Community Toxicity Testing

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editor

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Foreword

The ASTM Symposium on Community Toxicity Testing, sponsored by Committee D-19 on Water, was held in Colorado Springs, Colorado, on 6–7 May 1985. John Cairns, Jr., Virginia Polytechnic Institute & State University, served as symposium chairman and has edited this publication.

Related ASTM Publications

Validation and Predictability of Laboratory Methods for Assessing the Fate and Effects of Contaminants in Aquatic Ecosystems, STP 865 (1985), 04-865000-16

Aquatic Toxicology and Hazard Assessment (Seventh Symposium), STP 854 (1985), 04-854000-16

Ecological Assessment of Macrophyton: Collection, Use and Meaning of Data, STP 843 (1984), 04-843000-16

Aquatic Toxicology and Hazard Assessment (Sixth Symposium), STP 802 (1983), 04-802000-16

Estimating the Hazard of Chemical Substances to Aquatic Life, STP 657 (1978), 04-657000-16

A Note of Appreciation to Reviewers

The quality of the papers that appear in this publication reflects not only the obvious efforts of the authors but also the unheralded, though essential, work of the reviewers. On behalf of ASTM we acknowledge with appreciation their dedication to high professional standards and their sacrifice of time and effort.

ASTM Committee on Publications

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Overview

The well known Welsh ecologist John Harper [*1*] feels that ecology has tended to be highly descriptive in nature and has thus far made little progress towards reaching maturity as a rigorous experimental and predictive science. In Harper's opinion, one of the reasons for this is that ecology is using conceptual equipment that may be inadequate for the tasks of predicting environmental toxicology and the like. He also feels that, so long as ecological work remains basically descriptive, *these weaknesses are not evident because validation of predictive models etc. is either not done or is not done as it should be* (italics mine). Sloof [*2*] puts it more bluntly: "Around the turn of the century aquatic toxicology was born as an illegitimate child of classical (mammalian) toxicology."

The disparity between the ecological complexity of our most common single-species toxicological test systems and the natural environment and the number of species used for such testing and the number of species in natural systems had bothered me for years as a toothache not quite bad enough to require an immediate visit to the dentist. However, at the end of the 1970s, I was asked to chair the Committee to Review Methods for Ecotoxicology for the Commission on Natural Resources of the Natural Research Council. This ultimately led to the publication of *Testing for Effects of Chemicals on Ecosystems* [*3*]. Discussion of these and other difficulties with the committee members[1] and National Academy of Sciences personnel[2] finally convinced the committee members and me that testing for effects of chemicals on ecosystems was seriously deficient in both available methodology and the ways in which it was used. A key paragraph from the executive summary reads: "The vulnerability of a system to the presence of a chemical will depend on many factors, including the chemical, physical, and

[1] Martin Alexander, Cornell University; Kenneth W. Cummins, then of Oregon State University; W. Thomas Edmonson, University of Washington; Charles R. Goldman, University of California, Davis; John Harte, University of California at Berkeley; Rolf Hartung, University of Michigan; Alan R. Isensee, U.S. Department of Agriculture-SEA; Richard Levins, Harvard School of Public Health; J. Frank McCormick, University of Tennessee; Tony J. Peterle, Ohio State University; and Jerrold H. Zar, Northern Illinois University.

[2] Senior Staff Officer Suellen W. Pirages, Staff Officer Lawrence C. Wallace, and Administrative Assistant Elizabeth G. Panos.

biological properties of the ecosystem, as well as the characteristics and mode of entry of the chemical. Because of these factors, evaluations of impact cannot be made solely on the basis of data generated by single-species tests.'' The strength of such committee reports, which are thoroughly and carefully reviewed, is that they represent a consensus of a small but carefully selected group of representatives of the larger academic community. However, each member of the committee also has individual opinions. I expressed mine further [*4,5*]. Somewhat later, a symposium jointly sponsored by the Ecological Society of America and the Society for Environmental Toxicology and Chemistry (SETAC) was published as *Multispecies Toxicity Testing*, the first book in SETAC's special publication series [*6*]. It is worth noting that this series was initiated by some of the questions raised in *ASTM Special Technical Publication (STP) 657, Estimating the Hazard of Chemical Substances to Aquatic Life* [*7*], and the four books that followed, now known in the profession as the ''Pellston Series'' after the airport near the University of Michigan Biological Station where the symposium that led to *ASTM STP 657* was held.

The ASTM series described above established the theoretical and conceptual basis for more environmentally realistic test systems than were then available. *Multispecies Toxicity Testing* served as the first bridge between the conceptual process and the practical day-to-day application by including the industrial, regulatory, and ecological views of such testing, some illustrative examples of the type of testing possible, a tentative proposal for quality assurance procedures, an extensive discussion of problems of replication (which turned out not to be as troublesome as was originally supposed), and a variety of other topics. The present volume, *Community Toxicity Testing*, takes this process one step further by providing a series of case histories of actual use of more complex test systems together with a discussion of their advantages and disadvantages. This seems to be a logical progression in the evolution of environmentally realistic toxicological test systems before ASTM members begin to consider them as standard methods.

This publication provides illustrative examples of community level tests carried out under a variety of circumstances. It also provides an example of a surrogate for a community level test. Toxicity testing at this particular level of biological organization has a number of advantages, particularly if indigenous organisms are used (as they frequently are):

1. Validation in complex natural systems is less difficult because one will be carrying out the prediction and the validation at more comparable levels of biological organization than is the case when single-species tests are used and the results extrapolated to the response of a complex natural system.
2. Critical response thresholds can be measured directly instead of using extrapolations from single-species tests that are not sufficiently complex or high enough in environmental realism to make direct measurement possible.
3. Community level testing is less expensive than was once thought. When

the field develops further, these tests will probably be only a little more expensive than some of the elaborate single-species tests now in vogue.

4. Because of the larger number of organisms involved, errors caused by the extreme sensitivity or tolerance of a single species to the test material are eliminated or markedly reduced.

5. Although the conventional wisdom is that community level testing is more sensitive than single-species tests because a larger array of species would include some with greater sensitivity, the functional redundancy built into complex systems may well prove this assumption false.

One of the intriguing possibilities accompanying the development of community level toxicity testing is the possibility of avoiding the use of application factors. Application factors either implicitly or explicitly include allowance for a multiplicity of possible errors:

1. Errors in the test itself.
2. Errors involved in extrapolating from one level of biological organization to another (e.g., from single-species to community).
3. Errors involved in extrapolating from test species not indigenous to the ecosystem receiving the toxic materials to those that are resident in this ecosystem.
4. Errors resulting from lack of environmental realism in the test itself.
5. A safety factor similar to that used for bridges, elevators, and the like.

All the items in the above list except the last are a matter of scientific judgment ideally based on probabilistic evidence. The last is a social judgment based on society's perception of the benefits and risks involved. Clearly, it is desirable to separate these to quite distinct activities and, if one can determine the critical response threshold(s) for a particular ecosystem, one can then avoid extrapolation to them, which is certainly highly desirable. The judgment of the degree of safety provided can then be an entirely separate matter. Direct measurements are almost always more precise than extrapolations, particularly when the information base for the extrapolations is inadequate. The disadvantage of this system is that different end points and therefore different thresholds would be used for different ecosystems. Therefore the possibility of the "all-purpose toxicity test" for all ecosystems would be practically nil. However, the standardization of testing on which the all-purpose toxicity test is based is an illusion because the ecosystems where the information must be applied are far from uniform. Therefore the "standardization" provided by the use of a single test for the entire country is most likely an illusion unless it is used in conjunction with an application factor so severe that the worst possible case for the most sensitive ecosystem anywhere in the country is taken into account. If the application factor is based on a worst-possible-case scenario, there is a virtual certainty of overtreatment of wastes being required in a very large number of cases. In this sense, overtreatment means reaching a level or a concentration of the toxicant in question well below the point at which deleterious biological effects can be observed in the ecosystem.

ASTM STP 657 recommended the following sequence in hazard evaluation: (*a*) screening tests, (*b*) predictive tests, (*c*) confirming or validating tests, and (*d*) monitoring. Most of the components of this sequence were covered in *ASTM STP 528* [*8*] and *ASTM STP 607* [*9*] and more recently in the ASTM series on aquatic toxicology. The problem of validating the results of predictive tests was also given serious attention in *Testing for Effects of Chemicals on Ecosystems*. Cairns [*10*] has an extensive discussion on this problem entirely from a conceptual standpoint. Cairns and Cherry [*11*] have extensive hard data on field validation of laboratory results but only at the single-species level of biological organization. *Community Toxicity Testing* provides a substantial amount of information and methodology that can be used in the validation process at the community level of biological organization for which there is little substantive evidence in the professional literature. Thus it will be fulfilling one of the major needs identified in the aforementioned National Research Council volume, *Testing for Effects of Chemicals on Ecosystems*.

Although community level toxicity testing is now being used for practical purposes, it is not the intent of this book to espouse the use of community level testing in all situations or to replace single-species tests that are the best source of information on growth, reproductive success, behavior, and a variety of other end points. On the other hand, since field validation of laboratory predictions is becoming increasingly important and since community level testing offers the possibility of validation by using more comparable or identical end points in complex natural systems, which is not possible for single-species tests, it is now worthy of attention by ASTM members. It is my opinion that, over the next ten years, protocols will develop involving toxicity tests at different levels of biological organization and that this mixture of tests will prove more efficacious in influencing the types of decisions now being made than single-species tests alone.

I am indebted to Darla Donald for the many organizational and editorial duties rendered during the planning of the symposium and the publication of this volume. I gratefully acknowledge the office staff in the University Center for Environmental Studies for the many clerical activities that made this work possible.

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Danny C. Reinke[1]

Evaluation of the Use of Community Similarity Techniques As Applied to Phytoplankton Communities

REFERENCE: Reinke, D. C., "**Evaluation of the Use of Community Similarity Techniques As Applied to Phytoplankton Communities,**" *Community Toxicity Testing, ASTM STP 920,* John Cairns, Jr., Ed., American Society for Testing and Materials, Philadelphia, 1986, pp. 6–17.

ABSTRACT: Seven community similarity indices were compared using a manipulated data set with known changes and an experimental data set of phytoplankton community data. Community similarities were calculated based on (1) strict number of individuals per species and (2) corrected for species size with an estimate of total biomass. The similarity techniques used in this study were heavily affected by the abundant species, and changes in the minor taxa were frequently undetectable. Two of the seven statistics were previously unpublished modifications of the Percent Similarity method of Whittaker [*1*], which were specifically modified to enhance the sensitivity to changes in low frequency species and proportional changes.

While complex numerical techniques are commonplace in ecological literature, there is no generally accepted mathematical definition of community similarity. Ideally community comparison techniques should be sensitive to the loss or gain of a species and to changes in abundance of low and high frequency taxa. They should also detect proportional changes. None of the community similarity techniques used in this study fulfilled all the above requirements completely. All the similarity techniques assigned similarity values based on the presence of individuals. Perfect replication of cell counts for scarce species added little or nothing to the similarity values. At this time, a combination of statistical techniques using both numbers per taxa and an estimate of total biomass per taxa is recommended for the analysis of phytoplankton community data.

KEY WORDS: community similarity indices, phytoplankton, evaluation community species composition

Complex numerical techniques are commonplace in the ecological literature today. However, with the large number of texts and publications on statistical analysis, it is surprising that there are only a few methods for community comparisons and that most of these are not multi-variant techniques. It is not uncommon to find community comparisons which are represented by a bar or line graph of three or four of the common species or tables of raw data. The primary problem encountered when comparing communities is the precise mathematical

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definition of similarity. A definition of similarity may vary considerably depending on the investigator's point of view. Consider the following examples: Community A consisting of 24 species; Community B with the same 24 species as Community A but in ½× abundance; Community C which has 12 species of equal abundance in common with Community A and 12 unique species; Community D which has 23 of the 24 species in common with Community A, but the one species which makes up 95% of the total biomass (or individuals) in this community is unique to Sample D. How similar are Samples A and B—100%, 50%, or some other value? Does Sample C have a 50% similarity to Sample A? Does Sample D have a 95% similarity to Sample A or only 5%?

Communities can differ in several ways. For example, two communities could have the same biomass but have few-to-no species in common. Likewise, two communities could have the same species, but very different biomass values. To assess the effects of sublethal toxicant or other perturbations on a community a statistic should be sensitive to the loss of a species and to changes in abundance of low and high frequency species. It should also detect proportional changes.

This study was designed to evaluate seven community comparison techniques. A small test data set [*2*] was selected to evaluate the various statistical techniques (Table 1). The test data set consisted of 22 phytoplankton species, their size in cubic micrometres, and the number of individuals per millilitre. A second manipulated data set (Table 2) based on the test data set was constructed with known

TABLE 1—*Test data set* [2] *of five natural phytoplankton populations.*

Species No.	Size, μm^3	Individuals/mL for				
		A	B	C	D	E
1	26.0	17.0	13.0	10.0	1 746.0	13.0
2	65 416.0	2.2	1.8	1.4	0.72	0.36
3	75.0	549.0	54.0	11.0	200.0	17.0
4	8.2	549.0	499.0	299.0	150.0	33.0
5	2 200.0	2.2	0.36	0.72	2.8	0.0
6	942.0	0.72	0.18	3.3	1 163.0	3.3
7	14.0	200.0	200.0	100.0	18 007.0	76.0
8	11.0	76.0	22.0	109.0	3 492.0	33.0
9	5.3	100.0	449.0	648.0	3 192.0	119.0
10	0.52	15 362.0	13 766.0	17 556.0	50 274.0	6 883.0
11	628.0	1.1	0.72	0.72	23.0	0.36
12	13.0	65.0	6.7	6.7	200.0	13.0
13	80.0	499.0	2 195.0	1 047.0	499.0	120.0
14	19.0	0.72	0.72	0.72	250.0	0.72
15	25.0	549.0	599.0	499.0	299.0	10.0
16	300.0	0.36	3.3	0.36	87.0	0.36
17	13.0	27.0	22.0	87.0	898.0	100.0
18	1 668.0	1.4	0.48	0.40	37.0	13.0
19	3 730.0	0.025	0.05	0.025	0.30	0.15
20	477.0	0.72	1.4	0.36	22.0	1.8
21	310.0	43.0	98.0	249.0	200.0	1.1
22	35.0	0.0	0.0	0.0	87.0	0.0