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Meta-analysis in environmental research

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Meta-analysis is becoming popular in environmental research. Key-words search in Web of Science resulted in over 3000 abstracts mentioned “meta-analysis" in combination with “environment”, over 800 studies used “meta-analysis” together with “climate change” or “pollution”. What is meta-analysis? In the most general terms, meta-analysis is one method of research synthesis. In contrast to narrative review, meta-analysis is a set of statistical methods for combining the magnitudes of the outcomes (effect sizes) across different data sets addressing the same research question. Meta-analysis provides a powerful, informative, and unbiased set of tools for summarizing the results of studies on the same topic. An important contribution of meta-analyses can be to identify gaps in the literature where more research is needed, and also to identify areas where the answer is definitive and no new studies of the same type are necessary.

However, the implementation of a meta-analysis requires special care and its value may be greatly reduced by the use of inappropriate techniques. Particularly, the quality of a review must be carefully evaluated when the decision is supposed to be made on the bases of that review. Unfortunately, a large number of environmental researchers understand meta-analysis incorrectly, namely as a simple extraction of all values that are available in articles on a certain topic and summarizing them across the studies by performing conventional statistical analyses. One must clearly understand that meta-analysis neither operates with absolute values as ANOVA or regressions, nor with ranks as a rank-based non-parametric test. A pitfall in analyzing a number of independent studies lies in their methodological diversity. In addition, the study-specific sampling-error variances are almost never identical across studies, violating the underlying assumptions of conventional statistical analysis. Also there is a problem with non-independence of effect sizes within a study, reporting the results of multi-treatments or multi-years, or involving several studied objects.

Once the data are collected, the process of carrying out a meta-analysis typically involves: choosing an appropriate metric for the effect size, calculating the grand-mean effect size across the studies and the means for different categories of explanatory variables (or slopes, were the explanatory variable is continuous), determining the confidence intervals around the means or slopes, and then carrying out statistical tests to determine consistency of the effects within and between categories of studies. A key aspect of modern approaches to meta-analysis is accounting for unequal precision in the magnitude of the effect among studies by weighting each study’s effect size by the inverse of its variance.

The term meta-analysis should be applied only to studies that use well-established statistical procedures, such as appropriate effect-size calculation, weighting and heterogeneity analysis, and statistical models that take into account the distinct hierarchical structure of meta-analytic data.