Preface: A millennial view of ecology and systematics, and ARES at Age 30

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PREFACE: A Millennial View of Ecology and Systematics, and *ARES* at Age 30

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INTRODUCTION

The convention of a temporal millennium reflects, among other matters, the historical decision of the West to use a decimal arithmetic. Arbitrary and artificial as observance of a millennial ending may be, it nevertheless provides an occasion for celebrations, as well as invitations for examining the past. I am pleased to respond to an invitation to discuss some of our better efforts in past time, although social and political incompetence in the second Christian millennium also invites comment. Selected fragments of the history of biology, especially of ecology and systematics, are my focus; ultimately I aim at a paternal assessment of this *Annual Review*.

SYSTEMATICS AND ECOLOGY

Achievements in systematics and ecology occurred late in the second Christian millennium. Earlier developments were indifferent, which is true for much early science. For most of the past thousand years in the West (even currently in some intellectual deserts) the supernatural, magic, and superstition were more important than science (6, 17). Significantly, theology was long considered to be a fundamental part of science, with all other sciences generally subordinate to it (17). Nevertheless, theologians as well as scientists had difficulties as a result of, or were punished for, their work in the millennium, because novel points of view or new knowledge could contradict received wisdom and easy answers or would threaten vested interests. That modern science actually developed in the last millennium is one of the triumphs of human understanding (14). Other branches of science had some early successes, but biology was slow to develop, perhaps because it gradually included study of humans. For whatever reasons, biology was "a catastrophe" (20) and poorly pursued through most of those thousand years. We really have had only 200 years of scientific biology, or, for that matter, science in general (18). In medicine, an applied field in which the need for information, as distinguished from opinion, was of immediate practical importance, some practitioners were

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still bleeding people for a variety of ailments as late as the nineteenth century. Perversely, some patients actually survived and, the placebo effect being unrecognized, supported the status quo.

The development of systematics required accumulation of a great deal of descriptive information about organisms of the world. Although that remains critical, the discipline could barely define itself, much less flourish, before an evolutionary biology existed. Earlier efforts at systematics were on record since at least the time of Aristotle (1), one of whose contributions was to show how difficult such study was going to be for most of the succeeding two millennia. Later, at the end of the eighteenth century, an evolutionary view of life gradually became possible through the work of Lamarck (e.g. 13). Then, after another 50 years, systematics was fundamentally reorganized by the Darwin-Wallace hypothesis of evolution by natural selection (2). The hypothesis, the Big Bang of theoretical biology, reorganized the science and made an informed systematics a necessity (e.g. 12). Such reorganization also required a change in social and political thinking, a change not yet complete at this writing (e.g. 4).

With a workable theory of evolution, the paleontologic record became understandable, and systematics gradually was transformed into a discipline with promise of becoming a science. Its continued development, however, depended on the incorporation of genetics, which required another 50 to 60 years (3, 14). In the interim, systematists split into a number of irreconcilable cliques seemingly dedicated to producing irreproducible phylogenies, programs that persisted into the twentieth century. Later, toward mid-century, Hennig (7) and Sokal & Sneath (21) showed that reproducible phylogenies could be made by using either of two, quite different, assumptions. Systematics, no longer an idiosyncratic art, was largely restructured (12), and its current condition, augmented by molecular biology (8) and electronic data processing, is more robust than at any previous time. It is orders of magnitude more complex and demanding a field of study than anyone could have imagined at the opening of the past century.

Ecology, only the faint outlines of which are detectable in ancient time (22), has no 2000-year, or even millennial, history to live down. Ecology is more complicated, or has to consider more variables, than other sciences. At least for this reason hard-core ecology developed notably late, and we were into the twentieth century before ecologists could identify their concern as scientific natural history. British ecologists formed a scientific society in 1912 and Americans in 1915. But it took another five years before the Americans announced, "...the future is in our own hands" (16). The subsequent proliferation of the formal literature of ecology has been astounding, as your library stacks attest.

Evolutionary biology was naturally introduced into ecology through the subfield of population biology, and today the whole of ecology presents an evolutionary face. Thus, the science has been good. The social ramifications of ecologic thought nevertheless (or perhaps therefore) have generated persistent political resistance. This almost wholly reflects social and political irresponsibility; the general public has been slow to comprehend the significance of conclusions framed within probability theory, conclusions that reflect the inordinately complex and multivariate nature of ecological processes (and are responsible for the canard that ecologists cannot communicate). It is nevertheless clear that ecology, to its everlasting credit, will almost certainly continue to show that easy answers, and those based upon greed, are not answers at all.

THE REVIEW

Significance of the Series

The *Annual Review of Ecology and Systematics* (*ARES*) has been with us for the last third of the last century, precisely the period in which the most important developments in ecology and systematics have occurred. Ecology and systematics are today at levels of sophistication and substantive accomplishment that were not anticipated when *ARES* was conceived in 1968. It therefore seems fair to ask whether or to what extent *ARES* has participated in this development. I must note that, as the original Editor of *ARES*, I have a conflict of interest in making this assessment.

The role assumed by *ARES* from the beginning has been largely reactive. A review, by definition, reacts, or is responsible, to the knowledge within the boundaries of its concern, tracking developments but not causing them. Perceptive tracking alone could have kept *ARES* acceptably current. But, in addition, *ARES* has always included, directly or implicitly, critical commentary resulting from input of advisory committees by what they recommend, of editors by what they include, and, ultimately, of authors by what they write. We also hoped to direct interest to those fields of study in which potential for advance seemed likely. And, because the advancement of science is largely the purview of working scientists who publish in research journals, members of that population were solicited to do the reviews.

Responsive tracking of the field and knitting up threads of independent lines of research by competent members of the guild are ample evidence of good intentions. But what we really wish to know is whether such intentions have been realized—how well has the review done its job? Aside from Volume 1, critical reviewers have not said a lot about *ARES*, and mostly they have noted that it covers an enormous field of study, worrying that specialists—a grasslands botanist, an arachnologist, a zooplankton ecologist—might find nothing of specialty interest in a given volume of *ARES*. The concern is real enough, and there is not much of an explanatory response to it. I note, however, that this problem accompanies the territory: even specialty journals regularly cover phenomena or taxa peripheral to a reader's interest or competence.

Fortunately, and independent of opinion, some quantitative measures of the value of at least part of what has appeared in *ARES* actually exist, because the Institute for Scientific Information (ISI) produces the *Science Citation Index* (SCI; e.g. 19), an annual catalog over a great range of sciences that notes which articles are cited, who cited them, and where and when they were cited. Most published papers are never cited, so one that is can be taken to be a paper of above-average quality, and its long-term citation record probably is an index to the level of that quality. These assumptions are supported by a recent analysis (5), which shows, among other matters, that authors tend to cite papers that enhance their own, thus usually selecting papers of high quality. Beyond this, ISI provides some descriptive statistics: review articles tend to be cited more frequently than articles reporting new research; the average cited item is cited about two times per year, and the average cited author about eight times. Papers three to six years old are cited most frequently, and in most years about half the citations are seven years old or less. After ten years an article has a low probability of being cited—papers 25 years old receive three quarters of one per cent of all citations, and those 30 years old one half of one per cent.

Under such a strict regime of selection, the citation record of a paper is clearly a meaningful measure of its quality and utility. I examined the SCI for 1998 (19) to see if any of the 15 reviews in Volume 1 of *ARES* were cited after 28 years and found that nearly half of them had at least one citation. Since we know that the probability of finding an unspecified 30-year-old article out of a set of 200 citations chosen at random is 0.005, the probability of finding citations to seven 28-year-old articles from a specific volume of one of the hundreds of journals examined by ISI is certainly represented by a smaller number.

Articles from other volumes of *ARES* also show substantial lifespans, and for most volumes of *ARES*, the average half-lives of cited articles exceed ten years. Long half-lives are characteristic of review articles; research reports have lesser citation lifespans. As an example, authors of articles appearing in *ARES* for 1998 deal mostly with the research literature, and they cite papers with half-lives of 7.1 years.

ARES can be accessed on the World Wide Web, so it has a record of its utility there (9). JSTOR is a nonprofit organization offering electronic access to a wide

TABLE 1 Most frequently accessed articles from *ARES* (JSTOR ranking by total viewings plus total printings as of June 28, 1999)

1. Human Population Growth and Global Land-Use/Cover Change, WL, Meyer, BL Turner II; vol. 23, 1992.
2. Global Change and Coral Reef Ecosystems, SV Smith, RW Buddemeier; vol. 23, 1992.
3. Landscape Ecology: The Effect of Pattern on Process, MG Turner; vol. 20, 1989.
4. Global Environmental Change: An Introduction, PM Vitousek; vol. 23, 1992.
5. Front Matter and Preface, the Editors and the Editorial Committee; vol. 1, 1970.
6. The Role of Disturbance in Natural Communities, WP Sousa; vol. 15, 1984.
7. Global Change and Freshwater Ecosystems, SR Carpenter, SG Fisher, NB Grimm, JF Kitchell; vol. 23, 1992.
8. Biological Invasions by Exotic Grasses, the Grass/Fire Cycle, and Global Change, CM D'Antonio, PM Vitousek; vol. 23, 1992.
9. Multivariate Analysis in Ecology and Systematics: Panacea or Pandora's Box?, FC James, CE McCulloch; vol. 21, 1990.
10. Population Viability Analysis, MS Boyce; vol. 23, 1992.

variety of scholarly journals; it has included *ARES* since January 1998. From Volumes 1 through 24, 527 articles from *ARES* have been stored and are available for viewing and/or printing. Of these, 98.1% had been viewed, and 85.2% printed, as of early summer 1999. At that time, JSTOR actually offered a total of 21,294 articles from *ARES* and four additional journals in ecology; of these, 65.8% had been viewed and 41.2% had been printed. The differences in usage of articles in *ARES* and the larger sample are probably owing to the review function of *ARES*.

The top ten articles in *ARES* (see Table 1), based on viewed plus printed scores, include six from 1992, and one each from 1970, 1984, 1989, and 1990. The 25 articles most frequently requested for viewing or printing refer to 11 different volumes.

Additional information on the point of concern can be found in the *Journal Citation Report* (*JCR;*11), also published annually by ISI. The *JCR* computes an "impact factor" for journals (as well as the "publication half-life" noted earlier). The impact factor is a number indicating a ratio of the number of citations in the scientific literature of articles from a journal divided by the number of citable items published in that journal, over a two-year period. The impact factor is generally taken to represent the significance or clout of a publication. ISI notes that the impact factor tends to discount the advantages of a large journal over smaller ones, of frequently published journals over those of lesser frequency, and of older versus newer journals.

In ISI's category "ecology," *ARES* began recording high impact factor scores in the mid-1970s and was ranked first for a long time. Scores have remained high, and *ARES* has regularly been among the top four journals in the world in ISI's ecological impact factor. The other journals of the top four in recent years are *Trends in Ecology and Evolution* (*TREE*), *Advances in Ecological Research*, *Evolution*, *Wildlife Monographs*, and *Ecological Monographs*. The last three are research journals; the others are reviews but differ from *ARES* by covering only the field of ecology. *Advances* is a review annual, featuring about four long reviews per volume. *TREE* is a monthly review. The schedule permits *TREE* to secure articles of some immediacy on hot research areas and to be more proactive than other journals. One possible result of this is that *TREE* currently ranks first in impact factor in ISI's ecology category. Another result can be seen in the citation-life of articles, the average for which in *TREE* runs from three to four years; those in *Advances*, *Monographs*, and *ARES* are from eight to more than ten years. The journals are topically distinct, their preferred numbers and lengths of articles differ, and their temporal appearance varies; they provide broadly intersecting but generally different services to the scientific community.

If we examine journals that have scored in the top ten in *JCR* impact factor in ISI's ecology category in recent years, some 15 publications are included. The journals show reasonably broad niche diversification but are fairly readily identifiable as ecological: *TREE*, *Advances in Ecological Research*, *Ecology*, *Ecological Monographs*, *Journal of Animal Ecology*, *Evolutionary Ecology*, *Journal of Ecology*, *Molecular Ecology*, *Advances in Microbial Ecology*, *Ecological Applications*, and *Microbial Ecology*. The remaining four are broader in topical content: *Evolution*, *Wildlife Monographs*, *The American Naturalist*, and *ARES*. None other than

ARES regularly addresses systematics, although *The American Naturalist* and *Evolution* occasionally do so. To the point of this assessment, judging by citation-life of articles and impact factor scores, *ARES* stands in good company and clearly has played a significant role in the recent development of ecology. The assessment of course cannot be applied to systematics.

Current Developments

The short review emphasized by *TREE* has recently become important in *Science*, a weekly journal that now includes commentaries on research papers, each being a mini-review of a part of the scientific endeavor. Other journals also include reviews as regular items—*The Auk*, a specialized research journal in ornithology, already features at least one review in each quarterly number. And the current reorganization of publications of the Ecological Society of America actually includes plans for an American *TREE*. The expansion of knowledge in all biological specialties generates need for more reviews on ever more tightly focused information subsets. Users are now required to spend ever more time on journals in their specialties. That requirement must dilute readership for journals of heterogeneous scope.

Because impact factor scores have achieved widespread attention and significance, the way in which the scores are computed is obviously also of significance. Currently, the computation of factor scores for "ecological" journals is inadequate, because for *ARES, Evolution,* and *The American Naturalist,* to consider three publications in the ecological top ten, undefined fields (systematics, behavior, genetics, non-ecologic theory) are included in ISI's statistical manipulations for the defined field (ecology). What this can mean to impact factor scores can be judged by some history of *ARES*. In the beginning, pages for systematics in *ARES* ran at less than 30% of the total. At that time, annual impact factor scores for *ARES* in ISI's ecology were the highest. More recently, systematics has secured about half the pages in *ARES*, reflecting the increase of topical range in, as well as the remarkable quality of, recent developments in systematics. Relative to the numbers in ecology, there are fewer systematists, fewer journals devoted to systematics, and fewer citations of articles in systematics; as a consequence, *ARES* now ranks third in annual "ecological" impact factor score. Were ISI to remove non-ecological articles in computing ecological impact factor scores, a more realistic ranking of journals publishing ecological studies would result. If such a move were made, working out impact factor scores in systematics would then become a responsible endeavor for ISI.

The Future

ISI's impact factor scores lead to annual bragging rights, and publications ranking high now include their ranks in advertising circulars. This recognizes the meeting of the academy with the marketplace, which is as it should be—it surely cannot be avoided. This is one reason I hope ISI can provide some intelligence in the allocation of articles to its category of ecology. Additionally, bragging rights aside, users or potential users deserve to be informed, and current practice by ISI in treating all articles in *ARES* as ecological is misleading.

Some readers may remember that Charles Michener and I went to some lengths to ensure that *ARES* would concern both ecology and systematics. This was not because the two disciplines are interchangeable but because they are mutually supportive—the systematic (evolutionary) play occurs in the ecologic theater (10). I think the relationship is worth emphasizing even now, and it is good to see that the disciplines (which ought to be separated by ISI) are still steadily united by *ARES*.

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