Setting Water Quality Objectives to Ensure the Health of Freshwater Fish

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Equation Free Summary

An important statutory role of EPA is to set objectives that specify environmental quality requirements for protection of beneficial uses of the Victorian environment.

EPA environmental objectives usually take the form of limiting values for specific environmental pollutants, and are often set as absolute limits for individual values of a pollutant, or as a population parameter for the pollutant, e.g. a 75th percentile.

In many instances objectives are derived based on results of studies of biological effects of pollutants on organisms. Such studies determine the concentrations at which organisms show undesirable effects given exposure to the pollutant for a particular duration.

Although derivations of EPA environmental objectives tend to be based on effects of exposure concentrations, they do not make explicit use of the exposure durations. However, it is known that exposure concentrations and durations are jointly very important for determining the severity of biological effects. Methods are needed for calculating objectives that more completely use both pieces of information.
The study group was provided with information in order to investigate methods for deriving environmental objectives for limiting the probability of harmful biological episodes for freshwater fish. Since data provided were from North American studies of a particular pollutant, suspended solids concentrations in freshwater streams, and its effects on a particular animal, fish, this investigation comprises a general proof of concept study.

The information provided was as follows:

1. Data published by Newcombe and Jensen [1] summarised from 80 laboratory studies of biological effects of clean suspended solids on freshwater fish. Included was Newcombe and Jensen’s severity of effects scale (SEV) and regression equations relating SEV to the logarithms of exposure concentrations and durations.

2. Daily time series data of suspended solids concentrations in freshwater streams extracted from the United States Geological Survey (USGS) website.

Using this information the study group made considerable progress with the following aspects:

(i) Development of a better understanding of the Newcombe and Jensen data. In particular, recognition that the dataset would need to be analysed with a greater degree of caution to be able to avoid the various asymmetries in the data. For example, (a) eggs were included with other life stages in models although the SEV scale consists of behavioural responses for part of its range, and (b) some life stages were almost exclusively from particular environment types, suggesting that data sub-setting would be required. Lessons learned may help EPA to make better use of published data for meta studies.

(ii) An alternative, and potentially more reliable, method was investigated for separating the authors’ SEV scale into lethal and sub-lethal biological effects of suspended solids on fish. Our investigation suggested that some of the authors’ sub-lethal SEV levels should be included among the lethal SEV levels. It was also discovered that the form of separation
between lethal and sub-lethal effects may not necessarily be linear with respect to the logarithms of exposure concentration and duration, as the authors had assumed.

(iii) Derivation and limited investigation of two candidate mathematical models for the harmful effects of suspended solids on the gills of fish. Daily suspended solids observations may be input to the models, however the expertise of a fish biologist is now required to validate biological assumptions and to help in establishing ranges for the model constants.

(vi) A graphical investigation was done, in which maximum exposure durations for a range of concentration thresholds in the stream data were overlaid on a scatter plot of the Newcombe and Jensen concentration and duration data and the derived boundary of lethal and sub-lethal effects. This provided a direct visual identification of sections of the times series data in which fish could potentially be harmed by suspended solids.

Reference: