On both the Challenger Plateau and the Chatham Rise, sites with the highest numbers of high sensitivity taxa were scattered across the location (Figure 11). On the Challenger high numbers of high sensitivity taxa were less likely to be found in the shallow central ridge (< 500 m water depth), while on the Chatham Rise, they were less likely to be found on the southern side around the 1000 m contour (Figure 11).

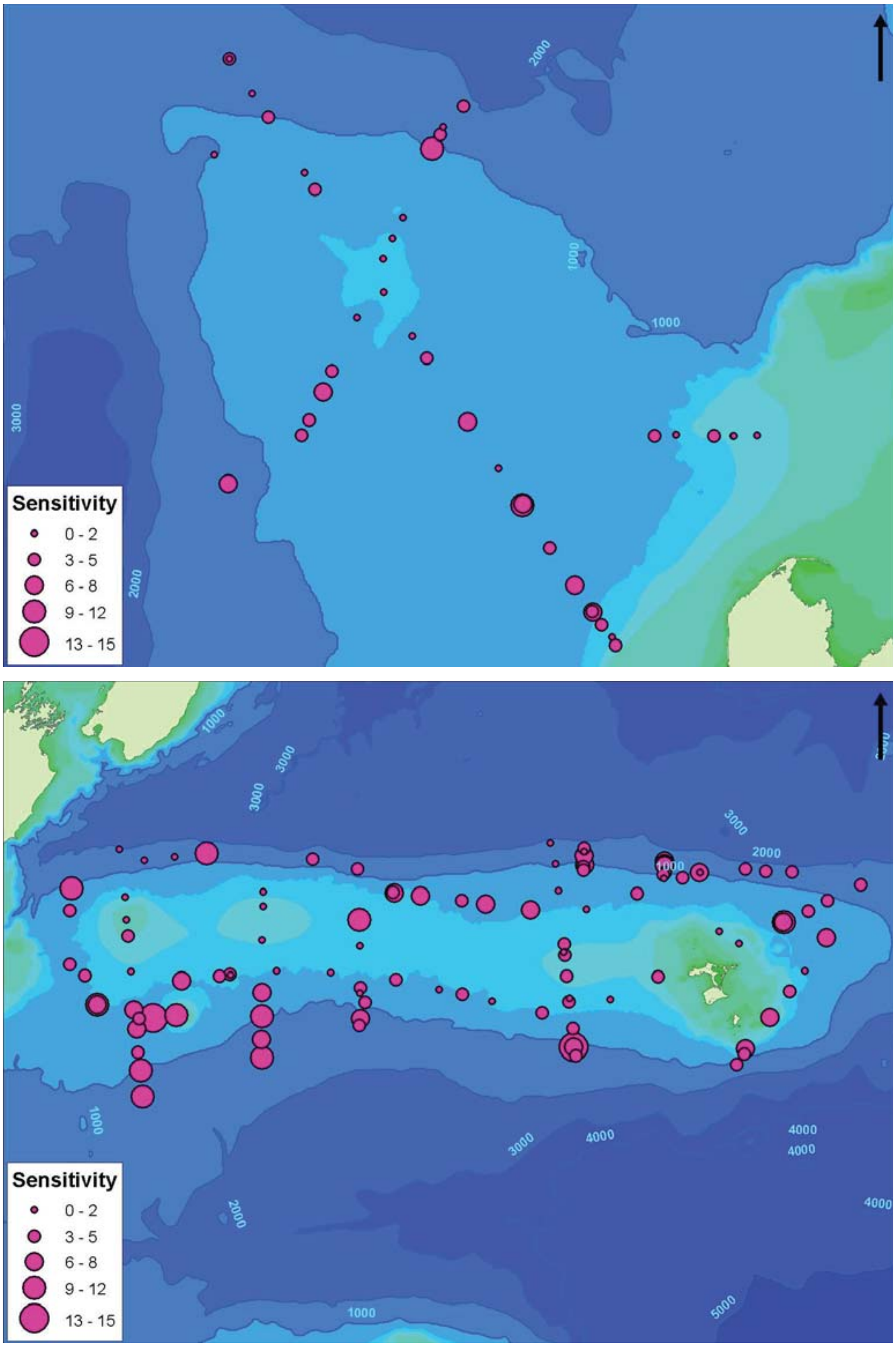

Figure 11. Number of taxa categorised as having a high sensitivity to a light surface disturbance at each of the sampled sites across the Challenger Plateau (upper) and Chatham Rise (lower) regions.

For taxa assessed as being intermediate in sensitivity to a light surface disturbance, highest densities on the Challenger Plateau were found at intermediate water depths (500 – 1000 m; Figure 12upper panel. Across the Chatham Rise, highest densities were found across the depth range, but similar to the pattern observed for numbers of highly sensitive taxa, high densities were infrequently found on the southern side around 1000 m (Figure 12).

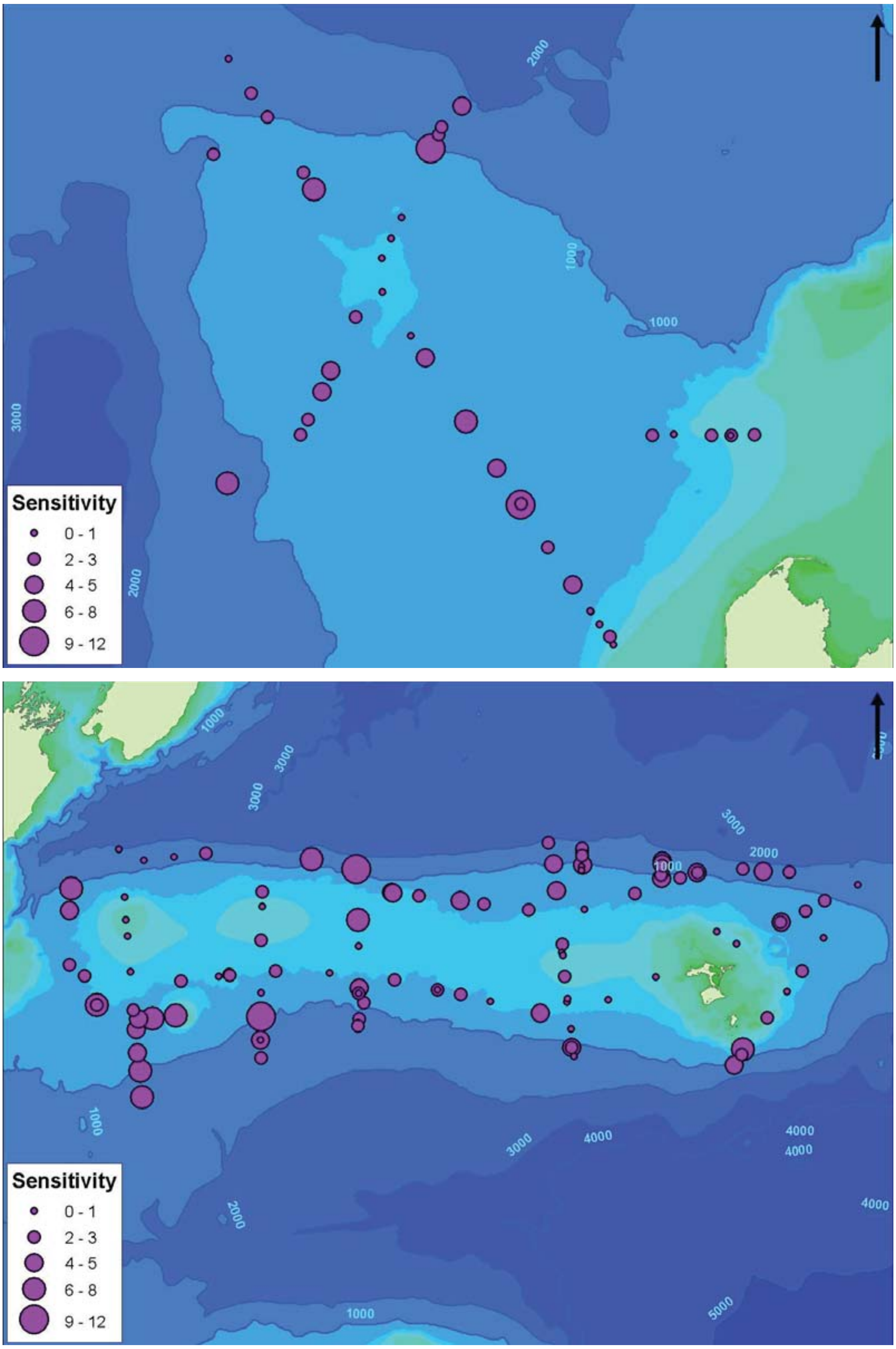

Figure 12. Number of taxa assessed as having an intermediate sensitivity to a light surface disturbance at each of the sampled sites across the Challenger Plateau (upper) and Chatham Rise (lower) regions.

The number of taxa at each site categorised as being of high sensitivity to a light surface disturbance, using the taxa method, declined with increasing fishing intensity (Figure 13a), and this pattern remained when the numbers were converted into percentages (Figure 13b), suggesting that the decrease was not being driven simply by decreased species richness. Numbers (Figure 13c) and percentage of taxa assessed as intermediate in sensitivity showed a similar pattern. In contrast, both the number and the percentages of favoured species at each site, showed no relationship with increasing fishing intensity (see Figure 13d for the relationship for number of taxa).

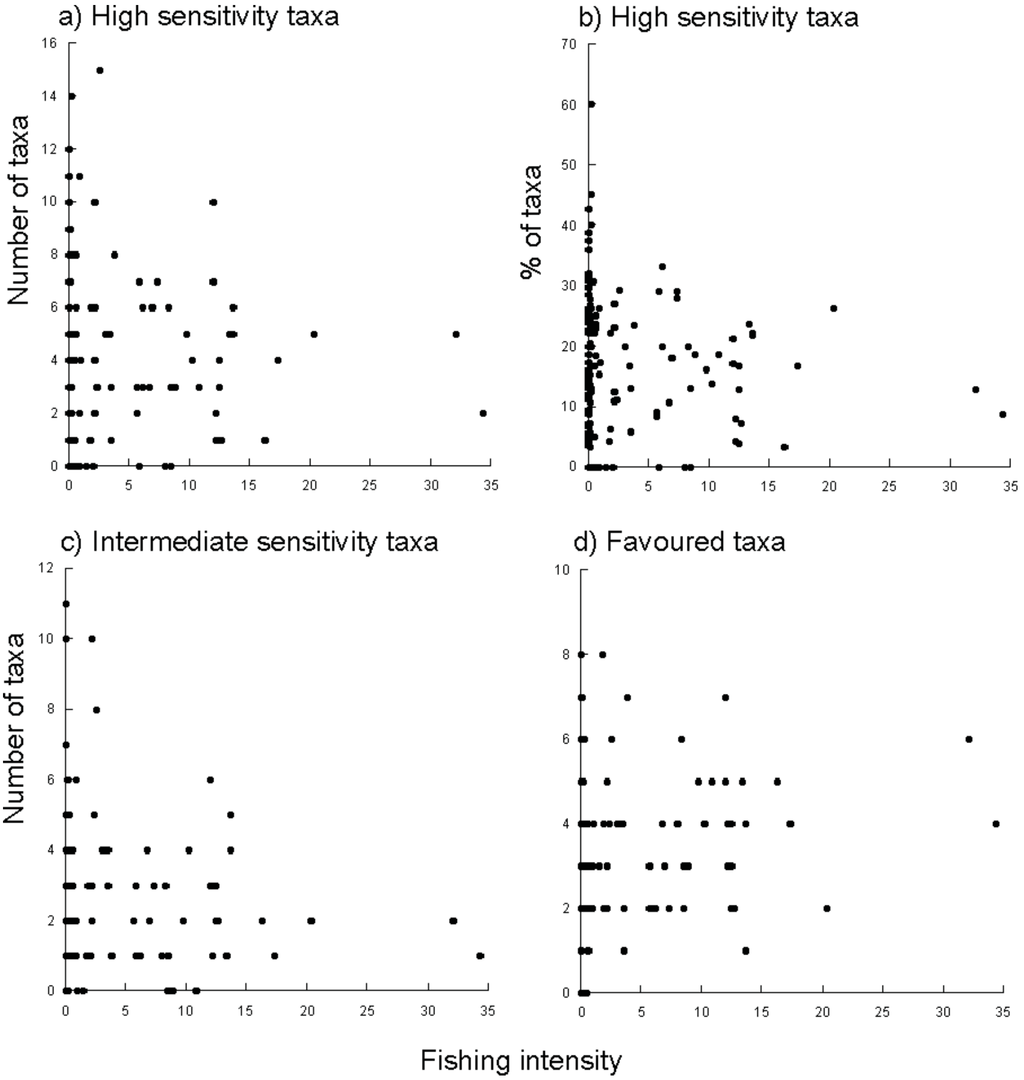

Figure 13. Relationship between fishing intensity (proportion of 25 km^2 cells trawled over 16 years) and site sensitivity to a light surface disturbance using the taxa method, a) number of taxa with high sensitivities, b) percentage of taxa with high sensitivities, c) number of intermediate sensitivity taxa, (d) number of taxa that may be favoured by disturbance.

DISCUSSION

This report covers a number of aspects relevant to the definition and utility of biotic habitat classification as applied to the Chatham Rise and Challenger Plateau Ocean Survey 20/20 surveys in 2006-2007. Key issues include: the spatial scale at which the biotic habitats are defined; the patterns in biotic habitat type observed; how they reflect dominant taxa, biodiversity, ecological function and environmental characteristics; and their relative sensitivity to physical disturbance.

Biotic habitats

Biotic habitats were defined at the scale of the sampling (average distance between sites 20 km), with many biotic habitats spatially consistent across a 75 km scale on the Challenger Plateau. On the Chatham Rise many biotic habitats were spatially consistent at a 100 km scale along depth contours and 50 km across depth contours.

The Challenger Plateau had fewer biotic habitats than the Chatham Rise and these biotic habitats were more functionally similar to each other than those observed on the Chatham Rise (Table 6). The three main biotic habitats of the Challenger Plateau (B3, B7 and B8) were characterised by mobile bioturbators, although B3, which was found extensively across the centre of the Plateau, also contained suspension-feeding hydroids and, closer towards the coast, biotic habitat B7 contained a moderate amount of biotic habitat structure in the form of polychaete tubes.

Different areas of the Chatham Rise generally had different biotic habitats, e.g., the northern versus the southern side of the Rise, the shallower central area versus the deeper areas, and the east versus the west. Chatham Rise biotic habitats exhibited a more diverse suite of biological traits (and thus potentially ecosystem functions) than the Challenger Plateau, with biotic habitats often dominated by suspension feeding and arborescent sessile species, including sponges, anemones and bryozoans (Table 6).

In deep soft-sediment marine ecosystems, important functions delivered by the benthic organisms include biodiversity, habitat engineering, sediment stability/transport, nutrient fluxes at the water-sediment interface, secondary production and carbon sequestration. All of these underpin the delivery of important ecosystem services. This range of functions occurs as a result of a full range of biological traits. Suspension-feeders play an important role in benthic-pelagic coupling, enhancing fluxes of nutrients, oxygen and carbon between the water and the seafloor. Bioturbating organisms increase sediment permeability and water and oxygen content, destabilising chemical gradients in pore water, and influencing rates of remineralization and inorganic nutrient efflux. Both bioturbating and suspension-feeding organisms strongly affect productivity of the benthic system. Finally, species that provide habitat structure on the seafloor (e.g., tube worms, sponges, bryzoans) increase productivity by providing both a surface for other individuals to grow on, and, if densities are sufficient, a refuge for other species from predators, often acting as nursery areas for juveniles. Many of the biotic habitats observed on both the Challenger Plateau and the Chatham Rise, thus, provide important ecosystem functions.

Comparison of methods for assessing sensitivity

1. Certainty in estimates of sensitivity

The three methods, based on either habitats, abundance or number of taxa, evaluated within this study provide different levels of accuracy and uncertainty for different aspects of assessment of sensitivity (Table 8).

Table 8: Relative levels of certainty (L, low; M, medium; H, high) in evaluating site and biotic habitat vulnerability to disturbance based on the three methods used in the present study, for each of the tasks required by each method. Blank cells appear where the method does not require that task.

TASK	LEVEL OF CERTAINTY		
	HABITAT METHOD	ABUNDANCE METHOD	TAXA METHOD
Estimate number of taxa	H	M	L
Estimate abundance	M	M	
Determine taxon traits	H	M	L
Determine sensitivity from traits	H	H	H
Assign sites to biotic habitats	M		
Determine characterising taxa	H		
Determine dominant taxa	H		

Gear type used to sample the benthos will have a big influence on estimates of sensitivity because of differences in gear selectivity. In this study, we focussed on using the DTIS video data for two reasons: (1) DTIS samples were the most spatially comprehensive, and (2) the sampling provided the highest possible sample area per site, which should result in higher accuracy in estimating the number of taxa at a site, as well as more certainty in estimating their abundance. In contrast to other sampling gear such as the sediment corer and epibenthic sled, however, DTIS video sampling provides data on fewer taxa than other methods because detection of organisms is generally limited to larger taxa, and taxonomic identification is more challenging.

Estimating the number of taxa. Sensitivity based on taxa is the only method affected by lack of certainty around whether we adequately sampled taxa richness. A relative quantification of the uncertainty for this method could be gained by using the difference between proportions of rare taxa observed here and those found in other deep sea soft-sediments. However, this would require the assumption that the number of rare taxa is not affected by disturbance, which is certainly not the case in shallower waters (Ellis et al 2000, Hewitt et al 2009).

Estimating abundance. Lack of accuracy in estimates of abundance is usually driven by the patchy spatial distributions that species frequently demonstrate. Certainty is however increased through the sampling of large areas by the DTIS video system.

Defining the biological traits for taxa. We have limited knowledge of the biological traits of many taxa, especially those that rare. The traits we have used are amongst the most well-known (sedentary, predator/scavenger, fragility) and most easily determined from the video data (e.g., erect habitat). However, we assessed the effect of lack of knowledge of traits by changing the assignment of the taxa to either a more sensitive or a less sensitive trait. This analysis suggests that uncertainty associated with determining traits is generally low for sensitivity based on the taxa method (Table 9). Uncertainty is higher for sensivity based on the abundance method, driven mainly by the very high numbers of *Ophiomusium lymani* in some samples. Interestingly, however, the general relationship to fishing intensity did not change with the changes in trait assignment.

Table 9: Average (±standard error) percent change in sensitivity ranking (Abundance method) and number of taxa in the high and intermediate sensitivity categories (Taxa Method). Overestimate = uncertain trait is changed to a more sensitive rank, Underestimate = uncertain trait is changed to a less sensitive rank

	ABUNDANCE METHOD	TAXA METHOD , NUMBER WITH HIGH SENSITIVITY	TAXA METHOD , NUMBER WITH INTERMEDIATE SENSITIVITY
Overestimate	15.5±3.8	0	13.3±1.7
Underestimate	51.6±4.6	0	5.5±1.2

Determining sensitivity from traits. Published information on the effects of different types of physical disturbances on certain biological traits were used, nevertheless we assessed this source of uncertainty. Low levels of uncertainty were associated with the Abundance method (13.1±3.5) and the high sensitivity category of the Taxa method (14.3±1.8). However, the number of taxa with intermediate sensitivity (Taxa method) exhibited higher levels of uncertainty (~26%).

Assigning sites to biotic habitats. An assessment of how well this was achieved can be gained from both the relative degree of dissimilarity within and between biotic habitats and the percentage of times a replicate sample from the same site was assigned to a different DTIS group (Objective 9; Floerl & Hewitt 2010). While the relative degree of dissimilarity was high (~0.7 for most biotic habitats), assignment to different groups was low (~0.2).

Determining characterising taxa. The statistical method developed for this (SIMPER, Clarke 1993) is robust to determining how consistent the presence or abundance of a taxon is across a set of sites and gives the percentage contribution of the taxa to the similarities in community composition within and between groups of sites. Within Objective 9 any uncertainty related to defining the characterising taxa was reduced to a low level by ensuring that the characterising taxa had to contribute at least 5% to overall similarity. Note that characterising taxa are not necessarily abundant.

Determining dominant taxa. This is a standard technique and uncertainty is largely related to the degree of within- and between-site heterogeneity.

2. Overall assessment of utility of methods for defining sensitivity

Defining sensitivity based on biological traits that render individual organisms sensitive to a particular type of physical disturbance should prove to be a powerful tool in the future. At present, it is in a developmental stage around the world. Here, we have tested three different methods of compiling information from the taxon level to a community/area level, using a physical disturbance, such as a trawl, that drags over the surface of the sediment but is not focussed on removing sediment or organisms, or digging deeply into the sediment.

Method 1, based on biotic habitats, is classified as the 'worst-case' scenario (using terminology from Tyler-Walters et al. 2009), appeared the least useful method. It is most likely to be insensitive to assessing impacts because, as long as a single individual of a highly sensitive species characterises the biotic habitat, the biotic habitat (and thus the site) is designated as highly sensitive. Thus, monitoring of a site over time is unlikely to pick up a change, even though the abundance of sensitive organisms may have declined markedly. The compression of the assessment towards the high end of the sensitivity spectra will also provide managers with little scope by which to make decisions about priority areas for protection. If all areas are classified as sensitive, how is prioritisation to be carried out? However, the method may be useful to indicate that the area does contain sensitive taxa and thus may benefit from protection with an aim to restoration.

Method 2, relative sensitivity based on abundances, demonstrated a broad range of values across all sites in response to the Table 2 disturbance. Although abundant species might be over-represented in the final scores, with the effect of potentially under-estimating the relative sensitivity of a site, this method showed a surprisingly strong negative relationship with fishing intensity. If this method is used, it should be kept in mind that it is likely to provide a conservative estimate of the effects of disturbance, as rare species will have a limited influence on the overall ranking of a given site.

Method 3, sensitivity based on the number of taxa in different sensitivity categories, also demonstrated a broad range of values across all sites in response to the light surface disturbance. It does incorporate rare species, and both the number and proportion of taxa in the high and intermediate sensitivity categories showed a reasonably strong negative response to fishing intensity.

Our recommendation is that the relative sensitivity based on abundances and the number of taxa in the high and intermediate categories from the method based on number of taxa provide the most useful assessment of sensitivity of sites and biotic habitats, despite the associated uncertainties. If they are both used in future, observing consistent patterns with both methods will increase confidence in the results. We have applied the approach in a conservative fashion and also recommend that further refinement of the approach is needed (through improved understanding of biological trails and sensitivities) to derive a less biased analysis.

Sensitivity of the Challenger Plateau and Chatham Rise

1. Patterns related to a light surface disturbance

Regardless of the method used to determine sensitivity to the light surface disturbance, no real differences were observed between the Challenger Plateau and Chatham Rise, with both locations showing a full range of values.

However, within each location, slightly different patterns of sensitivities to the light surface disturbance were apparent depending on which methods were used. While methods based on both abundance and taxa suggested that the southwest corner of the Challenger Plateau was sensitive, the taxa method suggested the deeper areas to the northwest and the < 500 m central ridge were the least sensitive. On the Chatham Rise both methods identified the southern side around 1000 m as being least sensitive, but the taxa method again identified more areas as having higher sensitivity than did the abundance method. It is interesting to note that the area in the Chatham Rise identified by both methods as lacking high sensitivity taxa correspond to the area characterised by demersal fish communities including hoki and ling (Leathwick et al. 2006), with much of the area subjected to bottom fishing (Figure 14; Ministry of Fisheries project BEN200601, Baird et al. in review).

Importantly, comparisons of taxa sensitivities with available information on known distribution of fishing effort over a 16 year period suggest that the Chatham Rise, despite its biological diversity, is being affected by fishing. Fishing appears to constrain the variability of richness and abundance of sensitive taxa such that maximum richness and abundance decreases with recorded fishing effort (see Figure 8 and 13). The loss of traits and trait diversity in turn implies constraints on the functionality of the ecosystem, as sensitive taxa generally are those that provide erect habitat structure on the seafloor, are large and long-lived and frequently are suspension-feeders.

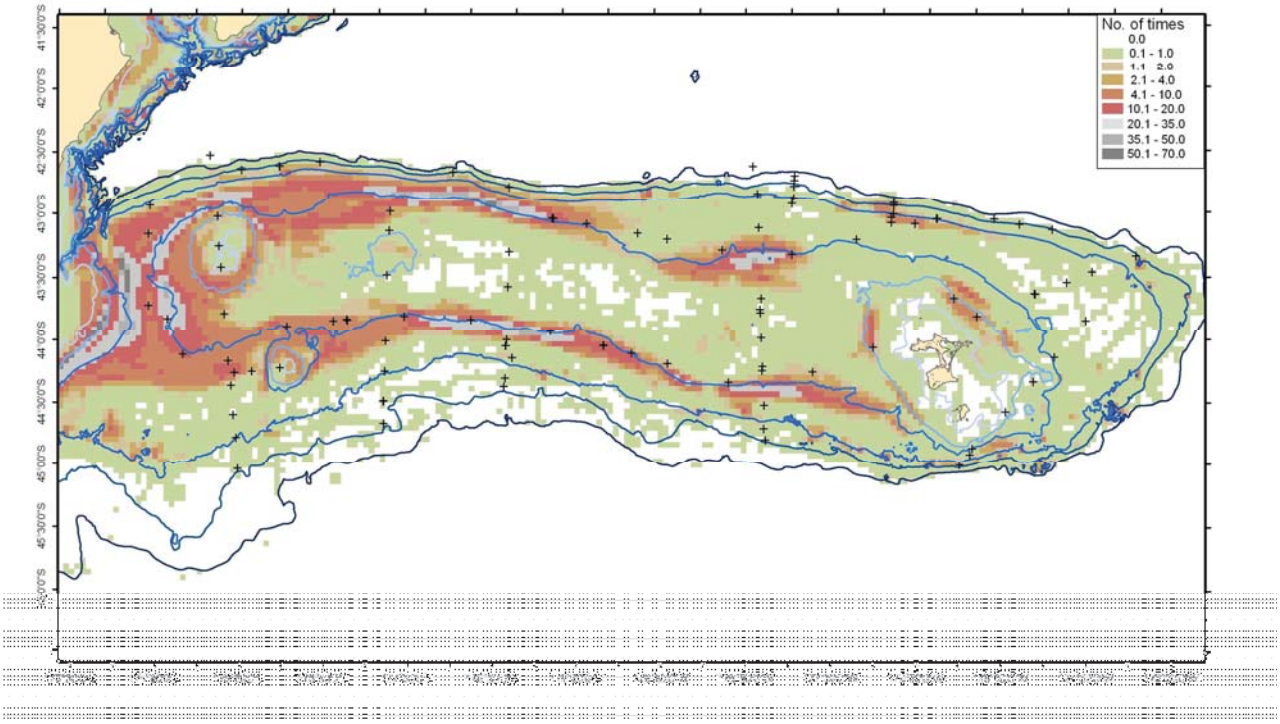

Figure 14. Distribution of fishing intensity as a proportion of 25 km^2 cell trawled over 16 years (Ministry of Fisheries project BEN200601, Baird et al. in review) on the Chatham Rise. Sampled sites are overlaid as crosses.

2. Other factors affecting sensitivity

The present study evaluated the efficacy of three different methods for assessing the sensitivity of benthic biotic habitats to physical disturbance. The size of area disturbed (by a single tow) is assumed to be sufficiently small that the mobility of some taxa will allow them to move back into the area post-disturbance to utilise new food resources. The depth to which sediment is disturbed is also assumed to be only of the order of 0–2 cm, such that deeper-dwelling individuals are unaffected and tube dwellers or fast burrowers could withdraw to safe depths. Many more taxa will be sensitive to activities that disturb deeper into the sediment.

However, assessing sensitivity, especially sensitivity based on individual traits, is only part of any assessment of potential impacts. Impacts on population dynamics and meta-communities are also important and their magnitude will be affected by the history and current areal extent and frequency of the disturbance, and potential recovery rates of the impacted benthic community. Frequently occurring disturbances of the surface of the sea floor over large areas (such as may occur with bottom trawling) may result in the inability of fragile, long-lived species to maintain population levels, changing communities to those dominated by opportunistic species (Thrush et al 2005). In disturbed systems, recovery rates are also frequently controlled by how isolated the disturbed area is from potential sources of colonists, and whether environmental characteristics such as sediment type and chemical makeup have changed.

Future research

The data collected by this Ocean Survey 20/20 project offer an unparalleled opportunity to increase our knowledge of many of the biological traits needed to assess sensitivities to different disturbances. For example, analysis of the different types of taxa (and their abundances) collected across environmental and anthropogenic gradients will improve our ability to determine environmental drivers and predict how taxa and diversity will be impacted by anthropogenic disturbance. The DTIS imagery (both video and still cameras) can be analysed to increase our knowledge of species behaviour (feeding, mobility, small scale patchiness and living position) all of which will increase our ability to predict impacts and assess ecosystem function. For any management use of these techniques at the scale of the Chatham Rise and Challenger Plateau, it is important to note that despite the broad coverage of the 2007 OS 20/20 surveys, there are likely to be some significant benthic biotic habitats are not represented and there others that we do not yet know of (Levin and Dayton 2009). Comparable data from surveys other than the OS 20/20 voyages already exist and could be incorporated in analyses to provide representation of biotic habitats not covered by the 2007 surveys. Examples include biotic habitats on the Westpac hills on Challenger Plateau, for which DTIS and epibenthic sled data are available.

Moreover, analysing the data across the very broad scales utilised in these projects will allow us to assess the relative importance of regional species pools and spatial connectivity, and environmental gradients, on the maintenance of marine biodiversity in New Zealand.

Finally, further research funded under Ministry of Fisheries contract #ZBD2009-25 (Predicting impacts of increasing rates of disturbance on functional diversity in marine benthic ecosystems) is planned to expand on the results reported here, and place the relationships between functional traits and fishing effort within the context of a conceptual model of disturbance and recovery dynamics. The data from the Oceans Survey 20/20 Challenger/Chatham series of reports will be used in this new project to quantify rare species abundance, biomass, functional diversity, relative importance of habitat structure, and ecosystem productivity of the different biotic assemblages to parameterise recovery dynamics within the disturbance/recovery model.

ACKNOWLEDGEMENTS

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PUBLICATIONS

NA

DATA STORAGE

Data generated by this objective is currently held in the ZBD200701A database (MS Access) and consists of the biotic habitat identifier for each site, taxon information, and the site sensitivities based on the three methods. On completion of the review process, these data will be submitted to the Ministry of Fisheries data manager at NIWA for loading in to the BIODS database.