ICES CM 2010/H:03 (Benthic indicators: responding to different human pressures and assessing integrative quality status)

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Title: A practical evaluation of biotic indices and indicators of benthic health as a means to assess the sustainability of integrated aquaculture operations in Southern Temperate ecosystems.

Abstract:
Aquaculture is an important component of New Zealand's economy and, like many other countries, there is increasing pressure on scientists to ensure operations are sustainable. Although long-line mussel culture dominates, high production salmon farms are increasingly being interspersed amongst existing shellfish leases, providing a unique set of environmental impacts. Most production in New Zealand is focussed in the South Island (Marlborough Sounds) and as a result site morphologies and substrates are very similar, although water velocities can vary considerably (from 2 – 25 cm s^{-1}). Natural infaunal populations are relatively diverse but marked changes have been observed in areas associated with aquaculture operations. The communities associated with impacted conditions vary dramatically, depending on the type and intensity of farming and natural background environmental conditions. At high flow sites (>15 cm s^{-1}) abundances of enrichment tolerant species can be exceptionally high (>100,000 individuals m^{-2}) whilst at low flow sites diversity and abundance can be greatly reduced (almost azoic) under the worst case conditions. In contrast the benthos beneath mussel farms tends to display a weaker response and sometimes can even have elevated diversity and abundance as a result of substrate modification from mussel shell and other organic debris.

It is important for both sustainable environmental and farm management to ensure that sediment conditions associated with do not deteriorate to the extent that they are irreversibly degraded; consequently it is important to monitor the benthic environmental conditions. Change in benthic community structure is well established as one of the most sensitive approaches for determining sediment condition. However, there are many different ways in which this can be evaluated and there is a need for a standard approach to evaluation of enrichment status. In the northern hemisphere a variety of biotic indices/ indicators have been established as reliable approaches for evaluation of environmental condition. However, these frequently require a complex understanding of species taxonomy and functional biology; something which is often lacking in southern temperate faunas. This study reviews the performance and transferability of selected biotic indices to some southern hemisphere ecosystems and considers the levels of functional understanding needed to assess benthic health.

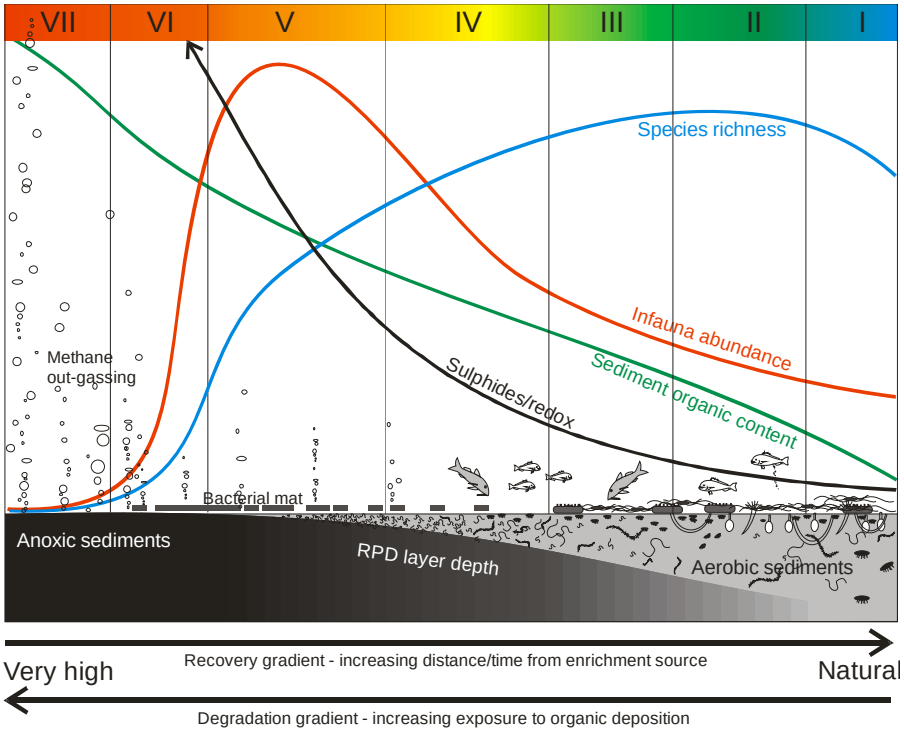

Figure 1: Standard enrichment gradient showing defined impact levels determined by a combination of "expert" knowledge and local regulatory conditions.

In order to establish a consistent benchmark for comparison of all indices an enrichment gradient was defined and categorized based on overseas experiences, collective knowledge of local benthic scientists, and local requirements for regulation and management (Fig. 1). Average expert opinion of impact level was obtained for 118 historical 'sampling events' to serve as a baseline, or reference, against which the performance of selected indices could be assessed, and to assist in characterising species according to trophic group. A range of biotic indices/metrics were selected for testing based on pre-specified criteria; these included infauna abundance, richness, Shannon diversity, AMBI (Borja et al. 2000), M-AMBI (Muxika et al. 2007), ITI (Word 1978), BENTIX & MEDOCC (Simboura & Zenetos 2002), BMR (Edgar et al. 2005), BOPA (Dauvin & Ruelette 2007). The dearth of published information relating to Eco-Groups and functional feeding groups for southern hemisphere infauna was addressed by selecting and classifying the key contributing species. Using historical data, the response of 35 key species to enrichment was modelled using quantile (0.95) regression splines (Fig. 2). This provided a numerical framework for determining the sediment organic content (shown as ash free dry weight (AFDW)) and 'Impact stage' associated with maximum abundance of each species (selection shown in Fig. 3). The results were then used to verify the Eco-Group allocations for those taxa which co-occur between the Northern Hemisphere and New Zealand, and to determine groupings for any additional "key species". Finally, the relative performance of each of the biotic indices was compared to the average expert evaluation of the sediment condition and the indices ranked accordingly.

Quantile regression splines, as proposed by Anderson (2009), proved a useful means for characterising individual species responses to organic enrichment. Using this method in combination with other multivariate analyses techniques (i.e. multi-dimensional scaling (MDS) and Canonical analysis of Principal Co-ordinates (CAP)

analysis and vector correlation overlays), we were able to confidently allocate Eco-Groupings to 8 taxa that hadn't previously been classified. Equally importantly, we were able to validate the existing Eco-group status for the most of the remaining key taxa identified for our particular conditions. The agreement between our Eco-group allocations and previous (Northern Hemisphere) allocations was on the whole good. However, the analysis did identify some discrepancies; highlighting potential problems with the inter-regional transferability of related indices and the need for regional validation. The analysis also highlighted some potential risks in making assumptions based on higher trophic level groupings. In comparing the performance of the selected biotic indices, AMBI, MEDOCC and the M-AMBI were identified as the best individual predictors of 'Impact Level' along strong enrichment gradients such as the ones encountered beneath salmon farms. Some problems were encountered with the use of biotic indices at the upper end of the enrichment spectrum, however some simpler metrics (e.g. %AFDW) proved to be reasonably good secondary predictors of Impact Level and may be useful when used in combination.

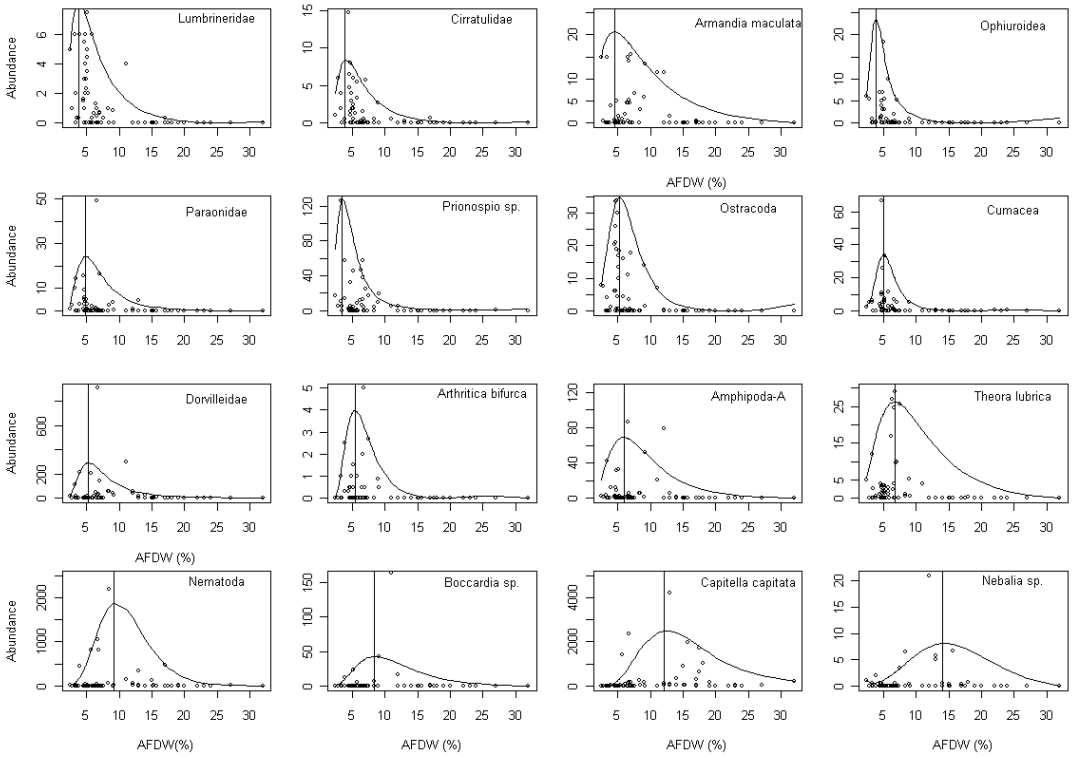

Figure 2. Abundance of selected key species versus % Ash Free Dry Weight (AFDW) in sediments, where AFDW is an indication of the level of organic enrichment and therefore impact level. The regression spline model for the 95th percentile is shown, with the maximum model (interpreted as an estimated optimum for the species) indicated by vertical line.

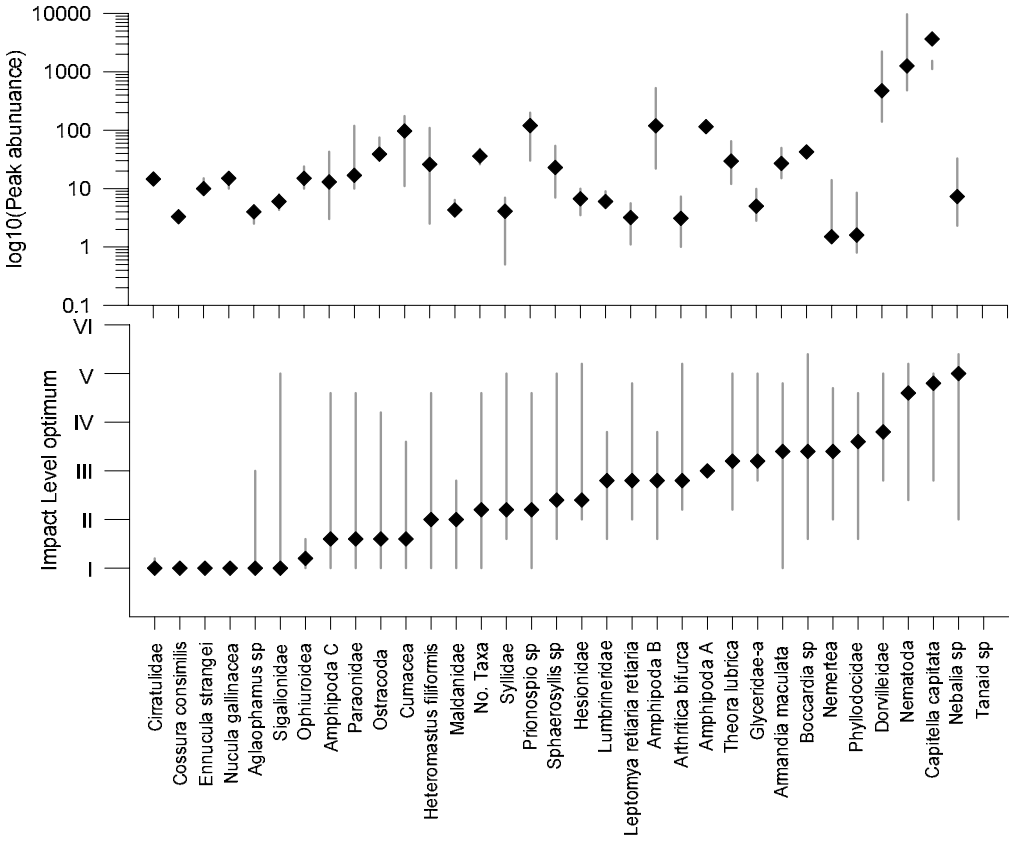

Figure 3. Abundance (Log 10 transformed) and numerically derived impact levels associated with key selected taxa.

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