4. ECOLOGICAL RISK ASSESSMENT

The context for this section includes the requirement for a risk assessment of the effects of fishing in New Zealand waters, the attendant concepts of ecological risk, and what is meant by measures and indicators of risk. These features of ecological risk assessment are discussed separately below.

4.1 The national requirement for risk assessment

The marine environment provides a number of resources for humankind. Fish, in particular, provide a valuable social and economic resource. Unfortunately, fishing, commercial fishing in particular, has and can significantly impact the seabed environment (see papers in Barnes & Thomas (2005), and references cited therein). Fishing activity in New Zealand is no exception as regards its influence upon benthic habitats, communities and species (e.g., Thrush et al. 1998). However, there is in New Zealand a body of legislation that aims to ensure that the impact of fishing activity is minimised while allowing for a sustainable fishery. The single most significant piece of legislation for this purpose is the Fisheries Act of 1996. This Act establishes a number of obligations, including a requirement "to avoid, remedy or mitigate any adverse effects of fishing on the aquatic environment". While there have been, and are, a number of initiatives to address specific issues that relate to the adverse effects of fishing, it is only relatively recently that MFish established an overall strategy specifically aimed at managing the effects of fishing. The Strategy for Managing the Environmental Effects of Fishing (SMEEF) sets out the approach that MFish is in the process of implementing in order to meet environmental obligations across all its activities and procedures (Ministry of Fisheries 2005). Fundamental to the SMEEF framework is the setting of 'Environmental Standards' which define "the point at which the effects of fishing on an element of the aquatic environment moves from being acceptable to unacceptable, or adverse." (section 2.2.2, p 6, Ministry of Fisheries 2005). As part of the "process a fishery manager should use to identify environmental standards relevant to a fishery and determine the appropriate management response", there is a requirement for a "risk assessment process by which species and habitats requiring standards as a high priority are identified" (section 2.3.3, p 8, Ministry of Fisheries 2005). It is important to note here also that the SMEEF implementation process (for setting standards) identifies that it will be necessary for MFish to "establish and maintain links with relevant research and management organisations", such as NIWA, and "develop systems to obtain necessary information on the threat status of species and habitats", such as the SEAMOUNT database (section 4.3, p 20, Ministry of Fisheries 2005).

4.2 Concepts of risk

The SMEEF notes that the system of determining and prioritising the setting of Environmental Standards, the fundamental unit of the strategy, "should be based on the level of risk to each species and habitat, including consideration of the likelihood of an adverse effect, the severity and reversibility of the effect, and the nature of available information." (section 2.2.3, p 7, Ministry of Fisheries 2005). Here, then, the SMEEF refers to the 'concepts of risk' – "likelihood" of an adverse effect, the "severity" of an effect and the "reversibility" of the effect".

MFish is not alone in attempting to address the risk that is posed by anthropogenic activities to the marine environment, and other bodies elsewhere have adopted similar concepts of risk when attempting to manage, conserve, or protect the environment (e.g., the United Kingdom and the Republic of Ireland's MarLIN scheme; see Hiscock & Tyler-Walters (2006) for most recent summary of this scheme). To some extent the terms used to describe these concepts have become standardised and thus the terms for the overarching concept of 'level of risk' or 'threat status' used by the SMEEF are hereafter (for the sake of commonality and possible comparability with already established schemes) referred to singularly as 'sensitivity'. The related risk concepts 'likelihood' and 'severity' are often combined under the term 'vulnerability', while 'reversibility' is more often termed 'recoverability', and so these more standard terms are also used here. The SMEEF is unusual in using the term "species and habitat" as a shorthand way of referring "to all the elements and relationships within the aquatic environment that may be affected by fishing" (section 1.4, p 3, Ministry of Fisheries 2005). In other words the term is intended to imply consideration of the "species' role in the ecosystem", for example, in the way in which it contributes to the biological unit commonly refereed to as a 'community'. Again for the sake of consistency with other schemes that seek to assess the risk to the marine environment posed by anthropogenic activities, hereafter reference will be made to the biological concept of communities.

4.3 Measures and indicators of risk

The United Kingdom and the Republic of Ireland's Marine Life Information Network (MarLIN)[2] has been at the forefront of attempts to develop various measures (and the means to assess them, see Section 6) which can be used in processes for the conservation and management of the marine environment (http://www.marlin.ac.uk/sah/baskitemplate.php?sens_ass_rat – hereafter referred to as MarLIN website). The concept of risk, for which MarLIN has developed a measure and an assessment technique, is **sensitivity** (Hiscock & Tyler-Walters 2006). MarLIN was by no means the first or only concerned body to devise a means to assess sensitivity (or a sensitivity index) (see, for example, MacDonald et al. (1996)). Other national schemes are under development in Canada (Arbour 2004) and Australia (Hobday et al. 2007). However, it appears that the MarLIN approach is currently the most well developed, and has already been implemented and incorporated into conservation/management practice in Europe (see examples in Tyler-Walters & Hiscock (2005)), and thus it will be used here as the basis for discussion. However, it is noted that the Australian scheme is the one that any scheme for New Zealand will need to be fully cognisant of, or even comparable to/compatible with [At the time this project report was submitted for publication the final CSIRO-AFMA report that describes the Australian scheme was not officially available for consultation.]

MarLIN notes that "sensitivity is dependent on the intolerance of a species or habitat to damage from an external factor and the time taken for its subsequent recovery. For example, a very sensitive species or habitat is one that is very adversely affected by an external factor arising from human activities or natural events (killed/destroyed, 'high' intolerance) and is expected to recover over a very long period of time, i.e., >10 or up to 25 years ('low'; recoverability). Intolerance and hence sensitivity must be assessed relative to change in a specific factor" (MarLIN website). Thus, sensitivity involves measures of two other concepts of risk, **intolerance** and **recoverability**. MarLIN defines intolerance as "the susceptibility of a habitat, community or species (i.e., the components of a biotope) to damage, or death, from an external factor. Intolerance must be assessed relative to change in a specific factor"; and recoverability as "the ability of a habitat, community, or species (i.e., the components of a biotope) to return to a state close to that which existed before the activity or event caused change" (MarLIN website). In other sensitivity assessment schemes, the concept of intolerance is replaced with the related (and sometimes synonymous) concept of **vulnerability** (e.g., DFO 2005). The concept of vulnerability can capture not only the intolerance of a biological unit to disturbance, but also "the likelihood that a [biological] component will be exposed to some impacting factor" (DFO 2005). In the context of the present project's aim to identify measures suitable for the

[2] The UK's MarLIN is not to be confused with the MFish meta database managed by NIWA and also called MarLIN.

assessment of risk pertaining to the effects of fishing disturbance on the benthic communities of seamounts, it seems sensible to adopt the risk concept of sensitivity, and the associated concepts of vulnerability and recoverability. However, the above definitions of these concepts can be modified according to the specific context in which they are to be used.

Here, sensitivity is defined as:

> The vulnerability of a habitat, community, population, or individual (or individual colony) of species to disturbance from the direct, or indirect, effects of fishing, relative to its recoverability from such a disturbance.

The component concept of vulnerability is defined as:

> The likelihood and degree of disturbance to a habitat, community, population, or individual (or individual colony) of species from fishing activities;

and recoverability is defined as the:

> Ability of a habitat, community, population, or individual (or individual colony) of a species to return to a state close to that which existed before fishing activities caused change.

It should be noted that while the MarLIN sensitivity assessment scheme offers useful guidance for the development of measures/indicators for an ecological risk assessment of seamounts, the other related national schemes or international sensitivity initiatives which are somewhat more complicated in structure also provide helpful direction. These schemes concern themselves with identifying areas, for example, of "particularly high ecological or biological significance" (DFO 2004), often with the view of affording protection to these areas, and include an assessment process that examines data under a number of "criteria". Of these criteria, at least one – **representiveness** – is not directly or indirectly captured within the concepts of vulnerability and recoverability, and yet a measure of this concept could be useful for the development of an ecological risk assessment for disturbance by fishing of seamounts. As such, MFish requested that representativeness to be specifically considered by this project. Representiveness is variously defined (e.g., "Typical of a feature, habitat or assemblage of species. Representative examples are identified from the range of natural or semi-natural habitats and associated communities (biotopes) within a biogeographically distinct area or the boundaries of a national territory", MarLIN website), but in the context of the present issue it could be more specifically defined as:

Typical of a seamount or habitat within an environmentally distinct area.

5. DEVELOPING INDICATORS AND MEASURES OF RISK

The MarLIN scheme and others identify that in order to assess the sensitivity of a habitat, community, etc, there is a need to collate "key information" which can be used as indicators or measures of the various risk concepts. In the MarLIN scheme, this information is systematically collected and stored in a database ('Biology and Key Information' database) available to those who undertake the formal assessment of sensitivity. Similarly the SMEEF notes that in order to assess the risk to the environment from fishing it is desirable to be able to identify "biological reference points", which may for example, relate to the "role of the species or habitat in the functioning of the ecosystem in which it occurs" (section 3.3, p 15, Ministry of Fisheries 2005). Again context is important and it is necessary to identify the types of key information and data that are specific to benthic habitat, communities, etc, of seamounts so that appropriate measures/indicators are developed. However, while it is possible in theory to identify a large set of key information for assessing the sensitivity of the environment to a form of disturbance, data relevant to seamounts are not always (or indeed often) available. The SMEEF recognises that appropriate information might be limited, but notes that the assessment of risk should proceed nonetheless using the "best available" information, while also indicating that assessments of risk "should be updated periodically to include assessment" of "new information" (section 2.2.3, p 7, Ministry of Fisheries 2005). Hence the following elaboration of key information and indicators/measures takes into account the present availability, and likely future availability, of the type and quality of data collected for habitat, communities and species, and fishing, associated with seamounts in the New Zealand region.

The proposed indicators and measures of the various concepts of risk associated with assessing the impact of fishing on seamounts should be able to be extracted directly, or determined via the use of some simple associated automation script, from the database. Those indicators/measures already available via data stored in SEAMOUNT (v2) and those likely to be added in the near future (1 to 5 years) are italicised in the text below. A complete list of the proposed indicators/measures, including those which might become available in the more distant future (over 5 years), appears in Table 1.

5.1 Vulnerability

Many factors can make an environment and its biota vulnerable to fishing disturbance, and some of these features, which could be used in an assessment of sensitivity, have already been identified by previous risk assessment schemes. These include what the MarLIN sensitivity assessment scheme terms "structural", "functional", "characterising", and "other important" species (Hiscock & Tyler-Walters 2003). That is, species whose population degradation or loss would likely influence the integrity of the community as a whole. Our current knowledge of seamount communities in the New Zealand region means that only a measure of the structural species, and, in a restrictive sense, the presence of species that characterise a particular community/habitat are applicable.

Structural species are those that "provide a distinct habitat that supports an associated community" (Hiscock & Tyler-Walters 2003) (these species are also sometimes functional). Such species for seamounts include the corals, particularly matrix-forming scleractinians (e.g., *Solensmilia variablis, Madrepora oculata*), and sponges. The physical structures formed by both these groups of organisms can provide habitat for rich and diverse communities of other fauna, and the structures are often relatively large and fragile and therefore vulnerable to damage or destruction caused by bottom trawling (Koslow et al. 2001, Clark & Koslow 2007). Thus, the *presence of habitat-forming species (corals and sponges)* on a seamount is a useful indicator of vulnerability.

There are many good quality presence records for corals and sponges from seamounts in the New Zealand region, but most seamounts have not been biologically sampled and no information on the widespread presence/absence of habitat-forming species is available. However, in the future it will be possible, and it is planned, to model the distribution of these taxa on seamounts and so a measure will be available that relates to the predicted occurrence of the number of habitat-forming species (FRST-funded biodiversity project BFBB082). The results of future study might also reveal that other taxa (e.g., brachipods) provide important structural habitat on some seamounts, and data for these species can also be incorporated into such a measure.

The planned analysis of biotic data gathered by NIWA's Seamount Programme will result in the identification of species that characterise particular communities on New Zealand seamounts

(Rowden & Clark, unpublished data). Until that analysis is completed, the only species that can be said with any degree of certainty to be characterising species of a specific community are the bathymodiolid mussels that are obligate inhabitants of hydothermal vent habitats on the seamounts of the Kermadec volcanic arc. Hydrothermal vent habitats can posses a rich and diverse community, and because they are relatively small in area they are typically more isolated than other deep-sea environments. This isolation means deep-sea vent habitats possess communities with relatively high levels of endemism (Wolff 2005). Indeed, the mussel *Gigantidas gladius* (von Cosel & Marshall 2003), and two other unnamed species of bathymodiolid mussel, are to date thought to occur only at vents in New Zealand waters (Smith et al. 2004b). Such qualities make hydrothermal vent habitats and their fauna vulnerable to disturbance by fishing. Thus, the *presence of vent mussels* and *venting* are useful indicators of a seamount's vulnerability to fishing activities.

Vent mussels, along with a number of other marine invertebrate taxa, are currently listed as 'threatened' species under the "New Zealand Threat Classification System" of the Department of Conservation (DoC) (Hitchmough et al. 2007). The appropriateness of the designation procedure for marine species used by DoC is presently under review (and by default the list of 'threatened' species itself). In the future there is potential worth (if the flaws inherent in the present designation scheme are addressed) in including the *presence of threatened species* as an indicator of the vulnerability of seamounts. In the meantime, the related *presence of legally protected species* can act as an indicator of the vulnerability of a seamount to fishing disturbance. Currently, "black" corals of the order Antipatharia and "red" corals (a definition not strictly confined to a specific taxonomic group, but including the stylastrid 'coral' *Errina novaezelandia*) are afforded protection. Again because of recent review and applications for additional species to receive protected status, the number (and identity) of taxa covered by this indicator is likely to change. Therefore, in the future, information included for this indicator will require modification.

Protection is also afforded to species that comprise communities on seamounts by other means. At least two seamounts (Brothers, Rumble III) that are known to possess hydrothermal vent communities are protected from bottom fishing by the 2001 designation of 'protected status' to 19 seamounts in the New Zealand region (Anon 2001, Brodie & Clark 2003). Clearly, if a seamount is protected from fishing then it is no longer vulnerable to disturbance from this activity. As well as this seamount-specific protection from fishing, there are seamounts which are protected via other forms of legal protection e.g., Marine Protected Areas (MPAs), which afford protection to the Kermadec Islands, Auckland Islands, Mayor Island, and Volkner Rocks. Some seamounts in the New Zealand region are also protected by the MPAs of Australia (e.g., Macquarie Island and Lord Howe Island Marine Parks) (see Rowden et al. (2005) for detail). In other instances the purpose that brings about protection might be unrelated to conservation aims but will nonetheless prevent disturbance of the seabed by fishing (e.g. cable corridors). Thus, whether or not a *seamount is legally protected* is a useful measure of its lack of vulnerability to fishing (though not necessarily mining). Should further legal protection status be achieved for seamounts in the New Zealand region through other means in the future, then information on whether or not a seamount falls within such an area can also be used to evaluate vulnerability. For example, since the database was compiled, Benthic Protection Areas (BPAs) have been designated (15 November 2007, Ministry of Fisheries 2007).

Seamounts are also effectively prevented from being fished by technical restrictions. At present fishing is limited to seamounts (or portions of seamounts) above 1200 m water depth by the difficulties of deploying fishing gear onto a small seamount target below this depth (in contrast to slope areas where gear can be deployed more successfully). Thus, the many seamounts (about 400, see Rowden et al. (2005)) which have a *peak below 1200 m* are also not vulnerable to fishing, while those with a *proportion of seamount below 1200 m* are only partially vulnerable to such a disturbance.

Should fishing on seamounts become possible at greater depths in the future, then clearly the limits of this measure will need to be adjusted accordingly.

The degree to which a seamount is vulnerable to fishing is in part related to its distance from a major fishing port. The cost of fuel (and other costs associated with time spent at sea) is likely to deter vessels from fishing seamounts that are far from their home port. Thus, the *distance from the continental shelf*, a measure in version 1 of the SEAMOUNT database, can be used as a proxy measure of the vulnerability of a seamount to fishing.

Seamounts will be particularly vulnerable if they are a specific target of the fishery. An index to describe the relative importance of a seamount to the fishery has already been devised, which includes measures of fishing effort (number of years fished, number of tows) and catch (total catch over time of the target species). This index is called the *Fishing Importance Index* (or FII) (Clark & O'Driscoll 2003). Thus, the FII is a measure of the vulnerability of a seamount to fishing disturbance, under the assumption that what has been a target for fishing will continue to be a target. In the future, as the means to assign fishing effort to individual seamounts improves, and the index is calculated for those smaller seamounts as yet unfished, the utility of this measure to assess vulnerability will be significantly enhanced.

5.2 Recoverability

After a disturbance event, or a succession of such events, a species, community, or habitat may never recover, recover quickly (days to years), or take a great deal of time (decades to hundreds of years) to obtain its prior status (Hall 1994). With disturbance caused by fishing in shallow/shelf waters, estimates of community recovery range from days to decades, depending on a number of variables, including the type of species present, which will in part be related to the type of substrate on which the fishing has taken place (see for example studies reported in a review by Kaiser et al. (2002)). The information available suggests, for example, that communities of sand habitat will take less time to recover than those of mud or hard substrate with emergent structural fauna (Collie et al. 2000, Dernie et al. 2003, Kaiser et al. 2006). Thus, the type of substrate, or proportion of different substrate types on a seamount, could potentially be a useful indicator and measure of recoverability. However, the results of the previously cited works indicate that the relationship between substrate type and recovery is not straightforward and therefore the general usefulness of the aforementioned indicator/measure is open to question. As already noted (see Section 3), information for substrates on seamounts is relatively scarce so as yet no such indicator or measure can be developed.

Estimates of the time it takes for an individual benthic organism, species population, or community to recover from fishing are not generally available for the deep-sea, let alone for seamounts (see Kaiser et al. (2006) for meta-analysis of intertidal and shelf habitats). However, some New Zealand region-specific information is available for some key structural species that occur on seamounts. Recent research on octocorals indicates that radial growth rates are in the order of 0.18 mm/yr and that it might take an individual colony over 40 years to grow to maturity following damage or death (Tracey et al. 2007). Thus, the *presence of generally long-lived corals* on a seamount (in the context of the SEAMOUNT (v2) database, data in the field 'structure-forming corals') can act as a useful indicator of recoverability of a seamount community (e.g., "very low/none = Partial recovery is only likely to occur after about 10 years and full recovery may take over 25 years or never occur", MarLIN website). It is possible with the wholesale removal of structural species such as corals (or ecosystem engineers *sensu* Jones et al. (1994)) from a habitat that conditions will change to the extent that these organisms are highly unlikely to successfully recolonise to any great degree, and the community that