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Managing the effects of fishing on the environment: what does it mean for the rock lobster (*Jasus edwardsii*) fishery?

P. A. Breen

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EXECUTIVE SUMMARY

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This study addresses Objective 11 of the MFish contract CRA2000-01, held by the NZ Rock Lobster Industry Council, to conduct a desktop study to identify and explore data needs associated with managing the effects of rock lobster fishing on the environment. It reviews the MFish Strategy to identify those specific requirements likely to affect the rock lobster industry and to identify the directions that management is likely to take, including a quick look at New Zealand's Biodiversity Strategy.

Australian experiences with a similar process are examined to see how the Western Australia and South Australia lobster fisheries coped with environmental requirements and risk assessments.

Finally, the study identifies the specific topics likely to be listed in a risk assessment, briefly considers the likely risk considerations, and examines whether required data are available and adequate.

The study recommends that the rock lobster industry should convene a workshop, with government and other stakeholders, to identify and agree severity, likelihood and risk for a number of possible topics. Data collection should then be revised and improved and short directed programs conducted to
address the tractable items.

The industry should also establish representation on the Aquatic Environment Working Group and participate in the Aquatic Environment Research Planning Group. A purely reactive stance is not likely to be of greatest benefit to stakeholders: the management of environmental effects of fishing is new and fluid, and stakeholders can do much to help guide this in productive directions.

CONTENTS

1. INTRODUCTION

This document describes a study undertaken to address Objective 11 of the MFish contract CRA2000-01, held by the NZ Rock Lobster Industry Council (NZ RLIC). That objective was:

Objective 11: *To conduct a desktop study to identify and explore data needs associated with managing the effects of rock lobster fishing on the environment.*

This report was written in 2004, reviewed by MFish, and has been revised for publication in mid-2005. After revision, the draft Strategy referred to was replaced with a revised Strategy, but another revision of this report was not possible.

1.1 Overview

This study is based on the Ministry of Fisheries (MFish) draft *Strategy for Managing the Environmental Effects of Fishing* (MFish 2003). A premise of the study is that MFish requirements for managing environmental effects of fishing are inevitable, but that there is some scope for considering priorities and for collecting data earlier rather than later so that required risk assessments can be advanced.

This study first reviews the MFish Strategy to identify the specific requirements likely to affect the rock lobster industry. Then the topics identified by the Strategy are explored in more detail to identify what direction management is most likely to take. This involves a quick look at New Zealand's Biodiversity Strategy.

The Australian experience is examined: the Ecologically Sustainable Development approach is summarised, and this study looks at how two Australian rock lobster fisheries have coped with requirements and risk assessments.

Finally, the study identifies the specific topics likely to be listed in a risk assessment, briefly considers likely risk considerations, and examines whether data are available and adequate.

This document is not presented as a scientific review document with a list of references as long as possible. It considers the target audience to be stakeholders; language is adjusted accordingly. Wherever possible, web addresses are provided for the material discussed: in the text if the website is the primary source, otherwise in the references.

In what follows, "the Strategy" refers to the MFish Strategy described above; where there is a danger of ambiguity "MFish Strategy" is used. Material in italics is quoted either from the Strategy or from the source made obvious in the text.

The topic extends past science, as illustrated below in Section 2.3.1. The focus of this study is only on contributions that can be made by scientific information, not necessarily because other considerations are irrelevant or inappropriate, but because the author's expertise is limited to scientific issues.

1.2 Background

Management of the environmental effects of fishing is a hot topic in the scientific literature, in government policy statements and mission statements, and on the web. Damage from fishing is seen by some (e.g., Jackson et al. 2001) as a prime source of damage to coastal ecosystems. For instance, in the United States the Pew Oceans Commission (2003) (a summary is available at http://pewoceans.org/oceans/downloads/oceans_summary.pdf) calls for a "sea change" in oceans management to respond to a long list of problems including depleted fish stocks, commercial extinctions, endangered marine mammals, birds and turtles, bycatch discards, poor knowledge of fish stocks, habitat alteration by fishing, pollution, etc.

Concern about these topics has led to an expansion of the concept of fisheries management into thinking about ecosystems, and the effect of fishing on them. An FAO-sponsored conference in Reyjavik in 2001(Sinclair et al. 2003) was the most recent in a series of international initiatives in the direction of ecosystem approaches to managing fisheries (see Garcia et al. (2003) for the history).

Dayton et al. (2003) defined "ecosystem overfishing" as *fishing-induced ecosystem impacts, including reductions in species diversity and changes in community composition; large variations in abundance., biomass and production in some of the species; declines in mean trophic levels within ecological systems; and significant habitat modification or destruction.*

Most advanced countries are exploring how to expand fisheries management to ensure that management of individual species is effective and that ecosystem considerations are addressed. Link (2002a) suggested a list of 63 questions that should be asked of the ecosystem in which a fishery operates, to help in devising an ecosystem approach. Although some seem of dubious utility (*How strong are tidal influences? Have they changed?*), many underscore the limited knowledge available for ecosystem considerations: *What are the key species in the ecosystem? Is there one species that is clearly a competitive dominant? What is the productivity of the ecosystem?*

In Australia, as described in more detail below, environmental considerations have been legislated into the management of Commonwealth-managed and export fisheries, and these have been adopted by the various States.

The Fisheries Act 1996 ("the Act") contains sections that address environmental considerations: for instance, in Section 8 the definition of *ensuring sustainability* includes *avoiding, remedying, or mitigating the adverse effects of fishing on the aquatic environment.* Section 9 covers the viability of associated or dependent species, maintenance of aquatic biological diversity and protection of habitats that are of particular significance for fisheries management. The Strategy is a move to implement these legal requirements in practice.

In New Zealand, stakeholders have already recognized the need for environmental assessments for fisheries: a checklist (Seafood Industry Council et al. 2003) is available but has been partly overtaken by the Strategy.

2. DRAFT MFISH STRATEGY

The stated purpose of the Strategy is threefold:

- *implement an Ecosystem Approach to Fisheries*
- *make significant improvements in managing the environmental effects of fishing*
- *ensure the Ministry of Fisheries (MFish) meets its environmental obligations under the Fisheries Act 1996 and other legislation in an efficient and consistent manner.*

This study will focus on determining what **operational** goals will need to be addressed. Operational goals are those that can be measured quantitatively. The first bullet point above is an example: implementation of an approach could be defined to allow an independent observer to recognise whether it had been achieved. The second is probably not operational definable, because to "make significant improvements" is qualitative, open-ended and subjective.

2.1 The Ecosystem Approach to Fisheries (EAF)

In the Strategy's glossary, MFish defines the Ecosystem Approach to Fisheries ("EAF") as *the management of ecosystems and natural habitats to meet human requirements to use natural resources,* *while maintaining the biological richness and ecological processes necessary to sustain the composition, structure and function of the habitats or ecosystems concerned.*

The Strategy (paragraph 3) distinguishes between managing ecosystems and managing the effects of fishing: MFish is concerned with the latter, not with managing ecosystems.

The EAF concept has not been universally well defined, despite a huge scientific and policy literature. In that literature, EAF is often entangled with Marine Protected Areas (MPAs). The scientific basis for setting specific goals or taking specific action under EAF is sometimes weak: paragraph 4 of the Strategy recognises this.

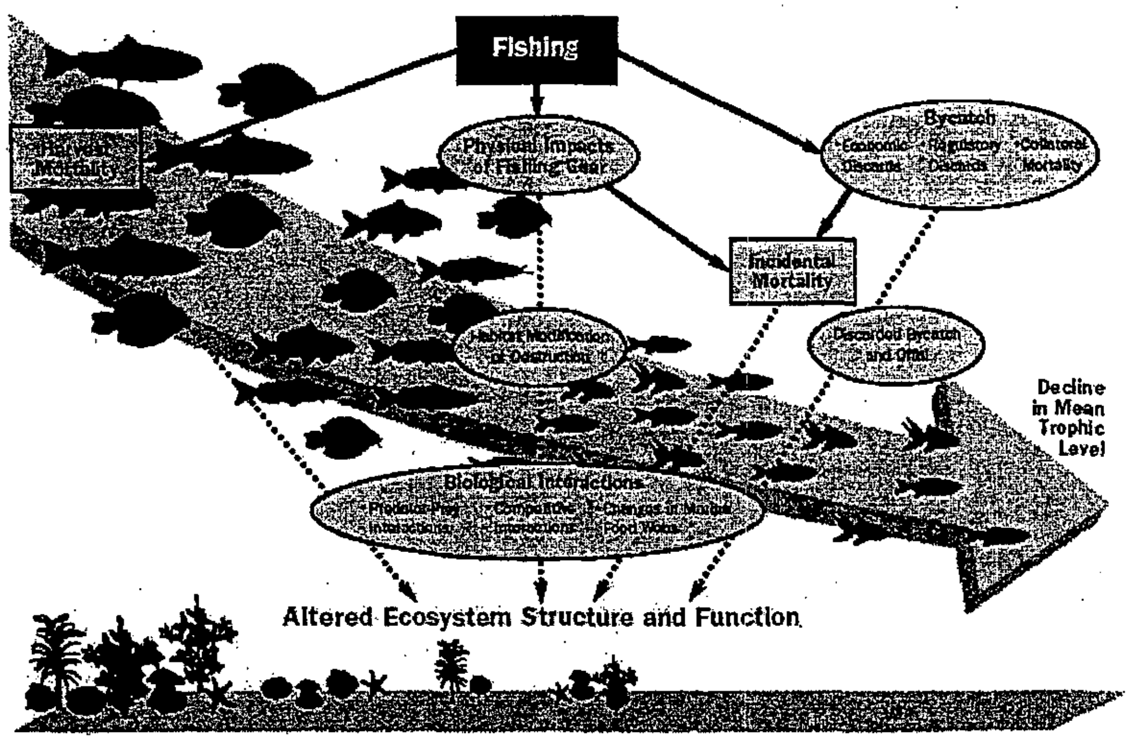
The MFish philosophical approach is summarised in paragraph 9: *we aim to achieve a balance that allows fishery resources to be used whilst ensuring that the effects of fishing on fishery resources and the ecosystems in which they occur do not compromise their sustainability.*

The strategy discusses EAF under three main headings that were useful in structuring this report (paragraphs 29 and 156):

- managing the effects on **non-target species**, including handling mortality on the target species, bycatch of other species, "associated or dependent species", and protected species,
- managing the effects on **habitats**, by maintaining diversity, addressing sustainability of associated and dependent species, protecting habitats of particular significance and
- managing **indirect effects on ecosystems**, including trophic effects (i.e., food web interactions).

Presentations by MFish (e.g., Peacey & Randall 2003) suggest that MFish thinking is structured around these three "specific management areas". These topics are not a mutually exclusive group and there is considerable overlap. For instance, bycatch can comprise members of "associated or dependent species"; managing the effects on bycatch must include addressing sustainability of bycatch species; managing the indirect effects on ecosystems may involve managing associated or dependent species. Some topics found in the literature are omitted, most notably ghost fishing. When this report considers the New Zealand rock lobster fishery, the list above is restructured.

These main areas are common in the literature. The summary diagram of Dayton et al. (2003) (Figure 1) lists "bycatch" as a main effect, with subheadings of discards and collateral mortality; they list habitat modification or destruction as another main effect, with predator-prey interactions, competitive interactions and changes in marine food webs all leading to altered ecosystem structure and function.



Source: Adapted from Pauly et al., 1998; Goñi, 2000.

Figure 1: Diagram of the environmental effects of fishing (with permission from Dayton et al. 2003).

As an example of ecosystem change, Dayton et al. (2003) listed the spectacular effects of sea otter removal on eastern Pacific kelp forests and the more recent hypothesis that whaling may be involved indirectly by causing a diet shift in orcas (Springer et al. 2003). Sea otters are widely listed as a "keystone species", but few other keystone species are as well documented. These authors also listed large marine fish species – cod, wolffish and halibut – having a similar effect in the northwestern Atlantic, although this system is more controversial and far less well studied. The effect described has been termed a "trophic cascade" (Pinnegar et al. 2000), of which those authors list 39 examples, mostly from hard shallow substrates in the northeastern Pacific. They suggest that many more trophic cascades will become apparent as MPAs become available for study and when researchers begin to study less obvious groups.

These ideas will be discussed further below when describing the data needs generated by EAF for the rock lobster fishery.

2.2 Scope of the Strategy

The Strategy addresses managing all types of fishing, non-commercial as well as commercial (paragraph 17), but it excludes (paragraph 18) the direct management of target fishstocks (presumably because these are already addressed by the existing fisheries management system), biosecurity (i.e., introduced species), aquaculture and non-fisheries effects on ecosystems (e.g., oil spills or pollution from the land). However, (paragraph 93) *when setting species-specific environmental standards, non-fisheries effects need to be taken into account.*

To anticipate what managing EAF is likely to involve for a practical fishery, one must appreciate the interactions between MFish and other agencies. Paragraph 25 illustrates this: the Strategy has "linkages" with DoC's Biodiversity Strategy, the Marine Protected Areas Strategy, area-based management and taxonomic (species-group) management such as the Marine Mammal Protection Act, the MFish Vision (paragraph 82), the Wildlife Act 1953 (e.g., corals, paragraph 128), the Resource Management Act (paragraph 110) and the Oceans policy under development (paragraph 170).

Thus stakeholders must accept that a great deal of external influence is active.

2.3 Implementation

Expanding fishery management to incorporate EAF will involve costs (paragraph 4), directly and also indirectly if "utilisation" is constrained because of EAF. MFish appear to recognise that costs must be shared by government, although (paragraph 5) *stakeholders will face increased business compliance costs.*

The Strategy also recognises that required information will often be unavailable, and even that some aspects of EAF (paragraph 6) may require *an understanding of marine ecosystems that is currently beyond the ability of science to deliver.* Some research has already been conducted, commissioned by MFish (Campbell 2003). An industry imperative should be to follow closely and even participate in the MFish Aquatic Environment Research Planning Group. Such research is funded largely by the Crown, but the directions chosen could have strong effects on the standard-setting process and on specific implementation of the Strategy.

Implementation will be staged over several years (paragraph 78). *In the meantime, [fisheries management] will take into account whatever relevant environmental standards have been developed.*

From the stakeholder viewpoint, MFish's implementing the Strategy involves (paragraph 26):

- defining stakeholder vs government responsibilities,
- defining environmental standards,
- assessing and reporting on the status of species and habitats,
- requiring environmental risk assessments for all fisheries, and
- requiring management to demonstrate compliance with environmental standards.

2.3.1 Environmental standards

Development of environmental standards is seen as an MFish organisational responsibility (paragraphs 116–117). The target dates for "process" standards (see below) are in the 2004–2005 range (page 41). In keeping with the plan to implement EAF over several years, MFish propose to develop generic standards first and then refine them (paragraphs 104–105).

Proposed consultation on standards involves the existing Aquatic Environment Research Planning and Aquatic Environment Working Groups, a proposed Aquatic Environment Management Advisory Group and Regional Iwi Forums (paragraph 147).

The MFish list of factors to be considered when setting standards illustrates that EAF extends past purely technical issues (this is from Peacey & Randall 2003):

- *environmental obligations*
- *treaty considerations*
- *societal expectations*
- *utilisation considerations*
- *incentives and compliance realities*
- *evaluation of performance*
- *based on risk management approach*

In paragraph 92 *MFish proposes, in the first instance, establishing species-specific and habitat-specific environmental standards rather than fishery-specific standards.* Thus different fisheries affecting the same species or habitats or ecosystems will be working to a common set of standards, but it is possible (paragraph 94) that coordination will be required between *the managers and participants in different fisheries.*

The Strategy describes "process" and "performance" standards (paragraphs 97 –99). As they affect a practical fishery, process standards are those that define data quality, monitoring standards, environmental risk assessments, management performance, etc. *Performance standards will establish the acceptable limits of the effects of a fishery on the aquatic environment.* Paragraph 99 describes these in a way analogous to fishery assessment reference points. They are based (paragraph 102) *on managing the level of risk to which species and habitats requiring specific management are exposed. Risk-based management approaches are common in many areas of natural resource management and, more recently, are being used in fisheries management. Risk is usually assessed in terms of the likelihood of an effect and the consequence of the effect.*

These standards are seen as the basis for simple decision rules (not management procedures) analogous with simple decision rules used to manage fisheries (paragraph 103): *It is proposed that environmental standards should require management actions and reporting appropriate to the level of risk. The higher the level of risk, the more immediate the management actions and the higher the level of reporting required. In keeping with the operating principle of continual improvement, it is proposed that for all risk levels of moderate and above, standards should require management measures to reduce the level of risk; the rate of reduction required will depend on the level of risk.*
In addition to species- or habitat-specific performance standards, MFish propose to "assess" the effects of fishing with macroscopic indicators (paragraph 153) such as:

- *number of species and types of aquatic habitat affected by fishing for which information is being collected,*
- *number of species and types of aquatic habitat affected by fishing for which fisheries management standards have been set,*
- *number of species and types of aquatic habitat about which we are confident that the effects of fishing are within agreed limits, and*
- *level of tangata whenua, stakeholder and public satisfaction with the partnership, participation and consultation opportunities provided in the process of managing the environmental effects of fishing.*

The development of "ecosystem indicators" is not well advanced. These were the subject of an international meeting in Paris at the end of March 2004, based on the activities of an international working group on ecosystem indicators (Cury & Christensen 2001). The conference results were reported by Daan et al. (2005). It is safe to say that the development of useable ecosystem indicators is still not well advanced, and is dominated so far by ingenious but ad hoc statistical measures.

Link et al. (2002) illustrated a suggested multivariate approach to developing indicators for the Northwest Atlantic. Link (2002b) listed, as emergent properties of ecosystems, diversity indices and size spectra, various indices describing the structure of food webs (connectivity, linkage density, interaction strength, etc.), and energy storage and flow, resilience, persistence, and stability. It is probably optimistic to think that any of these can be translated simply into operational indicators.

Garcia et al. (2003) were unable to find a straight definition of ecosystem well-being. They suggested that ecosystems *do not maximize their functions but tend to optimize them*, and thus that maximisation targets will not work. As much as anything, this illustrates what an embryonic field ecosystem science is, and how far away we are from having operational objectives for ecosystem management.

2.3.2 Responsibility for implementing

In the Strategy this was to be addressed through the Fisheries Plan proposal (paragraph 78). Stakeholders could "*take increased responsibility for management*" by developing a Fishery Plan (paragraphs 112 and 148) that conformed with the environmental standards set by MFish. If they chose not to do so, MFish would develop a Fish Stock Strategy (paragraph 114).

However, this arrangement was abandoned in early 2005 (http://www.mfish.govt.nz/current/press/pr19505.htm), but a replacement approach has not yet been documented on the MFish website.

2.3.3 Environmental risk assessment

This topic is seen (paragraph 119) as an expansion of existing risk assessment-based management for well-assessed species such as lobsters, hoki, and paua. It is an integral part of EAF as it has been implemented in Australia (Section 4). The proposal is that an environmental risk assessment should be done as part of fisheries planning (paragraph 120, although the specific references there are obsolete now).

The time scale proposed for these is 2007 except for new or expanded fisheries (paragraph 121). This could mean that rock lobster TACC or TAC changes resulting from assessments could be subject to environmental risk assessment, although it could be argued that TACC increases under existing decision rules or management procedures should be exempt.

3. EAF IN MORE DETAIL

Above, the MFish view of EAF was briefly listed under three main headings. This section takes a more detailed look at these topics with references to the literature where appropriate.

3.1 Non-target species

Ghost fishing is a feature of the Australian implementation of EAF, but is not mentioned by the Strategy. Ghost fishing happens when lost gear continues to catch and kill animals.

The Strategy is vague about effects on non-target species. The effects are to be managed (paragraph 157) through mitigation and limits on the catch, implying that bycatch is the main concern. The concept is intended to apply to a broad range of species (paragraph 160).

The Strategy suggests (paragraph 168) that considerable cost might be expected in this topic area to comply with the intent: *The current paucity of information on many Associated or Dependent Species means that it may be difficult for fishery managers to demonstrate that the fishery is allowing these species to be maintained above viable levels. Fishery managers may be faced with the choice of undertaking extensive research on a wide range of Associated or Dependent Species to demonstrate that the effects of the fishery on these species are within acceptable limits, or setting aside adequate areas as no-fishing or restricted fishing zones to ensure the viability of the species.*

Thus there is a choice: spend money on research for these species, or establish area protections. However, in the context of the section, this paragraph refers mainly to "associated or dependent species" that attract a "threat classification", meaning species that are endangered, or threatened or vulnerable (see paragraph 169, which clearly focuses research priorities on threat classification).

3.1.1 Protected species

Avoiding the effects of fishing on protected species is carefully defined by the Act: Section 15(2) provides for, in the absence of a population management plan, the Minister of Fisheries taking *such measures as he or she considers necessary to avoid, remedy, or mitigate the effect of fishing-related mortality on any protected species*. Effects may be direct or indirect, such as those that reduce food supply or modify habitat. Measures taken may include spatial management (i.e., closed areas such as the exclusion zone for trawling around the Auckland Islands), catch limits such as the FRML (fisheries-related mortality limit) for Hooker's sea lions in SQU 6T, mitigation technology such as sea lion excluders on trawl nets or tori lines on longliners, and codes of practice.

MFish has designed a flow chart that describes how to proceed in assessing effects on protected species (Figure 2) that should be considered in the environmental risk assessments described by the Strategy.

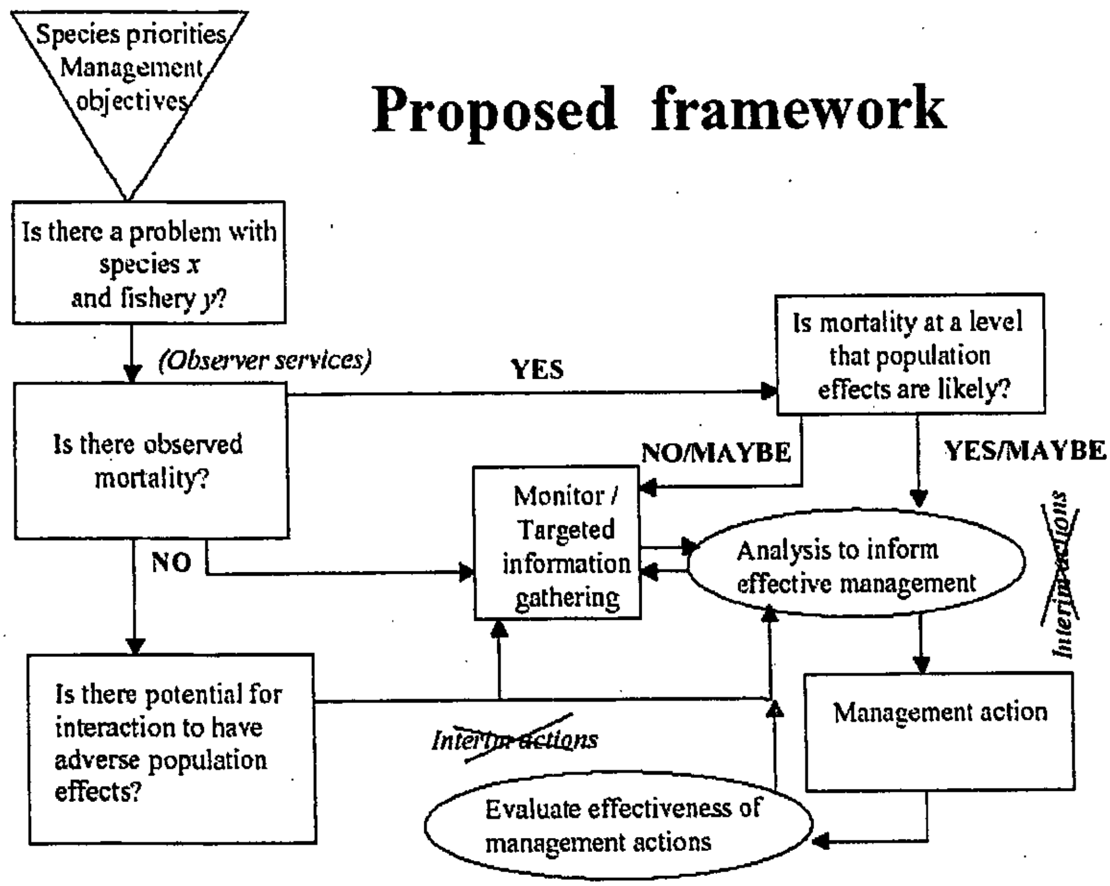


Figure 2: Flow chart proposed for decision-making with respect to protected species (from Waugh 2003).

The Strategy (paragraphs 85 and 161) proposes that the *Species Threat Status Classification System developed by DoC be used to assess the status of species.* The DoC threat classification system is described by Molloy et al. (2002); it has so far not been applied to many marine species apart from marine mammals (see Hitchmough 2002), and the Strategy proposes to apply it to a wide range of associated and dependent species.

This exercise may also identify some potentially vulnerable ecosystems (paragraph 165), but the primary protection for ecosystems will be provided through direct habitat protection measures.

For protected species the Strategy suggests (paragraph 133) that expectations are often higher than, for example, the requirement to maintain a Protected Species at viable levels. There is an expectation that, at a minimum, all reasonable steps are being taken to avoid the effects on Protected Species. This probably applies to icon species such as sea lions and dolphins: the statement means that it is not enough to maintain populations at viable levels; instead all steps must be taken to avoid fishing-related mortality.

In environmental risk assessments, *the effect of the fishery on all relevant Protected Species and other Associated or Dependent Species will need to be assessed. Where particular standards have been set ... the stock management plan or fish plan will need to meet those standards. Where there are no* *species-specific standards, there will be a requirement to meet generic standards.* This implies that risk assessments cannot be finalised until at least the generic standards have been developed by MFish.

3.2 Habitats

The focus in the Strategy with respect to managing effects on habitats is strongly based on using MPAs as the primary tool. Examples include:

- the goal for habitats is described in the MFish Vision (paragraph 82) as representative areas of each type of habitat are protected and habitat of particular significance for fisheries management is protected. The definition of the latter is under review (paragraph 197).
- paragraph 85 of the Strategy: *the preliminary draft of the Marine Protected Areas Strategy (currently under development) proposes an annual inventory of marine habitats and marine protected areas as a basis for prioritising future habitat protection initiatives.*
- paragraph 157 of the Strategy refers to management through area closures and area-based method restrictions. There are currently several kinds of spatial controls (paragraphs 171 and 172), and the Strategy proposes to coordinate these with the proposed Marine Protected Areas Strategy (paragraphs 173–180).
- research priorities of relevance involve classification of habitat and *determining the amount of each habitat type that requires different levels of protection* (Paragraph 181).

3.2.1 Biodiversity

3.2.1.1 Diversity and stability

A common reaction of fisheries biologists, when faced with modern biodiversity topics, is some version of "what is biodiversity?" This is perhaps because the diversity-stability debate was hot when most fishery biologists were students. A good (simple and non-technical) treatment of this controversy was given by Holsinger (2003). Relevant points follow.

1) "Diversity" can be used to mean many different things: number of species in a system, relative abundance within different species (more evenness implies higher diversity), ecological distinctiveness of different species, or evolutionary distinctiveness of different species.

All of those are "species diversity" topics. MFish and DoC thinking appears to be wider; for instance, Anon. (2003) in a list of "knowledge gaps" for seamount protection includes:

- *habitat diversity*
- *ecosystem diversity*
- *species diversity*
- *genetic diversity*

2) "Stability" similarly can mean many different things, including (Creel 2003):

- persistence – the time a variable lasts before changing to a new value,
- resistance – how large a disturbance is needed to perturb system,
- variability – the normal range of values at equilibrium,
- constancy – resistance to changes in composition,
- resilience – ability to return to a pre-disturbance state after perturbation and
- dynamic stability – future states – these have more influence on future state than perturbation.

3) The original idea that diversity confers stability on ecosystems has little empirical support and is now considered an over-simplification. For instance, *there is no simple relationship between diversity and stability in equilibrium deterministic systems, whether at the level of populations or aggregated ecosystem processes* (Loreau & Behera 1999).

4) Changing the number of species in an ecosystem (both loss and addition) can cause major ecosystem changes.

5) High species diversity reduces the risk of large changes in ecosystem processes in response to directional or stochastic variation in the environment, or in response to invasions of pathogens and other species (Chapin et al. 1998).

3.2.1.2 New Zealand Biodiversity Strategy

This is available at http://www.biodiversity.govt.nz/picture/doing/nzbs/contents.html

It defines biodiversity as *native species, their genetic diversity, and the habitats and ecosystems that support them.* The Glossary definition is: *the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (Convention on Biological Diversity).*

The Biodiversity Strategy describes biodiversity being "in decline" through species extinctions and also through introductions and loss and disruption of habitats, implying that "decline" is more than the reduction of species numbers. However, discussion of biodiversity decline appears to be intimately related to extinctions: eg., Figure 1.1 of the Biodiversity Strategy and adjacent text. Figure 2.2 shows a "schematic" decline in the "biodiversity index", which is *based on what is known about changes in the extent and condition of natural habitats and ecosystems and changes in the distribution of indigenous species, their loss from some habitats (local extinction) as well as complete extinction.* In this Figure, neither decline nor the "biodiversity index" is defined. It is unclear what the Figure shows.

In fact, the Biodiversity Strategy appears to have few quantitative definitions. Whether the qualitative definitions are operationally useful is open to question. For instance, a "healthy ecosystem" is defined as *an ecosystem which is stable and sustainable, maintaining its organisation and autonomy over time and its resilience to stress. Ecosystem health can be assessed using measures of resilience, vigour and organisation.* "Resilience" is defined as *the ability of a species, or variety or breed of species, to respond and adapt to external environmental stresses*, but "organisation" and "vigour" are undefined. Whether a healthy ecosystem could be identified under the definition is not clear and seems unlikely.

Specific goals of the Biodiversity Strategy are:

Goal One: Community and individual action, responsibility and benefits

> *Enhance community and individual understanding about biodiversity, and inform, motivate and support widespread and coordinated community action to conserve and sustainably use biodiversity; and*
>
> *Enable communities and individuals to equitably share responsibility for, and benefits from, conserving and sustainably using New Zealand's biodiversity, including the benefits from the use of indigenous genetic resources.*

Goal Two: Treaty of Waitangi

> *Actively protect iwi and hapu interests in indigenous biodiversity, and build and strengthen partnerships between government agencies and iwi and hapu in conserving and sustainably using indigenous biodiversity.*

Goal Three: Halt the decline in New Zealand's indigenous biodiversity

> *Maintain and restore a full range of remaining natural habitats and ecosystems15 to a healthy functioning state, enhance critically scarce habitats, and sustain the more modified ecosystems*
>
> *in production and urban environments; and do what else is necessary to*
>
> *Maintain and restore viable populations of all indigenous species and subspecies across their natural range and maintain their genetic diversity.*

Goal Four: Genetic resources of introduced species

Maintain the genetic resources of introduced species that are important for economic, biological
and cultural reasons by conserving their genetic diversity.

Of this mixture, goal three is of most relevance to an environmental risk assessment for the lobster fishery.

With specific reference to coastal and marine ecosystems, the desired outcomes of the Biodiversity Strategy are:

Desired outcome for 2020

- *New Zealand's natural marine habitats and ecosystems are maintained in a healthy functioning state. Degraded marine habitats are recovering. A full range of marine habitats and ecosystems representative of New Zealand's indigenous marine biodiversity is protected.*
- *No human-induced extinctions of marine species within New Zealand's marine environment have occurred. Rare or threatened marine species are adequately protected from harvesting and other human threats, enabling them to recover.*
- *Marine biodiversity is appreciated, and any harvesting or marine development is done in an informed, controlled and ecologically sustainable manner.*
- *No new undesirable introduced species are established, and threats to indigenous biodiversity from established exotic organisms are being reduced and controlled.*

In the discussion of coastal and marine ecosystems, the Biodiversity Strategy makes specific reference to the lobster fishery:

Some of our coastal and marine species are at risk from human activities, in particular fishing and land-based activities.

- *Commercial fishing, although managed through the QMS, has depleted stocks of some target species (for example, snapper, orange roughy and rock lobster) to below levels judged desirable by fisheries scientists and managers. Management should focus on rebuilding depleted stocks and avoiding, remedying or mitigating any negative effects of fishing on ecosystems.*
- *Commercial fishing impacts include: the capture (by-catch) of non-target species, such as fish, marine mammals (dolphins, sea lions and fur seals), marine invertebrates and seabirds; genetic changes in response to fishing; effects on predator/prey relationships and damage to benthic communities.*

In the "Action Plan" for this section, the parts of the long list relevant to this report are habitat definition and mapping, identification and protection of "critical" species and habitats, implementation of EAF, environmental risk assessments, implementation of a strategy for marine protected areas, protection of 10% of the "marine environment" by 2010, and extension of the threat classification system to marine species. Note the high overlap with the MFish Strategy.

The biodiversity goal is described in the MFish Vision (paragraph 82) as *...the richness of our biodiversity is vigilantly maintained"* and, with respect to environmental standards (paragraph 83), *biodiversity is maintained and there have been no fishing-induced extinctions.*

With reference to the New Zealand Biodiversity Strategy (paragraph 128), relevant goals are described as *maintenance of natural marine habitats and ecosystems* and *protection of rare and threatened species.*

3.3 Indirect effects of fishing

The Strategy recognises that information is poor (paragraph 183), and proposes to use overseas research as a guide to New Zealand processes as well as commissioning (paragraphs 51 and 86) limited New Zealand research. Paragraph 86 proposes *that New Zealand should undertake enough research in this area to ensure that major indirect effects can be identified and managed. However, the main focus of research in the short to medium term should be to obtain enough information to manage the direct effects of fishing.*

It appears that predator-prey relations are the main idea imagined by the Strategy: examples are seabirds and anchovies in paragraph 49, Steller's sea lions and pollock in Alaska in paragraph 186. The trophic relations involving Steller's sea lions are far from understood: the author participated in a conference in Alaska in 2004, which underscored the lack of consensus about causes of the sea lion decline and the role of commercial fishing.

However, other views emerge from MFish: for instance, Anon (2003) described a research goal for seamounts as: *Determining the spatial impacts of trawling on fished seamounts and to measure the significance of the impact on the long-term sustainability of seamount habitats and ecosystems.* The Strategy itself doesn't develop concepts of ecosystem and habitat "sustainability" except in the definition of EAF.

3.4 The pressure - state - response framework

There is some evidence (Campbell 2003) that MFish plans to use this framework (OECD 1997) in considering and developing EAF. This framework appears to be widely used in environmental policy approaches. A report on New Zealand's state of the environment published by the Ministry for the Environment (http://www.mfe.govt.nz/publications/ser/ser1997/chapter1.pdf) explains: *This framework is based on a concept of causality. Human activities exert pressures on the environment, changing both its quality and the quantity of natural resources. These changes alter the state, or condition, of the environment. The human responses to these changes include any organised behaviour which aims to reduce, prevent or mitigate undesirable changes.*

Campbell (2003) stated that 30 research projects have been done so far, most concerned with "pressure" under the headings:

- *water clarity/quality*
- *physical damage*
- *invasives and biosecurity* (note that this heading is excluded by the Strategy)
- *loss of and damage to non-target species*
- *fishing practices*

She enumerates projects in the "state" section under the headings

- *plants*
- *animals*
- *gene flow*
- *habitats - ecological*
- *biodiversity*
- *ecosystems*

Under the "response topic" she lists two headings: "management tools", including the Act, input and output controls, environmental indicators, management indicators and monitoring, and "impacts/responses", including environmental impacts, reduced fish stocks and unsustainable fisheries.

This presentation is described mostly to demonstrate apparent avenues of MFish thinking and to show the embryonic nature of development of defined environmental goals and indicators. The presentation concluded with an interesting list of questions (paraphrased):

- have we identified the pressures?
- do we have an appropriate awareness of how these pressures relate to natural variability?
- do we know what natural variability actually is?
- can we differentiate fishing pressure from natural pressure and variability?
- can we assign priorities to the pressures according to their effect?
- how do we cope with trophic cascades?
- time to recovery (resilience) - can it be measured?
- can we enhance recovery through rehabilitation and mitigation?

3.5 Summary

To summarise this section:

- managing the effects of fishing on non-target species is concerned most immediately with bycatch and icon species, although clearly the focus will expand;
- there is a strong immediate focus from MFish and DoC on preventing extinctions;
- effects on habitats will probably be addressed most immediately with MPAs of various kinds; and representative habitats and critical habitats will be protected;
- the specific relevant actions suggested by the Biodiversity Strategy are already incorporated in the MFish Strategy;
- the Biodiversity Strategy gives an insight into the qualitative and often nebulous nature of the various underlying ideas;
- operational goals of measures to preserve or enhance "biodiversity" are not defined and
- the main focus on indirect effects of fishing is predator-prey relations.

4. ENVIRONMENTAL MANAGEMENT OF FISHERIES IN AUSTRALIA

The government of Australia has adopted the concept of "ecologically sustainable development" (ESD) to address environmental concerns associated with fishing. ESD is defined (cited by Fletcher et al. 2000) as *Using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased.*

The ESD website (http://www.fisheries-esd.com/c/home/index.cfm) describes ESD as the kind of development that: *meets the needs of the present without compromising the ability of future generations to meet their own needs.* This is similar to a section in the New Zealand Fisheries Act 1996.

All States have adopted the strategy (Whitworth et al. 2002) and most have adopted ESD into their own fisheries legislation. All Commonwealth-managed fisheries and other fisheries "based on export of marine species" are required to be managed in compliance with ESD.

Application of ESD to fisheries involves a set of principles and component objectives (Commonwealth of Australia 2001), available at
http://www.deh.gov.au/coasts/fisheries/assessment/guidelines.html#download

4.1 The Australian how-to guide

A wide range of information is available to assist fishery managers and industry in compiling the information required to comply with ESD:
http://www.fisheries-esd.com/c/implement/implement0200.cfm#download
One of the documents is a "How-to Guide" (Fletcher et al. 2000).

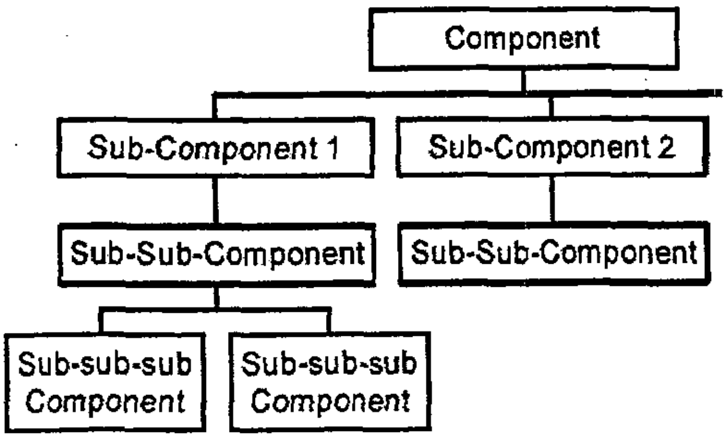
Major components of ESD are described as:

Contributions of the fishery to ecological well-being
1. Retained species
2. Non-retained species
3. General ecosystem
Contributions of the fishery to human well-being
4. Indigenous well-being
5. Community and regional well-being
6. National social and economic well-being
Factors affecting the ability of the fishery to contribute to ESD
7. Impact of the environment on the fishery
8. Governance arrangements

The first three are obviously most relevant to this study and to the MFish Strategy. For each topic, the ESD approach is to define an **objective**, define an **indicator** (what is measured to track performance), define an acceptable **range** of the indicator, discuss the **data** collection required, data **evaluation** and **robustness** of the result, discuss **management responses**, and consider **external influences** (other than fishing) on the indicator. A detailed assessment, such as that for Western Australian rock lobsters described below, lists all these topics explicitly for each sub-heading. ESD principles list a set of "objectives" under both of the ESD principles.

An analogy between ESD and the MFish EAF Strategy is likely to appear in the environmental standards that will be defined by MFish. Ideally, the generic standards could define the objective and define indicators and their acceptable ranges; the specific standards or specific fisheries plans could define the remainder for specific fisheries.

The How-to Guide suggests a workshop approach in identifying risks, gives detailed instructions on how to run one and gives a procedure for hierarchical classification of elements to be addressed:



Generic trees for wild capture fisheries are given at http://www.fisheries-esd.com/c/implement/implement0200.cfm; these could be used as initial templates for risk assessment in New Zealand.

A detailed "formal approach to qualitative" (semi-quantitative on an ordinal scale) risk assessment is given: this involves determining the consequences and likelihoods of identified risks, evaluating the product, treating unacceptable risks and setting up procedures to monitor and review acceptable risks. This is based on Australian/New Zealand Standard AS/NZS 4360:1999 Risk Management, and the companion paper on Environmental Risk Management – Principles and Process (HB 203:2000). An example of this approach is documented by IRC (2001) for the Western Australian rock lobster fishery.

The approach considers that risk is the severity of an event times its probability. An air crash is severe but very unlikely, and has very low risk for any specific passenger. The common cold occurs with high frequency but is not very consequential, so has a low risk for the opposite reason. An example of the approach from Australia (IRC 2001) is described as follows. This example deals with single-species management, which is outside the scope of the Strategy, but it illustrates the risk assessment approach:
If ... the greatest consequence that may happen to a particular harvested stock was that it could become recruitment overfished (which is a 'severe' consequence with a score of 4), but the likelihood of this occurring was unlikely (which is a score of only 3) this combination would generate a risk rating of 12, ...considered a 'moderate' risk – suggesting that continued management was required to ensure the risk was maintained at an acceptable level.

What follows is a condensation of the various requirements for fisheries, focusing on those that are relevant to the MFish Strategy. ESD has an emphasis on sustainable single-species management, whereas the MFish Strategy excludes this because it addressed elsewhere, so these aspects are not discussed.

PRINCIPLE 1: A fishery must be conducted in a manner that does not lead to over-fishing, or for those stocks that are over-fished, the fishery must be conducted such that there is a high degree of probability the stock(s) will recover.
This relates mostly to the single-species conservations not relevant to the MFish EAF Strategy, but of special interest for the rock lobster fishery are (emphasis added):

1.1.4 *There are reliable estimates of all removals, including commercial (landings and* ***discards), recreational and indigenous****, from the fished stock. These estimates have been factored into stock assessments and target species catch levels.*

1.1.8 *Fishing is conducted in a manner that does not threaten stocks of by-product species. (Guidelines 1.1.1 to 1.1.7 should be applied to by-product species to an appropriate level)*

The second principle is:
PRINCIPLE 2: Fishing operations should be managed to minimise their impact on the structure, productivity, function and biological diversity of the ecosystem.

Objective 1. The fishery is conducted in a manner that does not threaten bycatch species.
This objective requires information on, and a risk assessment for, the bycatch species, and the fishery must be managed to avoid bycatch capture unless it is determined to be sustainable.

Objective 2. The fishery is conducted in a manner that avoids mortality of or injuries to, endangered, threatened or protected species and avoids or minimises impacts on threatened ecological communities.
This objective requires reliable information to be collected on the effect of the fishery, and "impact assessments" of the effects on threatened species and ecosystems.

Objective 3. The fishery is conducted in a manner that minimises the impact of fishing operations on the ecosystem generally.
This requires information to be collected for a risk analysis:
Information is collected and a risk analysis, appropriate to the scale of the fishery and its potential impacts, is conducted into the susceptibility of each of the following ecosystem components to the fishery:

1) Impacts on ecological communities: Benthic communities, ecologically related, associated or dependent species, and water column communities
2) Impacts on food chains: structure, productivity and flows
3) Impacts on the physical environment: physical habitat and water quality
Management actions must ensure that "significant damage" does not arise from these effects.

4.2 ESD manual: rock lobsters

In the ESD manual, Fletcher et al. (2003) suggest that for "effects on prey and community structure, the effects of temperate rock lobsters are likely to be 'low to moderate". They list the main issue as whether lobsters are the major predator of species that play a significant role in structuring the *community where the fishery operates.*

They suggest that *rock lobsters are generalist feeders, known to consume a diverse range of benthic plant and animal material (Lipcius & Eggleston, 2000). There are a few examples where indirect impacts on community structure may have occurred, [following] overfishing of lobsters. These have all been related to interactions between the lobsters with sea urchins and algal communities.*

They dismiss the idea that overfishing of lobsters was implicated in sea urchins barren grounds in eastern Canada, but they suggest that recent evidence implicates lobsters in controlling sea urchins in the marine reserve at Leigh and in South Africa. They consider that *there is no evidence in Australia of any major community level changes following reductions in the abundance of either* Jasus *or* Panulirus. *However, none of these areas have been "overfished"* (!)

Fletcher et al. (2003) suggested that for *effects on predators*, the likely risk rating is *low*, because *lobsters are prey to a series of larger predators including various finfish, sharks and octopus*, but there are no documented examples of significant effects on predators from reduced lobster abundance.

4.3 Western Australian rock lobsters

WA Fisheries developed a report addressing the ESD requirements (WA Fisheries 2001). They began with a stakeholder workshop, as suggested by Whitworth et al. (2002), with representation from the commercial and recreational fisheries, environmental groups, government and researchers. Their risk assessment process was very detailed and complex because Marine Stewardship Council (MSC) certification was also sought and obtained for this fishery.

Some points to note from this report are as follows.

1. Bycatch is monitored through an observer catch sampling program. Only octopus were caught in sufficient quantities to "warrant detailed attention"; two other components (fish and sharks, and deep-sea crabs) were caught only in small quantities and assessments for these species are done elsewhere. The risk to octopus populations was considered "low" because octopus occupies a larger habitat than is fished by lobster pots and because escape gaps reduce the exploitation rate on octopus. The catch rate of octopus will be monitored against the recent 10-year average, and the risk will be considered low unless this catch rate declines by more than 25% from the recorded range. (This is a considerable condensation from the report section, which is given in Appendix 2 to show the level of detail involved.)

2. There is an annual phone survey of licensed recreational lobster fishers, giving levels of effort and catch.

3. The rock lobster fishery captures two non-retained species: sea lions and moray eels, of which the first is a threatened species. Informal analysis suggested a moderate risk to sea lions (there is no New Zealand analogy here), and moray eels are returned alive to the sea.

4. The fishery has a direct impact on some threatened species not captured in pots – turtles, whales and dolphins – and on non-threatened manta rays. A few turtles are struck by vessels or entangled in buoy lines each year; similarly there are infrequent reports of cetacean entanglements. Data have been collected through observers and industry logbooks in a new program since 2001. The performance measure is "any increase in logged observations, media reports or other recorded interactions with whales and dolphins" and similarly for manta rays.

5. A formal risk assessment for each of the threatened species concluded that the risks were low for cetaceans and moderate for sea lions and leatherback turtles. This was formal but qualitative: methodology involved the workshop setting and consideration of the range of potential consequences and their likelihoods. *The consequence and the likelihood were combined to produce an estimated level of risk associated with the particular hazardous event in question. A realistic estimate was made by the group for the consequence level from 1–5, with 1 being minor and 5 being catastrophic/irreversible. This assessment was based upon the collective judgement of the participants at the workshop who together have considerable expertise in the areas examined. Similarly, in assigning likelihood to one of six levels from remote to likely, the workshop group considered the likelihood of the hazardous event actually occurring based upon their collective wisdom including an understanding of the scale of impact required.* These rankings were then combined and integrated for an overall rating.

6. Effects on the environment (Objective 3 of Principle 2) were identified by the workshop in the generic tree structure (Figure 3) format recommended for ESD assessments by Fletcher et al. (2000). A risk assessment of the type just described was performed for each potential effect, and only the effect on coral (moderate) was deemed to be higher than low risk. Some of these elements are worth examining in more detail because of their relevance to New Zealand; the list of topics examined, although many do not have New Zealand analogs, is summarised to show the scope of the risk assessment.

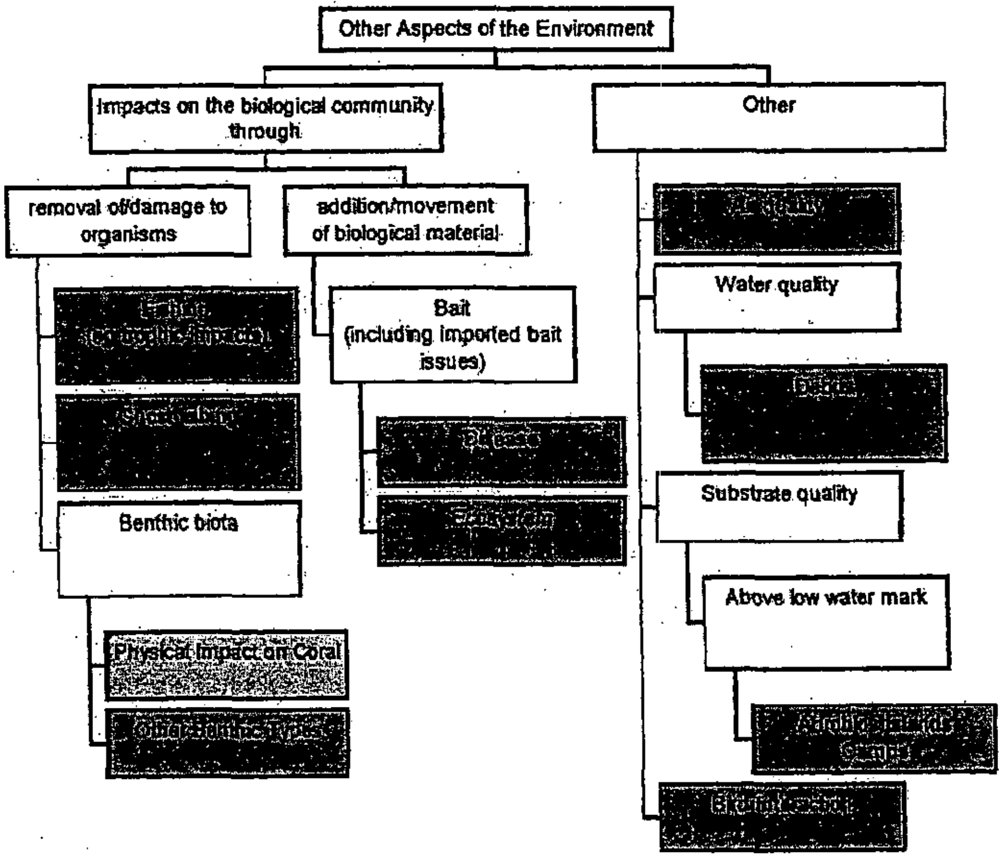


Figure 3: Effects on the environment identified for the WA rock lobster fishery.

7. For trophic impacts, the analysis determined that the biomass of lobsters is now not much reduced: the sublegals are not affected by fishing, and the breeding stock is as high as it was 30 years ago. An analysis by Phillips (not in their references) suggested that fishing decreases the total biomass by only 10% (!), which is much less than natural fluctuations. Some work with their Table 5 shows that this is based on an extremely high implicit M, whereas the New Zealand lobster has an M of 0.10 to 0.30.

8. There are no known predators of larger western rock lobsters. The role of lobsters as predators was reviewed, based on a number of ecological studies conducted in WA, and was concluded to be minimal because the prey species have high turnover rates and other predators are more important than lobsters. Because lobster abundance has higher natural variability than that caused by the fishery, the trophic effects of fishing lobsters were argued to be small. Trophic cascades involving lobsters, described in the literature, were reviewed and rejected.

9. Ghost fishing was considered a low risk because of wooden pot construction that allows rapid decay after loss. Data are now being collected on pot loss.

10. Damage to coral was assessed as a moderate risk, based on knowledge of coral cover in the habitats fished, diver estimates of damage and estimates of potting intensity. Direct damage from vessels through grounding was also considered.

11. Disease introduction through imported bait was considered a low risk based on a published *risk assessment. The trophic effects of bait* were discounted after dividing the bait biomass by the area fished and calculating that annual bait use was only 5 kg per hectare.

12. Damage to the limestone reef structure was considered a low risk based on estimates of the reef area and the relative area affected by pots annually (0.4%). Effects on the seagrass community were also considered a low risk.

13. Effects of fishing on shearwater and dolphin behaviour were examined briefly; also air quality and marine debris. Camping and waste disposal at the Abrolhos Islands were examined in a special section.

Some insight into additional issues that could be called "environmental", although perhaps not really "ecosystem" issues, can be seen from an issue dealt with by the WA Rock Lobster Industry Council (http://www.mccn.org.au/wa/default.asp?page=newsitem&newsid=6). In one area the number of commercial lobster vessels increased from 3 to 40 in 2 years, and the local community expressed concern about:

- the safety of divers, swimmers and surfers when the pots are set close to shore,
- interference in the use of water,
- competition with commercial fishers at public ramps and facilities,
- competition/interference between the recreational and commercial fishers,
- local lobster sustainability,
- habitat damage,
- oil and fuel spills,
- unplanned moorings and anchorages,
- noise and
- loss of general tourism amenity.

4.4 South Australian rock lobster

An exercise generally similar to the Western Australian one, but less comprehensive, was done by Sloan (2003). Points to note include the following.

1. The compulsory "logbook" requires information on octopus, giant crabs and *the species, weight, number and form of any marine scalefish species taken*, but **not** including non-retained fish. Further data on non-target species are being collected in a low level monitoring program involving SARDI observers, with a coverage of just under 0.1% of pot-lifts. The risk assessment provides a long list of fish and invertebrates caught as bycatch, emphasises the selective nature of pots, and outlines plans to analyse bycatch data. Risk assessment for finfish has not yet been done, but the report notes the low quantities of most fish taken and relies on escape gaps as the measure for avoiding finfish bycatch.

2. The octopus bycatch was assessed from records of CPUE back to 1983, provided by fishers on the compulsory reporting forms. A previous study had concluded that there was no change in octopus abundance, and that lobster fishing has no measurable effect on the octopus population.

3. Recreational fishing surveys are conducted regularly and the catch has been estimated. Indigenous and illegal catches are unknown.

4. The risk assessment concluded that *there is no evidence to suggest that reductions in biological diversity of* J. edwardsii *have occurred as a result of fishing in South Australia* but acknowledged that genetic diversity had not been well studied.

5. Protected species listed are cetaceans, chelonians and pinnipeds. Data are *ad hoc*: there is no formal data collection in place so there is no risk assessment. An on-board monitoring program is proposed. Many fishers already use seal excluders. For all groups, the effect of fishing is thought to be low because interactions are rare.

6. Marine debris is listed:- it is dealt with by industry collection in ports.

7. The report states that there are no threatened ecological communities in South Australia, but points out that there are several MPAs.

8. The report states that there is little information about effects of lobster fishing on the ecosystem, but concludes that such effects are likely to be low. Much less discussion and analysis is presented on this point compared with Western Australia. An FRDC project has been proposed *to assist the process of developing a representative system of Marine Protected Areas (MPAs) for South Australia and improve the scope for fisheries managers to integrate broader ecosystem requirements into fisheries management regimes.*

9. A previous study examined the physical effects of lobster potting and concluded they were low. There is now a 40 kg weight limit for pots to minimise their effects on reefs. Water quality is not considered a problem, and "Clean Green" programs address these topics.

5. NEW ZEALAND ROCK LOBSTERS

This section reviews the data available for New Zealand rock lobster (*Jasus edwardsii* only) fisheries, using headings suggested by the MFish Strategy and expanding where necessary into headings suggested by the Australian work.

Identification of a topic is not to be taken as an opinion that the topic involves a risk; it signifies only that the topic should be addressed by a formal risk assessment.

5.1 Managing the effects on non-target species

5.1.1 Handling mortality on the target species

There are five sub-headings: direct handling of lobsters returned to the sea (this would apply to sub-legals, berried females and legal lobsters rejected by high-grading), mortality caused by octopus that enter pots and possible mortalities from tail fan necrosis, mating problems and ghost fishing.

5.1.1.1 Handling mortality of lobsters

There is no published New Zealand study of direct mortality of lobsters returned to the sea, although some information might exist in privately commissioned research.

In theory, direct handling mortality could be a problem. A study in Hawaii (DiNardo et al. 2002) found high mortalities in spiny lobsters that were not kept wet and shaded and found no mortality in lobsters kept wet and shaded. Current New Zealand stock assessment usage is to assume 10% mortality of returned lobsters (Kim et al. 2004).

However, most rock lobsters caught in the New Zealand fishery are exported live, creating a strong incentive to treat lobsters very carefully: not to damage antennae or legs, to sort and measure lobsters quickly and to discard the sublegals immediately. Anecdotal evidence in the past suggested some poor handling practice in New Zealand, such as delayed sorting and leaving lobsters on deck in sunlight or rain, but handling practice is now much improved and handling mortality is likely to be low, perhaps even lower than the value assumed in stock assessments. The likely low mortality is reflected in high-grading, which MFish considers of such low risk that it is permitted for rock lobsters.

Although there is limited information on this mortality, the risk is likely to be scored as low and probably no substantial problem requires to be managed. Any other score will require additional data.

5.1.1.2 Octopus mortality

Octopuses enter lobster pots and eat lobsters; it may be easier for an octopus to catch a lobster cornered in a pot than in the natural habitat. This mortality was represented as a major effect in 1993 when the CRA 3 management package was developed by industry (Breen & Kendrick 1997); in South Australia it has a large effect and is addressed by the stock assessment (Sloan 2003). If this mortality is significant in New Zealand it should be considered a sort of handling mortality.

There are some data but there have been no analyses. The CELRs contain information on octopus bycatch (see below). The voluntary logbooks and the observer catch sampling forms both request information on the numbers of octopus and the numbers of associated dead lobsters. There is no current analysis of the predation rate but the data should be sufficient to address this topic.

5.1.1.3 Necrosis

"Tail rot" or "tail fan necrosis" (TFN) is a bacterial infection of chitin, and is more usually associated with lobsters in captivity than in the wild (Sindermann 1989). Reuter et al. (2000) studied *Jasus edwardsii* in Australia, and concluded the disease was likely associated with handling stress and perhaps elevated water temperatures. Degraded water quality is implicated in North American studies (Sindermann 1989). Musgrove et al. (2005) concluded that handling and crowding damage (but not elevated temperature) were implicated in South Australia.

Some instances of this disease have been found in wild New Zealand lobsters, although localised in space and time. Sample sizes in a small study (NZ RLIC, unpublished data) are too small to support strong conclusions, but the data support the working hypothesis that TFN is associated with handling: prevalence is highest in lobsters just below the MLS (those that would be most handled), and there appears to be a positive relation with injuries, probably also caused by handling.

Whether TFN is a cause of indirect fishing mortality is unknown, and indeed whether TFN is related to fishing is not known. Although this is now only a localised problem in New Zealand, it should be flagged as a topic that could require more data in future.

5.1.1.4 Mating problems

A current theory is that fishing may skew the population sex ratio in favour of females by selectively removing males, with possible population consequences because, although lobsters are polygynous, sperm is limited (MacDiarmid & Butler 1999) and small males may be unable to mate with large females. Females who fail to mate may show health problems and suffer mortality (J. Mauger, NIWA, unpublished data).

There is likely sufficient data to evaluate the risk from this hypothetical problem in New Zealand. The population sex ratio is known from catch sampling and logbook programs. Fishing does not take lobsters in strict proportion to their actual population abundance, but these data are used successfully in stock assessments, where the sex- and season-specific vulnerability and size selectivities are estimated. Some sex ratio analysis would be required to support a risk analysis.

Unmated females can be identified from external appearance, although some experience is required to avoid mistakes. The current prevalence of these females in pots appears low (but perhaps unmated females avoid pots).

Based on the extant data, the risk would likely be scored as low, with reservations. The current data are likely adequate for risk assessment.

5.1.1.5 Ghost fishing

Although not mentioned by the MFish Strategy, ghost fishing is clearly a component of risk assessments in Australia under ESD and it should be considered.

There is no published information for New Zealand rock lobsters. It is known from overseas studies (reviewed by Breen 1990) that lost pots may continue to catch and kill crabs and lobsters, not necessarily or even primarily through the "auto-rebaiting" mechanism in which mortality in the pot effectively baits the pot and attracts more prey. Empty pots may catch and kill crabs.

It has been argued that the scale of the problem in New Zealand is low: there is anecdotal evidence from fishers who pull unattended pots after storms that lobsters escape pots after the bait is gone; this is supported by a formal Hawaiian study (Parrish & Kazama 1992). Escape gaps allow the small lobsters to escape; and video studies of traps in Australia show high escapement (B. Green, University of Tasmania, unpublished data).

Data available are insufficient for a formal risk assessment if one is required. The minimum requirement would be a video study of *Jasus edwardsii* in the various kinds of pot used in New Zealand, to determine the size and sex-specific escape rate over several weeks. If (and only if) this showed poor escapement, a carefully designed field study would be necessary. Based on the results, estimates of pot loss and pot life might then be required.

If ghost fishing were demonstrated to be a problem, it would be best addressed by requiring timed-failure panels such as those required in North America (Breen 1990) in addition to currently required escape gaps.

5.1.2 Bycatch of other species

5.1.2.1 Identification and quantification

As in Australia, rock lobster potting is one of the most tightly directed fisheries in New Zealand. The pots are designed to be most effective for lobsters, so fish catch is incidental. Escape gaps provided for sublegal lobsters to escape also allow many fish and invertebrates to escape.

The currently required catch and effort landing forms (CELRs) require fishers to record the most abundant five species caught for each trip. Documentation of the CRACE database (Bentley et al. 2005) presents (their Table 26) an analysis of the most commonly landed species by QMA. In all, 129 bycatch species are reported. Lobsters (both species) are 91–98% of the catch.

The most frequently reported bycatch species are, in order, octopus, conger eel, blue cod, trumpeter, sea perch, red cod, butterfish and leatherjackets.

The voluntary logbook forms also request information on octopus and "other", which can be named. Observer catch sampling records only octopus bycatch.

Miller (1995) listed several approaches to minimising bycatch:

- using bait with an odour that repels unwanted species,
- using pot entrances that admit only the desired catch,
- choosing escape openings to retain desired catch and release bycatch,
- sorting bycatch on deck and promptly returning it.

However, the first three approaches are unnecessary if bycatch is not a problem, as is likely in the New Zealand lobster fishery.

For a first approach, especially given the relatively low prevalence of bycatch, the data may be adequate for identifying the major bycatch species and making a rough estimate of their total catches by area. Uncertainty would be associated with non-reporting on the CELR and voluntary logbook forms, and the bycatch not reported on CELRs because it was not in the top five species for one CELR form.

5.1.2.2 Population consequences of bycatch

5.1.3 Associated or dependent species

Associated or dependent species (paragraph 32) are *all marine mammals, seabirds, fish species, and benthic animals and plants for which no targeted fishing is permitted but which are affected by fishing targeted at other species. When taken as a non-target catch in legitimate fishing operations, catches of some Associated or Dependent Species may be sold.*

The nature of lobster fishing is such that bycatch, interactions with buoy lines and direct physical effects on the bottom are probably the only significant effects to be addressed for associated or dependent species. These are addressed above for bycatch, below for the sustainability of bycatch species, immediately below for protected species and further below for direct physical effects.

Paragraph 169 of the Strategy, in discussing what should be research priorities, reflects an immediate concern with threat classification and mitigation, suggesting that the primary concern is with endangered, threatened and vulnerable species. This may in turn reflect concern about the effects of fishing on what MFish calls "icon" species such as Hector's dolphins, Maui's dolphins, albatrosses and Hooker's sea lions. Given present states of knowledge, effects by lobster fishing on associated and dependent species can be addressed under the bycatch, protected species and direct physical effects headings, as is done here.

5.1.4 Protected species

Protected species are (paragraph 32) *a subset of Associated or Dependent Species that are specifically protected under the Wildlife Act 1953 or the Marine Mammal Protection Act 1978. These species may not be landed for commercial gain. Protected Species includes seabirds, marine mammals, and corals. Species are designated as protected not necessarily because they are at risk of serious decline but because a decision has been made that they should not be available for commercial exploitation—even when taken as an unintended non-target catch.*

There is no published information on the interaction between the lobster fishery and protected species. Possible interactions that could be of interest include entanglement of dolphins (for instance, sketchy anecdotal evidence was provided to the RLFAWG one year that a Hector's dolphin had been entangled and drowned somewhere) or whales (a well-publicised tragic incident in 2003 involved a humpback whale). The interaction between humpback whales and lobster pots is represented as a frequent occurrence.

Although the environmental effects of lobster fishing on protected species are likely to be small, as in Western Australia although the species mix is different, the New Zealand data are poor. It is likely that better data will be required for a credible environmental risk assessment. In the first instance these data – any interaction with a protected species – should be collected by the industry. Interactions are likely to be far too rare for a directed observer program to be feasible.

5.2 Managing the effects on habitats

"Habitats" are not formally defined in New Zealand. Most descriptions of habitat begin with a physical description, such as sand or rocky reef, modified by a description of depth, wave exposure and latitude (e.g., Schiel 2003). Rocky substrates are far more studied worldwide than soft bottoms. In a common approach, Schiel & Hickford (2001) described nearshore rocky reef habitats based on the dominant algal and invertebrate species. For some years, habitats in the marine reserve at Leigh have been identified with descriptions such as "*Ecklonia* forest" and "sponge garden", and these classifications have recently been the subject of quantitative evaluation (Shears et al. 2004).

Obvious problems include first the complex biogeography of New Zealand: species used to define a habitat in one area may not occur elsewhere, making a local approach mandatory. For instance, *Macrocystis* forests are an obvious "habitat" that does not occur over much of the North Island. Second, systems that occupy habitats can be fluid. For instance, many kelp forest habitats are the scene of long-term change, just as in terrestrial forests: the kelp species are replaced by sea urchins, sea urchins disappear and kelp returns, the species composition of kelp changes with time, invertebrates re-appear in the understorey, sea urchins increase in abundance...... A definition of habitat that focuses on one phase of this process ignores the community dynamics. Finally, communities in a location may change as marine climate changes; as an example, Polovina & Haight (1999) described a dramatic ecosystem shift apparently associated with changed current and weather patterns in the northwestern Hawaiian archipelago.

In the Strategy these issues are not addressed. Western Australia was able to identify the habitats most likely to be affected by lobster fishing (seagrass meadows, coral reefs, limestone reefs) as a starting point for assessing the effects, but there is no such obvious starting point in New Zealand. This is a major data deficiency, but is one that the lobster industry would have trouble addressing.

5.2.1 Direct effects of fishing

Lobster potting is a comparatively quiet, benign method of fishing compared with trawling or gill-netting. Apart from the potential entanglements with buoy lines discussed above, direct effects are caused when a pot lands on the bottom. On the mostly hard rock substrates, and certainly on soft substrates, there is little likelihood of harmful effects to the substrate itself. In Western Australia, concern was addressed about damage to limestone reefs. Prevalence of substrates likely to be damaged mechanically in New Zealand is unknown but probably small.

Direct effects may occur on the animals and plants inhabiting the substrate. On soft substrates these would be mobile surface-dwellers such as starfish, which are remarkably hardy, and protruding burrowers such as horse mussels and sea pens. Damage to infauna is probably negligible. Sea pens were affected but not damaged in the experimental study of Eno et al. (2001).

On hard substrates, a wide variety of plants and animals might be involved. Fleshy macrophytes are very resilient and are probably not at risk; some fragile decumbent rhodophytes might be damaged. Animals that could be destroyed by a pot are very diverse, and range from sponges and corals (black and gorgonian corals) through nearly all the phyla. Some species might be locally important, such as black corals in Fiordland, brachipods in Paterson Inlet, pennatulids in the Narrows, bryozoans in parts of Tasman Bay, etc.

Eno et al. (2001) studied effects of potting by direct diving observations, and concluded that even four weeks' intense potting had little effect on the species they selected for study, although one species of coral was damaged.

The Australian fisheries addressed this issue by calculating the proportions of reef area affected annually by potting and showing that it was low. This is a reasonable approach, but New Zealand data are likely to be inadequate, and some areas of special interest might not be adequately protected. Soft substrates could be ignored. The coarse-scale "habitats" on which pots are placed are undefined, and there are no data on what proportion of pots are placed on rocky reefs. The extent of such rocky reef habitats is also unknown. This deficiency could be addressed with a short-term industry study, best undertaken when small-scale reporting of effort has been resolved. In the longer term, some systematic habitat mapping (e.g., Jordan et al. 2004) will be required from government.

5.2.2 Maintaining diversity and protecting habitats of particular significance

The Strategy discusses this goal in paragraph 43. The goal is to *maintain biological diversity of the aquatic environment (including diversity within species between species, and of ecosystems).* As described above, the NZ Biodiversity Strategy is of limited help in suggesting what the operational goals or standards would contain.

Discussion in the MFish Strategy focuses on area closures as the primary tool to protect specific habitats. This is in line with the Biodiversity Strategy's approach to protecting 10% of the marine environment. The MFish Strategy briefly discusses *habitats of particular significance to fisheries management* but does not define these further. They might be areas important to juveniles, spawning habitat, etc. No such habitats of relevance have been defined for rock lobsters, although an area near North Cape is currently closed to fishing to protect egg release and prevent handling disturbance for packhorse lobsters (Booth 1979).

An exemplary approach is taken by the Fiordland Marine Conservation Society (Teirney 2003) for Fiordland. In a consultative process, they identified "china shops" as *small discrete areas that are outstanding for the abundance and/or diversity of animal or mixed animal and plant communities or for the abundance of particular animal species.*

They identified 23 such areas. The area called the Narrows features *sea pens mixed with scallops on the sand, holothurians, red coral and white brachiopods.* Management includes *creating a no take area for scallops, ... creating a no anchoring zone, ensuring rock lobster pots are not stored in the area and developing a code of practice for the site.*

The Fiordland Marine Conservation Society also describes an approach to defining representative areas and identifying whether and how they should be protected.

For most lobster fishing areas that do not support intense diver interest, fishing habitats are undescribed and undefined. To anticipate the MFish Strategy, the lobster fishery could adopt a reactive approach – wait to see what is proposed for protected areas and make submissions. The Fiordland approach is more constructive and gives fishers much greater control of the process. As Teirney (2003) said: *this collaborative approach is an excellent example to people in other coastal regions around New Zealand who are concerned about the health and management of their local fisheries and marine environment.*

Establishment of protected areas of any kind can affect lobster fishing. In CRA 3, when the Te Tapuwae o Rongokako Marine Reserve was first established, fishers could not demonstrate their extant involvement in the proposed reserve area and could not formally demonstrate the economic importance of the area. An obvious data requirement is for more exact information on fishing locations. A study of spatial reporting of fishing effort on CELRs was conducted by Bentley et al. (2003). They included, when listing advantages to fishers of finer-scale reporting:

- *improved ability to demonstrate current and potential importance of areas that are threatened by uses that exclude fishing (eg., no-take reserves, ...)* and
- *ability to develop proposals for voluntary "no-go" zones to underpin agreements with non-commercial stakeholders within Fishery Plans.*

If the lobster industry adopts some form of the Bentley et al. (2003) recommendations and can involve itself in habitat mapping, it will be well placed to deal with this aspect of the Strategy. Otherwise, some other form of fine-scale spatial data capture will be required.

5.2.3 Addressing sustainability of associated and dependent species

For bycatch species within the QMS, bycatch mortality caused by the rock lobster fishery is properly assessed through the stock assessment processes for those species.

For bycatch species not in the QMS, population consequences will be more difficult to assess. The Western and South Australian risk assessments tended to conclude that risks for finfish species were low because the catch rates were low, with the exception of octopus. The approach taken for octopus in those Australian fisheries has been to monitor octopus catch and catch rate to ensure that they are stable, and to commission further work if they fall.

It is likely that octopus will be the most important bycatch species, as in South Australia, although this is pre-judging the analysis described above. It is possible that, to do a credible risk assessment, a short directed observer study of bycatch will be required for validation of the existing data collection programs. MFish or a reviewer could ask whether the current reporting of octopus is adequate for the monitoring and assessment of octopus populations.

5.3 Managing the indirect effects on ecosystems

5.3.1 Trophic effects

5.3.1.1 Bait

In lobster fishing, a considerable volume of food is used as bait. The Western Australian environmental assessment (WA Fisheries 2001) considered the trophic effect of imported bait and concluded that it was negligible because the annual mass used per area fished was small: 5 kg per hectare or 0.5 $g/m^2/yr$. By contrast in the Gulf of Maine, Saila et al. (2002) estimated 85 kg, or 8.5 $g/m^2/yr$, and concluded that bait, which is mostly imported to the system, was a significant factor in lobster production.

As well as on quantity, the effect of bait depends on whether it comes from the local system or is imported, and on who eats it. If bait is local, then the effect is simply to increase turnover rate in the bait species. If bait is eaten mostly by retained lobsters, there is little trophic effect. If bait is eaten mostly by lobsters that escape or are returned to the sea, bait acts effectively as a culture process. If bait is eaten by scavengers, for instance amphipods or fish, the effect depends on how this affects community composition, and whether the bait is imported. There appear to be no published studies of this effect.

In New Zealand, the effect of bait is likely to be small: the intensity of potting is far lower than in North America or even Western Australia. Some information on bait composition is available from the observer catch sampling database. For a risk assessment, information would be required on bait quantity, and on composition in areas without observer programs. This could be obtained with a short and simple project.

5.3.1.2 Community composition

There is a vast literature on this topic, much of which relates to sea urchins and their effects on kelp communities. Reviews were provided by Pinnegar et al. (2000) and Sala et al. (1998).

Sea urchins in many parts of the world have been observed clearing plants from shallow habitats, usually rock reef but sometimes seagrass beds in sandy habitats. The process is reversible: when sea urchins are removed by predators or experimentally, when they die off, algae return.

Sea otters are a major predator of sea urchins in the northeast Pacific, and were hunted to local extinctions and near-global extinction by the early 20th century. The rebounding sea otter populations in Alaska and British Columbia greatly reduced the abundance of red sea urchins in the habitats of overlap, and caused dramatic shifts from sea urchin barrens to kelp forests (Breen et al. 1982).

Do other predators control sea urchins so simply? And if so, does fishing on those predators allow sea urchins to become abundant and change kelp forests into barrens? This is controversial, because

- *appropriate controlled experiments are difficult or impossible,*
- the structure of food webs (who eats sea urchins?) is difficult to dissect, and
- marine systems are also affected by constantly changing environmental influences, which themselves may affect the plants, sea urchins and predators.

In Nova Scotia, where the lobster control hypothesis was developed by Mann & Breen (1972), sea urchins removed kelps from large areas in the 1970s, then died off and the kelp returned. The role of lobsters was hotly contested, especially by Canadian Department of Fisheries and Oceans scientists (see Miller 1985, Breen 1987). It remains unclear. Some now believe that sea urchins are controlled by predation, but by large fishes rather than lobsters (Dayton et al. 2003), although the data are fewer than they were for the lobster hypothesis.

Western Atlantic sea urchins have many predators that may act at different life history stages. Recruitment and mortality of sea urchins may both be affected by marine climate, as are the kelps. The predation-control hypothesis is very difficult either to demonstrate (no scientific hypothesis can ever be proven) or to refute.

In New Zealand the same hypothesis has been proposed, based on work in the marine reserve at Leigh (Babcock et al. 1999). It is claimed that snapper and rock lobsters became more abundant in the reserve as a result of protection from fishing, sea urchins decreased because of predation and kelp beds became more extensive. An earlier study by Andrew (1988) concluded that lobsters, while a predator, are not a controlling predator of sea urchins in the marine reserve. Comparisons made treating the reserve as an "after" treatment and other areas as "before" treatments are potentially flawed (Cole & Keuskamp 1998). Unfortunately, only sketchy surveys were made at the time the reserve was created.

The controversy deals with a complex set of ecological interactions, not simple ones. It is fuelled by issues such as:

- how representative the study areas are of larger scale process,
- how representative the study periods are in larger time scales,
- what the role is of physical disturbance, especially wave exposure, light and water temperature,
- how and why sea urchins change their behaviour from cryptic drift-feeders to aggregated attackers of whole plants and
- how sea urchin size structure is involved.

For an interesting but unreviewed and informal discussion see
http://www.seafriends.org.nz/issues/cons/science.htm#own%20research

A similar hypothesis obtains in Tasmania, where Edgar & Barrett (1999 suggested that barrens begin with unusually good sea urchin recruitment, which swamps lobster predation if lobsters are fished and otherwise does not. The broad dynamics are not understood fully, but conceivably managers might try to maintain specific lobster densities in an attempt to control sea urchin densities. Edyvane (2003) stressed the importance of climate events, especially El Nino, on kelp losses, but also recommended sea urchin management through control of lobster fishing.

The marine reserve at Leigh undoubtedly contains the best studied of New Zealand's shallow rock reef habitat. Lobsters, snapper and sea urchins are among the largest and most obvious of the fauna. The extent to which there can be a scientific controversy about ecosystem processes involving these species says much about the ecological complexities involved and the difficulty of managing fisheries so as to produce a simplistic result.

It seems probable that simple trophic cascades such as the sea otter example are rare. Even if they exist, they may not be widespread: Pinnegar et al. (2000) suggested they are found only at small scales. Trophic cascades are simple to consider compared with other fishing-induced changes to community structure: more subtle effects will be much harder to elucidate and even more controversial.

Data are generally inadequate to address these indirect effects of fishing on predatory lobsters, but the example above suggests that these issues are highly fraught and that answers will be very slow to obtain. There is no simple approach that can remedy this. The industry should keep a watching brief on development of standards to ensure that inappropriate directions are not followed.

5.4 Summary

The topics above are summarised in Table 1 with respect to the likely risk components of severity and probability, overall risk and the degree to which that risk might be a liability to the rock lobster fishery, the amenability of the topic to study and a suggested priority for study. These are suggestions only: the industry could usefully sponsor a workshop, as suggested elsewhere, to explore and elaborate on a table such as this, following the Australian model.

The most likely areas to cause concern for rock lobster fishing in a detailed risk assessment are: ghost fishing, everyday bycatch and its effect on bycatch species, effects on habitats and protected species, and indirect effects on marine communities caused by the removal of large predators.

Of these, bycatch is the easiest to address, both by analysing the current data and by revising data collection to ensure data become adequate. The effect on bycatch species can best be addressed by monitoring changes in catch rates, again requiring adequate data.

The scale of ghost fishing is unknown, so the first step should be a short directed study to determine whether lobsters can or cannot escape. Further work would depend on the results.

Tail fan necrosis is a minor problem overall but is a serious problem in localised areas. The data are poor, and the first step should be to improve data collection.

Effects on protected species (turtles, whales, dolphins, diving birds) are probably small because events are rare, but given the high profile of icon species in New Zealand, any possibility of interaction will be treated very seriously. Current data are inadequate, and the first step should be to collect encounter data.

Community effects of lobster fishing have a high profile, although the literature abounds with controversy. There is little that the industry can do to address this problem realistically.

Table 1: Summary of information, likely risks, liability to the fishery and study potential of the main topics discussed in the text.

	Information	Severity	Probability	Risk	Liability	Amenability to study	Priority
Mortality on *Jasus edwardsii*							
Handling mortality	none	~10%?	high	low	low	difficult	low
Octopus mortality	poor	?	?	low?	low	yes	low
Tail fan necrosis	some	localised	locally high	locally high	medium	difficult	medium
Mating problems	some	low	?	low	low	difficult	low
Ghost fishing	none	?	high	?	medium	phase 1 yes	medium
Other species							
Bycatch composition	needs analysis	low	high	medium	low-medium	yes	high
Sustainability of effects on bycatch species	none	*likely to be* low	high	low	medium until analysed	monitor catch rates	medium
Protected species	none	high	very low	low	medium until analysed	collect encounter data	medium
Community effects							
Direct effects on habitats	none	?	?	likely to be low	some	no	low
Community composition	some, controversial	some, controversial	some, controversial	some, controversial	high	very difficult	low
Trophic effects - bait	*none*	low	high	low	nah	yes	low

6. SUMMARY AND RECOMMENDATIONS

Management of fishing will expand to consider effects on the environment, and at some stage (it is not clear when, but it is inevitable) this will require an environmental risk assessment for rock lobster fishing. A good first step would be for industry to convene a short workshop of the type held by Western Australia, as in Figure 3 but less formally. The sections above are not more than a first brush at identifying deficiencies and priorities. This workshop should have the goal of reaching consensus between stakeholders and government on what are the high-priority (highest risk) issues and about where data are inadequate.

Compared with Australia's legislation, the New Zealand environmental management proposals (those in the Strategy) are often vague, but the MFish Strategy is much more clear than the NZ Biodiversity Strategy. Clear indications of likely risks are available from the Australian lobster fisheries. The rock lobster fishery is likely to have low or moderate risks compared with some other New Zealand fisheries.

There is likely to be a focus on bycatch species and protected species that are affected by infrequent entanglements in lobster buoy lines. Octopus is likely to be the main bycatch species; data are probably adequate for a risk assessment at this stage. For protected species such as whales, the risk is unknown and data are likely to be inadequate, although encounter rates may be low.

Effects on habitats will be addressed most immediately with MPAs of various kinds, protecting representative habitats and special habitats. Data on habitats and habitat use by the fishery are both very poor. "Biodiversity" objectives are especially poorly defined, but the immediate focus will be on extinctions, which are not implicated for lobster fishing.

The main focus on indirect effects of fishing will be on predator-prey relations. Implementation of the Strategy will be phased and gradual. Because this fishery has one of the lowest levels of environmental impact, it could be one of the first to complete an environmental risk assessment. The industry could identify information priorities early and phase their efforts to address these where possible.

NZ RLIC should be represented, through SeaFIC or on its own, at the Aquatic Environment Research Planning and Working Groups. This is where the main thrusts of the implementation will be developed, and participation would ensure a) that the lobster industry has up-to-date information, b) that the industry input is made available to these Groups and c) that the industry is able to obtain Crown-funded research to address data deficiencies in topics seen as a high priority.

In the medium term, planning should be started for a fishery plan.

NZ RLIC should also consider upgrading its Code of Practice (Harvie 1993) to begin to embrace environmental considerations.

Individual CRA associations could look at the Fiordland model for addressing protected areas. Rather than react to proposals, the industry should work with local groups to define areas that might be protected. The Strategy and Biodiversity Strategy both suggest that protection is inevitable.

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APPENDIX 1: PRINCIPLES AND OBJECTIVES OF ECOLOGICALLY SUSTAINABLE DEVELOPMENT (ESD)

Principles and objectives of ESD as it applies to fisheries (Commonwealth of Australia 2001) are as follows.

Principle 1

A fishery must be conducted in a manner that does not lead to over-fishing, or for those stocks that are over-fished, the fishery must be conducted such that there is a high degree of probability the stock(s) will recover.

Objective 1

The fishery shall be conducted at catch levels that maintain ecologically viable stock levels at an agreed point or range, with acceptable levels of probability

Information requirements

1.1.1 There is a reliable information collection system in place appropriate to the scale of the fishery. The level of data collection should be based upon an appropriate mix of fishery independent and dependent research and monitoring.

Assessment

1.1.2 There is a robust assessment of the dynamics and status of the species/fishery and periodic review of the process and the data collected. Assessment should include a process to identify any reduction in biological diversity and /or reproductive capacity. Review should take place at regular intervals but at least every three years.

1.1.3 The distribution and spatial structure of the stock(s) has been established and factored into management responses.

1.1.4 There are reliable estimates of all removals, including commercial (landings and discards), recreational and indigenous, from the fished stock. These estimates have been factored into stock assessments and target species catch levels.

1.1.5 There is a sound estimate of the potential productivity of the fished stock/s and the proportion that could be harvested.

Management responses

1.1.6 There are reference points (target and/or limit), that trigger management actions including a biological bottom line and/or a catch or effort upper limit beyond which the stock should not be taken.

1.1.7 There are management strategies in place capable of controlling the level of take.

1.1.8 Fishing is conducted in a manner that does not threaten stocks of by-product species. (Guidelines 1.1.1 to 1.1.7 should be applied to by-product species to an appropriate level)

1.1.9 The management response, considering uncertainties in the assessment and precautionary management actions, has a high chance of achieving the objective.

Objective 2

Where the fished stock(s) are below a defined reference point, fishery to be managed to promote recovery to ecologically viable levels within nominated timeframe.

Management responses

1.2.1 A precautionary recovery strategy is in place specifying management actions, or staged management responses, which are linked to reference points. The recovery strategy should apply until the stock recovers, and should aim for recovery within a specific time period appropriate to the biology of the stock.

1.2.2 If the stock is estimated as being at or below the biological and / or effort bottom line, management responses such as a zero targeted catch, temporary fishery closure or a 'whole of fishery' effort or quota reduction are implemented.

Principle 2

Fishing operations should be managed to minimise their impact on the structure, productivity, function and biological diversity of the ecosystem.

Objective 1

The fishery is conducted in a manner that does not threaten bycatch species.

Information requirements

2.1.1 Reliable information, appropriate to the scale of the fishery, is collected on the composition and abundance of bycatch.

Assessments

2.1.2 There is a risk analysis of the bycatch with respect to its vulnerability to fishing.

Management responses

2.1.3 Measures are in place to avoid capture and mortality of bycatch species unless it is determined that the level of catch is sustainable (except in relation to endangered, threatened or protected species). Steps must be taken to develop suitable technology if none is available.

2.1.4 An indicator group of bycatch species is monitored.

2.1.5 There are decision rules that trigger additional management measures when there are significant perturbations in the indicator species numbers.

2.1.6 The management response, considering uncertainties in the assessment and precautionary management actions, has a high chance of achieving the objective.

Objective 2

The fishery is conducted in a manner that avoids mortality of, or injuries to, endangered, threatened or protected species and avoids or minimizes impacts on threatened ecological communities.

Information requirements

2.2.1 Reliable information is collected on the interaction with endangered, threatened or protected species and threatened ecological communities.

Assessments

2.2.2 There is an assessment of the impact of the fishery on endangered, threatened or protected species.

2.2.3 There is an assessment of the impact of the fishery on threatened ecological communities.

Management responses

2.2.4 There are measures in place to avoid capture and/or mortality of endangered, threatened or protected species.

2.2.5 There are measures in place to avoid impact on threatened ecological communities.

2.2.6 The management response, considering uncertainties in the assessment and precautionary management actions, has a high chance of achieving the objective.

Objective 3

The fishery is conducted in a manner that minimizes the impact of fishing operations on the ecosystem generally.

Information requirements

2.3.1 Information appropriate for the analysis in 2.3.2 is collated and/or collected covering the fisheries impact on the ecosystem and environment generally.

Assessments

2.3.2 Information is collected and a risk analysis, appropriate to the scale of the fishery and its potential impacts, is conducted into the susceptibility of each of the following ecosystem components to the fishery.

1. Impacts on ecological communities
   - Benthic communities
   - Ecologically related, associated or dependent species
   - Water column communities
2. Impacts on food chains
   - Structure
   - Productivity/flows
3. Impacts on the physical environment
   - Physical habitat
   - Water quality

Management responses

2.3.3 Management actions are in place to ensure significant damage to ecosystems does not arise from the impacts described in 2.3.1.

2.3.4 There are decision rules that trigger further management responses when monitoring detects impacts on selected ecosystem indicators beyond a predetermined level, or where action is indicated by application of the precautionary approach.

2.3.5 The management response, considering uncertainties in the assessment and precautionary management actions, has a high chance of achieving the objective.

APPENDIX 2: OCTOPUS

The octopus section of WA Fisheries (2001) - references are not included in this report's references in Section 8.

5.1.2 BY-PRODUCTS
5.1.2.1 OCTOPUS
Rationale for Inclusion:
Octopuses have always been taken in rock lobster pots. As predators of rock lobster, it would appear that they are attracted to the pots by the opportunity of an "easy meal." There has been increasing interest both in overseas and local markets in octopus. This by-product was previously discarded or sold as bait, but is now being retained for sale to processors. At the same time, there has been increased interest in octopus fishing by both recreational and commercial fishers outside the rock lobster fishery. As a lobster predator, the octopus is also likely to be an important element in the rock lobster's ecosystem. Despite the low risk rating, currently lobster fishers are the main group impacting upon this species and there is a potential for a dedicated fishery to develop. Hence it is precautionary that this group be monitored annually.

ERA Risk Rating: Possible changes to octopus population (C1 L2 LOW)
Octopus have a short (1 year) lifespan and their recruitment appears to be highly variable (Joll 1977a). Their habitat extends beyond the habitat utilised by the rock lobster fishery eg sea grass, so that only a proportion of their population would be exploited. The increase in the number escape gaps in the rock lobster pots has allowed more octopus to escape from the pots.

Operational objective
Minimise the risk of overfishing by limiting catches of the WRL fishery to historical, sustainable levels.

Justification
Octopuses are widely distributed along the Western Australian coast including waters not subject to rock lobster or other forms of octopus fishing. These refuge areas, in combination with the inefficiency of the current lobster pots to catch and retain the octopus should provide sufficient protection and ensure that sustainable populations are maintained.

Indicator
Recorded catch rate information for octopus by lobster fishing by independent observers.

Performance measure
A decline in the calculated rate per pot lift more than 25% outside the range of recorded variation.

Justification
The biology and ecology of the species of octopus caught by the WRL suggests that they should be very resilient to overfishing. The main species is *O. tretricus* has a life cycle of only 12–15 months (Joll, 1977a) but all octopus species have relatively short life cycles (Kailola et al., 1993). The limited range of fishing compared to the extensive range of the species (see Kailola et al. 1993) means that there will always be a major portion of the breeding stock not accessible to fishermen, ensuring biological sustainability will not be at risk. Thus the inclusion of this performance measure is a precautionary approach.

Data requirements for indicator
Annual weight of octopus per pot and trap lift as calculated from:

Data Required	Availability
Catch of octopus from rock lobster pots.	Yes, from fishery independent observer data

Evaluation

Unpublished fishery-independent monitoring data from on-board sampling of the commercial catch of rock lobster vessels indicates that the impact of rock lobster fishing on the by-catch of fish and invertebrates, other than octopus, is minimal. Octopus are caught in the pots generally in shallow water (0-20 fathoms; 0-37m) and catch rates of about 0.02–0.03 octopus per pot lift were recorded in voluntary research log-book data between 1992/93 and 1999/2000. This led to an estimated 220,000 to 300,000 octopus caught in all zones in each of the past eight seasons. The species composition of the octopus bycatch is generally considered to be composed of primarily of O. tetricus, although a number of other species are also taken.

Robustness medium

This data being collected by fisheries staff is of good quality covering the majority of the areas and times of fishing. Furthermore, there have been suggestions that faster pot hauling speeds now employed may have increased the catching efficiency of the commercial sector regardless of the introduction of escape gaps. There has been no assessment of catchability or catching efficiency of lobster pots for octopus. The use of this indicator (catch by lobster fishers) will only be appropriate while there is no directed commercial fishery for octopus. The establishment of a commercial octopus fishery is currently under consideration. If this does become established, then more sophisticated analyses may be necessary.

Fisheries management response

Current:

Despite the increase in pot hauling speeds, it is considered the increase in the number of required escape gaps and pot reductions introduced over the past 20 years has greatly reduced their potential catch.

Future:

Under the developing fisheries policy a number of commercial octopus fishermen will be licensed. Their records of catch and effort should allow a more informed measurement of stock abundance and more refined management may be eveloped if necessary.

Actions if performance limit is exceeded?

If the performance limits were triggered, a review of the situation would be initiated. If there was any evidence of a risk of stock collapse, measures that would need to be put in place to reduce the catch of octopus. This could include - a prohibition on rock lobster fishermen taking octopus or an annual limit of the catch taken by rock lobster fishermen.

Comments and action

Formal procedures for the assessment of octopus stocks through the analysis of catch records needs to be introduced. Monitoring of any new, dedicated octopus fishery would have to be introduced and the indicator of performance may have to change to reflect that more than one sector is targeting the resource.

External driver check list

There has been ongoing and increasing interest in octopus fishing by both other commercial sectors and recreational fishers. Rock lobster traps may make it easier for octopus to catch rock lobster and the lobster fishery may have both a positive and negative impact on octopus populations. Increased levels of recreational fishing, boating and tourism and associated developments in the more geographically isolated parts of the octopus range may also have an unforseen impact on both the catchability of octopus and the survival rates of juvenile octopus. The long-term impact of conservation measures and possible population increases of turtles, sea lions, dolphins and whales may also have an impact on the octopus population levels.