approximately to an area of 1-2 km^2 mined to a depth of 10 m each year, possibly for decades. Impressive though this sounds, this is likely to be a relatively small proportion of the total ironsand habitat in the EEZ.

The benthic ecosystem on the seafloor in and around the mining operations will be sequentially and severely impacted during the long production phase as areas are mined and backfilled with de-ored sediment and an area downstream of the mining operations will be affected by smothering from sediments falling out of suspension from sediment plumes. An idea of the likely impacts on the benthos can be gained from studies of sand and gravel extraction in North America and Europe (e.g. Boyd et al. 2005). Course grains will settle quickly but the fine-grained suspended fraction (finer silts and clays) may be carried some distance depending on current strength and resuspension due to wave activity. Smothering from the plume will decrease as the distance from the plume source increases. In areas being actively mined we surmise that probably close to 100% of the benthic organisms will be killed during the mining or ore concentration process. However, the affected proportion of the benthic habitat in the licence area and areas of broadly similar habitat is likely to be small. Thus, the functional impact on the benthic ecosystem as a whole, as well impacts on key species, are likely to be moderate (Table 4-4).

Although there are few data from offshore ironsand habitats it is quite possible that recovery of the benthic ecosystem on the ore depleted sediments will be moderately quick, on the order of months for the smaller meiofanua to years for the longer lived, slower growing macro-fauna such as bivalves, gastropods, crustaceans and echinoderms (e.g. Boyd et al 2005) (Table 4-4). This is a reflection of high levels of natural background disturbance due to the high wave environment on the west coast of the North Island that likely favours benthic species with fast to moderate growth, early maturation and high fecundity.

The sediment plumes may also impact the water column ecosystem by increasing turbidity, thereby shading phytoplankton, or through the irritation of gills of fish and invertebrates. The area affected may reach 5-20% of the licence area but effects on key species, protected species and ecosystem function possibly will be minor (Table 4-4). Recovery of the pelagic ecosystem is expected to be rapid once sediment plumes stop.

Mining ironsands in the EEZ close to the outer limit of the territorial sea, by altering the seafloor typography offshore, might affect the nearshore wave climate, and thus rates of beach accretion or erosion (e.g. Roos and van der Werf 2010). Storing de-ored sediment in very large stockpiles (i.e. building a shoal) could have a greater effect nearshore than digging pits to extract the ore. Rapid backfilling of pits as mining progresses will minimise any nearshore effects, although this could occur naturally with wave-driven resuspension. Only a small proportion of the shoreline is likely to be affected (<<1%) but recovery will possibly be moderate taking months to years once mining stopped (Table 4-4).

Mining activities on the seabed will produce some level of underwater noise from the suction head, and any submersed cutters, pumps, anchoring or tethering systems, or other machinery. This underwater noise may affect marine mammals, mainly causing then to avoid the area, but we assessed this to pose low risk (8) and that recovery would take weeks to months after the noise stopped.

Entanglement of megafauna in subsurface equipment including anchor lines, mooring lines, marker buoy lines, power cabling or hydraulic lines is a possibility. Only a tiny fraction of the area (<<1%) is likely to have such hazards to fauna. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk to protected marine mammals from this activity was assessed as moderate (9) with a high level of confidence (Table 4-4). Recovery of affected populations should these entanglement hazards be removed is expected to take years as the species concerned are slow growing, late maturing with low fecundity.

Ships brought in to New Zealand from Australia or further afield to concentrate ores may act as vectors for non-indigenous species but the likelihood is low for a vessel with fresh antifouling. New Zealand modified ships should pose little risk. The functional impact on the ecosystem surrounding the ore concentration vessel is probably minor as vectored species are unlikely to survive independently of the ship in deep offshore waters. However, the ship may act as a stepping stone for non-indigenous species to invade shallow coastal habitats.

Mining ironsands in the EEZ may affect stocks of fished species in two ways. There may be some direct effects on fish during extraction of the ore-bearing sand, and redeposited sands may take several years before they provide the full range of prey species to benthic foraging fish. Additionally fish may move away from the area of active mining and plume influence. Mining areas will invariably have a zone of restricted access around them that prevents fishing activity. Unless commercial fish quota is purposefully bought by the mining company and retired for the duration of the production phase then commercial fishing will be displaced into the remainder of the quota management area (QMA). The resulting fishing pressure has the potentail to affects some fish stocks, especially sedentary species with limited migrations. While the area of a QMA affected by direct effects on fish stocks is likely to be small, the effects of displaced fishing will be felt over a much greater area. We assessed there to be low (5) risks to key fish stocks and moderate (10) risks to ecosystem functioning from direct effects on fish stocks, and low risk (5) from displaced fishing to key fish stocks and ecosystem functioning (Table 4-4). Regulators need to be mindful, however, of the possibility for multiple mining operations to occur in a single region and direct and indirect effects on fish stocks to proportionally increase within a QMA.

Risk summary for iron sand mining

There were no activities associated with iron sand mining that were considered to represent an extreme environmental risk provisionally indicating prohibited status.

The following activities were considered to be of high environmental risk (15-20) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Support vessel activity causing strikes on marine mammals, fish and reptiles
- Surface flood lights at night
- Testing and operation of undersea mining equipment with associated hydraulic lines, power cables and umbilical’s creating an entanglement hazard

The following activities were considered to be of moderate environmental risk (7-12) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Seafloor suction / extraction
- Use of high resolution seismics e.g. Boomer, CHIRP
- Creation of sea floor pits or sediment stock piles
- Discharge of sediments causing plumes
- Placement of seafloor structures, anchors or moorings
- Import and provision of biofouling surfaces
- Seafloor slurry pipes
- Underwater flood lights
- Incidental underwater noise
- Declaration of mining area exclusion zone

The following activities were considered to be of low environmental risk (0-6) and should be categorised as permitted:

- Single and multibeam echo sounding
- Magnetometer surveys
- Small scale coring operations

4.4.3 Avoidance, mitigation, remediation

There are often ways of avoiding, remedying or mitigating the effects of activities that would otherwise put marine species or ecosystems at risk. Below we briefly discuss those relevant to iron sand mining.

Non-mandatory Department of Conservation guidelines (2006 and 2011) should be followed to avoid or mitigate acoustic impacts on marine mammals.

Avoidance or mitigation of seabird strikes is possible by limiting unnecessary use of vessel flood lights at night and ensuring that those that are required are directed approximately vertically onto work surfaces. Visual checks of the vessel super-structure at first light each day for the presence of dazed or injured birds and the provision of appropriate care may help to remedy this impact.

Avoidance or mitigation of vessels and underwater equipment acting as vectors for non-indigenous species is possible by appropriate checking, cleaning, and application of antifouling paints. We understand that Biosecurity New Zealand (MAF-BNZ) is developing an import health standard and legislation and relevant regulations may be put in place in next 2-3 years.

Pressure on fish stocks caused by a mining exclusion zone forcing fishing activities into the remainder of the quota management area can be reduced or eliminated by purchase and retirement of appropriate commercial fish quota for the duration of the production phase.

Assuming that iron sands occur to depths of 20-30m below the seafloor, impacts on benthic fauna will be minimised if fewer deeper pits are dug to extract a prescribed tonnage of ore. This is because most fauna is restricted to the upper 10-15 cm of sediment. A wide shallow pit will cause the maximum ecological damage for the least gain in ore extraction.

Table 4-4: Expert Panel Assessment: Ironsand mining. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. Activities are listed (a, b, c, etc) after each threat to which they contribute. The maximum possible level of environmental risk is 30. Extreme environmental risks are highlighted in red, high in yellow, and moderate in green. Low risk activities are not highlighted. *Threats managed under the Maritime Transport Act (1994). NA = not applicable as species assessed are all protected.

Expert Panel Assessment: Ironsand mining		**Recovery period**				**Key species**				**Protected species**				**Ecosystem functional impact**				**Proportion of habitat affected**			
Activity	**Threat**	**Consequence**	**Likelihood**	**Risk**	**Confidence**	**Consequence**	**Likelihood**	**Risk**	**Confidence**	**Consequence**	**Likelihood**	**Risk**	**Confidence**	**Consequence**	**Likelihood**	**Risk**	**Confidence**	**Consequence**	**Likelihood**	**Risk**	**Confidence**
Prospecting phase a) Surface flood lights & noise b) Aerial or towed magnetometer surveys c) Acoustic swath mapping d) High resolution seismics e.g. Boomer, CHIRP (use of air guns is unlikely) e) Core drilling over a wide area f) Survey vessel activities	*Seabird attraction, disturbance, collision (a, b)	1	6	6	2b	NA	NA	NA	NA	3	5	15	2b	0	6	0	2b	1	6	6	2b
	Acoustic impact from multi-beam echo sounders on marine mammals, reptiles, fish and invertebrates (c)	0	5	0	2a	0	6	0	2a	1	5	0	2a	0	6	0	2a	0	6	0	2a
	Acoustic impact from high resolution seismics on marine mammals, reptiles, fish and invertebrates (d)	1	4	4	2a	0	2	0	1c	2	4	8	2a	1	4	4	1c	1	6	6	1c
	*Ship strikes on marine mammals, fish, and reptiles (b, f)	3	6	18	2a	0	1	0	2b	3	3	9	2a	1	2	2	1c	1	6	6	2b
	Impact on benthos from coring operations (e)	0	4	0	1c	0	5	0	2b	NA	NA	NA	NA	0	6	0	2b	0	6	0	2b
	Impact on water column ecosystem (e)	0	4	0	2b	0	4	0	1c	0	4	0	1c	0	4	0	1c	0	5	0	1c
Exploration g) Surface flood lights & noise h) Core drilling at fewer sites i) Test pit excavation using different methods j) Sediment plume k) Incidental underwater	*Seabird attraction, disturbance, collision (g)	1	6	6	2b	NA	NA	NA	NA	2	5	10	2b	0	6	0	2b	1	6	6	2b
	Impact on benthos (h, i, j)	1	4	4	1c	1	5	5	2b	NA	NA	NA	NA	1	6	6	2b	1	6	6	2b
	Acoustic impact on marine mammals, reptiles, fish and invertebrates (k)	1	4	4	1c	0	2	0	1c	2	4	8	2a	1	4	4	1c	1	5	5	1c
	Entanglement of megafauna (h, i)	3	6	18	2b	1	3	3	2b	3	3	9	2b	0	6	0	2b	0	6	0	2b

noise l) Survey and support vessel activities	Impact on water column ecosystem (j)	1	4	4	2b	1	4	4	1c	1	4	4	1c	1	4	4	1c	1	5	5	1c
	*Ship strikes on marine mammals, fish and reptiles (l)	3	6	18	2a	2	2	4	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b
Mining phase m) Surface flood lights & noise n) Sea floor suction o) Extraction plume p) Sea floor slurry pipes q) Deposition of tailings in stock piles or pits r) Deposition plume s) Underwater lights and noise t) Mooring blocks or anchors u) Wash water return v) Swath mapping to determine change in bathymetry w) Bulk ore carrier x) Support vessel activities y) Mining exclusion zone	*Seabird attraction, disturbance, collision (m)	1	6	6	2b	NA	NA	NA	NA	3	5	15	2b	0	6	0	2b	1	6	6	2b
	Impact on water column ecosystem from plume sediments (p, r, u)	1	4	4	1c	1	4	4	1c	1	4	4	1c	1	4	4	1c	2	5	10	1c
	Acoustic impact on marine mammals, reptiles, fish and invertebrates (s, v)	1	4	4	2a	0	2	0	1c	2	4	8	2a	1	4	4	1c	1	5	5	1c
	Vector for non-indigenous species (w)	3	4	12	2b	1	4	4	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b
	Direct impact on fished species (n, o, p, q, r, s, t, u)	2	6	12	2b	1	5	5	2b	NA	NA	NA	NA	2	5	10	2b	1	6	6	2b
	Effects of spatial displacement of fishing on commercial fish stocks (y)	1	5	5	2b	1	5	5	2b	NA	NA	NA	NA	0	4	0	2b	2	5	10	2b
	*Ship strikes on marine mammals, fish and reptiles from support vessels (w, x)	3	6	18	2a	2	2	4	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b
	Nearshore impact of altered wave climate (m, q)	2	4	8	2a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	4	0	2a
	Entanglement of megafauna (n, p, q, r, s, t)	3	6	18	2b	1	3	3	2b	3	3	9	2b	0	6	0	2b	0	6	0	2b
	Impact on benthos (n, o, p, q, t)	3	4	12	1c	2	5	10	2b	NA	NA	NA	NA	2	6	12	2b	1	6	6	2b

4.5 Placer gold

4.5.1 Background

Placer gold deposits share a similar genesis to ironsands, but rather than being sourced from volcanic rocks, gold is the product of fluvial or glacial erosion of gold-bearing metamorphic rocks, which are most prominent along the Southern Alps. Buried river channels, submerged shorelines and glacial outwash deposits from Quaternary sea-level change on the South Island West Coast shelf are likely targets for the highest concentrations of placer-gold. The continental shelf of the South Island west coast is narrow, and subject to a vigorous wave climate driven by the prevailing westerly winds and southerly storms, and accordingly, the seabed of the inner and mid-shelf is naturally subjected to frequent resuspension and energetic near-bed currents. South Westland also receives sediment from several large rivers with significant sediment-carrying capacity (e.g. Arawata, Haast, and Hokitika rivers), which collectively deliver around 30% of the riverine sediment to the New Zealand coast today (Hicks and Shankar, 2003).

4.5.2 Assessment

We assessed three phases of New Zealand’s fledgling placer gold mining industry; prospecting, exploration, and production. Compared to the oil industry where the production facilities may be largely static for decades, decommissioning in the placer gold mining industry is likely to be a relatively routine part of on-going production as equipment is moved around the mining site once ore-bearing sands and gravels in one part have been exhausted and any pit created in the process has been backfilled with de-ored sediments. Thus we have not considered decommissioning as a separate phase in this industry. For each phase we identified and assessed the ecological impact of several distinct activities (Table 4-4). Below we present the main results for each phase.

Prospecting

Obtaining cores of sediment through the ore bearing strata to quantify gold concentrations at various depths is likely to occur over a wide area during this phase. These cores are likely to be conducted from specially equipped small ships rather than from drill or coring platforms. Cores are likely to be about 12-15cm in diameter and affect a very small proportion of the sediment habitats in the area. The risk to benthic habitats and organisms from this activity is likely to be negligible (Table 4-5).

Ship strikes on marine mammals may occur during transits among coring sites. These effects are covered under the Maritime Transport Act (1994) and the Marine Mammal Protection Act (1978).

Lights on ships at night typically attract and disturb seabirds and may cause them to collide with the coring vessel (Black 2005). These effects are covered under the Maritime Transport Act (1994) and the Wildlife Act (1953).

Acoustic swath mapping may be used to define the bathymetry of promising areas and high resolution seismic (e.g. Boomer, CHIRP) may be used to define the sub-seafloor geological strata. Use of air guns to obtain deeper seismic information in these surveys is unlikely. The acoustic impact of seismic surveys on marine mammals, in particular, is well documented (Gordon & Moscrop 1996, Cox et al. 2006, Brandon et al. 2008, Di Iorio and Clark 2010) but may also affect a range of marine reptiles, fish and invertebrates. The consequences for marine mammals from the seismic gear likely to be used for these surveys will vary from none to behavioural (may leave area) perhaps to acute injury (ear drum damage) depending on noise level encountered, species and habitat. Beaked whales are thought to be particularly at risk. There may also be cumulative effects from repeated exposure.

Noise travels great distances underwater and so the footprint of this activity may be very broad though the greatest impacts will be much more restricted in area as sound intensity typically falls as the square of the distance from the source. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species such as southern right whales as these may occur throughout the EEZ though they occur in different areas at different times of the year. The risk from this activity was assessed to reach a moderate score of 8 with a high level of confidence (Table 4-5) indicating the need for this to be a discretionary activity. Use of air guns, though inappropriate for defining these near seabed surface deposits, would considerably increase this risk.

Exploration

In this phase more intensive evaluation of potential mining sites will take place. The focus is likely to be on areas of 30-50 km^2 capable of sustaining mining for a decade or more.

Within the more promising areas multi-beam echo-sounders are likely to be used to define the bathymetry and high resolution seismic (e.g. Boomer, CHIRP) may be used to define the sub-seafloor geological strata. The area affected is likely to be a small proportion (<1-5%) of the licence area or the area of broadly similar habitat. The risk to marine mammals and other organisms from this activity was assessed to reach a score of 8 with a high level of confidence (Table 4-5) indicating the need for this to be a discretionary activity. Use of air guns, though inappropriate for defining these near seabed surface deposits, would considerably increase this risk.

Obtaining of sediment cores to quantify gold concentrations at various depths is likely to continue during this phase but are very likely to be concentrated over a small proportion (<1-5%) of the licence area or area of broadly similar habitat. The risk to benthic habitats and organisms from this activity is likely to be minor (Table 4-5).

Production

The details of extraction methods for deeper areas in the EEZ are still unclear but may involve a seabed digger that pumps a slurry of sand and seawater to a surface vessel that extracts and concentrates the gold, and via a second pipeline sends the unwanted sediment back to the seafloor for stock-piling or back filling of the excavation pit that may be up to 10 m deep. The larger vessels may moor to ‘permanent’ anchors blocks or anchor moorings. There is likely to be a sediment plume originating from the active mine face as well as from the slurry pipe depositing sediments after the gold has been extracted. This style of extraction is more feasible in deeper water than in the shallower territorial sea, where a variety of standard suction-dredges might be used. Where placer gold deposits lie well below the seabed (many tens of metres) it is possible they could be removed via “keyhole” technologies *in situ* from within the gold bearing layers thereby minimising disruption of the top layers of sediment containing the majority of benthic organisms, but some slumping may still occur.

To be profitable many millions of tons of placer-gold bearing sands and gravels will need to be extracted each year by a mining operation but the exact tonnage is very uncertain as it is highly dependent on gold concentrations and ore grade. However, the area mined in any one operation is likely to be a relatively small proportion of the total habitat off the West Coast of the South Island.

The benthic ecosystem on the seafloor in and around the mining operations will be sequentially and severely impacted during the long production phase as areas are mined and backfilled with deored sediment and an area downstream of the mining operations will be affected by smothering from sediments from sediment plumes. Course grains will settle quickly but the fine-grained suspended component (finer silts and clays) may be carried some distance depending on current strength and resuspension due to wave activity. An idea of the likely impacts on the benthos can be gained from studies of sand and gravel extraction in North America and Europe (e.g. Boyd et al. 2005).In areas being actively mined we surmise probably close to 100% of the benthic organisms will be killed during the mining or ore concentration process. Smothering from the plume will decrease with distance from the plume source increases. However, the affected proportion of the benthic habitat in the licence area and areas of broadly similar habitat is likely to be small. Thus, the functional impact on the benthic ecosystem as a whole, as well impacts on key species, are likely to be moderate and the risk level consistent with the need for iron sand mining to be classified as discretionary (Table 4-5).

Although there are few data from offshore placer gold habitats it is quite possible that recovery of the benthic ecosystem on the ore depleted sediments will be moderately quick, on the order of months for the smaller meiofanua to years for the longer lived, slower growing macro-fauna such as bivalves, gastropods, crustaceans and echinoderms (Table 4-5). This is a reflection of high levels of natural background disturbance due to the high wave environment on the west coast of the South Island that likely favours benthic species with fast to moderate growth, early maturation and high fecundity.

The sediment plumes may also cause disruption to the water column ecosystem by increasing turbidity, thereby shading phytoplankton, or through the irritation of gills of fish and invertebrates. The area affected may reach 5-20% of the licence area but effects on key species, protected species and ecosystem function possibly will be minor (Table 4-5). Recovery of the pelagic ecosystem is expected to be rapid once sediment plumes stop.

Mining placer gold in the EEZ close to the outer limit of the territorial sea, by altering the seafloor typography offshore, has the potential to affect the nearshore wave climate and thus rates of beach accretion or erosion (e.g. Roos and van der Werf 2010). Storing tailings in very large stockpiles is likely to have a greater effect nearshore than digging pits to extract the gold. Rapid backfilling of pits as mining progresses will minimise any nearshore effects. Only a small proportion of the shoreline is likely to be affected (<<1%) but recovery will possibly be moderate taking months to years once mining stopped (Table 4-4).

Mining activities on the seabed will produce some level of underwater noise from the suction head, and any submersed cutters, pumps or other machinery. This underwater noise may affect marine mammals, mainly causing then to avoid the area, but we assessed this to pose low risk (8) and that recovery would take weeks to months after the noise stopped.

Entanglement of megafauna in subsurface equipment including anchor lines, mooring lines, marker buoy lines, power cabling or hydraulic lines is a possibility. Only a tiny fraction of the area (<<1%) is likely to have such hazards to fauna. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk to protected marine mammals from this activity was assessed as moderate (9) with a high level of confidence (Table 4-5). Recovery of affected populations should these entanglement hazards be removed is expected to take years as the species concerned are slow growing, late maturing with low fecundity.

Ships brought in to New Zealand from Australia or further afield to separate the gold from other sediments may act as vectors for non-indigenous species but the likelihood is low for a vessel with fresh antifouling. New Zealand modified ships should pose little risk. The functional impact on the ecosystem surrounding the gold concentration vessel is probably minor as vectored species are unlikely to survive independently of the ship in deep offshore waters. However, the ship may act as a stepping stone for non-indigenous species to invade shallow coastal habitats.

Mining placer gold deposits in the EEZ may affect stocks of fished species in two ways. There may be some direct effects on fish during extraction of the ore-bearing sand, and redeposited sands may take several years before they provide the full range of prey species to benthic foraging fish. Additionally fish may move away from the area of active mining and plume influence. Mining areas will invariably have a zone of restricted access around them that prevents fishing access. Unless commercial fish quota is purposefully bought by the mining company and retired for the duration of the production phase then commercial fishing will be displaced into the remainder of the quota management area (QMA). The resulting fishing pressure has the potentail to affects some fish stocks, especially sedentary species with limited migrations. While the area of a QMA affected by direct effects on fish stocks is likely to be small, the effects of displaced fishing will be felt over a much greater area. We assessed there to be low (5) risks to key fish stocks and moderate (10) risks to ecosystem functioning from direct effects on fish stocks, and low risk (5) from displaced fishing to key fish stocks and ecosystem functioning (Table 4-5). Regulators need to be mindful, however, of the possibility for multiple mining operations to occur in a single region and direct and indirect effects on fish stocks to proportionally increase with a QMA.

As mining placer gold deposits is very likely to utilise ships rather the specialised production platforms and though lights on these vessels will typically attract and disturb seabirds at night and may cause them to collide with the ship, These effects are covered under the Maritime Transport Act (1994) and the Wildlife Act (1953).

Risk summary for placer gold mining

There were no activities associated with placer gold mining that were considered to represent an extreme environmental risk provisionally indicating prohibited status.

The following activities were considered to be of high environmental risk (15-20) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Support vessel activity causing strikes on marine mammals, fish and reptiles
- Surface flood lights at night
- Testing and operation of undersea equipment with associated hydraulic lines, power cables and umbilical's creating an entanglement hazard

The following activities were considered to be of moderate environmental risk (7-12) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Seafloor suction / extraction
- Use of high resolution seismics e.g. Boomer, CHIRP
- Creation of sea floor pits or sediment stock piles
- Discharge of sediments causing plumes
- Placement of seafloor structures, anchors or moorings
- Import and provision of biofouling surfaces
- Seafloor slurry pipes
- Underwater flood lights
- Incidental underwater noise
- Declaration of mining area exclusion zone

The following activities were considered to be of low environmental risk (0-6) and should be categorised as permitted:

- Single and multibeam echo sounding
- Small scale coring operations

4.5.3 Avoidance, mitigation, remediation

There are often ways of avoiding, remedying or mitigating the effects of activities that would otherwise put marine species or ecosystems at risk. Below we briefly discuss those relevant to placer gold mining.

Non-mandatory Department of Conservation guidelines (2006 and 2011) should be followed to avoid or mitigate acoustic impacts on marine mammals.

Avoidance or mitigation of seabird strikes is possible by limiting unnecessary use of vessel flood lights at night and ensuring that those that are required are directed approximately vertically onto work surfaces. Visual checks of the vessel super-structure at first light each day for the presence of dazed or injured birds and the provision of appropriate care may help to remedy this impact.

Avoidance or mitigation of vessels and underwater equipment acting as vectors for non-indigenous species is possible by appropriate checking, cleaning, and application of antifouling paints. We understand that Biosecurity New Zealand (MAF-BNZ) is developing an import health standard and legislation and relevant regulations may be put in place in next 2-3 years.

Pressure on fish stocks caused by the mining exclusion zone forcing fishing activities into the remainder of the quota management area can be reduced or eliminated by purchase and retirement of appropriate commercial fish quota for the duration of the production phase.

Assuming that placer gold deposits occur to depths of 20-30m below the seafloor, impacts on benthic fauna will be minimised if fewer deeper pits are dug to extract a prescribed tonnage of gold. This is because most fauna is restricted to the upper 10-15 cm of sediment. A wide shallow pit will cause the maximum ecological damage for the least gain in gold extraction.

Table 4-5: Expert Panel Assessment: Placer gold mining. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. Activities are listed (a, b, c, etc) after each threat to which they contribute. The maximum possible level of environmental risk is 30. Extreme environmental risks are highlighted in red, high in yellow, and moderate in green. Low risk activities are not highlighted. *Threats managed under the Maritime Transport Act (1994). NA = not applicable as species assessed are all protected.

Expert Panel Assessment: Placer gold mining		Recovery period				Key species				Protected species				Ecosystem functional impact				Proportion of habitat affected			
Activity	Threat	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence
Prospecting phase a) Surface flood lights and noise b) Acoustic swath mapping c) High resolution seismics e.g. Boomer, CHIRP. (Use of air guns is unlikely) d) Core drilling over a wide area e) Survey vessel activities	*Seabird attraction, disturbance, collision (a)	1	6	6	2b	NA	NA	NA	NA	3	5	15	2b	0	6	0	2b	1	6	6	2b
	Acoustic impact from multi-beam echo sounders on marine mammals, reptiles, fish and invertebrates (b)	0	5	0	2a	0	6	0	2a	1	5	0	2a	0	6	0	2a	0	6	0	2a
	Acoustic impact from high resolution seismics on marine mammals, reptiles, fish and invertebrates (c)	1	4	4	2a	0	2	0	1c	2	4	8	2a	1	4	4	1c	3	5	15	1c
	*Ship strikes on marine mammals, fish, and reptiles (e)	3	6	18	2a	0	1	0	2b	3	3	9	2a	1	2	2	1c	1	6	6	2b
	Impact on benthos from coring operations (d)	0	4	0	1c	0	5	0	2b	NA	NA	NA	NA	0	6	0	2b	0	6	0	2b
	Impact on water column ecosystem (d)	0	4	0	2b	0	4	0	1c	0	4	0	1c	0	4	0	1c	0	5	0	1c
Exploration f) Surface flood lights and noise g) Core drilling at fewer sites h) Test pit excavation using different methods i) Sediment plume j) Underwater noise k) Support vessel activities	*Seabird attraction, disturbance, collision (f)	1	6	6	2b	NA	NA	NA	NA	2	5	10	2b	0	6	0	2b	1	6	6	2b
	Impact on benthos (g, h, i)	1	4	4	1c	1	5	5	2b	NA	NA	NA	NA	1	6	6	2b	1	6	6	2b
	Acoustic impact on marine mammals, reptiles, fish and invertebrates (j)	3	6	18	2a	0	2	0	1c	2	4	8	2a	1	4	4	1c	1	5	5	1c
	Entanglement of megafauna (h)	3	6	18	2b	1	3	3	2b	3	3	9	2b	0	6	0	2b	0	6	0	2b
	Impact on water column ecosystem (j)	1	4	4	2b	1	4	4	1c	1	4	4	1c	1	4	4	1c	1	5	5	1c

	*Ship strikes on marine mammals, fish and reptiles (k)	3	6	18	2a	2	2	4	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b
Mining phase l) Surface flood lights and noise m) Sea floor suction n) Extraction plume o) Sea floor slurry pipes p) Deposition of tailings in stock piles or pits q) Deposition plume r) Incidental underwater lights and noise s) Temporary mooring blocks or anchors t) Waste water return u) Swath mapping to determine change in bathymetry v) Support vessel activities w) Mining exclusion zone	*Seabird attraction, disturbance, collision (l)	1	6	6	2b	NA				3	5	15	2b	0	6	0	2b	1	6	6	2b
	Impact on water column ecosystem from plume sediments (n, q, t)	1	4	4	1c	1	4	4	1c	1	4	4	1c	1	4	4	1c	2	5	10	1c
	Acoustic impact on marine mammals, reptiles, fish and invertebrates (r)	1	4	4	2a	0	2	0	1c	2	4	8	2a	1	4	4	1c	1	5	5	1c
	Impact on fished species (m, n, o, p, q, s, t)	2	6	12	2b	1	5	5	2b	NA	NA	NA		2	5	10	2b	2	6	12	2b
	Vector for non-indigenous species (v)	3	4	12	2b	1	4	4	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b
	Effects of spatial displacement of fishing on commercial fish stocks (w)	1	5	5	2b	1	5	5	2b	NA	NA	NA		0	4	0	2b	1	5	5	2b
	*Ship strikes on marine mammals, fish and reptiles (v)	3	6	18	2a	2	2	4	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b
	Nearshore impact of altered wave climate (m, p)			0		NA	NA	NA	NA	NA	NA	NA		NA	NA	NA	NA			0	
	Entanglement of megafauna (m, o, p, s)	3	6	18	2b	1	3	3	2b	3	3	9	2b	0	6	0	2b	0	6	0	2b
	Impact on benthos (m, n, o, p, q, s)	3	4	12	1c	2	5	10	2b	NA	NA	NA	NA	2	6	12	2b	1	6	6	2b

4.6 Phosphorite nodules

4.6.1 Background

Phosphorite nodules (Figure 4-2) form potentially the most economically important and well-studied marine mineral deposit in the New Zealand EEZ (Cullen 1987; Glasby and Wright, 1990). These patchily distributed deposits occur in water depths of about 400 m on the crest of the Chatham Rise, especially between 179°E and 180°. The Chatham Rise phosphorites formed by the phosphatisation of fragmented hard ground chalk pebbles about 12-7 million years ago under conditions of low to no sedimentation, the development of a pronounced oxygen minimum zone and intensified flow and upwelling of P-rich waters over the ridge crest. Subsequent biological and iceberg activity disrupted the fragmented hard ground and led to the patchy distribution of phosphorite nodules within the top 1 m of the surficial glauconite-rich sandy muds on the crest of the Chatham Rise. Very minor phosphorite deposits have also been reported from shallow coastal environments, such as Raglan Harbour, Hauraki Gulf and off the Northland shelf (Glasby and Wright, 1990).

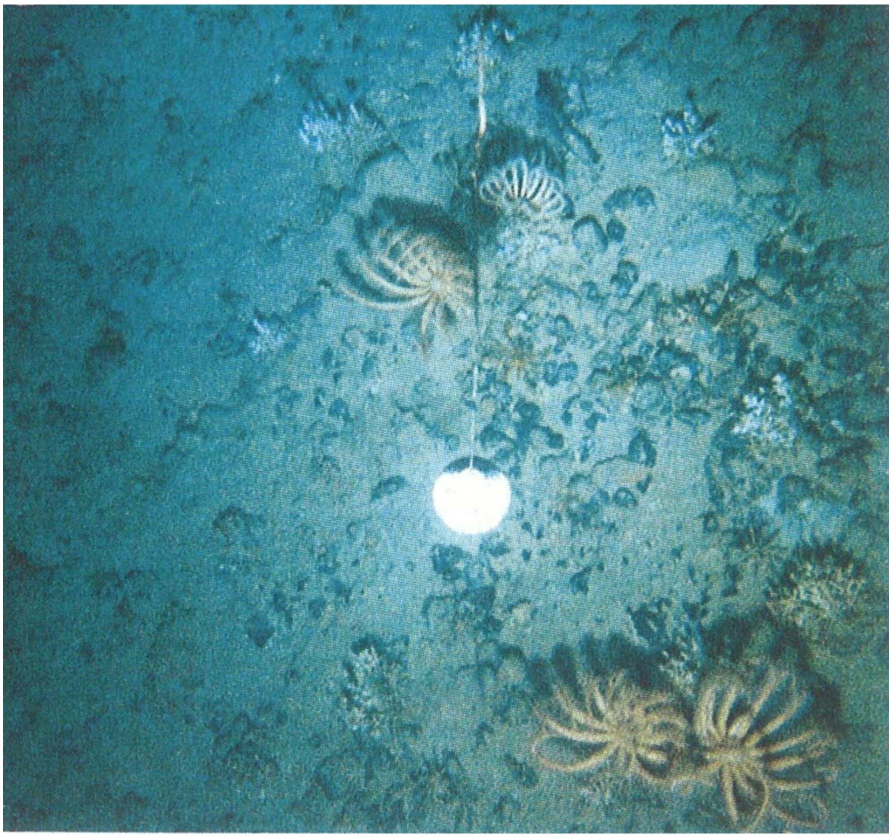


Figure 4-2: Phosphorites nodules. Dark, gavel-sized nodules exposed on the Chatham Rise seafloor, with feathery starfish, deepwater corals and small clumps of brachiopods.

Methods, similar to those proposed for extracting Polymetalic nodules, could be applied to the phosphorite deposits on the Chatham Rise, such as hydraulic suction dredging connected to a mining platform via a flexible hose and rigid pipe string for transporting the nodules from the seafloor to the sea surface (Cullen, 1987; ISA, 2008a). However, given the environmental concerns and potential impacts on other economic activities, especially fisheries, mining systems would need to be developed that minimise the direct and indirect impacts of the mining activities on the benthic and pelagic ecosystems of the Chatham Rise.

4.6.2 Assessment

We assessed three phases of New Zealand's fledgling phosphorite nodule mining industry; prospecting, exploration, and production. Compared to the oil industry where the production facilities may be largely static for decades, decommissioning in the phosphorite nodule mining industry is likely to be a relatively routine part of on-going production as equipment is moved around the mining site once nodules in one part have been exhausted. Thus we have not considered decommissioning as a separate phase in this industry. For each phase we identified and assessed the ecological impact of several distinct activities (Table 4-6). Below we present the main results for each phase.

Prospecting

Surveys using short cores, rock dredges, and camera systems to quantify nodule distribution and concentrations, are likely to occur over a wide area (~100s of km^2) during this phase. This sampling is likely to be conducted from specially equipped vessels rather than from drill or coring platforms. Cores are likely to be about 12-15cm in diameter while dredges may be up to 1-2 m wide and affect a very small proportion of the sediment habitats in the area. The risk to benthic habitats and organisms from this activity is likely to be minor to moderate but the recovery of directly impacted habitat patches is likely to take months to years (Table 4-6).

Acoustic swath mapping may be used to define the bathymetry of promising areas and high resolution seismic reflection techniques (e.g., CHIRP) may be used to define the sub-seafloor geological strata. Use of air guns to obtain deeper seismic information in these surveys is very unlikely. The acoustic impact of seismic surveys on marine mammals, in particular, is well documented (Gordon & Moscrop 1996, Cox et al. 2006, Brandon et al. 2008, Di Iorio and Clark 2010) but may also affect a range of marine reptiles, fish and invertebrates. The consequences for marine mammals from the seismic gear likely to be used for these surveys will vary from none to behavioural (may leave area) perhaps to acute injury (ear drum damage) depending on noise level encountered, species and habitat. Beaked whales are thought to be particularly at risk. There may also be cumulative effects from repeated exposure.

Noise travels great distances underwater and so the footprint of this activity may be very broad though the greatest impacts will be much more restricted in area as sound intensity typically falls as the square of the distance from the source. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species, such as southern right whales, as these may occur throughout the EEZ, but typically they occupy different areas at different times of the year. The risk from this activity was assessed to reach a score of 8 with a high level of confidence (Table 4-6) indicating the need for this to be a discretionary activity. Use of air guns, while inappropriate for defining these near seabed surface deposits, would considerably increase this risk.

Ship strikes on marine mammals may occur during transits among coring and dredging sites. These effects are covered under the Maritime Transport Act (1994) and the Marine Mammal Protection Act (1978).

Lights on ships at night typically attract and disturb seabirds and may cause them to collide with the sampling vessel (Black 2005). These effects are covered under the Maritime Transport Act (1994) and the Wildlife Act (1953).

Exploration

In this phase more intensive evaluation of potential mining sites will take place. The focus is likely to be on areas of 50-100 km^2 capable of sustaining mining for a decade or more.

Within the these areas multi-beam echo-sounders are likely to be used to define the bathymetry and high resolution seismics (e.g. CHIRP) may be used to define the sub-seafloor geological strata. The area affected is likely to be a very small proportion (<<1%) of the Chatham Rise nodule habitat. The risk to marine mammals and other organisms from this activity was assessed to reach a score of 12 with a high level of confidence (Table 4-6) indicating the need for this to be a discretionary activity. Use of air guns, though inappropriate for defining these near seabed surface deposits, would considerably increase this risk.

Further surveys using short cores, rock dredges, and camera systems to quantify nodule distribution and concentrations, are likely to occur during this phase but are very likely to be concentrated over a small proportion (<<1%) of the licence area or area of broadly similar habitat. There will also be some trials of extraction methods and bulk sampling. The risk to benthic habitats and organisms from this activity is likely to be minor to moderate depending on the quantities of sediment sampled but the recovery of directly impacted benthic habitat patches is likely to take decades given the slow growth of many species (Table 4-6).

Entanglement of megafauna in subsurface equipment including anchor lines, mooring lines, marker buoy lines, power cabling or hydraulic lines is a possibility during trials of extraction methods. Only a tiny fraction of the area (<<1%) is likely to have such hazards to fauna and these will probably be in place for only weeks to months. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk to protected marine mammals from this activity was assessed as low (3) with a high level of confidence (Table 4-4). Recovery of affected populations should these entanglement hazards be removed is expected to take years as the species concerned are slow growing, late maturing with low fecundity.

Production

The methods for extracting phosphorite nodules may involve a seabed hydraulic suction head perhaps attached to a crawler that pumps a slurry of surface sediments and nodules and seawater to a surface vessel that extracts the nodules and via a second pipeline sends the unwanted sediment back to the seafloor for back filling of the shallow excavation pit that may be approximately 1m deep. The larger vessels may moor to ‘permanent’ anchors blocks or anchor moorings. There is likely to be a sediment plume originating from the active mining face as well as from the slurry pipe depositing unwanted sediments. To be profitable a large area, perhaps 10km^2, will need to be mined each year to a depth of about 1m, possibly for decades. Over the lifetime of the mining operation it is possible that a significant proportion (20-50%) of the total phosphorite nodule habitat in the EEZ could be affected.

The benthic ecosystem on the seafloor in and around the mining operations will be sequentially and severely impacted during the long production phase as areas are mined and backfilled with sediment and an area downstream of the mining operations will be affected by smothering from sediments from sediment plumes. Course grains will settle quickly but finer silts, muds and clays may be carried some distance depending on current strength. In areas being actively mined probably close to 100% of the benthic organisms will be killed during the mining or nodule concentration process. Smothering from the plume will decrease as the distance from the plume source increases. As the total area affected is likely to be a significant proportion of the total nodule habitat, the functional impact on the benthic ecosystem as a whole, as well as impacts on key species, such as sponges, and protected benthic species, such as deepwater corals, is likely to be severe. Because the benthic fauna includes slow growing, long-lived species recovery is likely to be very long-term. If species are dependent on the presence of phosphorite nodules then recovery may never occur because these fauna relie up the nodules for attachment in an otherwise soft sediment environment (Dawson 1984). Overall, the risks of phosphorite nodule mining to the benthic ecosystems on the Chatham Rise were judged to be high (Table 4-6).

Sediment plumes arising from the mining face or slurry pipe depositing sediments may also cause disruption to the water column ecosystem by increasing turbidity, thereby restricting light availability for phytoplankton, or through the irritation of the gills of fish and invertebrates. The area affected at any one time is likely to be very small and effects on key species, protected species and ecosystem function possibly will be minor to moderate (Table 4-6). Recovery of the pelagic ecosystem is expected to be reasonably quick once sediment plumes stop.

Mining activities on the seabed will produce some level of underwater noise from the suction head, and any submersed cutters, pumps or other machinery. This underwater noise may affect marine mammals, mainly causing then to avoid the area, but we assessed this to pose moderate risk (12) and that recovery would be quick after the noise stopped.

Entanglement of megafauna in subsurface equipment, including anchor lines, mooring lines, marker buoy lines, power cabling or hydraulic lines, is a possibility. Only a tiny fraction of the area (<<1%) is likely to have such hazards to fauna. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk to protected marine mammals from this activity was assessed as low (3) with a high level of confidence (Table 4-6). Recovery of affected populations should these entanglement hazards be removed is expected to take years as the species concerned are slow growing, late maturing with low fecundity.

Mining phosphorite nodules on the Chatham Rise may affect stocks of fished species in two ways. There may be some direct effects on fish during extraction of the nodules, and redeposited sediment may take years before they provide the full range of prey species to benthic foraging fish. Additionally fish may move away from the area of active mining and plume influence. Mining areas will invariably have a zone of restricted access around them that prevents fishing access. Unless commercial fish quota is purposefully bought by the nodule mining company and retired for the duration of the production phase then commercial fishing will be displaced into the remainder of the quota management area (QMA). The resulting fishing pressure has the potentail to affects some fish stocks, especially sedentary species with limited migrations. While the area of a QMA affected by direct effects on fish stocks is likely to be small, the effects of displaced fishing will be felt over a much greater area. We assessed there to be moderate (15) risks to key fish stocks and ecosystem functioning from direct effects on fish stocks, and lower risk from displaced fishing effort to key fish stocks (10) and ecosystem functioning (8). Recovery of affected fish stocks, e.g. ling, from direct and indirect effects may take years to decades since some species are moderate growing (Table 4-6).

Ships brought in to New Zealand from Australia or further afield to separate the nodules from other sediments may act as vectors for non-indigenous species, but the likelihood is low for a vessel with fresh antifouling. New Zealand-modified ships should pose little risk. The functional impact on the ecosystem surrounding the nodule separation vessel is probably minor as vectored species are unlikely to survive independently of the ship in deep offshore waters. However, the ship may act as a stepping stone for non-indigenous species to invade shallow coastal habitats.

Since mining nodules is very likely to utilise ships rather the specialised production platforms and though lights on these vessels will typically attract and disturb seabirds at night and may cause them to collide with the ship. These effects are covered under the Maritime Transport Act (1994) and the Wildlife Act (1953).

Risk summary for phosphorite nodule mining

Several activities associated with phosphorite nodule mining were considered to represent an extreme environmental risk and should be prohibited if no way can be found to avoid, mitigate or remedy their impact. These activities include:

- Sea floor cutting/fragmentation/extraction
- Extraction plume
- Deposition of tailings in stock piles or pits
- Deposition plume

The following activities were considered to be of high environmental risk (15-20) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Support vessel activity causing strikes on marine mammals, fish and reptiles
- Surface flood lights at night
- Bulk sampling of deposits
- Testing and operation of undersea equipment with associated hydraulic lines, power cables and umbilical’s
- Declaration of a mining area exclusion zone
- Slurry pipes

The following activities were considered to be of moderate environmental risk (7-12) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Use of high resolution seismics e.g. Boomer, CHIRP
- Spot sampling using ROV, submersible, or rock dredge
- Provision of biofouling surfaces

- Underwater flood lights
- Underwater noise

The following activities were considered to be of low environmental risk (0-6) and should be categorised as permitted:

- Single and multibeam echo sounding
- ROV and other imaging surveys

4.6.3 Avoidance, mitigation, remediation

There are often ways of avoiding, remedying or mitigating the effects of activities that would otherwise put marine species or ecosystems at risk. Below we briefly discuss those relevant to phosphorite nodule mining.

Non-mandatory Department of Conservation guidelines (2006 and 2011) should be followed to avoid or mitigate acoustic impacts on marine mammals.

Avoidance or mitigation of seabird strikes is possible by limiting unnecessary use of vessel flood lights at night and ensuring that those that are required are directed approximately vertically onto work surfaces. Visual checks of the vessel super-structure at first light each day for the presence of dazed or injured birds and the provision of appropriate care may help to remedy this impact.

Avoidance or mitigation of vessels and underwater equipment acting as vectors for non-indigenous species is possible by appropriate checking, cleaning, and application of antifouling paints. We understand that Biosecurity New Zealand (MAF-BNZ) is developing an import health standard and legislation and relevant regulations may be put in place in next 2-3 years.

Pressure on fish stocks caused by a mining exclusion zone forcing fishing activities into the remainder of the quota management area can be reduced or eliminated by purchase and retirement of appropriate commercial fish quota for the duration of the production phase.

Actions that increase the rate of recovery of benthic fauna from the impacts of nodule mining will greatly reduce the risks associated with this industry. Recolonisation by larval settlement from adjacent populations may be increased by mining in a chequerboard or strip pattern or by leaving up current populations intact. Because so little is known about larval connectivity in these populations, the optimal size or distribution of mining is unknown.

Given that mining activity will remove most of the hard surfaces in this habitat, artificial hard surfaces could be placed on the sefloor to act as settlement and attachment surfaces for corals, sponges etc. Early trials of this approach should be encouraged.

Table 4-6: Expert Panel Assessment: Phosphorite nodule mining. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. Activities are listed (a, b, c, etc) after each threat to which they contribute. The maximum possible level of environmental risk is 30. Extreme environmental risks are highlighted in red, high in yellow, and moderate in green. Low risk activities are not highlighted. *Threats managed under the Maritime Transport Act (1994). NA = not applicable as species assessed are all protected.

Expert Panel Assessment: Phosphorite nodules		Recovery period				Key species				Protected species				Ecosystem functional impact				Proportion of habitat affected			
Activity	Threat	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence
Prospecting a) Surface flood lights and noise b) ROV and other imaging surveys c) Acoustic swath mapping d) Sub-bottom profiling using CHIRPS, boomers and sparkers e) Spot sampling using ROV, submersible, or rock dredge f) Survey ship activities	*Seabird attraction, disturbance, collision (a)	1	6	6	2b	NA	NA	NA	NA	3	5	15	2b	0	6	0	2b	1	6	6	1b
	Acoustic impact from multi-beam echo sounders on marine mammals, reptiles, fish and invertebrates (c)	0	5	0	2a	0	6	0	2a	1	5	0	2a	0	6	0	2a	0	6	0	2a
	Acoustic impact of high resolution acoustics on marine mammals, reptiles, fish and invertebrates (d)	1	4	4	2a	0	2	0	1c	2	4	8	2a	0	6	0	2a	1	6	6	1b
	*Ship strikes on marine mammals, fish, and reptiles (f)	3	6	18	2a	2	2	4	2b	2	2	4	1c	0	6	0	2b	0	4	0	1b
	Underwater flood lights (b)	0	5	0	2a	0	6	0	2a	0	5	0	2a	0	5	0	2a	0	5	0	2a
	Impact on benthos (e)	2	5	10	1c	1	4	4	2a	1	4	4	2a	2	5	10	1c	0	6	0	1b
Exploration g) Surface flood lights and noise h) Test extraction methods i) Bulk sampling j) Sediment plume k) Underwater noise l) Sub-bottom profiling using CHIRPS,	*Seabird attraction, disturbance, collision (g)	0	6	0	2b	NA	NA	NA	NA	2	5	10	2b	0	6	0	2b	0	6	0	1b
	Impact on benthos (h, i, j)	4	5	20	1c	2	4	8	2a	1	4	4	2b	2	5	10	2a	0	4	0	1b
	Acoustic impact on marine mammals, reptiles, fish and invertebrates (l)	1	6	6	2a	2	6	12	1c	2	6	12	2a	0	6	0	2b	0	6	0	1b
	Entanglement of megafauna (h)	3	6	18	2a	1	3	3	2b	1	3	3	2b	0	6	0	2b	0	6	0	2b

boomers and sparkers m) Site surveys using swath mapping &/or boomer surveys n) Survey vessel activities	*Ship strikes on marine mammals, fish, and reptiles from support vessels (n)	3	6	18	2a	2	2	4	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b
Mining o) Surface flood lights and noise p) Sea floor cutting/fragmentation q) Extraction plume r) Slurry pipes s) Deposition of tailings in stock piles or pits t) Deposition plume u) Underwater lights and incidental noise v) Waste water return w) Ore carrier activities x) Mining exclusion zone	Impact on water column ecosystem from plume sediments (q, t,)	1	6	6	2b	1	4	4	1c	1	4	4	1c	2	4	8	1c	0	6	0	1c
	Acoustic impact on marine mammals, reptiles, fish and invertebrates (p, u)	0	6	0	2a	1	6	6	1c	2	6	12	2a	0	6	0	2b	0	6	0	2b
	Impact on fished species (q, r, s, t,)	4	4	16	1c	3	5	15	1c	NA	NA	NA	NA	3	5	15	1c	3	4	12	1c
	Vector for non-indigenous species (w)	3	4	12	2b	1	4	4	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b
	Effects of spatial displacement of fishing on commercial fish stocks (x)	4	4	16	1c	2	5	10	1c	NA	NA	NA	NA	2	4	8	1c	2	5	10	1c
	*Ship strikes on marine mammals, fish, and reptiles (w)	3	6	18	2a	1	2	2	1c	3	3	9	2a	0	4	0	2b	0	5	0	2b
	*Seabird attraction, disturbance, collision (o)	0	6	0	2b	NA	NA	NA	NA	2	5	10	2b	0	6	0	2b	0	6	0	2b
	Entanglement of megafauna (p, r)	3	6	18	2a	1	3	3	2b	1	3	3	2b	0	6	0	2b	0	4	0	1c
	Impact on benthos (p, q, s, t,)	5	5	25	1c	3	4	12	1b	3	4	12	1b	3	4	12	1b	3	4	12	1b

4.7 Massive sulphides

4.7.1 Background

Seafloor Massive Sulphide deposits (SMS) form in submarine volcanic regions where sulphur-rich magmatic and hydrothermal fluids precipitate sulphur and metals around hydrothermal vents. The hydrothermal fields typically occur on mounds that contain precipitates and both high temperature ‘black smoker’ vents and lower temperature diffusive venting seen as gentle shimmering on the ocean floor. Where mineralization is extensive SMS deposits can form, consisting of economically viable reserves of Fe, Cu, Pb and Zn, with some also rich in Au and Ag (de Ronde et al. 2007) (Figure 4-3).

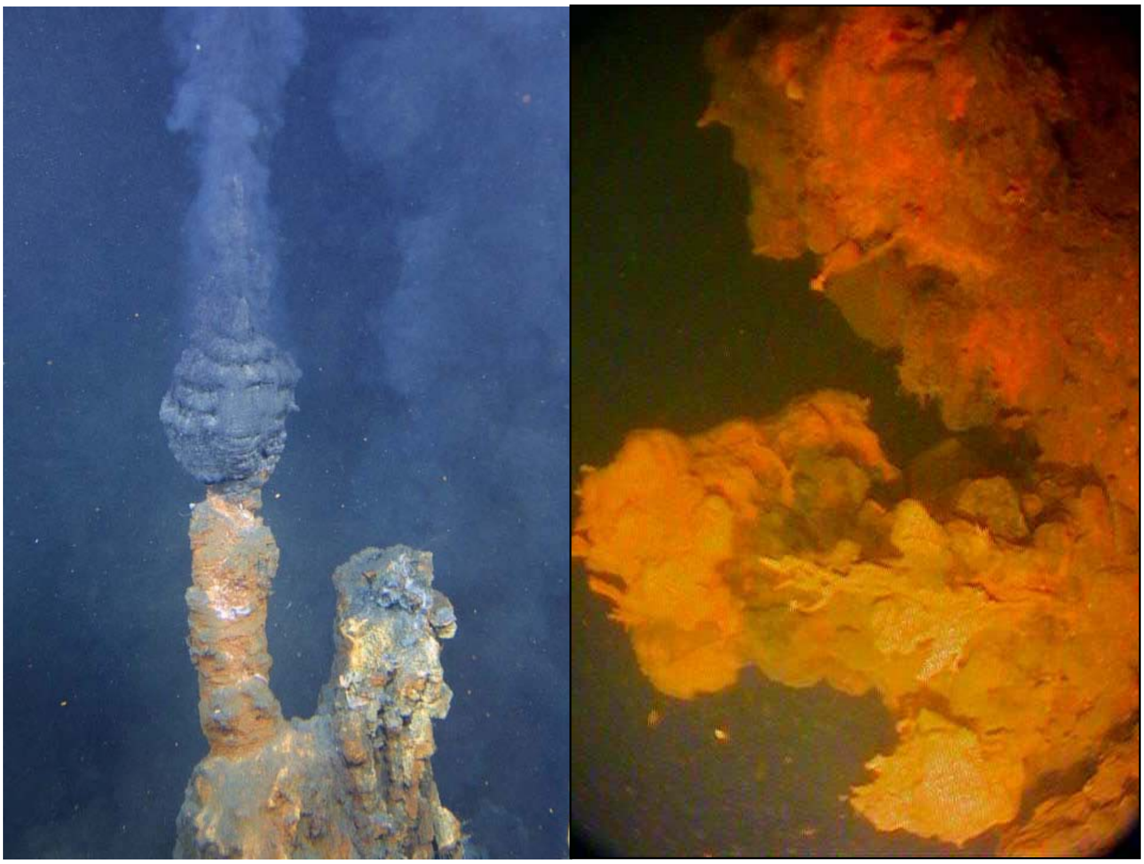


Figure 4-3: Black smoker chimney and massive sulphide deposit on the Kermadec Ridge.

Not all hydrothermal systems, however, are host to SMS deposits. In the New Zealand EEZ and ECS hydrothermal venting is known to occur on two-thirds of the ~30 Kermadec Arc volcanoes (de Ronde et al, 2007), but only two sites, Brothers and Rumble II West, are so far known to host SMS deposits. Deposits may also occur elsewhere in the Kermadec arc – Havre Trough volcanic system, although no hydrothermal activity has been found in the Havre Trough or on the Colville and Kermadec Ridges, which represent the proto-Kermadec arc (Wysoczanski and Clark, in press). However, the small number of known SMS deposits may simply be the result of limited exploration of these areas and other Kermadec arc volcanoes, as well as the Colville and Kermadec ridges, are likely to host active or old inactive deposits, respectively. All of these areas are currently of interest to mining companies and prospecting licences have been lodged for the entire area.

The technology to extract metals from SMS deposits from the ocean floor (at depths up to 4000 m) exists, but is as yet unproven. Different extraction methods are similar in that they require extraction mined material of the subsurface, transport to a large staffed mother ship, return of water and fine sediment to the ocean floor, and shipment of ore to land facilities. The most advanced proposal for exploration, by Nautilus Minerals in Papua New Guinea, involves remotely operated vehicles (ROVs), including the ocean bottom equivalent of bulldozers, and suction of ore to the mother ship (Nautilus website).

Active vent fields are home to some of the most highly specialised marine faunas known. Deep-sea vent ecosystems were first discovered in the late 1970s and are considered to be among the greatest scientific discoveries of the 20th century (van Dover et al. 2011). These ecosystems are fueled primarily by microbial primary production through a process known as chemosynthesis. Instead of using energy from sunlight to fix inorganic carbon into organic carbon (photosynthesis), microbes in vent ecosystems use chemical energy from the oxidation of reduced chemical compounds (van Dover et al. 2011). Hundreds of previously undescribed species have been discovered. Many are apparently endemic to the vent or seep environment, and may belong to higher-level taxa (genera and families) not previously known to science. Extractable resources at vents are fossil in nature and non-renewable. While mineral deposits can form quickly at vents, commercial ore deposits accumulate over millennia (van Dover et al. 2011).

4.7.2 Assessment

We assessed three probable phases of New Zealand's fledgling massive sulphide mining industry; prospecting, exploration, and production. Compared to the oil industry where the production facilities may be largely static for decades, decommissioning in this mining industry is likely to be a relatively routine part of on-going production as equipment is moved across a deposit. Thus we have not considered decommissioning as a separate phase in this industry. For each phase we identified and assessed the ecological impact of several distinct activities (Table 4-7). Below we present the main results for each phase.

Prospecting

Surveys using magnetometers coring devices, suspended camera systems, remotely operated vehicles (ROVs) and/or submersibles to quantify sulphide deposit distribution and chemical makeup are likely to occur over a wide area during this phase. This sampling is likely to be conducted from specially equipped vessels and affect a minor (<1-5%) proportion of deposits on a seamount. The risk to benthic habitats and organisms from this activity is likely to be minor to moderate but the recovery of directly impacted habitat patches of slower growing non-vent fauna (deep-sea corals and other filter feeders) is likely to take years to decades (Samadi et al. 2007) (Table 4-7). Faster growing vent fauna (e.g. vent mussels, tubeworms and staked barnacles, including nationally critical species) will probably recover in months to years (e.g. Southward et al. 1994).

Acoustic swath mapping may be used to define the bathymetry of promising areas and high resolution seismics (e.g. Boomer, CHIRP) will probably be used to define seafloor and sub-seafloor geological features. Use of air guns to obtain deeper seismic information in these surveys is possible.

The acoustic impact of seismic surveys on marine mammals, in particular, is well documented (Gordon & Moscrop 1996, Cox et al. 2006, Brandon et al. 2008, Di Iorio and Clark 2010) but may also affect a range of marine reptiles, fish and invertebrates. The consequences for marine mammals will vary from none, to behavioural (may leave area), to acute injury (ear drum damage), to serious (death) depending on noise level encountered, species and habitat. Beaked whales are thought to be particularly at risk. There may also be cumulative effects from repeated exposure.

Noise travels great distances underwater and so the footprint of this activity may be very broad though the greatest impacts will be much more restricted in area as sound intensity typically falls as the square of the distance from the source. Acoustic depth sounders and multibeam echo-sounders used for swath mapping pose little risk but high energy seismic devices such as air guns used for mapping sub seafloor geological structures pose a much greater risk. Using a precautionary approach our assessment assumed that air guns were used and the species affected was a nationally critical species such as southern right whales as these may occur throughout the EEZ though they occur in different areas at different times of the year. The risk from this activity was assessed to reach a score of 18 with a high level of confidence (Table 4-7) indicating the need for this to be a discretionary activity. .

Ship strikes on marine mammals may occur during transits among survey sites. These effects are covered under the Maritime Transport Act (1994) and the Marine Mammal Protection Act (1978).

Lights on ships at night typically attract and disturb seabirds and may cause them to collide with the coring vessel (Black 2005). These effects are covered under the Maritime Transport Act (1994) and the Wildlife Act (1953).

The magnetometer device is passive; merely recording variations in the local magnetic field so poses no threat to any part of the marine ecosystem.

Exploration

In this phase more intensive evaluation of potential mining sites will take place. The focus is likely to be on several deposits each approximately 0.01-1.0 km^2 perhaps on a single or several seamounts collectively capable of sustaining mining for a decade or more.

Within these areas multi-beam echo-sounders are likely to be used to further define the bathymetry and high resolution seismics (e.g. Boomer, CHIRP) will probably be used to define seafloor and immediate sub-seafloor geological features. Use of air guns to obtain deeper seismic information in these surveys is unlikely. The area affected is likely to be a minor proportion (<1-5%) of the crust habitat. The risk to marine mammals and other organisms from this activity was assessed to reach a score of 12 with a high level of confidence (Table 4-7) indicating the need for this to be a discretionary activity. Use of air guns would considerably increase this risk.

Further surveys using coring devices, suspended camera systems, ROVs and/or submersibles to quantify fine scale deposit distribution, thickness and chemical content are likely to occur during this phase over a moderate proportion (5-20%) of the sulphide deposits but a smaller proportion (<1-5%) of the non-vent area on a seamount habitat. There will also be some trials of extraction methods and some bulk sampling of several hundred tonnes of deposits. The risk to benthic habitats and organisms from this activity is likely to be moderate for non-vent fauna and minor for vent fauna. Recovery of directly impacted benthic habitat patches is likely to take months to years for vent fauna and years to decades for non-vent fauna (Table 4-7).

Entanglement of megafauna in subsurface equipment including anchor lines, mooring lines, marker buoy lines, power cabling or hydraulic lines is a possibility during trials of extraction methods. Only a tiny fraction of the area (<<1%) is likely to have such hazards to fauna and these will probably be in place for only weeks to months. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk to protected marine mammals from this activity was assessed as low (3) with a high level of confidence (Table 4-7).

Sediment plumes arising from the trials of mining equipment and processes may cause disruption to the water column ecosystem by increasing turbidity, thereby shading phytoplankton, or through the irritation of gills of fish and invertebrates. The deposits are poisonous. Anywhere from <1-5% of the pelagic habitat over a seamount may be affected at any one time and effects on key species, protected species and ecosystem functioning may be negligible to minor (Table 4-7). Recovery of the pelagic ecosystem is expected to be reasonably quick once sediment plumes stop.

Production

During mining a processing vessel is unlikely to moor to ‘permanent’ anchors blocks or anchor moorings. There is likely to be a sediment plume originating from the active mining face as well as from the slurry pipe depositing unwanted sediments.

The benthic ecosystem on the seafloor in and around the mining operations will be sequentially and severely impacted during the production phase as the sulphide deposits are mined and an area downstream of the mining operations is affected by smothering from sediments disturbed by mining operations. Course grains will settle quickly but finer particles may be carried some distance depending on current strength. In areas being actively mined probably close to 100% of the benthic organisms will be killed during the extraction process (ISA 2007, van Dover et al. 2011). Smothering from the sediment plume will decrease as the distance from the plume source increases. If vent areas are targeted, the total area affected is likely to be 20-50% of the non-vent fauna and a larger proportion (60-90%) of the vent habitat on a seamount. Consequently, the functional impact on the benthic ecosystem as a whole, as well impacts on key species, a nationally critical species and protected benthic species such as deepwater corals, are likely to be severe to catastrophic. Because the non-vent fauna includes slow-growing, long-lived species (Southward et al. 1994) their recovery is likely to be very long-term. Recovery of vent fauna is likely to take years. Overall, if vent areas are targeted the risks of mining massive sulphide deposits to the benthic ecosystems on seamounts were judged to be high (Table 4-7), consistent with other studies (ISA 2007, van Dover et al. 2011).

Sediment plumes arising from the mining face or slurry pipe depositing sediments may also cause disruption to the water column ecosystem by increasing turbidity, thereby shading phytoplankton, or through the irritation of gills of fish and invertebrates. The crusts are known to contain poisonous/toxic substances (ISA 2004). Anywhere from 5-20% of the pelagic habitat over a seamount may be affected at any one time and effects on key species, protected species and ecosystem function may be minor to moderate (Table 4-7). Recovery of the pelagic ecosystem is expected to be reasonably quick once sediment plumes stop.

Mining activities on the seabed will produce some level of underwater noise from the suction head, and any submersed cutters, pumps or other machinery. This underwater noise may affect marine mammals, probably causing then to avoid the area, posing low risk (6) and recovering soon after the noise stopped.

Entanglement of megafauna in subsurface equipment including anchor lines, mooring lines, marker buoy lines, power cabling or hydraulic lines is a possibility. Only a tiny fraction of the area (<<1%) is likely to have such hazards to fauna. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk to protected marine mammals from this activity was assessed as low (6) with a high level of confidence (Table 4-7). Recovery of affected populations should these entanglement hazards be removed is expected to take years as the species concerned are slow growing, late maturing with low fecundity.

Mining massive sulphide deposits may affect stocks of fished species in two ways. There may be some direct effects on fish during mining, and the seafloor may take years before the full range of prey species are available to benthic foraging fish. Additionally fish may move away from the area of active mining and plume influence. Mining areas will invariably have a zone of restricted access around them that prevents fishing access. Unless commercial fish quota is purposefully bought by the mining company and retired for the duration of the production phase then commercial fishing will be displaced into the remainder of the quota management area (QMA). The resulting increased fishing pressure has the potential to affect commercial fish stocks, though QMA 10 which includes many seamounts on the Kermadec Ridge has very low quota for most stocks. While the area of a QMA affected by direct effects on fish stocks is likely to be small, the effects of displaced fishing will be felt over a much greater area. We assessed there to be low (6) risks to key fish stocks and ecosystem functioning from direct effects on fish stocks, and lower risk from displaced fishing effort to key fish stocks (5) and ecosystem functioning (4). Recovery of affected fish stocks from direct and indirect effects may take months to years (Table 4-7).

Ships brought in to New Zealand from Australia or further afield to separate the sulphide deposits from other sediments may act as vectors for non-indigenous species but the likelihood is low for a vessel with fresh antifouling. New Zealand modified ships should pose little risk. The functional impact on the ecosystem surrounding the nodule separation vessel is probably negligible as vectored species are unlikely to survive independently of the ship in deep offshore waters. However, the ship may act as a stepping stone for non-indigenous species to invade shallow coastal habitats.

Mining activities on the seabed will produce some level of underwater noise from the suction head, and any submersed cutters, pumps or other machinery. This underwater noise may affect marine mammals, mainly causing then to avoid the area, but we assessed this to pose low risk (6) and that recovery would be rapid after the noise stopped.

Entanglement of megafauna in subsurface equipment including anchor lines, mooring lines, marker buoy lines, power cabling or hydraulic lines is a possibility. Only a tiny fraction of the area (<<1%) is likely to have such hazards to fauna. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk to protected marine mammals from this activity was assessed as low (6) with a high level of confidence (Table 4-7). Recovery of affected populations should these entanglement hazards be removed is expected to take months to years as the species concerned are slow growing, late maturing with low fecundity.

Risk summary for mining of massive sulphide deposits

Several activities associated with mining of massive sulphide deposits were considered to represent an extreme environmental risk and should be prohibited if no way can be found to avoid, mitigate or remedy their impact. These activities include:

- Creation of sediment plumes
- Use of slurry pipes
- Deposition of tailings in stock piles
- Toxic chemical release

The following activities were considered to be of high environmental risk (15-20) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Support vessel activity causing strikes on marine mammals, fish and reptiles
- Surface flood lights at night
- Testing and operation of undersea equipment with associated hydraulic lines, power cables and umbilical's creating an entanglement hazard
- Seafloor suction of deposits

The following activities were considered to be of moderate environmental risk (7-12) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Use of high resolution seismics e.g. Boomer, CHIRP
- Declaration of a mining area exclusion zone
- Spot sampling using ROV
- Bulk sampling of deposits
- Import and provision of biofouling surfaces
- ROV and other imaging surveys

The following activities were considered to be of low environmental risk (0-6) and should be categorised as permitted:

- Single and multibeam echo sounding
- Underwater imaging using ROV, AUV etc
- Incidental underwater noise
- Underwater flood lights

4.7.3 Avoidance, mitigation, remediation

There are often ways of avoiding, remedying or mitigating the effects of activities that would otherwise put marine species or ecosystems at risk. Below we briefly discuss those relevant to mining massive sulphide deposits.

Non-mandatory Department of Conservation guidelines (2006 and 2011) should be followed to avoid or mitigate acoustic impacts on marine mammals.

Avoidance or mitigation of seabird strikes is possible by limiting unnecessary use of vessel flood lights at night and ensuring that those that are required are directed approximately vertically onto work surfaces. Visual checks of the vessel super-structure at first light each day for the presence of dazed or injured birds and the provision of appropriate care may help to remedy this impact.

Avoidance or mitigation of vessels and underwater equipment acting as vectors for non-indigenous species is possible by appropriate checking, cleaning, and application of antifouling paints. We understand that Biosecurity New Zealand (MAF-BNZ) is developing an import health standard and legislation and relevant regulations may be put in place in next 2-3 years.

Pressure on fish stocks caused by a mining exclusion zone forcing fishing activities into the remainder of the quota management area can be reduced or eliminated by purchase and retirement of appropriate commercial fish quota for the duration of the production phase.

Actions that increase the rate of recovery of benthic fauna from the impacts of mining massive sulphide deposits will greatly reduce the risks associated with this industry. Recolonisation by larval settlement from adjacent populations may be increased by leaving adjacent vent communities intact to act as source populations. Because so little is known about larval connectivity in these populations, the minimum distances from source to impacted areas are unknown.

Many other potential mitigation methods are currently under development by mining companies (see http://www.nautilusminerals.com/s/Home.asp) but require testing and experimentation.

Table 4-7: Expert Panel Assessment: Massive sulphide deposit mining. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. Activities are listed (a, b, c, etc) after each threat to which they contribute. The maximum possible level of environmental risk is 30. Extreme environmental risks are highlighted in red, high in yellow, and moderate in green. Low risk activities are not highlighted. *Threats managed under the Maritime Transport Act (1994). NA = not applicable as species assessed are all protected.

Expert Panel Assessment: Massive sulphide deposits		Recovery period				Key species				Protected species				Ecosystem functional impact				Proportion of habitat affected			
Activity	**Threat**	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence
Prospecting a) Surface flood lights and noise b) ROV and other imaging surveys c) Acoustic swath mapping d) High resolution seismics e) Air gun seismic survey f) Spot sampling using ROV and AUV g) Survey vessel activities	*Seabird attraction, disturbance, collision (a)	1	6	6	2b	NA	NA	NA	NA	3	5	15	2b	0	6	0	2b	3	6	18	2b
	Acoustic impact from multi-beam echo sounders on marine mammals, reptiles, fish and invertebrates (c)	0	5	0	2a	0	6	0	2a	1	5	0	2a	0	6	0	2a	0	6	0	2a
	Acoustic impact from high resolution seismics on marine mammals, reptiles, fish and invertebrates (d)	2	5	10	2a	0	5	0	2a	2	6	12	2a	0	6	0	2a	0	6	0	2a
	Acoustic impact of air guns on marine mammals, reptiles, fish and invertebrates (e)	3	6	18	2a	3	6	18	1c	3	6	18	2a	0	6	0	2a	3	6	18	2a
	*Ship strikes on marine mammals, fish, and reptiles (g)	3	6	18	2a	2	2	4	2b	2	2	4	1c	0	6	0	2b	0	6	0	2b
	Small scale physical disturbance of vent fauna (b, f)	2	6	12	1c	1	4	4	2a	NA	NA	NA	NA	2	5	10	1c	1	6	6	2a
	Small scale physical disturbance of non-vent fauna (b, f)	4	3	12	1c	1	4	4	2a	1	4	4	2a	2	5	10	1c	1	6	6	2a
Exploration h) Surface flood lights and noise i) Test drilling j) Bulk sampling k) Test extraction methods l) Sediment plume m) Underwater noise	*Seabird attraction, disturbance, collision (h)	0	6	0	2b	NA	NA	NA	NA	2	5	10	2b	0	6	0	2b	0	6	0	2b
	Impact on vent fauna (i, j, k, l)	2	4	8	1c	2	4	8	1c	NA	NA	NA	NA	2	5	10	1c	2	4	8	1c
	Impact on non-vent fauna (l, j, k, l)	3	4	12	1c	1	4	4	2a	1	4	4	2a	2	5	10	1c	1	4	4	2c

n) Site surveys using swath mapping and/or boomer surveys o) Survey vessel activities	Impact on water column ecosystem (l)	1	6	6	2b	1	4	4	1c	1	4	4	1c	0	4	0	1c	1	6	6	2b
	Acoustic impact on marine mammals, reptiles, fish and invertebrates (n)	2	6	12	2a	1	6	6	1c	2	6	12	2a	0	6	0	2a	1	6	6	2a
	Entanglement of megafauna (l, j, k)	1	1	1	1b	NA	NA	NA	NA	1	3	3	1c	0	1	0	1b	0	1	0	1b
	*Ship strikes on marine mammals, fish, and reptiles from support vessels (o)	3	6	18	2a	2	2	4	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b
Mining p) Surface flood lights and noise q) Sea floor suction r) Extraction plume s) Slurry pipes t) Deposition of tailings in stock piles of pits u) Deposition plume v) Underwater lights and noise w) Waste water return x) Toxic chemical release y) Mining vessel activities z) Mining area exclusion zone	*Seabird attraction, disturbance, collision (p)	0	6	0	2b	NA	NA	NA	NA	3	5	15	2b	0	6	0	2b	0	6	0	2b
	Vector for non-indigenous species (y)	3	4	12	2b	1	4	4	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b
	Impact on water column ecosystem from plume sediments and toxins (r, u, w, x)	1	6	6	2b	1	4	4	1c	1	4	4	1c	2	4	8	1c	2	6	12	2b
	Acoustic impact from under-water noise from, suction heads, pumps, ROVs etc. (v)	0	6	0	2b	0	6	0	1c	1	6	6	1c	0	6	0	2b	1	6	6	2b
	Impact on fished species (q, r, s, t, u, w, x)	2	4	8	2a	2	3	6	1c	NA	NA	NA	NA	2	3	6	1c	2	4	8	2b
	Effects of spatial displacement of fishing on fish stocks (z)	2	4	8	1c	1	5	5	1c	NA	NA	NA	NA	1	4	4	1c	3	4	12	1c
	Impact on vent fauna (q, r, s, t, u, w, x)	3	4	12	1c	3	4	12	2b	NA	NA	NA	NA	5	4	20	1c	5	4	20	1c
	Impact on non-vent fauna (r, s, t, u, w, x)	4	6	24	1c	2	4	8	1c	2	4	8	2a	3	4	12	1c	2	4	8	1c
	Entanglement of megafauna (g, s)	2	1	2	1b	NA	NA	NA	NA	2	3	6	1c	2	1	2	1b	0	1	0	1b
	*Ship strikes on marine mammals, fish, and reptiles (y)	3	6	18	2a	2	2	4	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b

4.8 Polymetalic crusts

4.8.1 Background

Cobalt-rich ferromanganese crusts form on hard-rock substrates by the slow precipitation of minerals out of seawater, aided by the activities of micro-organisms, or associated with hydrothermal activity (ISA 2007, ISA 2008b). Such crusts are typically found in water depths of 1000-1500 m on the flanks and summits of seamounts in association with low rates of sedimentation, strong currents and a shallow and well-developed oxygen minimum layer (Hein et al., 1988 in Glasby and Wright, 1990). In the New Zealand EEZ, such crusts have been found previously on the Three Kings Ridge and SW Campbell Plateau (Glasby and Wright, 1990), while recently limonitic crusts have been discovered on the crest of the Challenger Plateau (Ocean Survey 20/20 voyage TAN0707, SD Nodder, pers. comm.). Hydrothermal-related crusts have also been found on Colville Ridge and on the western flanks of the Tonga-Kermadec Ridge (Glasby and Wright, 1990) (Figure 4-4).

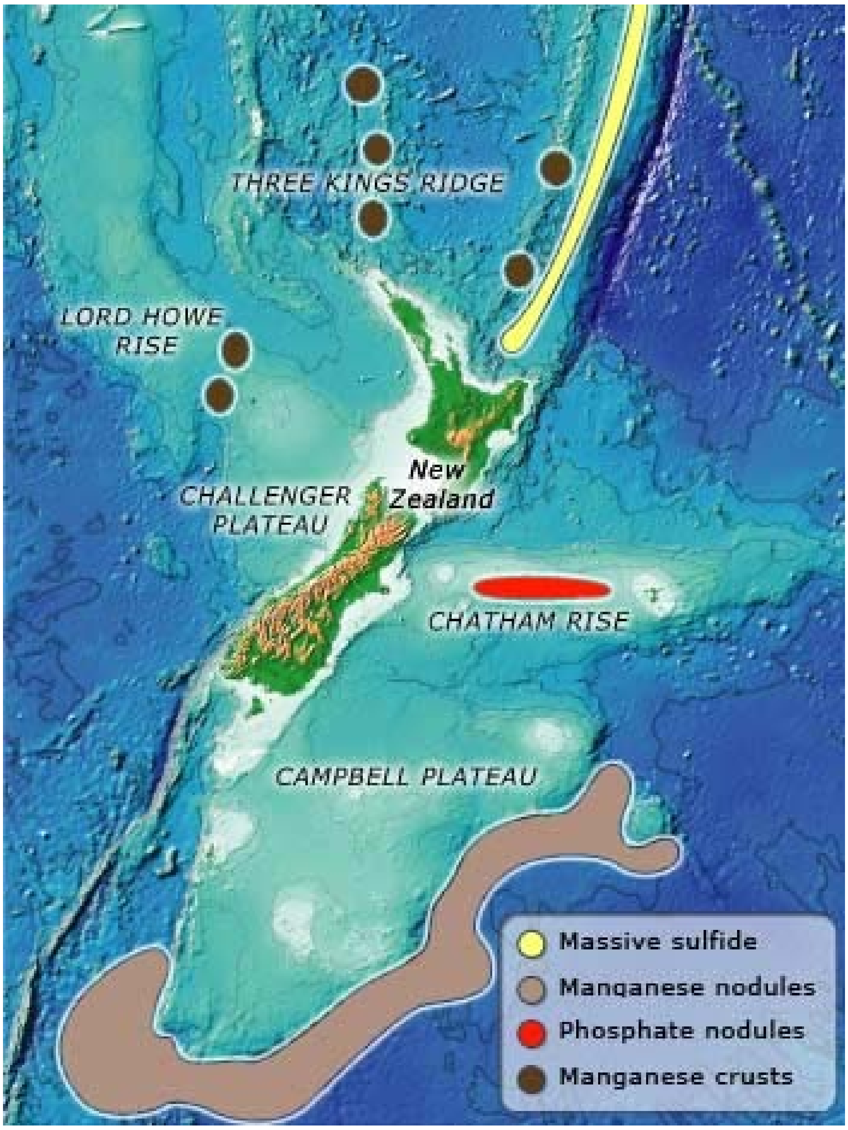


Figure 4-4: New Zealand EEZ distribution of mineral crusts and nodules.

The mining of Polymetalic crusts would be more difficult than for nodules because the crusts are attached to the underlying rock substrate (ISA, 2008). It is envisaged that articulated cutters on a mining dredge would fragment the crusts at the seafloor, which would then be transported to the surface tender platform and/or vessels using hydraulic lifting methods (ISA, 2008a). Other techniques for removing crusts from the underlying substrate might include water-jet stripping, chemical leaching and/or sonic separation (ISA, 2008b).

4.8.2 Assessment

We assessed three phases of a possible future Polymetalic crust mining industry; prospecting, exploration, and production. Compared to the oil industry where the production facilities may be largely static for decades, decommissioning in the Polymetalic nodule mining industry would likely be a relatively routine part of on-going production as equipment was moved among mining sites once crust in one part have been exhausted. Thus we have not considered decommissioning as a separate phase. For each phase we identified and assessed the potential ecological impact of several distinct activities (Table 4-9). Below we present the main results for each phase.

Prospecting

Surveys using rock dredges, suspended camera systems, remotely operated vehicles (ROVs) and/or submersibles to quantify crust distribution and concentrations are likely to occur over a wide area during this phase. This sampling is likely to be conducted from specially equipped vessels and affect a small (<<1-5%) proportion of a crust field. The risk to benthic habitats and organisms from this activity is likely to be minor to moderate, but the recovery of directly impacted habitat patches is likely to take years to decades (Table 4-8).

Acoustic swath mapping may be used to define the bathymetry of promising areas and high resolution seismic reflection techniques (e.g., Boomer, CHIRP) may be used to define seafloor and sub-seafloor geological features. Use of air guns to obtain deeper seismic information in these surveys is highly unlikely. The acoustic impact of seismic surveys on marine mammals, in particular, is well documented (Gordon & Moscrop 1996, Cox et al. 2006, Brandon et al. 2008, Di Iorio and Clark 2010), but may also affect a range of marine reptiles, fish and invertebrates. The consequences for marine mammals from the seismic gear likely to be used for these surveys will vary from none to behavioural (may leave area) perhaps to acute injury (ear drum damage) depending on noise level encountered, species and habitat. Beaked whales are thought to be particularly at risk. There may also be cumulative effects from repeated exposure.

Noise travels great distances underwater and so the footprint of this activity may be very broad though the greatest impacts will be much more restricted in area as sound intensity typically falls as the square of the distance from the source. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species, such as southern right whales, as these may occur throughout the EEZ though they occur in different areas at different times of the year. The risk from this activity was assessed to reach a score of 12 with a high level of confidence (Table 4-8) indicating the need for this to be a discretionary activity. Use of air guns, while inappropriate for defining these near seabed surface deposits, would considerably increase this risk.

Ship strikes on marine mammals may occur during transits among survey sites. These effects are covered under the Maritime Transport Act (1994) and the Marine Mammal Protection Act (1978).

Lights on ships at night typically attract and disturb seabirds and may cause them to collide with the coring vessel (Black 2005). These effects are covered under the Maritime Transport Act (1994) and the Wildlife Act (1953).

Exploration

In this phase more intensive evaluation of potential mining sites will take place. The focus is likely to be on areas of 30-50 km^2 capable of sustaining mining for a decade or more.

Within these areas multi-beam echo-sounders are likely to be used to define the bathymetry and high resolution seismic reflection techniques (e.g. Boomer, CHIRP) may be used to define seafloor and immediate sub-seafloor geological features. The area affected is likely to be a minor proportion (<1-5%) of the crust habitat. The risk to marine mammals and other organisms from this activity was assessed to reach a score of 12 with a high level of confidence (Table 4-8) indicating the need for this to be a discretionary activity. Use of air guns, though inappropriate for defining these near seabed surface deposits, would considerably increase this risk.

Further surveys using rock dredges, suspended camera systems, ROVs and/or submersibles to quantify crust distribution, thickness and chemical content are likely to occur during this phase, but are very likely to be concentrated over a small proportion (<1-5%) of the nodule habitat. There may also be some trials of extraction methods and bulk sampling of crusts. The risk to benthic habitats and organisms from this activity is likely to be minor to moderate, but the recovery of directly impacted benthic habitat patches is likely to take years to decades (Table 4-8).

Entanglement of megafauna in subsurface equipment, including anchor lines, mooring lines, marker buoy lines, power cabling or hydraulic lines, is a possibility during trials of extraction methods. Only a tiny fraction of the area (<<1%) is likely to have such hazards to fauna and these will probably be in place for only weeks to months. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk to protected marine mammals from this activity was assessed as low (3) with a high level of confidence (Table 4-8). Recovery of affected populations should these entanglement hazards be removed is expected to take years as the species concerned are slow growing and late maturing with low fecundity.

Production

During submarine crust mining a processing vessel is unlikely to moor to ‘permanent’ anchors blocks or anchor moorings. There is likely to be a sediment plume originating from the active mining face as well as from the slurry pipe depositing unwanted sediments. To be profitable a large area of Polymetalic crust, perhaps 5km^2, will need to be mined each year, possibly for decades. Over the lifetime of the mining operation it is possible that a considerable proportion of a ridge or seamount (60-90%) could be affected.

The benthic ecosystem on the seafloor in and around the mining operations will be sequentially and severely impacted during the long production phase as the relatively thin crust (5-20cm) is mined and an area downstream of the mining operations is affected by smothering and toxic effects from sediments disturbed by mining operations. Coarse grains will settle quickly, but finer particles may be carried some distance depending on current strength. In areas being actively mined probably close to 100% of the benthic organisms will be killed during the crust removal process. Smothering from the sediment plume will decrease as the distance from the plume source increases. As the total area affected is likely to be a significant proportion of the total crust habitat on a seamount, the functional impact on the benthic ecosystem as a whole, as well impacts on key species and protected benthic species, such as deepwater corals, are likely to be major. Because the benthic fauna includes slow-growing, long-lived species recovery of affected areas is likely to be very long-term. If species are dependent on the presence of the Polymetalic crust substrate then recovery may never occur in mined areas. Overall, the risks of this mining to the benthic ecosystems on ridges and seamounts were judged to be high (Table 4-8).

Sediment plumes arising from the mining face or slurry pipe depositing sediments may also cause disruption to the water column ecosystem by increasing turbidity, thereby restricting light availability for phytoplankton, or through the irritation of the gills of fish and invertebrates or through death from the toxic sediments. Anywhere from 5-20% of the pelagic habitat over a seamount may be affected at any one time and effects on key species, protected species and ecosystem function may be minor to moderate (Table 4-8). Recovery of the pelagic ecosystem is expected to be reasonably quick once sediment plumes stop.

Mining activities on the seabed will produce some level of underwater noise from the suction head, and any submersed cutters, pumps or other machinery. This underwater noise may affect marine mammals, mainly causing then to avoid the area, but we assessed this to pose moderate risk (12) and that recovery would be quick after the noise stopped.

Entanglement of megafauna in subsurface equipment including anchor lines, mooring lines, marker buoy lines, power cabling or hydraulic lines is a possibility. Only a tiny fraction of the area (<<1%) is likely to have such hazards to fauna. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk to protected marine mammals from this activity was assessed as low (3) with a high level of confidence (Table 4-9). Recovery of affected populations should these tangling hazards be removed is expected to take years as the species concerned are slow growing and late maturing with low fecundity.

Mining Polymetalic crusts may affect stocks of fished species in two ways. There may be some direct effects on fish during mining, especially on benthic foraging fish, and the seafloor may take years before the full range of prey species are available for such fish populations. Additionally fish may move away from the area of active mining and plume influence. Mining areas will invariably have a zone of restricted access around them that prevents fishing access. Unless commercial fish quota is purposefully bought by the mining company and retired for the duration of the production phase then commercial fishing will be displaced into the remainder of the quota management area (QMA). The resulting fishing pressure has the potentail to affects some fish stocks, especially sedentary species with limited migrations. While the area of a QMA affected by direct effects on fish stocks is likely to be small, the effects of displaced fishing will be felt over a much greater area. We assessed there to be moderate (8) risks to key fish stocks and ecosystem functioning from direct effects on fish stocks, and lower risk from displaced fishing effort to key fish stocks (5) and ecosystem functioning (4). Recovery of affected fish stocks from direct and indirect effects may take months to years (Table 4-8).

Ships brought in to New Zealand from Australia or further afield to separate the crust from other sediments may act as vectors for non-indigenous species, but the likelihood is low for a vessel with fresh antifouling. New Zealand-modified ships should pose little risk. The functional impact on the ecosystem surrounding the crust separation vessel is probably minor as vectored species are unlikely to survive independently of the ship in deep offshore waters. However, the ship may act as a stepping stone for non-indigenous species to invade shallow coastal habitats.

Risk summary for mining of Polymetalic crusts

Several activities associated with mining of Polymetalic crusts were considered to represent an extreme environmental risk and should be prohibited if no way can be found to avoid, mitigate or remedy their impact. These activities include:

- Testing of extraction methods
- Bulk sampling of crusts
- Sea floor cutting/fragmentation / extraction
- Extraction plume
- Slurry pipelines
- Deposition of tailings in stock piles or pits
- Deposition plume
- Toxic chemical release

The following activities were considered to be of high environmental risk (15-20) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Support vessel activity causing strikes on marine mammals, fish and reptiles
- Surface flood lights at night
- Testing and operation of undersea equipment with associated hydraulic lines, power cables and umbilical's

The following activities were considered to be of moderate environmental risk (7-12) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Spot sampling and imaging using ROV, AUV
- Use of high resolution seismics e.g. Boomer, CHIRP
- Import and provision of biofouling surfaces
- Incidental underwater noise

The following activities were considered to be of low environmental risk (0-6) and should be categorised as permitted:

- Single and multibeam echo sounding
- Underwater flood lights
- Declaration of a mining area exclusion zone
- ROV and other imaging surveys

4.8.3 Avoidance, mitigation, remediation

There are often ways of avoiding, remedying or mitigating the effects of activities that would otherwise put marine species or ecosystems at risk. Below we briefly discuss those relevant to mining Polymetalic crusts.

Non-mandatory Department of Conservation guidelines (2006 and 2011) should be followed to avoid or mitigate acoustic impacts on marine mammals.

Avoidance or mitigation of seabird strikes is possible by limiting unnecessary use of vessel flood lights at night and ensuring that those that are required are directed approximately vertically onto work surfaces. Visual checks of the vessel super-structure at first light each day for the presence of dazed or injured birds and the provision of appropriate care may help to remedy this impact.

Avoidance or mitigation of vessels and underwater equipment acting as vectors for non-indigenous species is possible by appropriate checking, cleaning, and application of antifouling paints. We understand that Biosecurity New Zealand (MAF-BNZ) is developing an import health standard and legislation and relevant regulations may be put in place in next 2-3 years.

Pressure on fish stocks caused by the mining exclusion zone forcing fishing activities into the remainder of the quota management area can be reduced or eliminated by purchase and retirement of appropriate commercial fish quota for the duration of the production phase.

Actions that increase the rate of recovery of benthic fauna from the impacts of crust mining will greatly reduce the risks associated with this industry. Recolonisation by larval settlement from adjacent populations may be increased by leaving adjacent communities intact to act as source populations. Because so little is known about larval connectivity in these populations, the minimum required distances from source to impacted area is unknown.

Table 4-8: Expert Panel Assessment: Polymetalic crust mining. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. Activities are listed (a, b, c, etc) after each threat to which they contribute. The maximum possible level of environmental risk is 30. Extreme environmental risks are highlighted in red, high in yellow, and moderate in green. Low risk activities are not highlighted. *Threats managed under the Maritime Transport Act (1994). NA = not applicable as species assessed are all protected.

Expert Panel Assessment: Polymetalic crusts		Recovery period				Key species				Protected species				Ecosystem functional impact				Proportion of habitat affected			
Activity	**Threat**	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence
Prospecting a) Surface flood lights and noise b) ROV and other imaging surveys c) Acoustic swath mapping d) Sub-bottom profiling using CHIRPS, boomers and sparkers e) Spot sampling using ROV, submersible, or rock dredge f) Survey vessel activities	*Seabird attraction, disturbance, collision (a)	1	6	6	2b	NA	NA	NA	NA	3	5	15	2b	0	6	0	2b	3	6	18	2b
	Acoustic impact from multi-beam echo sounders on marine mammals, reptiles, fish and invertebrates (c)	0	5	0	2a	0	6	0	2a	1	5	0	2a	0	6	0	2a	0	6	0	2a
	Acoustic impact of high resolution seismics on marine mammals, reptiles, fish and invertebrates (d)	1	6	6	2a	2	6	12	1c	2	6	12	2a	0	6	0	2b	2	6	12	2b
	*Ship strikes on marine mammals, fish, and reptiles (f)	3	6	18	2b	2	2	4	2b	2	2	4	1c	0	6	0	2b	0	6	0	2b
	Impact on benthos (b, e)	4	3	12	1c	1	4	4	2a	1	4	4	2a	2	5	10	1c	1	6	6	2a
Exploration g) Surface flood lights and noise h) Test extraction methods i) Bulk sampling j) Sediment plume k) Underwater noise l) Sub-bottom profiling using CHIRPS, boomers and sparkers m) Site surveys using swath	*Seabird attraction, disturbance, collision (g)	0	6	0	2b	NA	NA	NA	NA	2	5	10	2b	0	6	0	2b	0	6	0	2b
	Impact on benthos (h, i)	4	6	24	1c	2	4	8	2a	1	4	4	2a	2	5	10	2a	1	4	4	2b
	Acoustic impact on marine mammals, reptiles, fish and invertebrates (l, m)	1	6	6	2a	2	6	12	1c	2	6	12	2a	0	6	0	2b	2	6	12	2b
	Entanglement of megafauna (h, i)	3	5	15	2b	1	3	3	2b	1	3	3	2b	0	6	0	2b	0	6	0	2b
	*Ship strikes on marine mammals, fish, and reptiles from support vessels (n)	3	6	18	2a	2	2	4	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b

mapping &/or boomer surveys n) Mining vessel activities																					
Mining o) Surface flood lights and noise p) Sea floor cutting/fragmentation q) Extraction plume r) Sea floor slurry pipes s) Deposition of tailings in stock piles or pits t) Deposition plume u) Incidental underwater lights and noise v) Waste water return w) Toxic chemical release x) Mining vessel activities y) Mining area exclusion zone	Impact on water column ecosystem from plume sediments (g, t, w)	1	6	6	2b	1	4	4	1c	1	4	4	1c	2	4	8	1c	2	6	12	1c
	Acoustic impact on marine mammals, reptiles, fish and invertebrates (u)	1	6	6	2a	1	6	6	1c	2	6	12	2a	0	6	0	2b	1	6	6	2b
	Vector for non-indigenous species (x)	3	4	12	2b	1	4	4	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b
	Impact on fished species (p, q, r, s, t, v, w)	2	4	8	1c	2	4	8	1c	NA	NA	NA	NA	2	4	8	1c	2	4	8	2b
	Displacement of fishing activity (y)	1	5	5	2b	1	5	5	2b	1	4	4	2b	1	4	4	1c	1	4	4	2b
	*Ship strikes on marine mammals, fish and reptiles from support vessels (x)	3	6	18	2a	1	2	2	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b
	*Seabird attraction, disturbance, collision (o)	0	6	0	2b	NA	NA	NA	NA	3	5	15	2b	0	6	0	2b	0	6	0	2b
	Entanglement of megafauna (p, r)	3	5	15	2b	1	3	3	2b	1	3	3	2b	0	6	0	2b	0	6	0	2b
	Underwater lights (u)	0	4	0	2a	0	4	0	2a	0	4	0	2a	0	4	0	2a	0	4	0	2a
	Impact on benthos (p, q, r, s, t, w)	5	6	30	2a	4	5	20	1c	4	5	20	1c	4	4	16	1c	4	4	16	1c

4.9 Polymetalic nodules

4.9.1 Background

Polymetalic nodules are also known as manganese nodules, and are formed by the slow deposition (cm/millions of years) of manganese and iron hydroxides, as well as elements such as nickel, cobalt and copper, directly from seawater (authigenic processes) or at the sediment-water interface (diagenetic processes) (ISA, 2008a). Typically, nodules are formed of concentric layering around a central core that might be as small as a foraminifera (calcareous protozoan) test or comprise rock or nodule fragments. Nodule formation generally requires slow rates of sedimentation and/or strong currents that restrict sediment deposition, planktonic sources of various elements (Cu, Ni, Co) and micro-organism activity. Accordingly, in the New Zealand EEZ and ECS, nodules occur in abundance over a very large area (~250,000 km^2) in deep water (4000-5000 m) immediately southeast of the Campbell Plateau, south of 56°S (Glasby and Wright, 1990) and in the vicinity of Bollon's Seamount at 50°S (Carter, 1989) where the Deep Western Boundary Current brings Antarctic Bottom Water into the New Zealand region (see Figure 4-4). The nodules have relatively low Cu, Ni and Co contents, and may have over 75% areal coverage in certain locations on the seafloor, although the entire area has only been sparsely surveyed (Glasby and Wright, 1990) (Figure 4-5).

Considerable research has been undertaken on the manganese nodule deposits elsewhere in the Pacific and Indian oceans, such that the most likely extraction techniques would involve hydraulic mining methods, comprising a seafloor hydraulic suction dredge connected to a mining platform via a flexible hose and rigid pipe string for transporting the nodules from the seafloor to the sea surface (ISA, 2008a). Other alternatives that have been considered include continuous line bucket dredging systems (ISA, 2008a).

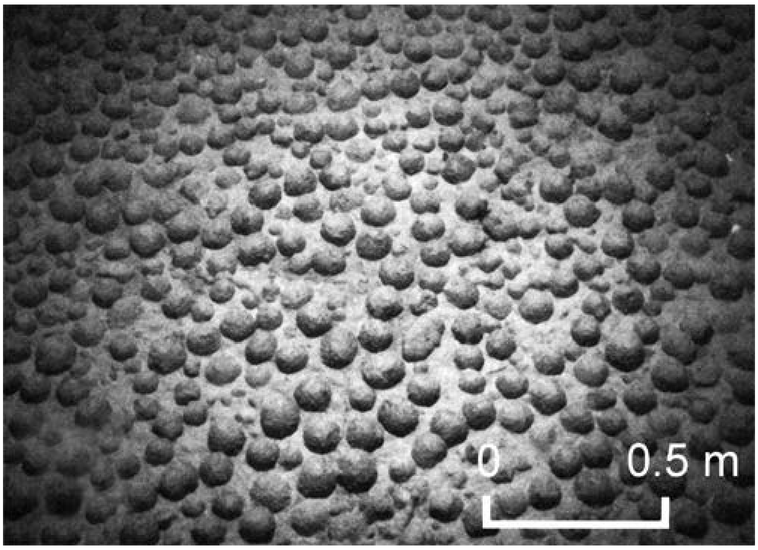


Figure 4-5: A dense field of Polymetalic (manganese) nodules from the Campbell plateau slope. Photograph courtesy Ashley Rowden.

4.9.2 Assessment

We assessed three phases of a possible future Polymetalic nodule mining industry; prospecting, exploration, and production. Compared to the oil industry where the production facilities may be largely static for decades, decommissioning in the Polymetalic nodule mining industry would likely be a relatively routine part of on-going production as equipment was moved around the mining site once nodules in one part have been exhausted. Thus we have not considered decommissioning as a separate phase. For each phase we identified and assessed the potential ecological impact of several distinct activities (Table 4-9). Below we present the main results for each phase.

Prospecting

Surveys using rock dredges, suspended camera systems, remotely operated vehicles (ROVs) and/or submersibles to quantify nodule distribution and concentrations are likely to occur over a wide area during this phase. This sampling is likely to be conducted from specially equipped vessels and affect a very small proportion of the nodule field. The risk to benthic habitats and organisms from this activity is likely to be minor to moderate, but directly impacted habitat patches may never recover if the fauna is reliant on the presence of nodules as a settlement surface (Table 4-9).

Acoustic swath mapping may be used to define the bathymetry of promising areas and high resolution seismic reflection techniques (e.g., Boomer, CHIRP) may be used to define seafloor and sub-seafloor geological features. Use of air guns to obtain deeper seismic information in these surveys is unlikely. The acoustic impact of seismic surveys on marine mammals, in particular, is well documented (Gordon & Moscrop 1996, Cox et al. 2006, Brandon et al. 2008, Di Iorio and Clark 2010), but may also affect a range of marine reptiles, fish and invertebrates. The consequences for marine mammals from the seismic gear likely to be used for these surveys will vary from none to behavioural (may leave area) perhaps to acute injury (ear drum damage) depending on noise level encountered, species and habitat. Beaked whales are thought to be particularly at risk. There may also be cumulative effects from repeated exposure.

Noise travels great distances underwater and so the footprint of this activity may be very broad although the greatest impacts will be much more restricted in area as sound intensity typically falls as the square of the distance from the source. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species, such as southern right whales, as these may occur throughout the EEZ, although they occupy different areas at different times of the year. The risk from this activity was assessed to reach a score of 12 with a high level of confidence (Table 4-9) indicating the need for this to be a discretionary activity. Use of air guns, while inappropriate for defining these near seabed surface deposits, would considerably increase this risk. Recently established non-mandatory DoC guidelines should be followed to avoid or minimise effects.

Ship strikes on marine mammals may occur during transits among coring sites. These effects are covered under the Maritime Transport Act (1994) and the Marine Mammal Protection Act (1978).

Lights on ships at night typically attract and disturb seabirds and may cause them to collide with the coring vessel (Black 2005). These effects are covered under the Maritime Transport Act (1994) and the Wildlife Act (1953).

Exploration

In this phase more intensive evaluation of potential mining sites will take place. The focus is likely to be on areas of 100-200 km^2 capable of sustaining mining for a decade or more.

Within these areas multi-beam echo-sounders are likely to be used to define the bathymetry and high resolution seismic reflection techniques (e.g., Boomer, CHIRP) may be used to define the sub-seafloor geological strata. The area affected is likely to be a very small proportion (<<1%) of the nodule habitat. The risk to marine mammals and other organisms from this activity was assessed to reach a score of 12 with a high level of confidence (Table 4-9). Use of air guns, while inappropriate for defining these near seabed surface deposits, would considerably increase this risk. Recently established non-mandatory DoC guidelines should be followed to avoid or minimise effects.

Further surveys using rock dredges, suspended camera systems, ROVs and/or submersibles to quantify nodule distribution and concentrations are likely to occur during this phase, but are very likely to be concentrated over a small proportion (<<1%) of the nodule habitat. There may also be some trials of extraction methods that will involve bulk sampling. The risk to benthic habitats and organisms from this activity is likely to be minor to moderate, but directly impacted habitat patches may never recover if the fauna is reliant on the presence of nodules as a settlement surface (Table 4-9).

Entanglement of megafauna in subsurface equipment, including marker buoy lines, power cabling or hydraulic lines, is a possibility during trials of extraction methods. Only a tiny fraction of the area (<<1%) is likely to have such hazards to fauna and these will probably be in place for only weeks to months. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk to protected marine mammals from this activity was assessed as moderate (9) with a high level of confidence (Table 4-9). Recovery of affected populations should these tangling hazards be removed is expected to take years as the species concerned are slow growing, and late maturing with low fecundity.

Production

During mining the processing vessel is unlikely to moor to ‘permanent’ anchors blocks or anchor moorings. There is likely to be a sediment plume originating from the active mining face as well as from the slurry pipe depositing unwanted sediments. To be profitable a large area, perhaps 10km^2, will need to be mined each year, possibly for decades. Over the lifetime of the mining operation it is possible that only a small proportion (<<1-5%) of the vast Polymetalic nodule habitat along the flanks of the Campbell Plateau would be affected.

The benthic ecosystem on the seafloor in and around the mining operations will be sequentially and severely impacted during the long production phase as areas are mined and backfilled with sediment and an area downstream of the mining operations will be affected by smothering from sediments from sediment plumes. Coarse grains will settle quickly, but finer silts, muds and clays may be carried some distance depending on current strength and resuspension. In areas being actively mined probably close to 100% of the benthic organisms will be killed during the mining or nodule concentration process. Smothering from sediment plumes will decrease as the distance from the plume source increases. As the total area affected is likely to be a small proportion of the total nodule habitat, the functional impact on the benthic ecosystem as a whole, as well impacts on key species and protected benthic species are likely to be moderate. Because the benthic fauna may include slow growing, long-lived species recovery of affected areas is likely to be very long-term. If species are dependent on the presence of Polymetalic nodules then recovery may never occur in mined areas. Overall, the risks of Polymetalic nodule mining to the benthic ecosystems around the southern flank of the Southern Plateau were judged to be moderate (Table 4-9).

Sediment plumes arising from the mining face or slurry pipe depositing sediments may also cause disruption to the water column ecosystem by increasing turbidity, thereby restricting light availability for phytoplankton, or through irritation of the gills of fish and invertebrates. The area affected at any one time is likely to be very small and effects on key species, protected species and ecosystem function possibly will be minor to moderate (Table 4-9). Recovery of the pelagic ecosystem is expected to be reasonably quick once sediment plumes stop.

Mining activities on the seabed will produce some level of underwater noise from the suction head, and any submersed cutters, pumps or other machinery. This underwater noise may affect marine mammals, mainly causing then to avoid the area, but we assessed this to pose moderate risk (12) and that recovery would be quick after the noise stopped.

Entanglement of megafauna in subsurface equipment, including marker buoy lines, power cabling or hydraulic lines, is a possibility. Only a tiny fraction of the area (<<1%) is likely to have such hazards to fauna. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk to protected marine mammals from this activity was assessed as moderate (9) with a high level of confidence (Table 4-9). Recovery of affected populations should these tangling hazards be removed is expected to take years as the species concerned are slow growing and late maturing with low fecundity.

Mining Polymetalic nodules will not affect commercial fish stocks as none are known to occur in these deep (4000-5000 m) waters.

Ships brought in to New Zealand from Australia or further afield to separate the nodules from other sediments may act as vectors for non-indigenous species, but the likelihood is low for a vessel with fresh antifouling. New Zealand modified ships should pose little risk. The functional impact on the ecosystem surrounding the nodule separation vessel is probably minor as vectored species are unlikely to survive independently of the ship in deep offshore waters. However, the ship may act as a stepping stone for non-indigenous species to invade shallow coastal habitats. We understand that Biosecurity New Zealand (MAF-BNZ) is developing an import health standard to cover the use of such ships and legislation and relevant regulations may be put in place in next 2-3 years.

Risk summary for mining of Polymetalic nodules

Several activities associated with mining of Polymetalic nodules were considered to represent an extreme environmental risk and should be prohibited if no way can be found to avoid, mitigate or remedy their impact. These activities include:

- Sea floor extraction / mining
- Creation of sediment plume
- Use of slurry pipes
- Deposition of tailings in stock piles
- Release of toxic chemicals

The following activities were considered to be of high environmental risk (15-20) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Support vessel activity causing strikes on marine mammals, fish and reptiles
- Surface flood lights at night
- Testing and operation of undersea mining equipment with associated hydraulic lines, power cables and umbilical's
- Bulk sampling of nodules

The following activities were considered to be of moderate environmental risk (7-12) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Spot sampling using ROV, AUV
- Use of high resolution seismics e.g. Boomer, CHIRP
- Import and provision of biofouling surfaces
- Incidental underwater noise

The following activities were considered to be of low environmental risk (0-6) and categorised as permitted:

- Multibeam echo sounding
- Underwater flood lights
- Imaging using ROV, AUV
- Declaration of exclusion zone

4.9.3 Avoidance, mitigation, remediation

There are often ways of avoiding, remedying or mitigating the effects of activities that would otherwise put marine species or ecosystems at risk. Below we briefly discuss those relevant to mining Polymetalic nodules.

Non-mandatory Department of Conservation guidelines (2006 and 2011) should be followed to avoid or mitigate acoustic impacts on marine mammals.

Avoidance or mitigation of seabird strikes is possible by limiting unnecessary use of vessel flood lights at night and ensuring that those that are required are directed approximately vertically onto work surfaces. Visual checks of the vessel super-structure at first light each day for the presence of dazed or injured birds and the provision of appropriate care may help to remedy this impact.

Avoidance or mitigation of vessels and underwater equipment acting as vectors for non-indigenous species is possible by appropriate checking, cleaning, and application of antifouling paints. We understand that Biosecurity New Zealand (MAF-BNZ) is developing an import health standard and legislation and relevant regulations may be put in place in next 2-3 years.

Actions that increase the rate of recovery of benthic fauna from the impacts of nodule mining will greatly reduce the risks associated with this industry. Recolonisation by larval settlement from adjacent populations may be increased by leaving adjacent communities intact to act as source populations. Because so little is known about larval connectivity in these populations, the maximum distance from source to impacted areas is unknown.

Table 4-9: Expert Panel Assessment: Polymetalic nodule mining. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. Activities are listed (a, b, c, etc) after each threat to which they contribute. The maximum possible level of environmental risk is 30. Extreme environmental risks are highlighted in red, high in yellow, and moderate in green. Low risk activities are not highlighted. *Threats managed under the Maritime Transport Act (1994). NA = not applicable as species assessed are all protected.

Expert Panel Assessment: Polymetalic nodules		Recovery period				Key species				Protected species				Ecosystem functional impact				Proportion of habitat affected			
Activity	**Threat**	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence
Prospecting a) Surface flood lights and noise b) ROV and other imaging surveys c) Acoustic swath mapping d) Sub-bottom profiling using CHIRPS, boomers and sparkers e) Spot sampling using ROV, submersible, or rock dredge f) Survey vessel operations	*Seabird attraction, disturbance, collision (a)	1	6	6	2b	NA	NA	NA	NA	3	5	15	2b	0	6	0	2b	1	6	6	1b
	Acoustic impact from multi-beam echo sounders on marine mammals, reptiles, fish and invertebrates (c)	0	5	0	2a	0	6	0	2a	1	5	0	2a	0	6	0	2a	0	6	0	2a
	Acoustic impact of high resolution seismics on marine mammals, reptiles, fish and invertebrates (d)	1	6	6	2a	2	6	12	1c	2	6	12	2a	0	6	0	2b	0	6	0	1b
	*Ship strikes on marine mammals, fish, and reptiles (f)	3	6	18	2a	2	2	4	2b	2	2	4	1c	0	6	0	2b	0	4	0	1b
	Impact on benthos (e)	4	3	12	1c	1	4	4	2a	1	4	4	2a	2	5	10	1c	0	6	0	1b
Exploration g) Surface flood lights and noise h) Test extraction methods i) Bulk sampling j) Sediment plume k) Underwater noise l) Site surveys using multi-beam echo sounding m) Sub-bottom profiling using CHIRPS, boomers and sparkers n) Support vessel	*Seabird attraction, disturbance, collision (g)	0	6	0	2b	NA	NA	NA	NA	2	5	10	2b	0	6	0	2b	0	6	0	1b
	Impact on benthos (h, i, j)	4	5	20	1c	2	4	8	2a	1	4	4	2a	2	5	10	2a	0	4	0	1b
	Acoustic impact from multi-beam echo sounders on marine mammals, reptiles, fish and invertebrates (l)	0	5	0	2a	0	6	0	2a	1	5	0	2a	0	6	0	2a	0	6	0	2a
	Acoustic impact on marine mammals, reptiles, fish and invertebrates (l, m)	1	6	6	2a	2	6	12	1c	2	6	12	2a	0	6	0	2b	0	6	0	1b
	Underwater flood lights	0	4	0	2a	0	4	0	2a	0	4	0	2a	0	4	0	2a	0	4	0	2a

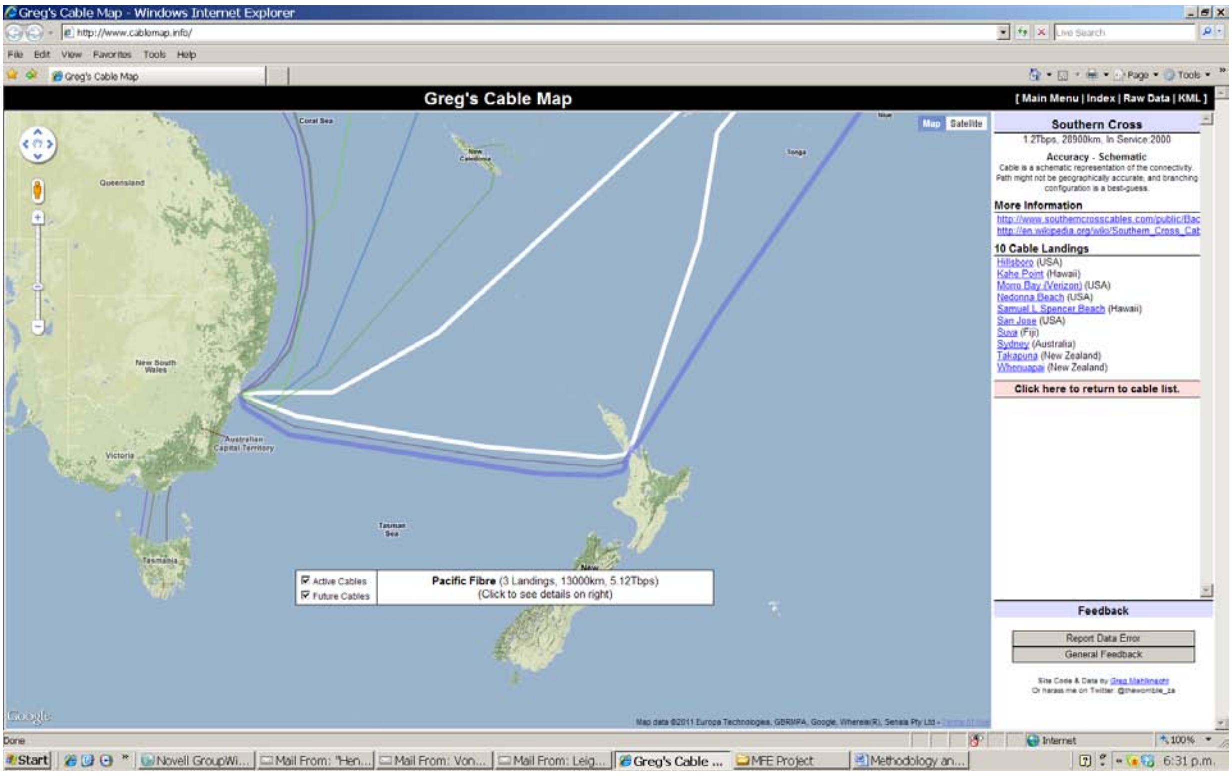
activities	Entanglement of megafauna (h, i)	3	5	15	2b	1	3	3	2b	3	3	9	2b	0	6	0	2b	0	6	0	2b
	*Ship strikes on marine mammals, fish and reptiles (n)	3	6	18	2a	2	2	4	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b
Mining o) Surface flood lights and noise p) Sea floor mining q) Extraction plume r) Slurry pipes s) Deposition of tailings in stock piles or pits t) Deposition plume u) Incidental underwater lights and noise v) Waste water return w) Toxic chemical release x) Support vessel activity y) Declaration of exclusion zone	Impact on water column ecosystem from plume sediments (q, t, w)	1	6	6	2b	1	4	4	1c	1	4	4	1c	2	4	8	1c	0	6	0	1c
	Acoustic impact on marine mammals, reptiles, fish and invertebrates (u)	0	6	0	2a	1	6	6	1c	2	6	12	2a	0	6	0	2b	0	6	0	2b
	*Ship strikes on marine mammals, fish and reptiles from support vessels (x)	3	6	18	2a	1	2	2	1c	3	3	9	2a	0	4	0	2b	0	5	0	2b
	*Seabird attraction, disturbance, collision (o)	0	6	0	2b	NA	NA	NA	NA	3	5	15	2b	0	6	0	2b	0	6	0	2b
	Vector for non-indigenous species (x)	3	4	12	2b	1	4	4	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b
	Entanglement of megafauna (r)	3	5	15	2b	1	3	3	2b	3	3	9	2b	0	6	0	2b	0	4	0	1c
	Underwater lights (u)	0	4	0	2a	0	4	0	2a	0	4	0	2a	0	4	0	2a	0	4	0	2a
	Impact on benthos (p, q, r, s, t, w)	5	5	25	1b	2	4	8	1b	1	2	2	1b	2	4	8	1b	1	4	4	1b

4.10 Ocean basin telecommunications cabling

4.10.1 Background

New Zealand has two existing telecommunications cables (Southern Cross & Tasman 2) that cross the EEZ and ECS. Another (Pacific Fibre) is proposed (Figure 4-6). The route of all three is broadly similar across the Tasman (from Sydney to Auckland) but only two (Pacific Fibre and Sothern Cross) are routed from New Zealand to the USA.

Both the Tasman Sea and the Pacific Ocean are challenging environments for laying cables. They reach great depths and have steep bathymetric features including numerous seamounts, ridges and troughs. The Pacific Ocean is tectonically active with the constant threat of volcanic activity, earthquakes and tsunamis that could damage or break cables. Routes are generally chosen to avoid hazard, such as areas of reef, steep bathymetry, active volcanoes, active faults and deep trenches.



☑ Active Cables
☑ Future Cables

Pacific Fibre (3 Landings, 13000km, 5.12Tbps)
(Click to see details on right)

Southern Cross
1.2Tbps, 28900km, In Service:2000

Accuracy - Schematic
Cable is a schematic representation of the connectivity. Path might not be geographically accurate, and branching configuration is a best-guess.

More Information
http://www.southerncrosscables.com/public/Bac
http://en.wikipedia.org/wiki/Southern_Cross_Cat

10 Cable Landings
Hillsboro (USA)
Kahe Point (Hawaii)
Morro Bay (Verizon) (USA)
Nedonna Beach (USA)
Samuel L Spencer Beach (Hawaii)
San Jose (USA)
Suva (Fiji)
Sydney (Australia)
Takapuna (New Zealand)
Whenuapai (New Zealand)

Click here to return to cable list.

Feedback
Report Data Error
General Feedback

Site Code & Data by Greg Mahlknecht
Or harass me on Twitter: @thewomble_za

Figure 4-6: Telecommunication routes in the New Zealand region.

4.10.2 Assessment

Laying new subsea cables is a major undertaking and generally can be broken into four distinct phases: route exploration, cable laying and maintenance, cable operation and abandonment. For each phase we identified and assessed the potential ecological impact of several distinct activities (Table 4-10). Below we present the main results for each phase.

Route exploration

Surveys of potential routes across the Tasman Sea and Pacific Ocean will include multibeam echo-sounding to map bathymetry, and high resolution seismics (e.g. Boomer, CHIRP) for substrate characterisation, while seismic air guns may be used for fault mapping and identifying deeper geological hazards. Acquisition of seismic data is via a streamer comprising multiple hydrophones that may be up to 15km long. The streamer is typically deployed at ~2 knots and acquisition of data occurs at 5 knots. A very large area, perhaps approaching 100% of the possible cable routes through the EEZ and ECS, may be surveyed during this phase though sequentially over a period of several weeks to a few months.

The acoustic impact of seismic surveys on marine mammals, in particular, is well documented (Gordon & Moscrop 1996, Cox et al. 2006, Brandon et al. 2008, Di Iorio and Clark 2010) but may also affect a range of marine reptiles, fish and invertebrates. The consequences for marine mammals will vary from none to behavioural (may leave area) to acute injury (ear drum damage) to serious (death) depending on noise level encountered, species and habitat. Beaked whales are thought to be particularly at risk. There may also be cumulative effects from repeated exposure. Noise travels great distances underwater and so the footprint of this activity may be very broad though fatal impacts will be much more restricted in area as sound intensity typically falls as the square of the distance from the source. Acoustic depth sounders and multibeam echo-sounders used for swath mapping pose little risk but high energy seismic devices such as air guns used for mapping sub seafloor geological structures pose a much greater risk. Using a precautionary approach our assessment assumed that air guns were used and that the species affected was a nationally critical species such as southern right whales as these may occur throughout the EEZ though they occur in different areas at different times of the year. The risk from this activity was assessed to reach a score of 18 with a high level of confidence (Table 4-10) indicating the need for this to be a permitted activity.

Samples of surface sediments may be taken using coring devices to indicate the suitability of substrates for trenching and burial of the cable. However the area affected is expected to be very small and carry low risk for all aspects of the benthic environment (Table 4-10).

Ship strikes on marine mammals may occur during the route surveys. These effects are covered under the Maritime Transport Act (1994) and the Marine Mammal Protection Act (1978).

Lights on ships at night typically attract and disturb seabirds and may cause them to collide with the survey vessel (Black 2005). These effects are covered under the Maritime Transport Act (1994) and the Wildlife Act (1953).

Cable laying and maintenance

For the past decade or so trans-ocean fibre-optic telecommunications cables have been manufactured on board the cable ship and laid in one seamless run. It is also common practice to bury the cable in a shallow narrow trench using a trenching plough to help eliminate accidental damage from bottom trawl gear. These practices have greatly reduced twisting of the cable during laying and ongoing maintenance requirements. The area of benthic habitat affected by burial and any associated sediment plume is expected to be a very small proportion of similar habitats in the northern part of the EEZ and ECS and carry low risk for all aspects of the benthic environment but recovery will takes months to a few years (Table 4-10).

During cable laying and maintenance the arc of cable between the cable ship and the seafloor poses some risk of entanglement to megafauna such as the larger baleen whales and sperm whales. In deep water this arc of cable may be up to 7-10 km long. The area of hazard is likely to be very small. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species as these may occur throughout the EEZ. The risk to protected marine mammals from this activity was assessed as low (3) with a low level of confidence as data about this hazard are few particularly in relation to modern cable designs and laying methods (Table 4-10). Recovery of affected populations once the cable is buried in the seafloor is expected to take years as the species concerned are slow growing, late maturing with low fecundity.

Cable laying is a slow speed operation and there is the potential for cable ships to act as a vector for non-indigenous species to enter New Zealand waters. However, the likelihood is low for a vessel with fresh antifouling. The functional impact on deepwater ecosystems in the EEZ and ECS is probably negligible as vectored species are highly unlikely to survive independently of the ship. However, as the cable laying operation nears shore the ship may act as a stepping stone for non-indigenous species to invade shallow coastal habitats.

Cable operation

Risks to the marine environment during this stage all arise from any part of the cable that is not buried in the sediment. Despite the best of plans cables may be suspended between high points or be undercut by strong currents. These cable suspensions pose ongoing but low (3) risks to deep-diving whales and the recovery of any affected population is expected to take years (Table 4-10).

Movement of suspended cable in currents may continuously damage small areas of benthic fauna but the ecological risks are negligible (Table 4-10).

Seafloor telecommunications cables may affect stocks of fished species. Cable routes invariably have a zone of restricted access around them that prevents fishing activity. Unless commercial fish quota is purposefully bought by the cable operator and retired for the duration of the cable operation then commercial fishing will be displaced into the remainder of the quota management area (QMA). The resulting fishing pressure has the potentail to affects some fish stocks, especially sedentary species with limited migrations. However, the area of a QMA affected is likely to be small (<1-5%) and we assessed there to be negligible risks to key fish stocks and ecosystem functioning (Table 4-10).

Abandonment

We have assumed that cables will be abandoned *in situ* at the end their working life rather than recovered. Recovery would be expensive and uncertain and removal of cables buried for decades has the potential to cause as much, if not more, ecological damage that when they were laid. Abandoned cables will slowly deteriorate and disintegrate over time but this may take decades or centuries. Steel reinforcing wires will eventually rust but glass fibres will remain. Exposed sections of cable have the potential to entangle deep-diving megafauna such as sperm whales and the risks are identical to those listed above during cable operation (Table 4-10).

Risks to benthic communities may be negligible, especially if most of the cable remains buried until it finally disintegrates (Table 4-10).

Risk summary for ocean basin telecommunications cabling

There were no activities associated with telecommunications cable installation or operation considered to represent an extreme environmental risk provisionally indicating prohibited status.

The following activities were considered to be of high environmental risk (15-20) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Surface flood lights at night causing bird strikes (regulated under the Maritime Transport Act (1994) and the Wildlife Act (1953)).
- Survey vessel activity causing strikes on marine mammals (regulated under the Maritime Transport Act (1994) and the Marine Mammal Protection Act (1978)).Use of high energy seismic devices such as airguns
- Cable lowering or raising activities

The following activities were considered to be of moderate environmental risk (7-12) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Provision of biofouling surfaces
- Use of high resolution seismics e.g. Boomer, CHIRP

The following activities were considered to be of low environmental risk (0-6) and should be categorised as permitted:

- Single and multibeam echo sounding
- Seabed sampling
- Cable trenching and installation
- Exposed cable movement
- Declaration of cable route exclusion zone
- Cable abandonment

4.10.3 Avoidance, mitigation, remediation

There are often ways of avoiding, remedying or mitigating the effects of activities that would otherwise put marine species or ecosystems at risk. Below we briefly discuss those relevant to ocean basin telecommunications cabling.

Non-mandatory Department of Conservation guidelines (2006 and 2011) should be followed to avoid or mitigate acoustic impacts on marine mammals.

Avoidance or mitigation of seabird strikes is possible by limiting unnecessary use of vessel flood lights at night and ensuring that those that are required are directed approximately vertically onto work surfaces. Visual checks of the vessel super-structure at first light each day for the presence of dazed or injured birds and the provision of appropriate care may help to remedy this impact.

Avoidance or mitigation of vessels and underwater equipment acting as vectors for non-indigenous species is possible by appropriate checking, cleaning, and application of antifouling paints. We understand that Biosecurity New Zealand (MAF-BNZ) is developing an import health standard and legislation and relevant regulations may be put in place in next 2-3 years.

Pressure on fish stocks caused by the cable exclusion zone forcing fishing activities into the remainder of the quota management area can be reduced or eliminated by purchase and retirement of appropriate commercial fish quota for the duration of the production phase.

Table 4-10: Expert Panel Assessment: Ocean basin telecommunications cabling. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. Activities are listed (a, b, c, etc) after each threat to which they contribute. The maximum possible level of environmental risk is 30. Extreme environmental risks are highlighted in red, high in yellow, and moderate in green. Low risk activities are not highlighted. *Threats managed under the Maritime Transport Act (1994). NA = not applicable as species assessed are all protected.

Expert Panel Assessment: Ocean basin telecommunications cabling		Recovery period				Key species				Protected species				Ecosystem functional impact				Proportion of habitat affected			
Activity	**Threat**	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence
Cable route exploration a) Acoustic multibeam for mapping bathymetry, b) High resolution seismics for substrate characterization c) Air guns for fault mapping and deeper geological hazards d) Surface flood lights and noise e) Cable route seabed sampling f) Survey ship activities	*Ship strikes on marine mammals, fish, and reptiles (f)	3	6	18	2b	1	2	2	2b	2	2	4	1c	0	6	0	2b	0	6	0	2b
	Acoustic impact from multi-beams echo sounders on marine mammals, reptiles, fish and invertebrates (a)	0	5	0	2a	0	6	0	2a	1	5	0	2a	0	6	0	2a	0	6	0	2a
	Acoustic impact from high resolution seismics on marine mammals, reptiles, fish and invertebrates (b)	2	5	10	2a	0	5	0	2a	2	6	12	2a	0	6	0	2a	0	6	0	2a
	Acoustic impact from air guns on marine mammals, reptiles, fish and invertebrates (c)	3	6	18	2a	2	4	8	1c	3	6	18	2a	0	6	0	2a	0	6	0	2a
	*Seabird attraction, disturbance, collision (d)	1	6	6	2b	NA	NA	NA	NA	3	5	15	2b	0	6	0	2b	0	6	0	2b
	Benthic disturbance (e)	0	5	0	2b	0	4	0	2b	NA	NA	NA	NA	0	6	0	2a	0	6	0	2a
Cable laying and maintenance g) Surface flood lights and noise h) Cable lowering/	*Seabird attraction, disturbance, collision (g)	1	6	6	2b	NA	NA	NA	NA	3	5	15	2b	0	6	0	2b	0	6	0	2b
	Entanglement of megafauna (h, i)	3	6	18	2a	NA	NA	NA	NA	3	1	3	1c	0	1	0	1c	0	6	0	2b

raising i) Cable trenching and installation j) Underwater lights & noise from ROVs and submersibles k) Cable ship activities	Vector for non-indigenous species (k)	3	4	12	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b
	Underwater flood lights (j)	0	4	0	2a	0	4	0	2a	0	4	0	2a	0	4	0	2a	0	4	0	2a
	Underwater noise (j)	0	4	0	2a	0	4	0	2a	0	4	0	2a	0	4	0	2a	0	4	0	2a
	Impact on benthos (i)	2	5	10	2b	0	6	0	2b	NA	NA	NA	NA	0	1	0	1c	0	6	0	2b
Cable operation l) Cable spanning and suspensions m) Biofouling n) Cable movement o) Cable route exclusion zone	Entanglement of megafauna (l)	3	6	18	2a	NA	NA	NA	NA	3	1	3	2a	0	4	0	1c	0	6	0	2b
	Impact on benthos (n)	0	5	0	2b	0	6	0	2b	NA	NA	NA	NA	0	1	0	2b	0	6	0	2b
	Effects of spatial displacement of fishing on fish stocks (o)	0	6	0	2b	0	6	0	2b	NA	NA	NA	NA	0	6	0	2b	1	6	6	2b
Abandonment p) Cable loss and degradation	Entanglement of megafauna (p)	3	6	18	2a	NA	NA	NA	NA	3	1	3	2a	0	4	0	1c	0	6	0	2b
	Impact on benthos (p)	0	5	0	2b	0	6	0	2b	NA	NA	NA	NA	0	1	0	2b	0	6	0	2b

4.11 Offshore renewable marine energy extraction

4.11.1 Background

Offshore "renewable" marine energy extraction involves capturing the kinetic and/or potential energy in the waves, tides, marine winds and ocean stratification. In all instances the technology is still very much under development and there are no clearly established dominant designs or approaches. This means there is a good deal of uncertainty. We can say, however, that any development will be in the form of arrays of devices linked in some way as with terrestrial wind farms in New Zealand. Remote human communities might use one or two devices. The present prohibitive cost of cabling and good territorial sea resources means that developments >12 NM offshore are unlikely any time in the next decade. However, there are a number of unique approaches around that are specifically designed to work well in far-offshore conditions and such locations are being considered elsewhere, serving to improve the economics of the cabling.

4.11.2 Assessment

There are likely to be three phases to any offshore energy extraction industry; trials and construction, operation and decommissioning. Below we present the main results for each phase.

Initial trials and construction

Because the technology is new and unproven initial trials of one or two energy extraction units will almost certainly take place before a larger 'energy farm' is established. Whatever the technology used to extract the energy there is likely to be some sort of surface and sub-surface structure, mooring lines and seafloor anchors as well as a cable to carry electricity to shore. The structures, mooring lines and cables may pose an entanglement hazard to marine megafauna. Although the area impacted is likely to be a small part of the broader marine habitat these hazards pose a moderate risk (9) to protected marine mammals and affected populations would take years to recover (Table 4-11).

Although the area likely to be impacted by mooring blocks and anchors is very small, if the trials occur over deepwater reefs, they pose some risk to protected species such as corals, which if damaged or destroyed may take decades to fully recover (Table 4-11).

Ship strikes on marine mammals may occur during the trial and construction phases. These effects are covered under the Maritime Transport Act (1994) and the Marine Mammal Protection Act (1978).

Lights on ships at night typically attract and disturb seabirds and may cause them to collide with support vessels (Black 2005). These effects are covered under the Maritime Transport Act (1994) and the Wildlife Act (1953).

Full operational phase

Although this phase is likely to comprise a number of replicate energy capture units the area occupied is likely to remain a very small proportion of the total area available. Thus the risks of entanglement to marine mammals remain identical to that during the trail phase (see above).

Depending on their design the energy capture devices may generate underwater noise and will also produce electro-magnetic frequencies. One or both of these may affect marine mammals, reptiles, fish and invertebrates. However, the area affected will be small and the risks to various aspects of the ecosystem are likely to be negligible to minor (Table 4-11).

Large arrays of offshore wave energy extraction devices have the potential to reduce the wave energy reaching the coast. It is possible that the area affected may be <1-5% of a particular coastline inshore of the energy farm and the risks to the near shore ecosystem may be minor to moderate (Table 4-11).

Large arrays of energy capture units will require substantial mooring or anchoring systems. A seabed cable may also be required to bring generated electricity onshore. Alternatively generated energy may be stored in the form of hydrogen and shipped onshore. Although the affected area of benthic habitat is likely to be small, if the energy farm is situated over deepwater reefs they pose some risk to protected species such as corals, which if damaged or destroyed may take decades to fully recover (Table 4-11).

If energy capture units are floated from overseas there is the potential them to act as a vector for non-indigenous species to enter New Zealand waters. However, the likelihood is low for newly constructed units with fresh antifouling. The functional impact on deepwater ecosystems in the EEZ and ECS is probably negligible as vectored species are highly unlikely to survive independently of the energy capture units (Table 4-11). However, energy farms may act as stepping stones for non-indigenous species to invade shallow coastal habitats. We understand that Biosecurity New Zealand (MAF-BNZ) is developing an import health standard to cover such situations and legislation and relevant regulations may be put in place in next 2-3 years.

Off-shore energy farms may affect stocks of fished species. The farms will invariably have a zone of restricted access around them that prevents fishing activity. Unless commercial fish quota is purposefully bought by the energy company and retired for the duration of the energy farm operation then commercial fishing will be displaced into the remainder of the quota management area (QMA). The resulting fishing pressure has the potentail to affects some fish stocks, especially sedentary species with limited migrations. However, the area of a QMA affected is likely to be small (<1-5%) and we assessed there to be negligible risks to key fish stocks and ecosystem functioning (Table 4-11).

Abandonment/ decommissioning

Recovery of electricity cables, mooring blocks, chains and anchors may disturb benthic habitats. However, the area affected is likely to be very small and ecological risks minor. It is likely that affected patches of benthic habitat may take years to recover (Table 4-11).

Underwater noise generated during this phase may disturb marine mammals but the effects are likely to be minor and risks low (Table 4-11).

Risk summary for offshore renewable energy extraction

There were no activities associated with offshore renewable energy extraction that were considered to represent an extreme environmental risk provisionally indicating prohibited status.

The following activities were considered to be of high environmental risk (15-20) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Survey vessel activity causing strikes on marine mammals (regulated under the Maritime Transport Act (1994) and the Marine Mammal Protection Act (1978)).
- Surface flood lights at night causing bird strikes (regulated under the Maritime Transport Act (1994) and the Wildlife Act (1953)).
- Installation of surface and subsurface floats and structures
- Installation of mooring blocks
- Installation of energy capture device

The following activities were considered to be of moderate environmental risk (7-12) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Cable trenching and installation
- Import and provision of biofouling surfaces

The following activities were considered to be of low environmental risk (0-6) and should be categorised as permitted:

- Production of an electromagnetic field
- Declaration of an exclusion zone
- Recovery of plant and equipment
- Power cable abandonment
- Under water flood lights
- Incidental underwater noise

4.11.3 Avoidance, mitigation, remediation

There are often ways of avoiding, remedying or mitigating the effects of activities that would otherwise put marine species or ecosystems at risk. Below we briefly discuss those relevant to offshore renewable energy extraction.

Non-mandatory Department of Conservation guidelines (2006 and 2011) should be followed to avoid or mitigate acoustic impacts on marine mammals.

Risks of marine mammal entanglement or injury could be minimised by locating marine energy devices away from whale migration routes.

Avoidance or mitigation of seabird strikes is possible by limiting unnecessary use of vessel flood lights at night and ensuring that those that are required are directed approximately vertically onto work surfaces. Visual checks of the vessel super-structure at first light each day for the presence of dazed or injured birds and the provision of appropriate care may help to remedy this impact.

Avoidance or mitigation of vessels and underwater equipment acting as vectors for non-indigenous species is possible by appropriate checking, cleaning, and application of antifouling paints.

Pressure on fish stocks caused by an exclusion zone forcing fishing activities into the remainder of the quota management area can be reduced or eliminated by purchase and retirement of appropriate commercial fish quota for the duration of the production phase.

Table 4-11: Expert Panel Assessment: Offshore renewable energy extraction. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. Activities are listed (a, b, c, etc) after each threat to which they contribute. The maximum possible level of environmental risk is 30. Extreme environmental risks are highlighted in red, high in yellow, and moderate in green. Low risk activities are not highlighted. *Threats managed under the Maritime Transport Act (1994). NA = not applicable as species assessed are all protected.

Expert Panel Assessment: Offshore renewable energy		Recovery period				Key species				Protected species				Ecosystem functional impact				Proportion of habitat affected			
Activity	**Threat**	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence
Initial trial and construction phase a) Surface flood lights and noise b) Surface floats and structures c) Subsurface structures d) Mooring blocks e) Support vessel activities	*Seabird attraction, disturbance, collision (a)	1	6	6	2b	NA	NA	NA	NA	2	5	10	2b	0	6	0	2b	0	6	0	2b
	Entanglement of megafauna (b, c)	3	6	18	2a	NA	NA	NA	NA	3	3	9	2b	0	6	0	2b	0	6	0	2b
	Impact on benthos (d)	3	6	18	2a	1	6	6	2a	1	6	6	2a	0	6	0	2a	0	6	0	2a
	*Ship strikes on marine mammals, fish, and reptiles (e)	3	6	18	2b	1	2	2	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b
Full operational phase f) Surface flood lights and noise g) Surface floats/structures h) Subsurface structures including energy capture devices i) Underwater lights and noise from ROV and energy plant j) Cable laying and maintenance k) Electromagnetic field l) Mooring blocks m) Maintenance n) Support vessel activity o) Declaration of exclusion zone	*Seabird attraction, disturbance, collision (f)	1	6	6	2b	NA	NA	NA	NA	4	5	20	2b	0	6	0	2b	0	6	0	2b
	Marine mammal entanglement or collision with energy capture device (g, h, j)	3	6	18	2a	NA	NA	NA	NA	3	3	9	2b	0	6	0	2b	0	6	0	2b
	Nearshore impact of altered wave climate (g, h)	2	4	8	2a	2	4	8	1c	1	2	2	1c	2	4	8	1c	1	4	4	2a
	Acoustic/EMF impact on marine mammals, reptiles, fish and invertebrates (j, k)	1	6	6	2a	0	6	0	1c	1	6	6	2a	0	6	0	2a	0	6	0	2a
	Disturbance of benthic fauna (j, l)	2	6	12	2a	1	6	6	2a	1	6	6	2a	0	6	0	2a	0	6	0	2a
	Vector for non-indigenous species (g, h)	3	4	12	2b	1	4	4	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b
	Displacement of fisheries affecting fish stocks (o)	1	4	4	2b	0	4	0	2b	NA	NA	NA	NA	0	4	0	2b	1	4	4	2b
	*Ship strikes on marine mammals, fish, and reptiles from support vessels (n)	3	6	18	2b	1	2	2	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b

Abandonment/ decommissioning p) Surface flood lights and noise q) Recovery of all equipment, plant & machinery r) Underwater lights and noise s) Mooring blocks t) Support vessel activity u) Abandonment of power cable	*Ship strikes on marine mammals, fish, and reptiles from support vessels (t)	3	6	18	2b	1	2	2	2b	3	3	9	2a	0	6	0	2b	0	6	0	2b
	*Seabird attraction, disturbance, collision (p)	1	6	6	2b	NA	NA	NA	NA	1	6	6	2b	0	6	0	2b	0	6	0	2b
	Marine mammal disturbance (q, r)	1	4	4	1c	NA	NA	NA	NA	1	6	6	2b	0	6	0	2b	0	6	0	2b
	Impact on benthos (s)	3	6	18	2a	1	6	6	2a	1	6	6	2a	0	6	0	2a	0	6	0	2a

4.12 Offshore Aquaculture

4.12.1 Background

In recent years the New Zealand aquaculture industry has expressed an interest in developing shellfish production units at more exposed offshore sites. Several offshore marine farm areas have been identified, mainly off the east coast of both the North and South Islands. Although these farms are within the 12 mile limit they represent a move to marine farming in more exposed locations. To date none of these farms have progressed beyond 'experimental' status and it looks unlikely that commercial operations will be established in the near future.

A number of countries are currently considering the potential for offshore production of both fish and shellfish (e.g. James and Slaski 2007). In most cases this represents a move to more exposed locations, rather than movement offshore by any significant distance. Almost universally the drive for offshore development is a result of limitations in the available inshore, or 'sheltered water' space available for the aquaculture industry to expand into (James and Slaski 2007).

Whilst legislative barriers to offshore developments may be lower than for inshore aquaculture, and the potential biological impacts are likely to be significantly diluted, there are technical and biological hurdles to overcome before the aquaculture industry can move to more exposed locations. These hurdles include the necessity for developing more robust systems to withstand exposed wave environments and developing systems that can remotely attend to feeding and veterinary care for the stock during periods of bad weather when farmers cannot access the site.

Designers of aquaculture systems for exposed areas tend to focus on submerged culture systems that are not therefore exposed to the high energy wave environments at the surface. For shellfish farms, the reduced density of planktonic feed offshore indicates that farms will be stocked at a lower density and therefore have a much larger footprint than inshore farms. Submerged systems that cover a large area are unlikely to represent a navigational hazard, but may interfere with fishing activities. From a biological standpoint such structures may act as artificial reefs offering potential benefits in terms of fish and invertebrate communities, but also potentially interrupting inshore migrations of some species.

Meeting the technological challenges associated with aquaculture in exposed areas inevitably increases the cost of production and risks associated with the development. Given the existing price structure for New Zealand shellfish products and the existing level of technical sophistication of the finfish farming industry, it currently looks unlikely that there will be significant development of the existing inshore exposed sites in the short to medium term and it therefore would appear unlikely that significant offshore aquaculture developments would occur in the next 20 to 30 years.

4.12.2 Assessment

There are likely to be three phases to any offshore energy extraction industry; trials and construction, full operation, and decommissioning. Below we present the main results for each phase.

Initial trials and construction

Because the technology is new and unproven initial trials of one or two production units will almost certainly take place before a larger farm is established. Farm structures and mooring lines may pose an entanglement hazard to marine megafauna. Although the area impacted is likely to be a small part of the broader marine habitat these hazards pose a moderate risk (9) to protected marine mammals and affected populations would take years to recover (Table 4-12). These risks could be minimised by locating offshore aquaculture farms away from whale migration routes or feeding grounds.

Although the area likely to be impacted by mooring blocks and anchors is very small, if the trials occur over deepwater reefs, they pose some risk to protected species such as corals, which if damaged or destroyed may take decades to fully recover (Table 4-12).

Ship strikes on marine mammals may occur during the trial and construction phases. These effects are covered under the Maritime Transport Act (1994) and the Marine Mammal Protection Act (1978).

Lights on ships at night typically attract and disturb seabirds and may cause them to collide with support vessels (Black 2005). These effects are covered under the Maritime Transport Act (1994) and the Wildlife Act (1953).

Full operational phase

Although this phase is likely to comprise a number of replicate production units on a single aquaculture enterprise the area occupied is likely to remain a very small proportion of the total area available. Thus the risks of entanglement to marine mammals remain identical to that during the trail phase (see above).

Large arrays of aquaculture production units will require substantial mooring or anchoring systems. Although the affected area of benthic habitat is likely to be a small proportion of the total available, if the energy farm is situated over deepwater reefs they pose some risk to protected species such as corals, which if damaged or destroyed may take decades to fully recover. The benthic fauna will also be affected by shell drop from cultured mussels and other shellfish and more severely by food waste, and faces particularly from farmed fish. (Table 4-12).

Aquaculture farms have the potential to affect water column productivity. Productivity may be enhanced downstream of fish farms because of nutrients from waste food and fish waste products. In contrast, productivity may be depleted downstream of shellfish farms because of filter feeding. As long as the area affected is a very small fraction of the total surface waters the ecological risks are likely to be negligible (Table 4-12).

If aquaculture production units are floated from overseas there is the potential them to act as a vector for non-indigenous species to enter New Zealand waters. However, it is more likely that units would be constructed in New Zealand. The functional impact on deepwater ecosystems in the EEZ and ECS is probably negligible as any vectored species are highly unlikely to survive independently of the aquaculture facilities (Table 4-12). However, offshore aquaculture farms may act as stepping stones for non-indigenous species to invade shallow coastal habitats. We understand that Biosecurity New Zealand (MAF-BNZ) is developing an import health standard to cover such situations and legislation and relevant regulations may be put in place in next 2-3 years.

Off-shore aquaculture has the potential to affect stocks of fished species. Farm structures may provide a new artificial reef-like surfaces and increase reef habitat in the area for reef associated fishes. The farms will invariably have a zone of restricted access around them that prevents fishing activity. Unless commercial fish quota is purposefully bought by the aquaculture company and retired for the duration of farming then commercial fishing will be displaced into the remainder of the quota management area (QMA). The resulting fishing pressure has the potentail to affects some fish stocks, especially sedentary species with limited migrations. However, the area of a QMA affected is likely to be small (<1-5%) and we assessed there to be negligible risks to key fish stocks and ecosystem functioning (Table 4-12).

Offshore aquaculture also has the potential to affect wild stocks of the same species by acting as a reservoir for disease and genetic pollution. Inshore farms of the same species pose the same potential problem. We assessed the risks to be minor if the species cultured was from the same stock area as the farm and therefore is unlikely to introduce new disease organisms or genes.

Abandonment/ decommissioning

Recovery of mooring blocks, chains and anchors may disturb benthic habitats. However, the area affected is likely to be very small and ecological risks minor. It is likely that affected patches of benthic habitat may take years to recover (Table 4-12).

Underwater noise generated during this phase may disturb marine mammals but the effects are likely to be minor and risks low (Table 4-12).

Risk summary for offshore aquaculture

There were no activities associated with offshore aquaculture that were considered to represent an extreme environmental risk provisionally indicating prohibited status.

The following activities were considered to be of high environmental risk (15-20) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Installation of surface and subsurface floats and structures

The following activities were considered to be of moderate environmental risk (7-12) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Surface flood lights at night causing bird strikes (regulated under the Maritime Transport Act (1994) and the Wildlife Act (1953))
- Installation of mooring blocks
- Seafloor deposition of organic waste

The following activities were considered to be of low environmental risk (0-6) and should be categorised as permitted:

- Multibeam echo-sounder survey of seabed

- Water column nutrient enrichment
- Water column production depletion
- High concentration of cultured species
- Recovery of all, equipment, plant and machinery
- Underwater lights and noise
- Declaration of exclusion zone

4.12.3 Avoidance, mitigation, remediation

There are often ways of avoiding, remedying or mitigating the effects of activities that would otherwise put marine species or ecosystems at risk. Below we briefly discuss those relevant to offshore aquaculture.

Avoidance or mitigation of seabird strikes is possible by limiting unnecessary use of vessel flood lights at night and ensuring that those that are required are directed approximately vertically onto work surfaces. Visual checks of the vessel super-structure at first light each day for the presence of dazed or injured birds and the provision of appropriate care may help to remedy this impact.

Avoidance or mitigation of vessels and underwater equipment acting as vectors for non-indigenous species is possible by appropriate checking, cleaning, and application of antifouling paints.

Pressure on fish stocks caused by the exclusion zone forcing fishing activities into the remainder of the quota management area can be reduced or eliminated by purchase and retirement of appropriate commercial fish quota for the duration of the production phase.

Table 4-12: Expert Panel Assessment: Offshore aquaculture. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. Activities are listed (a, b, c, etc) after each threat to which they contribute. The maximum possible level of environmental risk is 30. Extreme environmental risks are highlighted in red, high in yellow, and moderate in green. Low risk activities are not highlighted. *Threats managed under the Maritime Transport Act (1994). NA = not applicable as species assessed are all protected.

Expert Panel Assessment: Offshore aquaculture		Recovery period				Key species				Protected species				Ecosystem functional impact				Proportion of habitat affected			
Activity	**Threat**	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence
Construction and initial trial phase a) Surface flood lights and noise b) Surface floats & structures c) Subsurface structures d) Mooring blocks e) Lost or broken gear, nets, cages f) Multibeam acoustic survey of seabed	*Seabird attraction, disturbance, collision (a)	1	6	6	2b	NA	NA	NA	NA	2	5	10	2b	0	6	0	2b	0	6	0	2b
	Marine mammal entanglement (b, c, e)	3	5	15	2b	1	3	3	2b	3	3	9	2b	0	6	0	2b	0	6	0	2b
	Impact on benthos (d, e)	0	4	0	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b
	Acoustic impact from multibeam echo sounders on marine mammals, reptiles, fish and invertebrates (f)	1	4	4	2b	0	6	0	2b	1	5	5	2a	0	6	0	2a	0	6	0	2a
Full operational phase g) Surface flood lights and noise h) Surface floats/structures i) Subsurface structures j) Mooring blocks k) Harvesting operations l) Sea floor deposition of organic waste m) Biofouling n) Water column enrichment o) Maintenance p) Lost or broken gear, nets, cages q) Water column depletion by filter feeders (e.g. mussels) r) High concentration of	*Seabird attraction, disturbance, collision (g)	1	6	6	2b	NA	NA	NA	NA	2	5	10	2b	0	6	0	2b	0	6	0	2b
	Marine mammal entanglement (h, i, p)	3	5	15	2b	1	3	3	2b	3	3	9	2b	0	6	0	2b	0	6	0	2b
	Impact on benthos (j, l, p)	2	4	8	2b	1	4	4	2b	0	4	0	2b	1	4	4	2b	0	4	0	2b
	Impact on water column productivity (n, q)	0	4	0	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b
	Vector for non-indigenous species (h, i)	1	4	4	2b	1	4	4	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b
	Impact on fished species (l, n, p)	1	4	4	2b	0	4	0	2b	NA	NA	NA	NA	0	4	0	2b	0	4	0	2b
	Displacement of fisheries affecting fish stocks (s)	1	4	4	2b	0	4	0	2b	NA	NA	NA	NA	0	4	0	2b	1	4	4	2b

cultured species s) Declaration of exclusion zone	Effects on wild stocks due to disease and genetic pollution (r)	1	4	4	1c	1	4	4	1c	NA	NA	NA	NA	1	4	4	1c	0	4	0	2b
Abandonment/ decommissioning t) Surface flood lights and noise u) Recovery of all equipment, plant & machinery v) Underwater lights and noise w) Mooring blocks	Seabird attraction, disturbance, collision (t)	0	5	0	2b	1	3	3	2b	2	5	10	2b	0	6	0	2b	0	6	0	2b
	Marine mammal disturbance (u, v)	1	4	4	1c	NA	NA	NA	NA	1	6	6	2b	0	6	0	2b	0	6	0	2b
	Underwater flood lights	0	4	0	2a	0	4	0	2a	0	4	0	2a	0	4	0	2a	0	4	0	2a
	Impact on benthos (w)	0	4	0	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b	0	4	0	2b

4.13 Offshore ecotourism

4.13.1 Background

Ecotourism is a growing industry in the nearshore waters around New Zealand and is already starting to expand into the EEZ and ECS. Tourist ships regularly traverse offshore areas usually in transit to the sub-Antarctic Islands and the Ross Sea but surface wildlife (marine mammals and seabirds) fortuitously encountered on-route is part of the experience. More deliberate experiences are becoming more common as tourists seek close surface and underwater encounters with megafauna or densely shoaling smaller species. The line between charter fishing and tourism is now very blurred as ‘chumming’ is common to attract pelagic sharks and game-fish near the charter vessel, not for capture, but for the experience of viewing large pelagic predators either from the safety of the boat, an underwater cage or remotely via a towed camera. There is also a trend for charter boats to carry camera systems or remotely operated vehicles (ROVs) capable of encountering and viewing spectacular underwater scenery in the deep ocean. These trends are likely to increase over the next 20-30 years.

4.13.2 Assessment

We divided this growing industry into three components in order to assess their ecological impacts and risks; surface wildlife watching, underwater sea life watching via imaging systems or submersibles, and in situ sea-life encounters. Below we examine the main results of our assessment (Table 4-13).

Surface sea-life watching

Whale watching, dolphin watching and seabird spotting from a surface vessel are all part of this activity. The major impact is potentially on the modification of marine mammal behaviour, either by attracting mammals to the boat to bow wave for example, or by interfering with normal patterns of foraging, reproduction or resting. Numerous studies have indentified risks to inshore species (e.g. Constantine 2001, Constantine et al. 2004) but the risks to offshore deepwater species are less certain. In our assessment we assumed that the species affected was a nationally critical species as they occur throughout the EEZ. The area impacted will be small but tourist operators are likely to target areas with known concentrations at particular times of year. We assessed the risks to be low to moderate with recovery of normal behaviour likely to take months if the activity stopped (Table 4-13).

Ship strikes on marine mammals may occur during ecotourism activities. These effects are covered under the Maritime Transport Act (1994) and the Marine Mammal Protection Act (1978).

Lights on ecotourism ships at night typically attract and disturb seabirds and may cause them to collide with the vessel (Black 2005). These effects are covered under the Maritime Transport Act (1994) and the Wildlife Act (1953).

Remote underwater sea life watching

Underwater suspended or towed camera systems, ROVs and submersibles all have the capacity to disturb subsurface sea-life. This will particularly be the case if strong lights are used to illuminate the scene at night or in deeper water. The area of offshore waters likely to be affected at any one time is very small and the ecological risks negligible to minor (Table 4-

13). However, at particular localities if very regularly visited then risks will be increase correspondingly.

Seabed communities could be physically disturbed or impacted by camera systems, ROVs or submersibles through accidental collisions. The area of benthic habitat likely to be affected at any one time is very small and the ecological risks assessed as negligible to minor. However, at particular localities if very regularly visited then the risks will be increase correspondingly.. Recovery of impacted habitat patches may be slow, however, as many deepwater species grow slowly (Table 4-13).

In situ sea-life encounters

Dolphin swimming, whale swimming, shark encounters etc are all part of this group of activities and have the capacity to disturb surface and shallow subsurface species. For example, at Stewart Island the locals think the shark tourism is altering where the sharks are commonly found – this could have profound impacts if this area coincides with a conflicting mammal usage (Jenny Beaumont - personal comment). However, the area of habitat likely to be affected at any one time is very small and the risk to ecosystem functioning is probably negligible. However the risks to individual protected species and key species may be higher and affected individuals or populations may take months to recover (Table 4-13).

Risk summary for offshore ecotourism

There were no activities associated with offshore ecotourism that were considered to represent an extreme environmental risk and should be prohibited.

The following activities were considered to be of high environmental risk (15-20) and should be categorised as discretionary:

- Tourist vessel activity impacting marine mammals (regulated under the Maritime Transport Act (1994) and the Marine Mammal Protection Act (1978)).
- Surface flood lights at night causing bird strikes (regulated under the Maritime Transport Act (1994) and the Wildlife Act (1953)).

The following activities were considered to be of moderate environmental risk (7-12) and should be categorised as discretionary:

- Surface activity and noise
- Subsurface activity

The following activities were considered to be of low environmental risk (0-6) and should be categorised as permitted:

- Operations near the seafloor likely to result in collisions with benthic fauna
- Subsurface lights and noise generated by camera systems, ROVs and submersibles

4.13.3 Avoidance, mitigation, remediation

There are often ways of avoiding, remedying or mitigating the effects of activities that would otherwise put marine species or ecosystems at risk. Below we briefly discuss those relevant to offshore ecotourism.

Department of Conservation guidelines should be followed to avoid or mitigate the effects of tourist boat operations, *in situ* observation gear and human activity in the water on the behaviour of marine mammals and other protected species (e.g. great while sharks).

Avoidance or mitigation of seabird strikes is possible by limiting unnecessary use of vessel flood lights at night and ensuring that those that are required are directed approximately vertically onto work surfaces. Visual checks of the vessel super-structure at first light each day for the presence of dazed or injured birds and the provision of appropriate care may help to remedy this impact.

Impacts on vulnerable benthic species can be minimised by rotating visits around a number of sites. The appropriate rotation interval should be guided by the likely recovery time of the species concerned.

Table 4-13: Expert Panel Assessment: Offshore ecotourism. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. Activities are listed (a, b, c, etc) after each threat to which they contribute. The maximum possible level of environmental risk is 30. Extreme environmental risks are highlighted in red, high in yellow, and moderate in green. Low risk activities are not highlighted. *Threats managed under the Maritime Transport Act (1994). NA = not applicable as species assessed are all protected.

Expert Panel Assessment: Offshore Ecotourism		Recovery period				Key species				Protected species				Ecosystem functional impact				Proportion of habitat affected			
Activity	**Threat**	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence
Surface sea-life watching a) Surface flood lights and noise from ship activities b) Ship movements	*Seabird attraction, disturbance, collision (a)	1	6	6	2b	NA	NA	NA	NA	3	5	15	2b	0	6	0	2b	0	6	0	2b
	Effects on behaviour of marine mammals (a, b)	1	4	4	2b	NA	NA	NA	NA	1	6	6	2a	0	4	0	2b	0	4	0	2b
	*Ship strikes on marine mammals, fish, and reptiles (b)	3	6	18	2a	1	2	2	2b	2	3	6	2a	0	6	0	2b	0	6	0	2b
Underwater sea-life watching via remote sensing c) Subsurface flood lights and noise at depths including benthic imaging and exploration using ROVs and submersibles d) Accidental collisions with sea floor	Sub-surface sea life disturbance (c)	1	4	4	2b	1	4	4	2b	0	4	0	2b	0	4	0	1c	0	4	0	2b
	Physical impact on benthos (d)	4	1	4	2a	1	6	6	2a	0	6	0	2a	0	6	0	2a	0	4	0	2b
In situ sea-life encounters e) Surface activity and noise f) Subsurface activity	Surface sea life disturbance (e)	1	4	4	2b	1	4	4	2b	2	6	12	2a	0	4	0	1c	0	4	0	2b
	Sub-surface sea life disturbance (f)	1	4	4	2b	1	4	4	2b	2	6	12	2a	0	4	0	1c	0	4	0	2b

4.14 Scientific Exploration and Sampling

4.14.1 Background

Over large parts of the EEZ and ECS science activities may be the only human activity. Commercial bottom trawling is largely restricted to depths less than 1500 m, fishing for pelagic species is centred on feeding areas or migration routes and seafloor mining of minerals will be on specific ore bearing areas. Oil exploration and production will be restricted to favourable sedimentary basins. This leaves vast areas of the EEZ likely to be largely unvisited except for research purposes. Note that captures or sampling of marine organisms for scientific purposes are covered by MFish Special Permit conditions and capture and tagging are covered by the Fisheries Acts (1993 and 1996), the Marine Mammal Protection Act (1978) or by the Wildlife Act (1953).

4.14.2 Assessment

Scientific exploration and sampling can be grouped into four distinct activities:

- underway sampling,
- water column sampling and instrumentation,
- seafloor exploration, sampling and instrumentation, and
- loss or abandonment of scientific equipment.

Below we assess the ecological consequences and risks of each group of activities (Table 4-14).

Underway sampling

This includes a variety of sampling methods made form a research vessel while underway (Table 4-14). Various threats arise from these activities.

Acoustic swath mapping may be used to define the bathymetry and high resolution seismic reflection techniques (e.g. Boomer, CHIRP) may be used to define the sub-seafloor geological strata. Use of air guns to obtain deeper seismic information may occur. The acoustic impact of seismic surveys on marine mammals, in particular, is well documented (Gordon & Moscrop 1996, Cox et al. 2006, Brandon et al. 2008, Di Iorio and Clark 2010), but may also affect a range of marine reptiles, fish and invertebrates. The consequences for marine mammals from the seismic gear likely to be used for these surveys will vary from none to behavioural (may leave area) perhaps to acute injury (ear drum damage), to death depending on noise level encountered, species and habitat. Beaked whales are thought to be particularly at risk. There may also be cumulative effects from repeated exposure.

Noise travels great distances underwater and so the footprint of this activity may be very broad although the greatest impacts will be much more restricted in area as sound intensity typically falls as the square of the distance from the source. Using a precautionary approach our assessment assumed that the species affected was a nationally critical species, such as southern right whales, as these may occur throughout the EEZ though they occupy different areas at different times of the year. The risk from this activity if seismic air guns were used was assessed to reach a score of 18 with a high level of confidence (Table 4-14) indicating the need for this to be a discretionary activity.

Fur seals and sea lions may be attracted to the seismic streamer during deployment and retrieval and could become entangled and injured or drown. The number of individuals affected is likely to be small given the one-off nature of a seismic survey and impacts will be largely restricted to locations where deployment and retrieval takes place at slow speeds. Using a precautionary approach our assessment assumed that the species affected was the New Zealand sea lion although few occur north of about 45° S. The risk from this activity was assessed to reach a score of 3, but with a low level of confidence (Table 4-14) because few data exist about this effect. Populations are unlikely to be affected and ecosystem effects will be negligible.

It is possible that megafauna could become entangled in some of the other sampling gear towed behind research vessels. Although the area impacted is likely to be a small part of the broader marine habitat and these hazards pose only a low risk (3) to protected marine mammals, affected populations would take years to recover (Table 4-14).

Lights on survey ships at night typically attract and disturb seabirds and may cause them to collide with the ship (Black 2005). These effects are covered under the Maritime Transport Act (1994) and the Wildlife Act (1953).

Ship strikes on marine mammals, fish, and reptiles may occur during the survey and during transits to and from the survey area. These effects are covered under the Maritime Transport Act (1994) and the Marine Mammal Protection Act (1978).

Water column sampling and instrumentation

This includes a wide range of sampling methods giving rise to a number of potential threats (Table 4-14).

It is possible that megafauna could become entangled in the moorings used to suspend instruments in the water column. Although the area impacted is likely to be a very small part of the broader marine habitat and these hazards pose only a low risk (3) to protected marine mammals, affected populations would take years to recover (Table 4-14).

The location of moored arrays is always provided to fishermen and other mariners via Notices to Mariners warning that a navigational hazard is located at a certain point. In depths less than 1500 m this has the potential to displace fishing activity into the remainder of a quota management area (QMA). The resulting fishing pressure has the potentail to affects some fish stocks, especially sedentary species with limited migrations. However, the area of a QMA affected is likely to be small (<1-5%) and we assessed there to be negligible risks to key fish stocks and ecosystem functioning (Table 4-14).

Large scale experiments, such as iron fertilisation experiments, have the potential, indeed the purpose, of severely altering the abundance and composition of plankton communities in the upper ocean (de Baar et al. 2005). However, the area of the EEZ affected by such experiments is very small though measurable, perhaps <1-5%, and once the experiment is over (days to weeks) the pelagic ecosystem recovers to normal levels of productivity and species composition in a matter of weeks or months.

Chemical tracers, such as SF6, are used to track manipulated bodies of water and though these tracers have no known ecological impact there may be some social and cultural concerns with this practice.

Seafloor exploration, sampling and instrumentation

Physical disturbance of the benthos by commercial bottom trawling and dredging is well described (Dayton et al. 1995, Hall 1999, Kaiser et al. 2002, Millennium Ecosystem Assessment, 2005a & b, Dulvy et al. 2006, Myers et al. 2007, Donaldson et al. 2010, Williams et al. 2010) and research bottom trawling has similar effects though the spatial scale of impact is much less. However, over a 20-30 year horizon perhaps <<1% of the EEZ and ECS may be impacted in this way and there may be measurable ecosystem consequences, and some minor impacts on protected species, such as deep-sea corals, and on key species. It is important to note that the level of impact does depend upon the particular habitat and the size of the gear in proportion of these habitats. As some of the very deepwater species may be very slow growing, affected habitat patches may take decades to fully recover (Table 4-14). Effects of fishing in the EEZ are managed under the Fisheries Act (1996).

Small scale physical disturbance of the benthos is likely by a wide range of other scientific equipment including bottom sampling gear, by mooring blocks for instrument arrays, and by unintended impacts by ROVs, submersibles and towed camera systems. The areas affected are likely to be a small proportion of available habitats and the ecological consequences and risks minor (Table 4-14).

Other disturbance to deepwater seafloor habitats and species may occur because of underwater lights and noise from some of the instruments or sampling tools. The areas affected are likely to be a small proportion of available habitats and the ecological consequences and risks minor (Table 4-14).

Lost or abandoned scientific sampling equipment and instruments

Deepwater instrument moorings typically use steel (often old rail-wagon wheels) as the mooring block and typically these are left behind when the mooring instruments are acoustically released during the recovery process. Eventually these steel moorings rust and disintergrate but this may take decades. However each mooring block is comparatively small and the risks to the benthic community low.

Lost sampling gear may pose an ecological risk especially if it carries electronic equipment including batteries. Underwater housings, although routinely made of aluminium or stainless steel, will eventually corrode and leak contents into the surrounding ecosystem. However, such losses are infrequent, affecting only a tiny fraction of the EEZ and ECS and thus the overall ecological consequences and risks are low. However, affected patches of habitat may take years to decades to fully recover (Table 4-14).

Lost sampling gear may impact small areas of the benthos and associated benthic and bottom associated fauna. The ecological consequences negligible or minor and equipment losses are rare thus the risks are low (Table 4-14).

Risk summary for scientific exploration and sampling

No activities associated with scientific exploration and sampling were considered to represent an extreme environmental risk and provisionally indicating prohibited status.

The following activities were considered to be of high environmental risk (15-20) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Surface flood lights at night causing bird strikes (regulated under the Maritime Transport Act (1994) and the Wildlife Act (1953)).
- Use of air gun seismic devices
- Vessel activity impacting marine mammals (regulated under the Maritime Transport Act (1994) and the Marine Mammal Protection Act (1978)).
- Towed instrument arrays in core areas for nationally critical species
- Moored instrument arrays in core areas for nationally critical species
- Research bottom trawling and dredging.

The following activities were considered to be of moderate environmental risk (7-12) and may need to be categorised as discretionary unless conditions can be successfully applied to mitigate the risk:

- Use of high resolution seismics e.g. Boomer, CHIRP
- Large scale ocean productivity perturbation experiments

The following activities were considered to be of low environmental risk (0-6) and should be categorised as permitted:

- Single and multibeam echo sounding
- Displacement of fishing activities
- Use of small scale benthic sampling devices but as impact is habitat dependent standard regulations should be developed that prescribe the proportion of vulnerable habitats (e.g, vent and seep communities) that can be sampled within a period.
- Use of ROVs, submersibles, AUVs, Argo floats, underwater gliders and suspended imaging devices etc
- Use of electronic instrument systems

4.14.3 Avoidance, mitigation, remediation

There are often ways of avoiding, remedying or mitigating the effects of activities that would otherwise put marine species or ecosystems at risk. Below we briefly discuss those relevant to scientific exploration and sampling.

Non-mandatory Department of Conservation guidelines (2006 and 2011) should be followed to avoid or mitigate acoustic impacts on marine mammals.

Avoidance or mitigation of seabird strikes is possible by limiting unnecessary use of vessel flood lights at night and ensuring that those that are required are directed approximately vertically onto work surfaces. Visual checks of the vessel super-structure at first light each day for the presence of dazed or injured birds and the provision of appropriate care may help to remedy this impact.

Avoidance or mitigation of vessels and underwater equipment acting as vectors for non-indigenous species is possible by appropriate checking, cleaning, and application of antifouling paints.

Table 4-14: Expert Panel Assessment: Scientific exploration and sampling. Levels of consequence, likelihood, risk and confidence associated with this activity in the EEZ and ECS. Activities are listed (a, b, c, etc) after each threat to which they contribute. The maximum possible level of environmental risk is 30. Extreme environmental risks are highlighted in red, high in yellow, and moderate in green. Low risk activities are not highlighted. *Threats managed under the Maritime Transport Act (1994). NA = not applicable as species assessed are all protected.

Expert Panel Assessment: Scientific exploration and sampling		Recovery period				Key species				Protected species				Ecosystem functional impact				Proportion of habitat affected			
Activity	**Threat**	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence	Consequence	Likelihood	Risk	Confidence
Underway sampling a) Surface flood lights and noise b) Single and multi beam echo sounder operation c) High resolution seismics (e.g. CHIRP, boomer) for substrate characterization d) Air gun & streamers e) Sea floor explosives f) Towed instrumentation including magnetometers, gravity meters, CPRs, nets, CTDs, etc. g) Ship movements	*Seabird attraction, disturbance, collision (a)	1	6	6	2b	NA	NA	NA	NA	3	5	15	2b	0	6	0	2b	1	6	6	2b
	Acoustic impact from multi-beam echo sounders on marine mammals, reptiles, fish and invertebrates (b)	0	5	0	2a	0	6	0	2a	1	5	0	2a	0	6	0	2a	0	6	0	2a
	Acoustic impact from high resolution seismics on marine mammals, reptiles, fish and invertebrates (c)	2	5	10	2a	0	5	0	2a	2	6	12	2a	0	6	0	2a	0	6	0	2a
	Acoustic impact of air guns and seafloor explosives on marine mammals, reptiles, fish and invertebrates (d)	3	6	18	2a	3	6	18	1c	3	6	18	2a	0	6	0	2a	3	6	18	2a
	Fur seal and sea lion attraction during streamer deployment and retrieval (d)	0	6	0	2b	0	2	0	1c	1	3	3	1c	0	6	0	2b	0	6	0	2b
	*Ship strikes on marine mammals, fish, and reptiles (g)	3	6	18	2a	2	2	4	2b	2	2	4	1c	0	6	0	2b	0	6	0	2b
	Entanglement of megafauna (f)	3	6	18	2a	1	3	3	2b	1	3	3	2b	0	6	0	2b	0	6	0	2b
Water column sampling and instrumentation h) Moored arrays, buoys i) Argo floats/gliders, AUV j) Ship based stationary sampling k) Perturbation	Entanglement of megafauna (h)	3	5	15	2a	1	3	3	2b	1	3	3	2b	0	6	0	2b	0	6	0	2b
	Displacement of fishing activity at depths less than 1500m (h, i, j, k)	0	6	0	2b	0	5	0	2b	0	5	0	2b	0	5	0	2b	0	5	0	2b

experiments e.g. ocean fertilization experiment l) Chemical tracers e.g. SF6	Potential change in species composition and abundance (k)	1	6	6	2a	2	5	10	2b	1	4	4	1c	3	5	15	2a	1	5	5	2a
Seafloor exploration, sampling and instrumentation m) Moored arrays/buoys n) Argo floats/gliders, AUV o) ROVs, submersibles, towed imaging systems, causing underwater lights and noise p) Research bottom trawling and dredging q) Sea floor sampling via sleds, box cores, multi-cores, piston cores or directed sampling from ROVs or submersibles and unanticipated benthic impact of other sampling gear r) Research drilling s) Cabled offshore observatory	Benthic impacts of research bottom trawling and dredging (p)	3	6	18	2a	1	6	6	2a	1	6	6	2a	2	6	12	2a	1	6	6	2a
	Benthic impacts of sampling via sleds, coring devices, drilling etc (n, o, q, r, s)	1	6	6	2a	0	5	0	2a	0	5	0	2a	0	5	0	2a	0	5	0	2a
	Disturbance to benthic and demersal fauna due to underwater lights and noise (o, q, r)	1	4	4	2b	1	4	4	2b	1	4	4	2b	1	4	4	1c	1	4	4	2b
Lost scientific equipment t) Lost electronic instruments, ROVs, AUVs, camera platforms etc	Potential chemical pollution from electronics, sensors etc. (t)	3	2	6	1c	1	2	2	1c	0	2	0	2b	1	2	2	1c	0	5	0	2b
u) Lost research nets and other sampling gear	Impacts on demersal and benthic fauna (u)	0	1	0	1b	1	1	1	1b	1	1	1	1b	0	1	0	2b	0	1	0	2a

5 Summary and Conclusions

In order to support the regulations being developed for the new Exclusive Economic Zone and Extended Continental Shelf (Environmental Effects) Bill, NIWA was engaged by MfE to undertake a study that makes recommendations as to how activities in the Exclusive Economic Zone (EEZ) and Extended Continental Shelf (ECS) might be classified, based on levels of environmental risk.

In this study we adopted an Ecological Risk Assessment Framework and carried out a “Level 1” assessment in line with accepted New Zealand and Australian risk assessment standards. For this an expert Ecological Risk Assessment (ERA) Panel was convened that assessed the environmental consequences and likelihoods of activities that comprise 1present or potential marine industries as well as scientific exploration and sampling.

Scores were given to the potential consequence (6 levels from negligible to catastrophic) and to the likelihood of that consequence (remote to likely) using a set of standard tables that described each level, for a range of activities. Risk was then calculated as the product of consequence and likelihood. This process was repeated for each identified activity likely to occur in the EEZ or ECS.

Using the exposure – consequence risk assessment framework adopted in this study, ecological risk is defined as the product of consequence and likelihood. Using the tables of defined levels and scores of environmental consequences (Table 2-2) and likelihoods (Table 2-3) ecological risk can range from a minimum of 0 to a maximum of 30.

We consider that activities with low risk levels of 6 or less could be categorised as permitted – these arise from the lowest two levels of consequence (0 -negligible and 1- minor) (see Table 3-1) at all levels of likelihood (including 6, likely), from moderate levels of consequence (2) at unlikely (3) or lower levels of likelihood, from severe levels of consequence (3) at rare (2) or remote (1) levels of likelihood, or from major and catastrophic levels of consequence at remote levels of likelihood (see Table 3-1 for a summary of risk scores, their derivation and categorisation).

From an ecological perspective we consider that activities with extreme risk levels of 24 or more should be provisionally classified as prohibited (Table 3-1) unless some means of avoiding or reducing the ecological consequences can be found. These levels of risk arise only from those activities judged to have major consequences (4) at the highest level of likelihood (6) and catastrophic consequences (5) at the two highest levels of likelihood (5 and 6).

Activities over a broad range of moderate (8-12) and high (15-20) risk values, we consider, should be provisionally categorised as discretionary (Table 3-1) and conditions applied that monitor and reduce the associated ecological risk.Our recommendations for classifications are based only on the level of environmental risk from activities. Risk scores were established using a precautionary approach, taking into account the worst case scenario for environmental risks. We have also not taken into account how any mitigation measures might reduce environmental risk when recommending classifications. These recommendations should not be taken as a comprehensive assessment of how activities should be finally regulated. They serve primarily as an indication of the activities that might require special conditions and close monitoring, regardless of how they are ultimately classified.

The detailed assessments by the expert panel are provided in Section 4 while a summary of the categorisation of activities by industry is provided in Table 5-1 below.

A total of 207 assessments were made of 42 identified activities across 13 industries and scientific exploration and sampling. Of these just 19 (9.2%) were assessed as having extreme risks to the environment, 48 (23.2%) were assessed as high risk, 75 (36.2%) were assessed as moderate risk, and 64 (30.1%) as low risk.

The number of activities assessed for an industry ranged from 7 for offshore ecotourism to 17 for mining of massive sulphide deposits, polymetalic crusts and polymetalic nodules and renewable marine energy. Four industries had between 3 and 7 activities we classified as posing an extreme risk to the environment. These industries were mining for phosphorite nodules, massive sulphides, polymetalic crusts, and polymetalic nodules. All industries had one or more activities that pose a high risk to the environment and 2-10 activities that pose a moderate risk. The industry with the highest percentage of activities in the low risk range was offshore aquaculture though there is a high risk in this industry to marine mammals from surface and sub-surface buoys, ropes and structures.

There are often ways of avoiding, remedying or mitigating the effects of activities that would otherwise put marine species or ecosystems at extreme, high or moderate risk. In each section we discuss some useful mitigation strategies and some common strategies include:

- Following non-mandatory Department of Conservation guidelines (2006 and 2011) to avoid or mitigate acoustic impacts on marine mammals.
- Limiting unnecessary use of platform and vessel flood lights at night and ensuring that those that are required are directed approximately vertically onto work surfaces to avoid or mitigate seabird strikes. Visual checks of the super-structure at first light each day for the presence of dazed or injured birds and the provision of appropriate care may help to remedy this impact.
- Avoidance or mitigation of vessels and underwater equipment acting as vectors for non-indigenous species is possible by appropriate checking, cleaning, and application of antifouling paints. We understand that Biosecurity New Zealand (MAF-BNZ) is developing an import health standard and legislation and relevant regulations may be put in place in next 2-3 years.
- Pressure on fish stocks caused by the declaration of an exclusion zone around a drilling or mining site, pipeline or cable route, and forcing fishing activities into the remainder of the quota management area can be reduced or eliminated by purchase and retirement of appropriate commercial fish quota for the duration of the production phase.
- Avoidance or mitigation of seals hauling out on platform structures is possible by reducing access to potential haul-out areas but modifications to exploitation platforms is unlikely given that they invariably come to NZ from overseas for a relatively short period of intense exploration activity.
- Efforts should be made to avoid areas of protected deepwater corals within the footprint of the drilling, mining, energy, or aquaculture operation. Pipelines and cables should also be routed to avoid reef habitat and any other benthic habitat of high biodiversity.

- Risks to seep communities during the exploratory drilling process or through methane extraction altering fluid flow at seep sites and/or direct damage from rig or production facilities can be avoided or minimised through careful selection of drilling sites.
- Assuming that iron sands and placer gold deposits occur to depths of 20-30m below the seafloor, impacts on benthic fauna will be minimised if fewer deeper pits are dug to extract a prescribed tonnage of ore. This is because most fauna is restricted to the upper 10-15 cm of sediment. A wide shallow pit will cause the maximum ecological damage for the least gain in ore extraction.
- Actions that increase the rate of recovery of benthic fauna from the impacts of mining will greatly reduce the risks associated with these industries. Recolonisation by larval settlement from adjacent populations may be increased by mining in a chequerboard or strip pattern or by leaving up-current populations intact. So little is known about larval connectivity in these populations that the optimal size or arrangement of these mining patterns is unknown.
- Impacts of tourism activities on vulnerable benthic species can be minimised by rotating visits around a number of sites. The appropriate rotation interval should be guided by the likely recovery time of the species concerned.

For many of the activities associated with new or yet to be established industries there are insufficient details available to determine the best conditions to apply to avoid, remedy or mitigate their effects. These need to be determined during the consenting process.

We conclude that the most effective way to manage ecological risk is to regulate the individual activities that together make up a marine industry taking place within defined marine habitats.

Table 5-1: Summary of categorisation of activities as having extreme, high, moderate or low environmental risk. At the bottom of the table we summarise the total number of risks of each category for each industry and for scientific exploration and sampling**.**

Activity	**Oil and gas production**	**Carbon sequestration**	**Gas hydrates**	**Ironsand mining**	**Placer gold mining**	**Phosphorite nodule mining**	**Massive sulphides**	**Polymetalic crusts**	**Polymetalic nodules**	**Telecommunications cabling**	**Renewable marine energy**	**Offshore aquaculture**	**Offshore ecotourism**	**Scientific exploration and sampling**
Surface flood lights at night	High	High	High	High	High	High	High	High	High	High	High	Moderate	High	High
Airgun seismic surveys	High	-	High	-	-	-	-	-	-	High	-	-	-	High
Vessel activity causing strikes on marine mammals	High	High	High	High	High	High	High	High	High	High	High	-	High	High
High resolution seismics (boomer, CHIRP)	Moderate	-	-	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	-	-	-	Moderate
Presence of seafloor structures, mooring blocks, chains or anchors	Moderate	Moderate	High	Moderate	Moderate	-	-	-	-	-	High	Moderate	-	Low
Import and provision of biofouling surfaces	Moderate	Low	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Low	-	Low

Activity	Oil and gas production	Carbon sequestration	Gas hydrates	Ironsand mining	Placer gold mining	Phosphorite nodule mining	Massive sulphides	Polymetalic crusts	Polymetalic nodules	Telecommunications cabling	Renewable marine energy	Offshore aquaculture	Offshore ecotourism	Scientific exploration and sampling
Deployment of platform structure	Moderate	Low	Moderate	-	-	--	-	-	-	-	-	-	-	-
Underwater pipeline laying and trenching	Moderate	Moderate	Moderate	-	-	-	-	-	-	-	-	-	-	-
Well capping	Moderate	Moderate	High	-	-	-	-	-	-	-	-	-	-	-
Recovery of underwater equipment, plant and machinery	Moderate	Moderate	Moderate	-	-	-	-	-	-	-	Low	Low	-	-
Underwater flood lights	Moderate	Low	Moderate	Moderate	Moderate	Moderate	Low	Low	Low	Low	Low	Low	Low	Low
Incidental underwater noise	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Low	Moderate	Moderate	Low	Low	Low	Low	-
Abandonment, sinking of structures and	Moderate	Moderate	High	-	-	-	-	-	-	-	-	-	-	-

Activity	**Oil and gas production**	**Carbon sequestration**	**Gas hydrates**	**Ironsand mining**	**Placer gold mining**	**Phosphorite nodule mining**	**Massive sulphides**	**Polymetalic crusts**	**Polymetalic nodules**	**Telecommunications cabling**	**Renewable marine energy**	**Offshore aquaculture**	**Offshore ecotourism**	**Scientific exploration and sampling**
equipment														
Single and multibeam echo sounding	Low	-	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	-	Low
Testing of undersea mining equipment, bulk sampling	-	-	-	High	High	High	High	Extreme	High	-	-	-	-	-
Seafloor drilling, suction / cutting, extraction	High	-	High	Moderate	Moderate	Extreme	High	Extreme	Extreme	-	-	-	-	-
Creation of seafloor pits and stock-piles	-	-	-	Moderate	Moderate	Extreme	Extreme	Extreme	Extreme	-	-	-	-	-
Discharge of sediment plumes	-	-	-	Moderate	Moderate	Extreme	Extreme	Extreme	Extreme	-	-	-	-	-
Slurry pipelines	-	-	-	Moderate	Moderate	High	Extreme	Extreme	Extreme	-		-	-	-
Declaration of exclusion zone	Low	Low	Low	Moderate	Moderate	High	Moderate	Low	Low	Low	Low	Low	-	Low

Activity	Oil and gas production	Carbon sequestration	Gas hydrates	Ironsand mining	Placer gold mining	Phosphorite nodule mining	Massive sulphides	Polymetalic crusts	Polymetalic nodules	Telecommunications cabling	Renewable marine energy	Offshore aquaculture	Offshore ecotourism	Scientific exploration and sampling
Magnetometer surveys	-	-	-	Low	-	-	-	-	-	-	-	-	-	Low
Small scale coring and seabed sampling	-	-	-	Low	Low	Moderate	Moderate	Moderate	Moderate	Low	-	-	-	Low
Toxic chemical release	-	-	-	-	-		Extreme	Extreme	Extreme	-	-	-	-	-
Bulk sampling of deposits	-	-	-			High	Moderate	Extreme	High	-	-	-	-	-
ROV and other imaging surveys						Low	Low	Low	Low	Low	Low	Low	High	Low
Cable lowering and raising	-	-	-	-	-	-	-	-	-	High	Low	-	-	-
Cable trenching & installation	-	-	-	-	-	-	-	-	-	Moderate	Moderate	-	-	-
Cable abandonment	-	-	-	-	-	-	-	-	-	Low	Low	-	-	-
Exposed cable movement	-	-	-	-	-	-	-	-	-	Low	Low	-	-	-
Installation of surface and	-	-	-	-	-	-	-	-	-	-	High	High	-	Low

Activity	Oil and gas production	Carbon sequestration	Gas hydrates	Ironsand mining	Placer gold mining	Phosphorite nodule mining	Massive sulphides	Polymetalic crusts	Polymetalic nodules	Telecommunications cabling	Renewable marine energy	Offshore aquaculture	Offshore ecotourism	Scientific exploration and sampling
subsurface floats & structures														
Installation of energy capture device	-	-	-	-	-	-	-	-	-	-	High	-	-	-
Production of electro-magnetic field	-	-	-	-	-	-	-	-	-	-	Low	-	-	-
Seafloor deposition of organic waste	-	-	-	-	-	-	-	-	-	-	-	Moderate	-	-
Water column nutrient enrichment	-	-	-	-	-	-	-	-	-	-	-	Low	-	-
Water column production depletion	-	-	-	-	-	-	-	-	-	-	-	Low	-	-
High concentration of cultured species	-	-	-	-	-	-	-	-	-	-	-	Low	-	-
Surface activity and noise	-	-	-	-	-	-	-	-	-	-	-	-	Moderate	-
Subsurface activity	-	-	-	-	-	-	-	-	-	-	-	-	Moderate	-

Activity	**Oil and gas production**	**Carbon sequestration**	**Gas hydrates**	**Ironsand mining**	**Placer gold mining**	**Phosphorite nodule mining**	**Massive sulphides**	**Polymetalic crusts**	**Polymetalic nodules**	**Telecommunications cabling**	**Renewable marine energy**	**Offshore aquaculture**	**Offshore ecotourism**	**Scientific exploration and sampling**
Towed instrument arrays in core areas for nationally critical species	-	-	-	-	-	-	-	-	-	-	-	-	-	High
Moored instrument arrays in core areas for nationally critical species	-	-	-	-	-	-	-	-	-	-	-	-	-	High
Research bottom trawling	-	-	-	-	-	-	-	-	-	-	-	-	-	High
Large scale ocean productivity perturbation	-	-	-	-	-	-	-	-	-	-	-	-	-	Moderate
Extreme	0	0	0	0	0	3	4	7	5	0	0	0	0	0
High	4	2	7	3	3	6	4	2	4	3	5	1	3	6
Moderate	10	6	6	10	10	5	5	4	4	3	2	3	2	2
Low	2	4	2	3	3	2	4	4	4	8	10	10	2	9
Total	**16**	**12**	**15**	**16**	**16**	**16**	**17**	**17**	**17**	**14**	**17**	**14**	**7**	**17**

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