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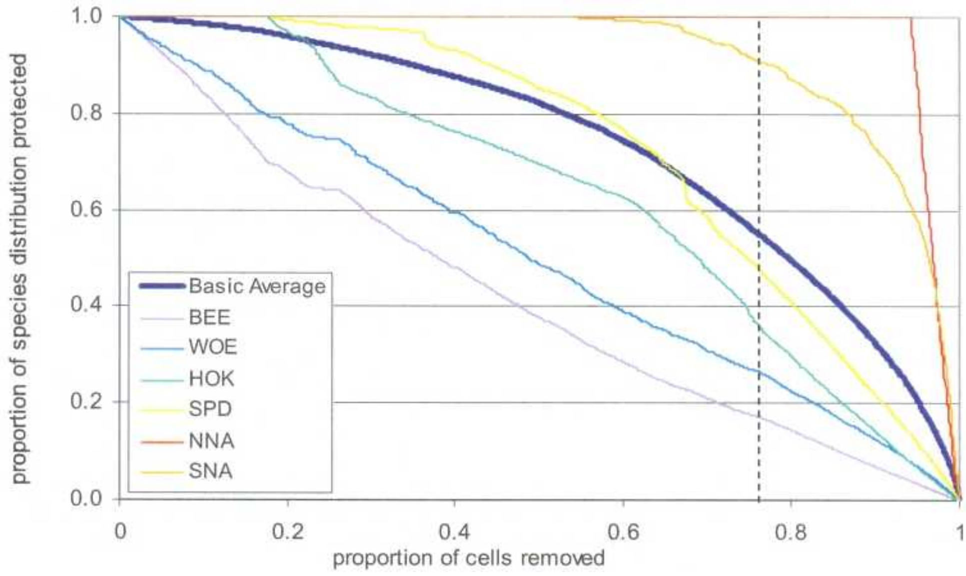

Figure 5: Relationship between conservation protection and cell removal as calculated from the basic analysis, both averaged across all species, and for selected species with contrasting protection: removal curves (BEE - Basketwork eel, HOK - hoki, NNA - *Nezumia namatahi*, SNA - snapper, SPD - spiny dogfish, WOE - warty oreo). The dashed vertical line indicates a 10% level of closure to fishing.

3.2 Weighting to increase protection for endemic species

Preferentially weighting endemic species increases the relative priority they receive in the calculation of the biodiversity protection offered by individual 1 km grid cells. This in turn alters the spatial distribution of the highest value cells (Fig. 6) compared to the configuration produced by the basic analysis (Fig. 4). Highest priorities for protection are similar to those in the basic analysis, but with greater emphasis both on inshore locations along the east and west coasts of the South Island and in certain offshore locations, particularly across the south east of Campbell Plateau, south-western Chatham Rise and at shallower depths on the Challenger Plateau. This solution also has a slightly lower ratio of boundary to area (0.61 km/km^2) than that produced from the basic analysis.

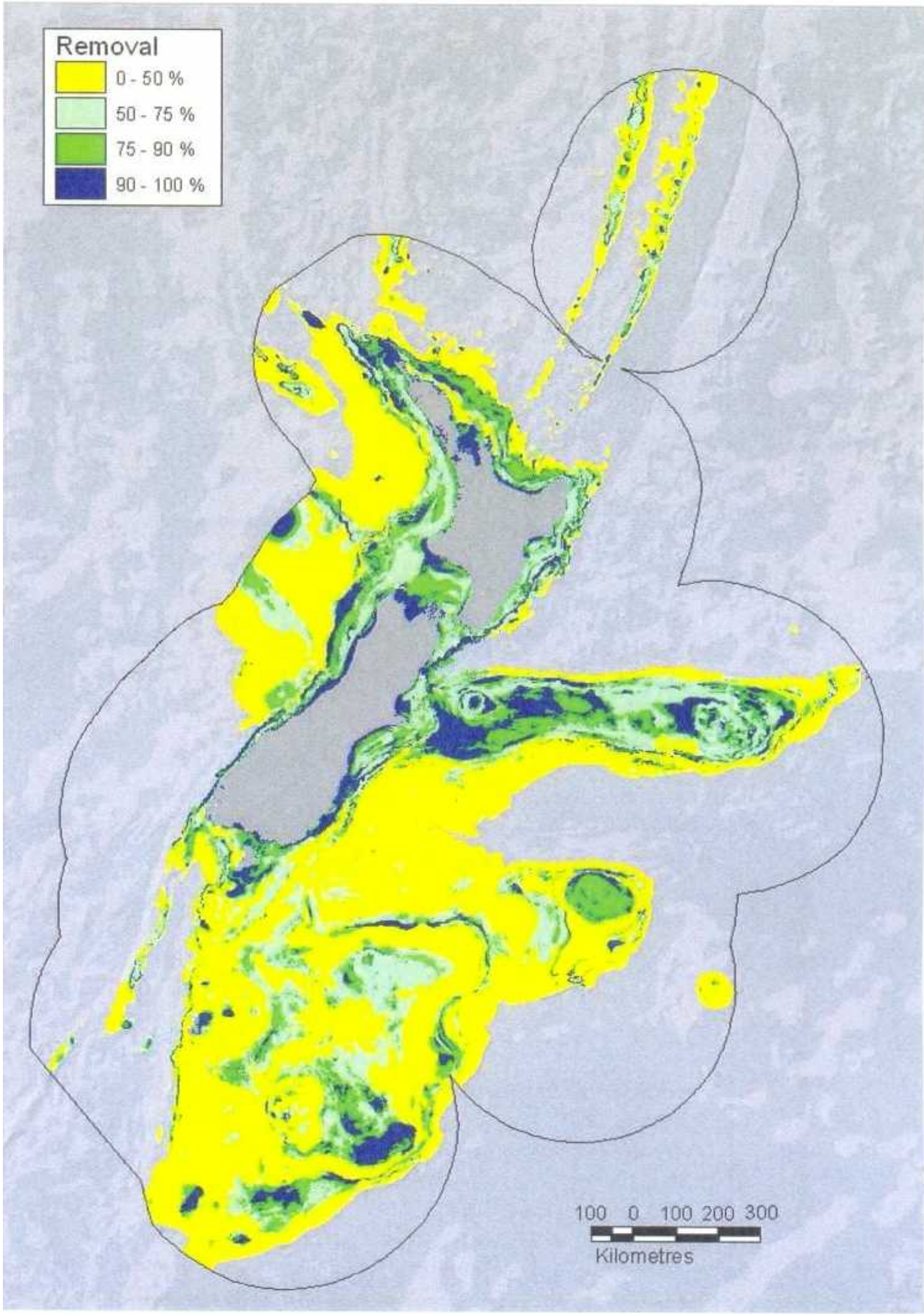

Figure 6: Relative conservation ranking of 1 km grid cells as calculated from an analysis in which endemic species were given a higher weighting. For details see text and Figure 4.

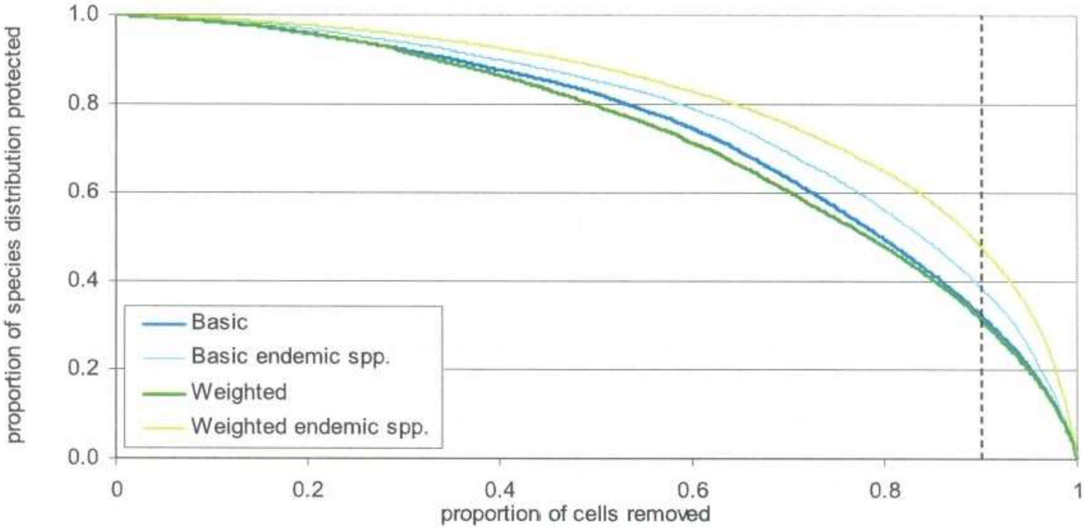

Figure 7: Comparison of the relationship between conservation protection and cell removal as calculated from the basic and weighted analyses. Results are shown averaged both for all species, and for endemic species. The dashed vertical line indicates a 10% level of closure to fishing.

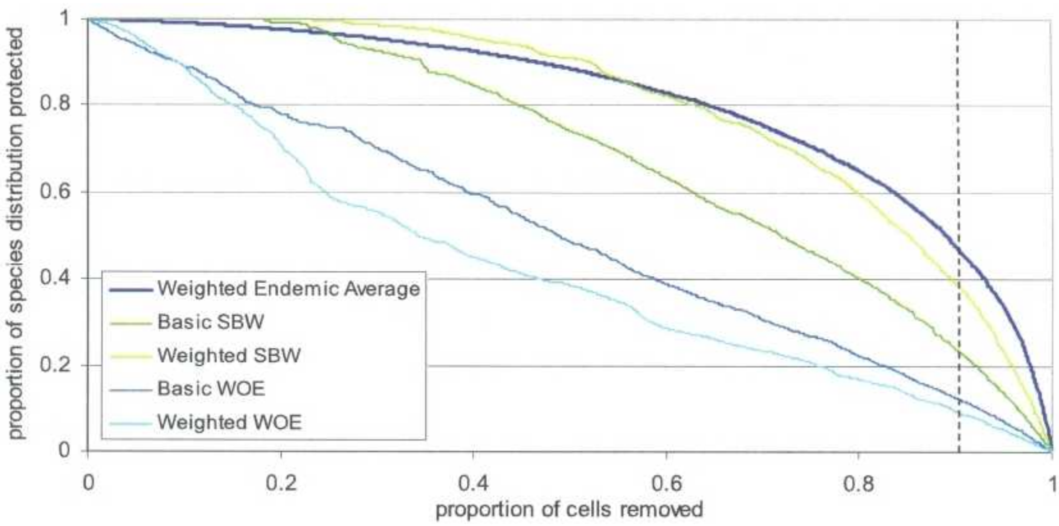

Figure 8: Protection: removal curves for the endemic southern blue whiting (SBW) and non-endemic warty oreo (WOE) as calculated by the basic and weighted analyses. The dashed vertical line indicates a 10% level of closure to fishing.

The relationship between cell removal and average proportion of ranges protected for all species for this analysis closely tracks that for the basic analysis (Fig. 5 vs. Fig. 7). However, the average protection for endemic species is increased, e.g., at a 90% level of removal, the protection for endemic species increases from 38.4% in the basics analysis to 47.8% in the weighted analysis. Protection curves for typical endemic and non-endemic species (Fig. 8) indicate that southern blue whiting (SBW), an endemic sub-species, is accorded increased levels of protection, while the non-endemic species warty oreo (WOE) shows a decrease in its protection of similar magnitude. Weighting as implemented here was used in all subsequent analyses.

3.3 Use of uncertainty estimates

We tested the feasibility of using uncertainty estimates for the individual predicted species distribution, working with a subset of 18 widespread species for which we used bootstrap resampling to estimate prediction uncertainty. This resulted in small changes in the spatial pattern of the results, with reduced conservation priority indicated for locations for which predictions were less certain. However, we were unable to fully implement this procedure in the time available for this study, because of the computer-intensive nature of the bootstrap procedure needed to produce realistic uncertainty estimates over these large areas. Nevertheless, it would be achievable in a more relaxed time frame.

3.4 Use of boundary quality constraints

Addition of boundary quality penalty (BQP) constraints to the configuration used for the weighted analysis substantially slows calculations because of the requirement to assess the degree of removal of neighbours when calculating the value of each cell. However, this results in a final solution that is much more ecologically realistic and more practical for management.

Combining a uniform 24-cell neighbourhood and a linear loss curve for all species produces a configuration (Fig. 9) that has a boundary to area ratio (0.26) less than half of that for an equivalent analysis without boundary constraints (0.61). However, maps for the respective solutions (Fig. 9 vs Fig. 6) show that, despite this reduction in fragmentation, the high priority locations (best 10%) from these analyses show strong overlap (81%). Both solutions also deliver similar levels of protection (Fig. 10), e.g., at a 10% level of reservation the BQP solution delivers average biodiversity protection of 32.1 % compared with 31.1 % for an equivalent unconstrained solution. Use of the more complex settings described in the methods section produced a result differing to only a minor degree from those for the analysis with uniform settings for all species.

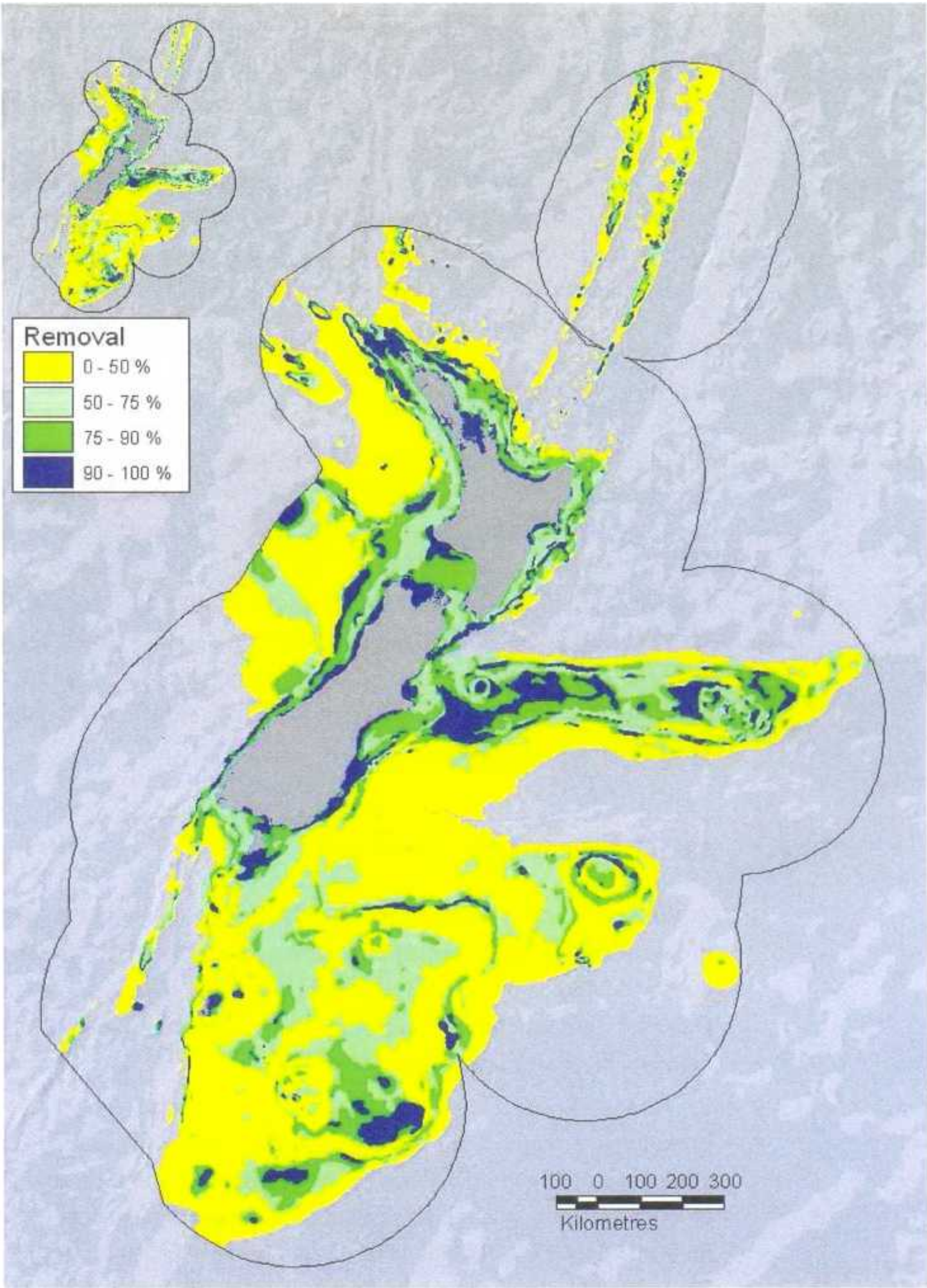

Figure 9: Relative conservation ranking of 1 km grid cells as calculated from an analysis using differential weighting of species and boundary quality penalties. Results from the weighted analysis are inset for comparison.

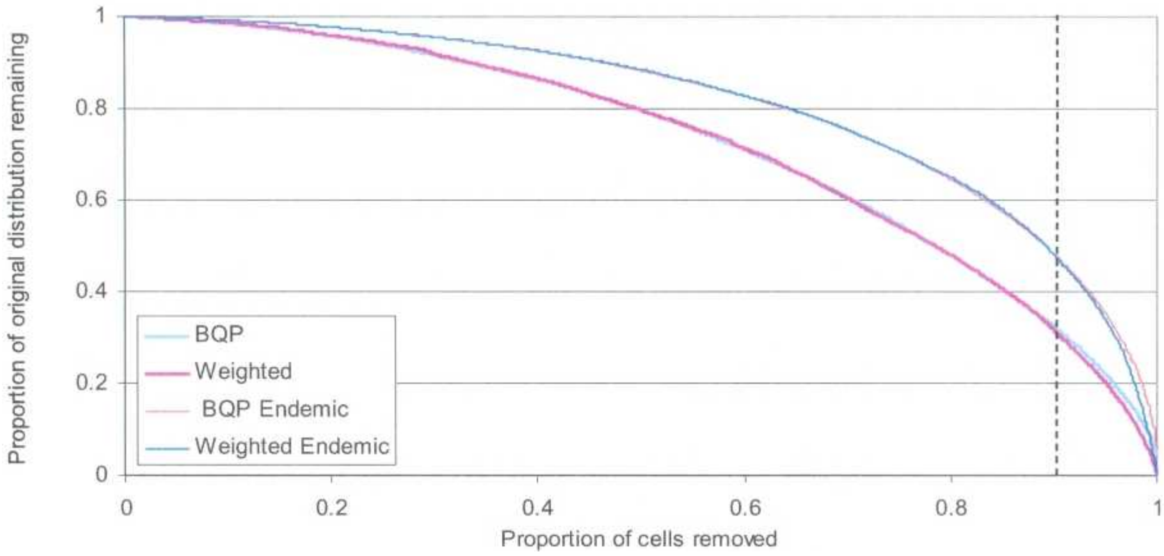

Figure 10: Comparison of the relationship between conservation protection and cell removal as calculated from the weighted analysis and an analysis using weighting and boundary quality penalties (BQP). Results are shown averaged both for all species, and for endemic species. The dashed vertical line indicates a 10% level of closure to fishing.

3.5 Introducing consideration of costs of protection

Adding consideration of the costs of protection, in this case indicated by the potential loss of trawling opportunity as measured by fishing effort during 2005, substantially changes the spatial distribution of sites having highest priority for protection (Fig. 11). In particular, it shifts the distribution away from sites favoured for trawling because of their high `cost', towards sites that are less suitable for trawling. In spatial terms, the most obvious changes are the reductions in conservation priority for sites on the continental shelf from eastern Northland to the Bay of Plenty (see inset of Fig. l1), along the shelf edge off the west coast of the South Island, and on the western end of the Chatham Rise, where areas previously identified as having high conservation value in the weighted analysis (Fig. 6) are now accorded much lower priority for conservation because of their high fishing value. These changes are matched by a concomitant increase in the cost-adjusted analysis in the protection priority for sites off the northern Taranaki coast, along the Fiordland coast, east of the Chatham Islands and on the Bounty Plateau, all of which are sites that have relatively low value for trawling (Fig. 2).

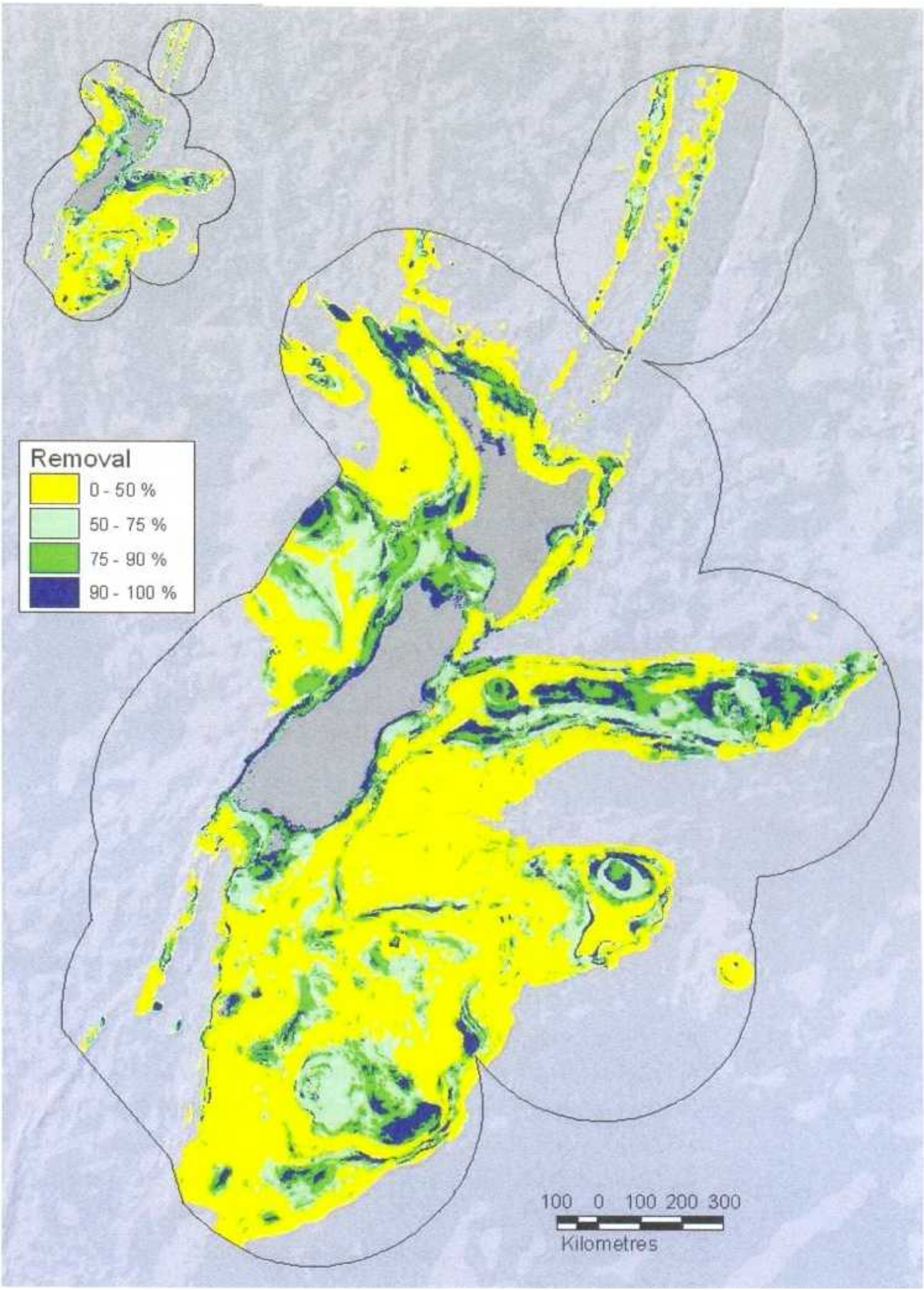

Figure 11: Relative conservation ranking of 1 km grid cells as calculated from an analysis using differential weighting of species and a cost layer describing spatial variation in trawl intensity. Results from the weighted analysis are inset for comparison.

Despite these relatively major changes in the geographic pattern of protection priority, the conservation returns provided by reservation of the highest priority 10% of sites (Fig. 12 - 28.6%) remains similar to that which would be provided by the preceding scenarios (c. 31-32%). However, at a species level there is a marked reduction in the protection provided for northern inshore species such as snapper, trevally, and kahawai, reflecting the way in which intense fishing occurs throughout the range of these species. By contrast, most offshore species maintain reasonable levels of protection, because fishing is generally concentrated in particular geographic subsets of their ranges. Protection of the 10% highest priority sites identified by this scenario would result in reserves having a boundary/area ratio of 0.59.

We note that development of a more spatially comprehensive description of fishing effort would be required before such a result could be used in an operational manner, and this would need to accurately reflect effort in inshore fisheries for which reporting of precise trawl locations is not currently obligatory.

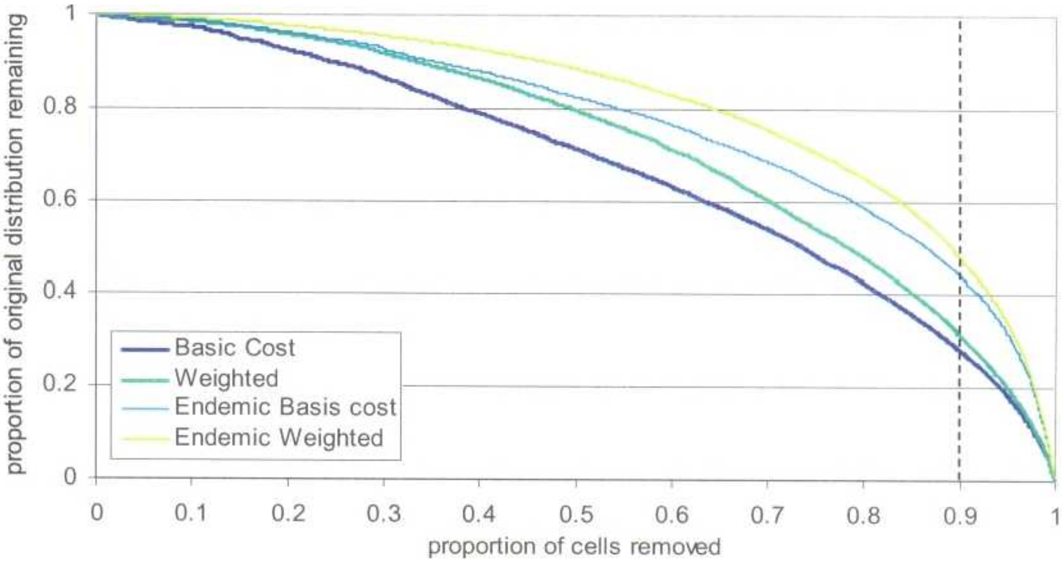

Figure 12: Comparison of the relationship between conservation protection and cell removal as calculated from the weighted analysis, and a weighted analysis in which conservation ranking was calculated using trawl intensity as a cost layer. Results are shown averaged both for all species, and for endemic species. The dashed vertical line indicates a 10% level of closure to fishing.

3.6 Conservation gains from existing and proposed reserves

Finally, we demonstrate how Zonation can be used to assess the biodiversity protection provided both by existing reserves (marine reserves and parks, and sea-mount protection zones) and the set of Benthic Protection Areas proposed by the fishing industry (Clement and Associates undated). These two reserve designations were analysed separately, and in each case, all 1 km squares located within reserves were tagged, resulting in their enforced retention until after all non-reserve squares had been removed. This allows objective assessment of the protection that these reserves currently or could potentially provide, compared to the protection provided by either the unconstrained or cost-adjusted selection of sites as described for the previous analyses.

3.6.1 Existing reserves

Analysis of existing reserves, which cover 22 922 km^2 or 1.26% of the area of the EEZ with trawlable depths, was carried out first. Because these reserves comprise such a relatively small proportion of the EEZ, their retention until the end of the analysis resulted in little change in the overall pattern of protection priority (Fig. 13) compared to that produced by an equivalent analysis without such constraints (i.e. 'weighted' - Fig. 6).

The small extent of the existing reserves also results in close similarities between the biodiversity protection curves for these two analyses (Fig. 14), which show only minimal differences throughout much of their range. However, the amount of protection provided by areas contained within the existing reserves (average = 1.48%) is less than 20% of the protection that would be provided by an equivalent area chosen solely for its biodiversity values (7.68%). This difference is a direct reflection of the non-representative nature of the existing reserves, which are biased towards both inshore waters and seamounts where they provide disproportionate protection of these habitats at the expense of habitats that support markedly different fish assemblages.

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