Environmental Science & Technology

Viewpoint

Cite This: Environ. Sci. Technol. 2018, 52, 8061−8062

pubs.acs.org/est

Improving Data Reporting in Ecotoxicological Studies

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SYNTHESIZING STUDIES

As ecotoxicologists, we are interested in how pollutants affect organisms and whether these effects manifest at higher levels of biological organization. A search for "pollutant" on Web of Science returns over 100 000 results, with an ever-increasing number of studies being published. Most studies in ecotoxicology are species-specific, making it pertinent to explore reported effects across studies and taxa.

Systematic reviews compare individual studies and quantify overall effects by statistical methods such as meta-analyses. Research synthesis has deep roots in medical sciences and human toxicology, which often quantify risk exposure across populations. Ecotoxicological meta-analyses are sparser but on the rise. To ensure that as many studies as possible can be included in research synthesis, we call for researchers to reflect upon data reporting procedures.

INGREDIENTS FOR SUCCESSFUL META-ANALYSIS

Formal meta-analysis requires statistical information when comparing individual studies. For response variables such as pollutant concentrations and response to exposure, this includes mean estimates, sample sizes and variances (e.g., standard deviations). Sample size and variance are needed to calculate precision when combining estimates across studies, as meta-analysis give more weighting to high precision studies (large sample size and smaller variance) than low precision ones. State variables are also essential, and these include information on individuals' age, sex or size, sampling time and pollutant solvent (e.g., lipid and protein content).

Meta-analysis utilizes article information available in all formats and extracts this data from text, figures, tables and Supporting Information. At first glance it may appear that ecotoxicological journals are rich in this information, but surprisingly many studies still lack in transparency and openness.

Let us take two hypothetical studies that investigate whether a particular chemical affects the growth of an organism. The two studies use near-identical experimental designs with treatment and control groups. Study A reports the response to exposure in both treatment and control groups as mean estimates, includes samples sizes and standard errors, and further separates this information between sexes. Study B reports mean estimates and sample size in the two groups, but does not report standard error (or other measures of spread or precision), and mentions that sex was recorded but does not separate this information within treatment and control groups. If we quantify the effect of sex on chemical response across studies by meta-analysis, then only Study A is applicable, as it allows us to calculate study precision and explore the effect of chemical exposure between sexes.

OPEN RESEARCH: CURRENT STATE

A call for improved data transparency in ecological studies is on the rise.[1] As a condition of publication, several scientific journals now require studies to archive data in Dryad Digital Repository or Figshare. Some ecotoxicological studies follow suit,[2,3] but we find there is room for significant improvement. If ecotoxicology emulates data reporting standards set in place by ecologists, then studies would not only increase in quality and transparency, but also become more accessible to a larger audience, including systematic reviewers and risk assessors. In the same way that we can score the quality of ecotoxicological studies using the Klimisch criteria,[4] perhaps we also need criteria for scoring data availability.

PROPOSED REQUIREMENTS FOR ECOTOXICOLOGICAL DATA REPORTING

For meta-analyses to encapsulate as many relevant studies as possible in ecotoxicology, we propose a checklist of requirements for authors when submitting articles to journals such as *Environmental Science & Technology* (Box 1). The most important thing is that authors include statistical information on mean estimates, sample sizes and variances for each variable

Received: June 18, 2018
Published: July 16, 2018

DOI: 10.1021/acs.est.8b03324
Environ. Sci. Technol. 2018, 52, 8061−8062

Box 1. Checklist of study requirements for inclusion in ecotoxicological meta-analyses

1. Does the study describe how all included response and state variables were measured?
2. For each variable measured, are means, sample sizes and variances (e.g., standard deviations) available? Or in a format that allows for independent calculation?
3. Is statistical information provided for each observational group (e.g., treatment vs control, males vs females)?
4. Can statistical information be effectively extracted from the study's main text or Supporting Information?
5. If state variables are described but are not significant or considered important to the study, is this information provided in Supporting Information, an online data set or a data repository?

measured, and separate this for each observational group. We also encourage reviewers and editors to participate in this process by giving direction and advice to authors during the peer-review process.

CHALLENGES ENCOUNTERED: A CASE STUDY

We conducted a meta-analysis on marine mammals to synthesize the maternal transfer of polychlorinated biphenyls (PCBs) and mercury.[5] To calculate an effect size that could be compared across species, we required papers to report mean pollutant concentrations, standard deviations and sample sizes in females and juveniles. Relevant studies reported separate concentrations for each group, as well as juvenile age. Most studies reported means and sample sizes, but many lacked information on standard deviation, or presented data in a way that prevented it from being calculated. Several studies pooled pollutant data for males and females, or pooled data across all age groups, preventing inclusion and restricting us from calculating an effect size which we could compare across all relevant published studies.

A study may measure many variables that may not be statistically significant or directly relevant to their research question(s) or hypotheses. While including such information in the main text may reduce the overall clarity of a study, we encourage researchers to remain transparent. For example, researchers could provide estimates or nonsignificant findings in Supporting Information, or upload a data set to an online repository.

CONCLUSIONS

An ideal meta-analysis would allow for efficient data extraction from all relevant published studies, and exploration of factors that contribute to between-study variation. This goal cannot be realized unless we achieve a completely transparent means of data reporting in ecotoxicology. Better data reporting would enable us to thoroughly test whether studies show idiosyncratic results or reflect a general theory, and whether these effects apply across species or taxa. If researchers take care in measuring and reporting life history estimates and associated variability, then meta-analyses can advance science in new directions by addressing mechanisms of pollutant effect and exposure within and across organisms, and make the "eco" in ecotoxicology much more powerful.

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Notes

The authors declare no competing financial interest.

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DOI: 10.1021/acs.est.8b03324
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