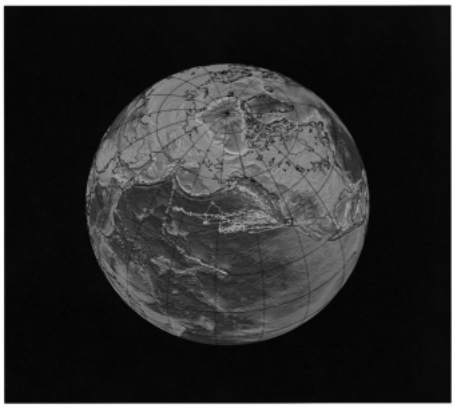

CONTRIBUTIONS

Commentary

How to Manage Data Badly (Part 2)

Preamble. Although managing data badly is difficult, given new developments in hardware and software and many sound recommendations for how to manage ecological data (ESA 1995, NRC 1995), it is still being done. In the spirit of Howard Wainer's (1984) article in *The American Statistician* on "How to Display Data Badly," Part 1 of this essay gave 10 rules for those database managers and administrators who are determined to manage their data badly. Part 2 gives some tips for scientists with the same objective.

Techniques for scientists

Rule 11. Hoard your data

The best technique for scientists to use in mismanaging data is simply to hoard the data. One fringe benefit of hoarding is that it eliminates the need to write those annoying metadata files that are apparently so useful to people trying to steal your results. The argument that citizens have a right to data that were collected using the citizens' money, sounds like a Utopia where the citizens might be smart enough to interpret the data correctly. Untold damage can result when people who cannot conceivably understand your data analyze them on their own and draw their own conclusions. Resolute data hoarders can carry their data to the grave. According to a report by the Ecological Society of America (ESA 1995), there are ". . . numerous incidences of researchers ending their careers without the resources to make provision for the curation and maintenance of their long-term data sets." Data sharing in many collaborative efforts is inhibited by ". . . unclear responsibilities, conflicting goals, misunderstandings, and outright rivalries" (NRC 1995).

Rule 12. It is better to get than to manage

Do not be misled by those who have tried to encourage slovenliness in scientists by proposing that they be rewarded for publishing high-quality data sets in the same way they are rewarded for publishing scientific papers. This could lead to the specter of a publishing person perishing. Do not waste time managing data that have already been used in a journal article. Axiom: It is always better to collect new data than to spend time managing existing data.

Corollary: Get into the field to collect new data before thinking about how those new data will be managed. After-the-fact databases create the same healthy tension as after-the-fact experimental designs.

Rule 13. Avoid tedium

How can you counter the tired cliché that because data are expensive to collect they are therefore worth saving? Simple: make them not worth saving. These next rules show two paths to follow, both of which allow you to avoid tedious work: (1) Do not verify the accuracy of your data; and (2) avoid writing metadata (information about data); instead, let the assumptions, processing steps, and quality of the data remain a mystery to future users.

Amusing things can result when data are not quality assured. For example, who would suspect that a field researcher could make the simple error of swapping latitude with longitude? Let those GIS people (Rule 8) try to lie about why they plotted a station from the east coast of the U. S. on the Greenland ice cap! Nothing is more effective in driving away users than an error-ridden database. Celko (1994) reminds us of opportunities to corrupt good data in the article "When good data goes [sic, but nice illustration of Rule 6] bad." Bad data are so powerful they can make the most elegant database system useless.

The only flawless database is one that has never been used for data analyses. Inspiration for analyses of bad data may be gained from the work of Huff (1954), who gave helpful advice in his book *How to Lie with Statistics*. But remember that although statisticians may be willing to belong to ". . . that group of people whose aim in life is to be wrong 5%

of the time" (Kempthorne and Doerfler 1969), people responsible for data can rarely afford to be this careless.

Rule 14. Avoid boredom

Although metadata are essential for sharing the data needed to understand and deal with the multidisciplinary complexities of natural systems (Michener 1998, Vogel 1998), they are boring to prepare. Just because database management software is fastidious about keeping track of everything it ever did, does not mean that people have to be so inclined. Perhaps you can pick an excuse from Vogel's (1998) account of "Why scientists don't write metadata" when submitting to the Global Change Master Directory. Omitting key metadata can be a foolproof way of rendering a data set useless, as shown by one study of benthic invertebrate communities, where the authors neglected to state what size of sieve was used. Codes in the data set that are not defined in the metadata can be really annoying to users. Another study, conducted by a group of "partners" measuring estuarine health, adopted the popular "Little Red Hen Syndrome," in which everyone wanted to analyze the data and write papers, but no one wanted to document the data. This study had to hire a metadata social worker to get the job done.

Rule 15. Integrity in integration

Apples and oranges can be mixed if they are first converted to juice. Database managers sometimes do this by squeezing all sorts of data into generic database models. As Katha Upanishad says, quoted in Martin (1976), "Who sees the variety and not the unity, wanders on from death to death." (This sounds like some data systems we know.) Scientists can benefit from this technique when they integrate data from different sources of mixed methods and unknown quality. If they avoid writing metadata (Rule 14), who will know the difference? Rotten apples and oranges can be integrated in a compost pile; rotten garbage in, fertile compost out. Further, we can frustrate the practitioners of the statistical art of meta-analysis when they try to rip out of our research articles the vital organs of sample size, mean, and variance. Apparently, we are already doing a good job at keeping these things out of our papers (Gurevitch and Hedges 1993).

You can use a database to integrate data that are too different to be integrated by any other means. This lets you solve an experimental design problem (such as different sampling methods) with a technical solution, as exemplified by one national study of fish pathologies. In another case, a report on watersheds made heavy use of Rule 13 (avoid quality assurance) to integrate data from widely different sources, and tried to make it palatable by use of Rule 8 (show the data on GIS maps). What they might have done is to include another GIS map showing the spatial distribution of data density and sample variance.

Rule 16. There is not much to learn about managing data

Spreadsheet software is so wonderfully versatile that you can use it for everything. A spreadsheet is the perfect tool to use for storing data. You can enter data without being slowed down by meddlesome error-checking routines; within a single column, you can mix units or methods or data formats and enter text into numeric fields; you can calculate new columns from existing columns and easily increase the number of significant digits with the push of a button; or you can add extensive footnotes to individual cells so that no cell can be interpreted in the same way as other cells in the column.

Given the power of spreadsheets, why invest in data managers and their arcane software? Samuel Johnson, in his 1755 preface to the *Dictionary of the English Language*, described the proper attitude toward data managers (lexicographers) as people ". . . whom mankind have considered, not as the pupil, but the slave of science, doomed only to remove rubbish and clear obstructions from the paths, through which Learning and Genius press forward to conquest and glory, without bestowing a smile on the humble drudge that facilitates their progress." An NRC (1995) committee concluded that ". . . there is a critical need to educate scientists about data management principles and to foster improved working relationships between scientists and information management professionals."

Conclusions: reaping what you have sown

Research projects that can bring database managers, scientists, and administrators together and apply several of the above techniques simultaneously will enjoy widespread recognition. The National Research Council (NRC 1995) reviewed the data management practices of six environmental research programs and condensed their findings into 18 recommendations and "Ten keys to success." The latter included such homilies as "Be practical," "Use appropriate information technology," and "Account for human behavior and motivation." Of course, as we all know from Martin's (1976) work almost 20 years earlier, few people would ever actually follow such advice. Alas, these are in effect "Ten keys to failure, or why nobody ever learns anything from lessons-learned reports." Recognition can also be earned from the popular media. One method (failure to share data effectively) was implicated in the very newsworthy nuclear accident at Three Mile Island (Gordon 1997). Although most groups cannot hope to achieve such spectacular results, assiduous application of the 16 rules in this paper will be sure to lead to some form of debased data.

In fairness to Wainer (1984) and his bad graphics, we must admit that data that survive being badly managed can then be badly displayed, thereby achieving the best from both worlds. Or, if displayed cleverly, the wretched data can be offered the comfort of appearing believable. We have seen that many organizations are already making wide use of the 16 rules (and others) to diminish the quality and usefulness of their data. Well done! However, we must never let down our guard against the many

research groups who knowingly violate these principles. New developments keep creeping in, making it increasingly difficult to claim that technology limits good data management. And just when you thought you had buried some data for good, along come "data rescue" missions to pull out the corpses and reincarnate them into new databases. We must be strong, ignore those National Research Council recommendations, and keep those horror stories coming!

Epilogue

Although this essay is written in an ironic style, the topic is serious and deserves more attention from administrators, scientists, and database managers, working together. The importance of managing data well increases as the volume and types of data increase and as more information is needed to manage natural resources in an increasingly complex society. Understanding the interactions between humans and the environment requires good-quality long-term data collected at different spatial scales from many scientific disciplines (ESA 1995). Because no single group can collect all the data needed for the necessary analyses and models, we must learn to share data effectively.

The 16 rules given here illustrate only a few of the areas where many of us go wrong, but they point to techniques we could use to do a better job. Three basic things are needed. (1) Place good quality data sets where they can be obtained. (2) Make entries in data directories so data sets can be found. (3) Write metadata files so data sets can be understood. Of course, much more can be done and is often appropriate, but the data system must be sustainable. Administrators and scientists need to make long-term commitments to manage data well, to invest adequate equipment and people, and to better understand data management. Data management people need to understand the science behind the data, to listen to what the administrators and scientists need, to use common standards (and common sense), and to build data systems at the appropriate scale. All three groups would benefit from careful study of the recommendations in the NRC (1995) and ESA (1995) reports.

Too many science data sets collected 20 years ago, back in the time of James Martin's book, are not as useful to us today as they could be because the three basic things listed above were not consistently done well. Even today, too many data sets being created are less than what they could be because those three things are not consistently done well. Will there be a need for a future James Martin or NRC committee to remind us again, 20 years hence?

Acknowledgments

I am grateful to numerous colleagues for supplying the inspirational examples because I swear that I have never used any of the 16 rules in my own work. Nor do the rules reflect the views of my employer, the U.S. Environmental Protection Agency, and no official endorsement should be inferred. I thank Ken Rahn for comments on the text.

Literature cited

Celko, J. 1994. When good data goes bad. American Programmer **7**:17.

ESA (Ecological Society of America). 1995. Report of the Ecological Society of America Committee on the future of long-term ecological data. <http://esa.sdsc.edu/FLED/ FLED.html>.

Gordon, M. D. 1997. It's 10 A.M. Do you know where your documents are? The nature and scope of information retrieval problems in business. Information Processing and Management **33**:107–122.

Gurevitch, L., and L. V. Hedges. 1993. Meta-analysis: combining the results of independent experiments. Pages 378–398 *in* S. M. Scheiner and J. Gurevitch, editors. Design and analysis of ecological experiments. Chapman and Hall, New York, New York, USA.

Huff, D. 1954. How to lie with statistics. W. W. Norton, New York, New York, USA.

Kempthorne, O., and T. E. Doerfler. 1969. The behavior of some significance tests under experimental randomization. Biometrika **56**:231–248.

Martin, J. 1976. Principles of database management. Prentice-Hall, Englewood Cliffs, New Jersey, USA.

Michener, W. K. 1998. Ecological metadata. *In* W. K. Michener, J. H. Porter, and S. G. Stafford, editors. Data and information management in the ecological sciences: a resource guide. LTER Network Office, University of New Mexico, Albuquerque, New Mexico, USA.

NRC (National Research Council). 1995. Finding the forest in the trees: the challenge of combining diverse environmental data. National Academy Press, Washington, D.C., USA.

Vogel, R. L. 1998. Why scientists have not been writing metadata. EOS, Transactions, American Geophysical Union **79**(31): 373, 380.

Wainer, H. 1984. How to display data badly. American Statistician **38**:137–147.

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On the Definitions of Scale

Recently, it was suggested that the traditional cartographic definition of scale, the ratio of map distance to earth surface distance, should be adopted as the sole definition (Silbernagle 1997). This was in response to the well-known inconsistency between geographic and ecological notions of scale. In describing the same spatial data, a geographer could refer to it as small scale whereas an ecologist could refer to it as large scale. The geographer is describing scale in reference to the ratio of map distance to earth distance. The ecologist is often describing scale in reference to the extent of the phenomenon studied or the spatial resolution that was incorporated in the study. For the ecologist, perhaps the adjectives fine or coarse are more appropriate than large or small, but beyond these semantic issues, there is a fundamental difference between the cartographer's and the ecologist's notion of scale. A contrasting opinion to Silbernagle (1997), on how to treat the terminology of scale, is to adopt pluralistic definitions that describe distinct aspects of the concept (e.g., Peterson and Parker 1999). In this paper we discuss various definitions of scale in the ecological context and explain why multiple meanings of the scale need to be recognized.

Historically, the cartographic definition of scale has been the most widely used. Cartographic scale is necessary for developing maps that describe real-world locations and distances between locations in a useful manner. A small-scale map would have a small map size relative to the earth area being depicted. (For the same size map, a country map is of a larger scale than a continental map.) This usage of the term scale has been sufficient for problems such as map making. Ecology, though, is more interested in describing patterns, understanding the processes responsible for these patterns, and exploring the ecological effect of the patterns. For ecology, knowing the cartographic scale is only one piece of the scale puzzle.

Why should we prefer a variety of scale definitions? What is missing from the cartographic definition of scale? In the engineering sciences, scale effects are those that result from size differences between a model and the real system. Even though a miniature model of a building made of wood is structurally sound, it is not necessarily appropriate to infer that the same process of maintaining structural stability could hold for a full-sized building made of wood. In ecology this concept is relevant because the majority of ecological studies occur for only a short amount of time and at a small plot scale. Understanding ecological scale effects is necessary to incorporate this localized information with processes occurring at regional, continental, and global scales.

These are two fundamentally distinct aspects of scale: accurately comparing a model to the real world and accurately translating a process between different physical or spatial sizes. Ecology, which includes the study of both pattern and process, needs to develop a synthetic understanding of scale. This need has led to the generation of a variety of definitions that partition scale into its various components. The increase in definitions assists the growth of ecology by articulating the different contexts in which scale can be important.

Geographic scale (see Lam and Quattrochi 1992) is defined as the scope of a particular map, which is equivalent to the term "extent" used in landscape ecology. The definition is germane to ecology because it defines the spatial environment within which a question is framed. As the extent of a study increases, the characterization of the environment changes. For example, examinations of the dynamics of nitrogen processing at a regional extent must include the examination of climatic patterns, geologic patterns, and other processes occurring over these large areas. This endeavor is in contrast to the examination of nitrogen dynamics within a cubic meter of soil, which would only consider localized phenomena of soil water content, organic material complexity, and microbial activities. Thus, a change in the extent (scale) for a question changes the relevance of specific environmental variables. Hierarchy theory, in particular, has identified the importance of this in describing patterns and understanding mechanisms in ecology (Allen and Starr 1982, O'Neill et al. 1986, Wu, *in press*).

Operational scale (see Lam and Quattrochi 1992) is defined as the spatial extent of the operation of a particular phenomenon. This is related, although not equivalent, to the geographic concept of the minimal mapping unit (for vector maps), the smallest size of object which is represented by the map, or grain size (for raster maps), the size of the pixels within which heterogeneity is not described. Operational scale is relevant to ecology because it relates to the process that is being addressed by a particular question.

Many of the classical ecological studies have examined questions for which the geographic and operational scales are the same. The Hubbard Brook ecosystem deforestation study is an example (Likens and Bormann 1995). The extent of the ecosystem was defined by the catchment boundary; this ecosystem was also the resolution of all processes; estimates of inputs and exports were made for the entire ecosystem only. Studies such as these, where the geographic and operational scales are equal, do not force an explicit recognition of scale phenomena. The recent development of a spatially explicit orientation in ecology, however, has led to a divergence between the geographic and operational scales. This divergence does necessitate an explicit consideration of scale. If the functioning of multiple watersheds nested within a hydrologic unit is considered, the role of scale should be examined.

Another definition of scale that incorporates the disparity between geographic and operational scale is relative scale. This is defined as the relationship between the smallest distinguishable unit, grain size, and the extent of the map (Meentemeyer 1989). This definition expresses scale as a

ratio, in this regard similar to the cartographic definition. Based on this definition of scale, comparisons of scale between studies are possible even if a large absolute difference in the geographic scale exists. An ecological study that examines a single biofilm could be coarser in relative scale than a global study that segregates the biosphere into several distinct units. Specifically, the relationship between the processes under study relative to the environment in which this process exists defines the relative scale.

Two important developments, the theory and application of fractal geometry, and geographic information systems (GIS), have shown the necessity of understanding additional aspects of scale aside from its cartographic notion. These two factors contributed to the realization that the degree of resolution at which a pattern is described influences the analysis of that pattern. One of the classical questions in geography asks, "What is the length of a coastline?" The answer depends on the length of the ruler used to measure it (Mandelbrot 1982). A shorter ruler measures the coastline variability that is smoothed over when a longer ruler is used; thus a smaller ruler results in a longer measure of the coastline than a larger ruler. This phenomenon is not captured by the cartographic definition of scale, but the definition of scale as grain size and extent addresses this issue.

Computing power, which has allowed for the rapid development of GIS, has also increased the importance of understanding scale beyond the cartographic definition. GIS software reduces the restrictions of the cartographic scale. Once a map is entered into a GIS, alterations of the cartographic scale are trivial. Zooming functions can instantaneously change the relationship between the map distance and real world distance. However, other aspects of scale, such as geographic, operational, and relative scale, are not easily adjusted. These aspects of scale depend on the underlying data that cannot be altered without collecting more data or resampling the current data. In principle, downscaling (generating patterns at a resolution below the grain of the data without auxiliary information) is inappropriate, whereas upscaling (aggregating fine-scale information to a coarser scale) should be attainable, although this still represents a challenge in ecology (Wu 1999). How should one aggregate or extrapolate fine-scale information to a coarse scale? One of the problems frequently encountered in translating information across scales is the modifiable areal unit problem (Jelinsky and Wu 1996). To deal with this problem, the definition of scale as grain and extent is imperative.

Clearly, scale has several ecologically meaningful aspects that are not contained in the cartographic definition. We agree with many ecologists that when describing scale, we should be explicit about which aspects are being addressed; it is neither necessary nor possible to restrict the use of scale to its cartographic connotation. Withers and Meentemeyer (1999) reasonably proposed that scale only be used with a context-specific modifier. As ecology progresses, we believe that definitions pertinent to ecological pattern and process will be retained, while others may be relegated to specific instances. Indeed, a quick examination of the literature in different fields such as engineering, physics, meteorology, biology, social sciences, and even geosciences reveals that scientists have long adopted multiple definitions of scale in their studies. Science is dynamic; so is its terminology.

Literature cited

Allen, T. F. H., and T. B. Starr. 1982. Hierarchy: perspectives for ecological complexity. University of Chicago Press, Chicago, Illinois, USA.

Jelinski, D. E., and J. Wu. 1996. The modifiable areal unit problem and implications for landscape ecology. Landscape Ecology **11**:129-140.

Lam, N. S. N., and D. A. Quattrochi. 1992. On the issues of scale, resolution, and fractal analysis in the mapping sciences. Professional Geographer **44**:88-98.

Likens, G. E., and F. H. Bormann. 1995. Biogeochemistry of a forested ecosystem. Second edition. Springer-Verlag, New York, New York, USA.

Mandelbrot, B. B. 1982. The fractal geometry of nature. Freeman, San Francisco, California, USA.

Meentemeyer, V. 1989. Geographical perceptions of space, time, and scale. Landscape Ecology **3**:163-173.

O'Neill, R. V., D. L. DeAngelis, J. B. Waide, and T. F. H. Allen. 1986. A hierarchical concept of ecosystems. Princeton University Press, Princeton, New Jersey, USA.

Peterson, D. L., and V. T. Parker. 1998. Dimensions of scale in ecology, resource management and society. *In* D. L. Peterson and V. T. Parker, editors. Ecological scale: theory and applications. Columbia University Press, New York, New York, USA.

Silbernagel, J. 1997. Scale perception—from cartography to ecology. ESA Bulletin **78**:166-169.

Withers, M. A., and V. Meentemeyer. 1999. Concepts of scale in landscape ecology. *In* J. M. Klopatek and R. H. Gardner, editors. Landscape ecological analysis: issues and applications. Springer-Verlag, New York, New York, USA.

Wu, J. 1999. Hierarchy and scaling: extrapolating information along a scaling ladder. Canadian Journal of Remote Sensing. *In press*.

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Where Have All the Developing Country Editions Gone?

A very large proportion of the world's biodiversity is confined to the tropical regions of the world. Typical examples of such biodiversity hotspots are Africa, India, Papua New Guinea, and Brazil. As a result, there has been tremendous interest in the ecology of such diverse regions. Furthermore, "biodiversity" has become a buzzword in ecology today, and a vast amount of effort, money, and time is invested in the study of diversity patterns in many parts of the developed world. Ecologists in Europe and North America, for example, have great resources at their disposal for investigations within their regions, and in tropical regions of significant biodiversity. So it is not surprising that these two regions produce ecological literature of tremendous value. This research translates into numerous publications in internationally known journals. Excellent volumes or monographs are published summarizing many years of research in the tropics. Simberloff (1999) in a recent article stressed the need for "a wealth of scientific research" for the preservation of biodiversity. As an ecologist, I cannot agree more with this point of view. What I find difficult to accept is that only a miniscule proportion of the current wealth of knowledge derived from the western scientific method has reached areas where it is likely to be tremendously beneficial.

Coincidentally, such biodiversity hotspots are among the poorest regions of the world. The people of the developing world have often been implicated (sometimes subtly and sometimes openly) as one the principal causes of rapid decline in biodiversity (WRI 1990). At least one of the reasons put forward for this is that they lack sufficient scientific knowledge to appropriately manage their resources. Such comments often ignore a glaring truth. We should acknowledge that international journals and monographs are precisely that, "international!" People in the developing world are unaware of a majority of these publications. Even when people are aware of them, they are unaffordable; even the sporadic information that reaches their shores seldom gets used.

I will illustrate my point based on the third-world currency that I am most familiar with, the Indian rupee. Table 1 presents basic statistics relating to income.

Let us examine the price of some of the better known ecological monographs and books (Table 2).

It is evident that the books mentioned are well beyond the means of most Indians, even if we assume that scientists earn 3–4 times the average wage. The price is even beyond the reach of many university libraries. To my knowledge, only one of the these books has a developing country reprint/edition. *Statistical Methods* by Snedecor and Cochran (1994) has a reprint for sale only in India for Rs. 250 ($US 5.70).

Developing country editions were quite common as recently as 5–10 years ago. Author(s)/ editor(s), in col-

Table 2. Relative price of ecological literature.

Title of book	International price in $US	Equivalent price in rupees
Statistical Methods	54.95	2391.97
Ecological Methodology	105.45	4570.65
Ecology: the experimental analysis of distribution and abundance	83.39	3629.97
Biological diversity: The coexistence of species on changing landscapes	39.95	1739.02
Tropical forest ecology: a view from Barro Colorado Island	35.00	1523.55
Tropical forest remnants: ecology and conservation of fragmented communities	38.00	1654.14
Tropical resources: ecology and development	36.00	1567.08
Biodiversity and ecosystem processes in tropical forests	79.95	3480.22
Last stand: protected areas and the defense of tropical biodiversity	45.00	1958.85
Biodiversity: a reference handbook	45.00	1958.85
Ecological communities: conceptual issues and the evidence	40.00	1741.20

Table 1. Comparison of average wages between India and the USA.

	India		USA
	Indian rupee	Rupees in $US	($US)
Average per capita income	10,070.00*	231.09	$37,005.00†
Average monthly wage	839.17*	19.26	$3,083.75†

*CSO (1999).
†U.S. Census Bureau (1998).

laboration with the publishers, negotiated a cheaper edition to be published in developing countries. The quality of paper was cheaper, and often such issues were available only in paperback. Although not as attractive as the international edition, at least a researcher in the developing world had access to the information contained in these texts at an affordable price. Some may argue that electronic publications over the Internet are likely to remedy such problems of access to scientific literature. In reality, even such an excellent medium of communication comes at a price, a price that many in developing nations cannot afford. The print medium is still the common denominator in most parts of the world, and parity in access to the printed literature needs to be established.

Globalization has progressed so rapidly that even we scientists and academics, the custodians of knowledge, have forgotten the underprivileged. We all seem to be caught up in the scientific norm of "publish or perish," or, should I say, "publish internationally or perish." The wealth of information generated by the developing world is seldom fed back to those in developing nations. To make matters worse, many authors from developing countries prefer to publish internationally, often without a developing country edition (Sukumar 1989, Gadgil and Guha 1995, Nadkarni 1999).

Although I do not doubt for an instant the value of the information contained in such landmark/seminal texts, this situation leaves me wondering if science is the pursuit of knowledge for progress of the individual, or for the betterment of the whole of humanity. We as ecologists must evaluate the growing craving for international recognition in the light of its effects on the poor and biodiverse countries of the tropics.

Literature cited

Becher, A. editor. 1998. Biodiversity: a reference handbook. Contemporary world issues. ABC-CLIO, Santa Barbara, California, USA.

CSO (Central Statistics Organisation). 1999. Government of India. <http://www.nic.in/stat/static.htm>, released on 30 June 1999.

Furtardo, J. I., W. B. Morgan, J. R. Pfafflina, and K. Ruddle, editors. 1990. Tropical resources: ecology and development. Harwood Academic, Chur, Switzerland.

Gadgil, M., and R. Guha. 1995. Ecology and equity: the use and abuse of nature in contemporary India. Routledge, London, UK.

Huston, M. A., editor. 1994. Biological diversity: the co-existence of species on changing landscapes. Cambridge University Press, Cambridge, UK.

Krebs, C. J. 1999. Ecological methodology. Second edition. Benjamin/Cummings, Menlo Park, California, USA.

Krebs, C. J. 1994. Ecology: the experimental analysis of distribution and abundance. Harper Collins, New York, New York, USA.

Laurance, W. F., and R. O. Bierregaard, editors. 1997. Tropical forest remnants: ecology, management and conservation of fragmented communities. University of Chicago Press, Chicago, Illinois, USA.

Leigh, E. G., Jr. 1999. Tropical forest ecology: a view from Barro Colorado Island. Oxford University Press, New York, New York, USA.

Nadkarni, N. M., and N. T. Wheelwright, editors. 1999. Monteverde: ecology and conservation of a tropical cloud forest. Oxford University Press, New York, New York, USA.

Orians, G. H., C. van Schaik, and J. Johnson, editors. 1997. Last stand: protected areas and the defense of tropical biodiversity. Oxford University Press, New York, New York, USA.

Simberloff, D. 1999. The role of science in the preservation of forest biodiversity. Forest Ecology and Management **115**:101–111.

Snedecor, G. W., and W. G. Cochran. 1989. Statistical methods. Eighth edition. Iowa State University Press, Ames, Iowa, USA.

Snedecor, G. W., and W. G. Cochran. 1994. Statistical methods. Eighth edition. First East–West Press edition. East–West Press Private Limited, New Delhi, India.

Strong, D. R., Jr., A. B. Thistle. and D. Simberloff. 1984. Ecological communities: conceptual issues and the evidence. Princeton University Press, Princeton, New Jersey, USA.

Sukumar, R. 1989. The Asian elephant: ecology and management. Cambridge University Press, Cambridge, UK.

U.S. Census Bureau. 1998. http://www.census.gov/Press-Release/cb98-175.html, U.S. Department of Commerce, released on 24 September 1998.

World Resources Institute (WRI). 1990. World resources 1990–1991. Oxford University Press, Oxford, UK.

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