Towards a risk model to assess the impact of dissolved salts in freshwater aquatic ecosystems

Jason Dunlop[1,2]
[1] Natural Resources Mines and Water, 120 Meiers Rd Indooroopilly, Brisbane Qld
[2] Griffith University, School of Public Health Logan, Brisbane Qld

Impacts from salinisation have been identified as one of Australia's most serious environmental issues. Accumulation of dissolved salts within the soil profile may lead to salination of adjacent freshwater ecosystems. Probabilistic risk assessment can be used to determine the concentrations of salinity required protect aquatic ecosystems and to assist managers of waterways to establish control plans to maintain ecosystem health. An important knowledge gap in the application of these methods is the lack of biological effects data for Queensland freshwater biota with which to assess salinity risk. In this study the 72-h acute salinity tolerance of a wide variety of macroinvertebrates was established from sites in four different bioregions including Northeast Queensland, Southwest Queensland and Southeast Queensland. The results of this study suggest that the acute salinity tolerance of macroinvertebrates communities in Queensland are highly variable between taxonomic groups ranging from highly sensitive (Leptophlebiidae, LC_{50} 6456 μScm^{-1}, Baetidae LC_{50} 8853 μScm^{-1}, and Caenidae LC_{50} 12552 μScm^{-1}) to highly tolerant (Palaemonidae LC_{50} 53283 μScm^{-1}, Parastacidae LC_{50} 45039 μScm^{-1}, and Dytiscidae LC_{50} 37554 μScm^{-1}). Comparisons between regional salinity sensitivity indicate that a similar pattern was observed in each of the regions tested. This indicates that of the macroinvertebrates tested in each region, as a group their sensitivity was observed to be similar. However, of all macroinvertebrate taxa tested the five most sensitive taxa were sampled in the Wet Tropics. The findings of this study have implications for the assessment of salinity risk and the determination of regionally relevant guidelines for salinity.

Introduction

Impacts from salinity have been identified as one of Australia's most serious environmental issues. Despite the fact that dissolved salts are natural components of rivers, it is now well recognised in the scientific literature that impacts from excessive concentrations of dissolved salts can have profound and measurable effects in freshwater aquatic ecosystems (Hart *et al*, 1991, James *et al*, 2003). The establishment of guidelines for salinity can provide a basis for its management, though there are currently no widely acceptable biological effect based guidelines that are applicable at a local or regional scale in Queensland. Probabilistic risk assessments can be used to determine safe salinity concentrations or guidelines.

Risk assessment involves combining information on the probability or likelihood of a hazard with the information on the consequence of hazard occurrence. Macroinvertebrates are an important component of freshwater ecosystems forming a vital link in aquatic food webs. As a group macroinvertebrates are known to respond at the community level to salinity impacts (Horrigan *et al*, 2005) and some taxa are known to be salinity sensitive (Kefford 2003a). For these reasons they are a useful

indicator of salinity impacts. Prior to this study no macroinvertebrate salinity tolerance information has been available for Queensland taxa. This information is required to provide a basis for assessing the risk of salinity to macroinvertebrates in Queensland. The objective of this study is to provide consequence information on salinity hazard to macroinvertebrates to determine regionally relevant to be undertaken to determine regional guidelines for salinity in Queensland.

Design

Test Method

The salinity tolerance of macroinvertebrates was investigated by measuring the acute response (LC_{50} concentrations) of macroinvertebrates over 72 hours to a standardised marine salt. The method used in this study is a rapid assessment approach aimed at sampling and testing the widest possible range of macroinvertebrates within practical and technical limitations. A rapid assessment technique developed by Kefford *et al*, (2003b) was used to establish the salinity sensitivity of a wide range of taxa. The construction of Species Sensitivity Distributions (SSDs) with this data provides a salinity risk assessment based on a large proportion of taxa including not only common taxa but also rare taxa making it more ecologically relevant to the protection of macroinvertebrate communities.

Study sites and field collection

To investigate the salinity tolerance of macroinvertebrates in Queensland, macroinvertebrates were collected from 11 locations representative of four known biological provinces in Queensland (refer to Figure 1). These biological provinces are known to have statistically different biological communities therefore collection of invertebrates from four of these allows a wide range of taxon to be collected. Macroinvertebrates were sampled and tested at total of 11 sites. Each site was sampled at least on two occasions and up to five occasions for sites in Southeast Queensland. The first visit to a site was regarded as a range finding test with subsequent site visits being more definitive of the 72h LC_{50}. In Southeast Queensland five sites were sampled. In the Queensland Murray Darling three sites were sampled. In the Dry Tropics two sites were sampled.

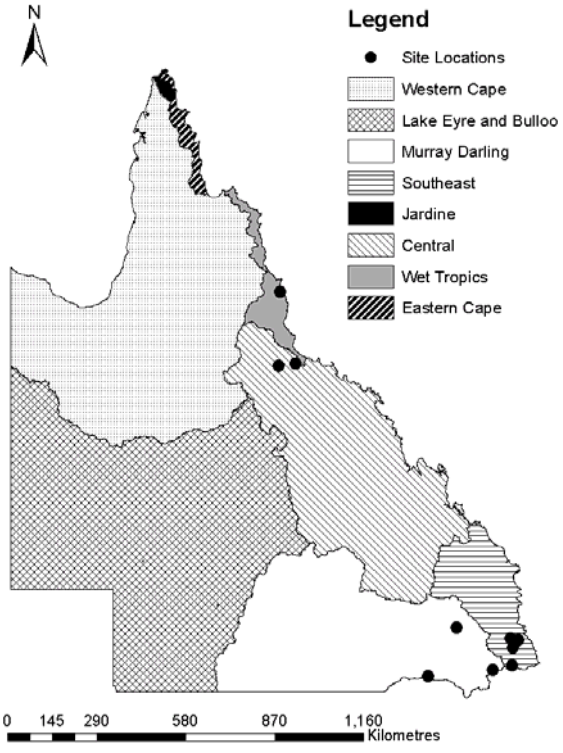

Figure 1 Location of study sites and Queensland biological provinces

Progress

Results

To allow comparison of macroinvertebrate salinity sensitivity between sites and between taxonomic groups, sensitivity data was pooled at the family level. Each data set was then used to either calculate point estimates from a logistic regression or to provide estimates of the 72h LC_{50} values. Sufficient data was available to calculate 72h LC_{50} values for 18 families. Where sufficient data was not available to calculate

point estimates, the 72h LC_{50} was estimated as being greater than the highest treatment where 100% survival was observed. Censored estimates of 72h LC_{50} values were able to be determined for 23 families. These results are shown as a Kaplan Meier survival function in Figure 2. This figure shows the wide range of sensitivities observed.

Differences between taxonomic groups

The results of this study suggest that the acute salinity tolerance of macroinvertebrates communities in Queensland are highly variable between taxonomic groups ranging from highly sensitive (Leptophlebiidae, 72h LC_{50} 6456 μScm^{-1}, Baetidae 72h LC_{50} 8853 μScm^{-1}, and Caenidae LC_{50} 12552 μScm^{-1}) to highly tolerant (Palaemonidae LC_{50} 53283 μScm^{-1}, Parastacidae LC_{50} 45039 μScm^{-1}, and Dytiscidae LC_{50} 37554 μScm^{-1}). These results are comparable to those results found in other parts of the country and around the world.

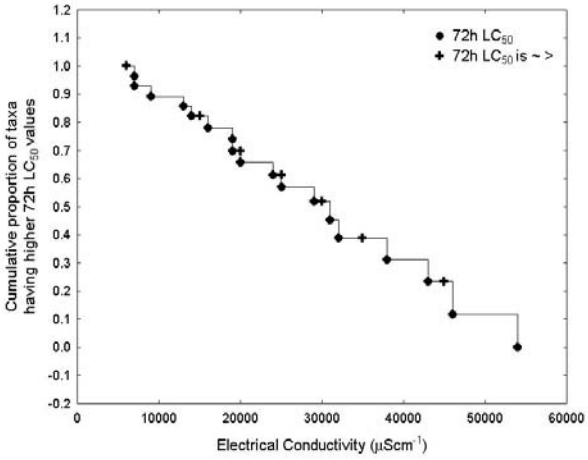

Figure 2 Kaplan Meier survival function of macroinvertebrate families tested

Differences between bio-regions tested

To establish if any statistical differences exist between the bio-regions a multiple sample test was conducted by assigning a score to each survival concentration using Mantel's procedure (Mantel, 1967). *Chi*-square values based on the sums (for each group) of this score were then calculated. Although some differences can be observed visually (refer to Figure 3), no statistically significant differences were found between the regions tested ($Chi^2 = 2.80752$, df = 4, p = 0.42228). This indicates that a similar pattern was observed in the sensitivity of the macroinvertebrates tested in each region. This does not necessarily indicate that macroinvertebrate communities from all areas within Queensland have the same sensitivity but does indicate that of the macroinvertebrates tested in each region, as a group their sensitivity was observed to be similar. Interestingly the five most sensitive taxa were sampled in the tropics from Barney Creek and Harvey Creek and were Leptophlebiidae and Baetidae.

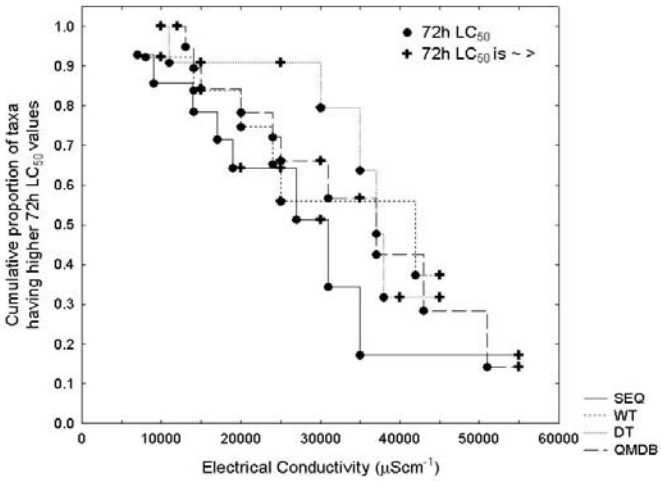

Figure 3 Kaplan Meier survival function of all taxa from Southeast Queensland, Wet Tropics, Dry Tropics, and the Queensland Murray Darling Basin

Conclusion

Probabilistic risk assessment can be used to determine the concentrations of salinity required protect aquatic ecosystems and to assist managers of waterways to establish

control plans to maintain optimal water quality and ecosystem health. To be effective, a salinity risk assessment requires an accurate ecosystem response model that describes how salinity is likely to impact an aquatic ecosystem. This study indicates that macroinvertebrates have a wide range of sensitivities to salinity. This has implications for the selection of taxa sensitivity values with which to derive Species Sensitivity Distribution (SSDs) suitable to protect aquatic ecosystems. Given the wide range of sensitivities observed, the use of all taxa to derive an SSD is likely to provide salinity guidelines that are under protective of many of the most sensitive taxa. The results of this study indicate that at the community level there is no significant difference between the salinity sensitivity of macroinvertebrates in the four bio-regions tested. However, the most sensitive taxa were sampled in the Wet Tropics. Results from this study can be used as a basis for conducting salinity risk assessments and the derivation of salinity guidelines in Queensland.

Planned Work

For all environmental toxicants, including salinity, the dosage duration of exposure and frequency of occurrence all contribute to their ecological impacts. Further research is currently being undertaken to investigate the effect of the rates and frequency of flows on salinity risk. Some systems have naturally higher concentrations of salinity and it is thought that this may increase the tolerance taxa. The effect of pre-exposure on tolerance is being investigated. As salinity is an integrative measure of the total concentration of anions and cations in solution, the toxicity of salinity to freshwater biota is also likely to be affected by the different components that contribute to its measurement as well as their total concentrations. The effect of ionic composition on the toxicity of salinity is also being investigated.

References

1. Hart, B.T., Bailey, P., Edwards, R., Hortle, K., James, K., McMahon, A., Meredith, C. & Swadling, K. 1991, A review of the salt sensitivity of the Australian freshwater biota, *Hydrobiologia*, vol. 210, pp. 105-144.
2. Horrigan *et al*, 2005 Response of stream macroinvertebrates to changes in salinity and the development of a salinity index, *Marine and Freshwater Research*, Vol. 56 No. 6 Pages 825 – 833.
3. James, K.R., Cant, B. & Ryan, T. 2003, Responses of freshwater biota to rising salinity levels and implications for saline water management: a review, *Australian Journal of Botany*, vol. 51, pp. 703-713.
4. Kefford B.J. Papas, P.J., and Nugegoda, D. 2003a, Relative Salinity Tolerance of Macroinvertebrates from the Barwon River, Victoria, Australia. Marine and freshwater Research, vol 54, 755 -765.
5. Kefford, B.J., Paradise, T., Papas, P.J., Fields, E. & Nugegoda, D. 2003b, Assessment of a System to Predict the Loss of Aquatic Biodiversity from Changes in Salinity, Land and Water Australia.
6. Mantel, N. 1967, Ranking procedure for arbitrarily restricted observations. *Biometrics*, 23 65-78.

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