Journal of Vegetation Science 16: 145-150, 2005

INVITED PERSPECTIVE

Milestones in ecological thought – A canon for plant ecology

Keddy, Paul A.

Department of Biological Sciences, Southeastern Louisiana University, Hammond, Louisiana 70402, USA; Fax +1 9855495640; E-mail pkeddy@selu.edu

Abstract. Scientific progress in plant ecology is at risk of being obscured by increasing ignorance of major works in the field. The driving force seems to be the twin seductions of novelty and crowd psychology. I illustrate this tendency with three examples from plant community ecology that span the past thirty years of ecological research. I offer, as one solution, the concept of a canon: a short list of essential books that we assume all students and co-workers have read, a short list that summarizes the wisdom of the discipline. A canon can be likened to DNA, be it in music, art, or science, as it carries forward through time the key ideas that have worked in the past. Without a canon, there is no memory of past achievement, no context for appreciating current work, and no way of judging the quality of newer productions. I suggest 20 essential books (the short canon), and 22 complementary readings, for a total of 42 books needed in any young professional's library on plant ecology.

Keywords: Canon; Concept; Community ecology; History; Internet; Progress.

Part 1: Foundations for plant ecology

Plants dominate the biosphere. Plants feed all of humanity. They provide food and shelter for nearly all wildlife, and even regulate the climate. More than 99.9 % of the biomass on Earth is plants (Whittaker 1975), comprising somewhere between 3.1 and 4.2×10^5 species, of which 30% to 50% are at risk of extinction (Pitman & Jörgensen 2002). That we understand and appreciate plants is an imperative for human survival.

In a typical landscape, the number of species of plants is roughly 10 times the number of species of birds, and 100 times the number of species of mammals. Hence, plant ecology has intrinsic difficulties. In his classic 1927 book on animal ecology, Charles Elton reports on his attempts at plant ecology as being "first of all disheartening, then terrific, and finally impossible." (p. 28) Given this inherent complexity, it is even more imperative that we not forget books with fundamental (or, if you prefer 'classical') ideas and already-established empirical models. Such books remain important for at least three reasons. 1. They allow us to judge how plant ecology has (or has not) progressed. 2. They keep us modest, reminding us that contemporary themes such as competition and disturbance are not new discoveries, but were appreciated early in the history of ecology. 3. They provide inspiring examples, showing us, for example, that even 100 years ago plant ecologists were trying to integrate basic research with conservation.

I cannot escape the worrying impression that the fundamentals of plant ecology are increasingly underappreciated or ignored. Too often, I see talks, papers, manuscripts and grant applications that are seriously deficient in their treatment of the fundamentals of our discipline. The attitude seems to be that anything more than ten years old is irrelevant, and 'newness' should be the principal criterion for judging value. Of course, the more one ignores the past, the more one can become intoxicated by ephemeral novelty. This may explain the regular announcements of new paradigms in ecology. A familiarity with the scientific literature, in contrast, is likely to promote a higher degree of modesty. The rush to get into print seems not only to engender carelessness about preceding work by other scholars, but it develops

a psychological momentum that feeds upon itself. Too often, recent papers cite other recent papers, while all ignore relevant work from the past. We know only too well how human crowds feed a psychology that overrides common sense – consider Mackay's 1841 book *Extraordinary popular delusions and the madness of crowds*, with its long forgotten examples such as tulipomania.

The problem seems to be growing worse. I recently attended a very pleasant meeting in California generously funded by a multimillion-dollar grant in which a roomful of serious young scientists laboured mightily, some around the clock, with networked lap top computers. I was disturbed to find that many seemed unaware of a significant proportion of the literature in the field they were trying to advance. To test this possibility, I dropped a few familiar and relevant scholarly names out of curiosity (e.g. Ellenberg, Peters) – and found that sometimes even the names (let alone their papers or books) were unrecognized!

This problem is not restricted to plant ecology. We seem to be witnessing what we might call the 'Alzheimerization' of ecology in particular, of science in general, and of human society altogether. While I hesitate to coin a new word, I cannot find a familiar verb that adequately describes the slow, progressive and debilitating loss of memory, of significance and of historical context, with the substitution of large gaps filled with short-term emotional reactions to immediate sensory phenomena.

Rosen (2003) has described how canons protect the integrity of our cultural traditions in the arts and sciences. The author, a pianist, was referring to music and literature, but of course, the same issues arise in science. Canon? Canonical? An editor suggested that younger readers would not even recognize the word. It seems then, that not only are we losing a canonical view of ecology, but we are *even losing the word that would describe the possibility*! A canon (as opposed to a cannon) is, according to my Concise Oxford Dictionary, a 'church decree; [or] collection or list of sacred books etc. regarded as genuine', although the term is more widely applied to art, music and books that have long-term value to society. An obvious example is *The origin of species*, which still provides essential context for most evolutionary papers.

Although the idea of a canon now seems quaintly medieval, it is needed more than ever. The volume of information produced and stored has doubled in just three years and, according to Holden (2003), in just one year, enough film, print, magnetic and optical storage information was produced to fill the Library of Congress half a million times – an amount of information equal to 5 exabytes (10^{18}). This is roughly equal to the number of words spoken by human beings since language began. Important works can easily be drowned in a mass of mediocrity and miscellanea. Even the internet needs a canon. A search engine like *Google* is a powerful tool if it is supported by a *pre-existing* framework to judge the context of information – otherwise it provides a flood of factoids, some right, some wrong, some relevant, some not. The internet, then, might complement our libraries, and supplement our understanding of a discipline, but even the internet needs a canon.

Part 2: Three examples of ignoring the historical roots of plant ecology

If you accept my thesis, that we are slowly losing track of the foundations of our discipline, then you can safely skip to part 3. If you doubt the seriousness of the problem, let me illustrate it with three examples. Please do not read this as an attack on particular colleagues, but to support my argument I have to provide some familiar examples. Many other examples exist, and could be similarly included. I have picked just one per decade.

Example 1:

My first ecology textbook was *Readings in population and community ecology* (1970), a book that originated as readings used by W.E. Hazen at the University of Chicago. As an undergraduate, I was impressed by this book, and I still have a battered and annotated copy. Yet with hindsight, we can also see within this book the beginning of a neurosis affecting the next 25 years of ecology.

Consider. There are 23 papers, and only one of these is by a plant ecologist (two if we include Ryther, who worked on oceanic productivity). Yet Hutchinson and MacArthur each were given two chapters. The sole botanist represented is Harper, and his essay (Harper 1967) does not address plant community ecology, but rather advocates the study of plant populations and evolution. Thus, the sole paper by a botanist has no references to Clements, Tansley, Gleason, Ellenberg or Whittaker! Young ecologists like me could quite naturally, then, assume that there was no worthwhile plant ecology before Hutchinson, MacArthur and Harper.

Example 2:

I once taught a course using *Ecological communities: Conceptual issues and the evidence* (Strong et al. 1984), treating it as a landmark in ecology. Upon revisiting this book, I find only one of the 29 chapters (3.4 percent) addresses plant communities – and this sole chapter addresses only the minor issue of flowering phenology! Turning to the index, there is no mention of

Clements, Tansley, Raunkiaer, Ellenberg, Braun, Richards, Watt, Kershaw, Davis, Delcourt, Gorham, Dansereau, Bazzaz, Silvertown, Schindler, Auclair, Loucks, Grubb, Likens, Major, Shugart, Junk, Woodwell, Givnish, Pickett, Austin, van der Valk, or White, to mention a few plant ecologists who have published important work on community ecology. Some of the chapters in the book lecture on the importance of experimental investigation of communities – yet without any mention of classical plant community manipulations (designed and executed not just years, but decades earlier) such as the Park Grass experiments (e.g. Silvertown 1980), the Brookhaven radiation experiments (Woodwell 1962; Woodwell & Whittaker 1968), the experimental lakes in Ontario (Schindler 1977), or the experimental watersheds in New England (Likens et al. 1977; Bormann & Likens 1981). These examples may comprise a set of the most important experiments in ecological history.

There is a token reference to each of Gleason, Harper, and Peet; Grime has two, Pielou and Mooney each receive three, and Whittaker gets four. Compare this with American zoologists: 11 each for Connell and Schoener, 12 to Cody, 16 to Wiens and 25 to Grant! The cause of such distortions is unclear, but one cannot help but wonder if it lies in part with those of us schooled with Hazen (1970).

Example 3:

If such errors pass on through the generations, we should be able to find more recent examples. Let us consider one from 1993, the commonly-cited book edited by Ricklefs & Schluter, *Species diversity in ecological communities*. For economy of space, consider just one chapter that addresses a central theme of plant ecology – the factors that maintain species richness in plant communities (Tilman & Pacala 1993). The chapter opens in a curious way, "In 1959, G.E. Hutchinson," thereby omitting more than half a century of plant ecology. Moreover, this is the very paper in which Hutchinson admits to wanting to understand plant diversity without knowing anything about plants. I am not being vulgar – Hutchinson says it up front – "[W]hy are there so many kinds of plants? As a zoologist I do not want to ask that question directly. I want to stick with animals but also get the answer." The chapter then leaps more than 20 years from Hutchinson (1959) to Tilman (1982), leaving the clear impression that nothing worthwhile was done on plant species richness between 1959 and 1982. After a total of seven dated references, the body of the paper, "Processes allowing persistence of numerous species," begins.

First comes 'Spatial heterogeneity'. The introduction lacks a single scholarly reference! Students would not know that Skellam (1951) produced an elegant model for how two species can coexist in a mosaic so long as the weaker can out disperse the stronger, that there have been field experiments of plant establishment in heterogeneous environments (Watt 1923), that patchiness is consistently encountered in early textbooks (Kershaw 1973), that there are books with entire chapters on how to measure the heterogeneity of mosaics (Pielou 1975), that plants are most sensitive to heterogeneity at the establishment phase (Harper 1977), that there are reviews on heterogeneity and diversity (Grubb 1977; Sousa 1984), that a phenomenon called the 'regeneration niche' is thought to enhance richness (Grubb 1977), that many plant ecologists use zonation as a tool for studying heterogeneity (Pielou 1975; Spence 1982; Keddy 1991), that infertile habitats have inordinately large numbers of rare plant species (Moore et al. 1989), that heterogeneity is thought to generate diversity in Amazonian floodplains (Salo et al. 1986), or that entire books address heterogeneity (Kolasa & Pickett 1991).

Moving on to 'Temporal heterogeneity', one might expect some reference to succession, and perhaps to Clements, Tansley or at least Major's classic work at Glacier Bay (Crocker & Major 1955). No, students read only about Levins and Chesson, and while both are fine ecologists, surely even they would be embarrassed by the absence of any reference to founders of plant ecology, not to mention Connell & Slatyer (1977), Connell (1978), Huston (1979), West et al. (1981), Salo et al. (1986) or reviews including White (1979), Sousa (1984) and Denslow (1987).

To save space, let us leap now to a concluding sentence that pleads for "significant increases in understanding of the fundamental forces that have led to the appearance and persistence of species-rich communities," leaving the vague impression of social concern, yet keeping students entirely ignorant of useful references in biogeography, conservation biology, restoration ecology, reserve design, and rare plant conservation (e.g. Takhtajan 1969; Ehrlich & Ehrlich 1981; Jordan et al. 1987; Myers 1988, and Groombridge 1992 to give just a few).

Part 3: The positive alternative: a canon for plant ecology

We seem to have a disturbing trend through these three examples. Generation by generation of students is misinformed about the origins and foundations of their discipline. Offering a canon for plant ecology may be one positive way to restore a semblance of order and reality. This is not an original idea. In *Great books of the Western World* Mortimer J. Adler tried, in 60 volumes,

to summarize human wisdom from Homer to Beckett. What would such a canon look like in plant ecology? I fully admit that my list is but one person's perspective – but to judge from the complaints of the moving company who carried my belongings to Louisiana, I own more books than most.

Below, then, are 20 essential books (the short canon) needed in a young professional's library on plant ecology. With the 22 complementary readings listed in App. 1, this brings the full canon to 42 books. I have cited first editions, and noted subsequent editions.

The short canon

1. Darwin, C. 1859. The origin of species by means of natural selection. In: Adler, M.J. (ed.). 1990. *Great books of the Western World*, 2nd. ed., Vol. 49, Encyclopaedia Britannica, Chicago, IL, US.
2. Williams, C.B. 1964. *Patterns in the balance of nature*. Academic Press, London, UK.
3. Morowitz, H.J. 1968. *Energy flow in biology: Biological organization as a problem in thermal physics*. Academic Press, New York, NY, US.
4. Whittaker, R.H. 1970. *Communities and ecosystems*. MacMillan, New York, NY, US. (2nd. ed. 1975.)
5. Shimwell, D.W. 1971. *The description and classification of vegetation*. Sidgwick & Jackson, London, UK. (also 1972 University of Washington Press, Seattle, WA, US.)
6. MacArthur, R.H. 1972. *Geographical ecology: Patterns in the distribution of species*. Harper & Row, New York, NY, US.
7. Mueller-Dombois, D. & Ellenberg, H. 1974. *Aims and methods of vegetation ecology*. Wiley and Sons, New York, NY, US.
8. Lieth, H. & Whittaker, R.H. (eds.) 1975. *Primary productivity of the biosphere*. Springer-Verlag, New York, NY.
9. Chapman, S.B. 1976. *Methods in plant ecology*. Blackwell, London, UK.
10. May, R.M. (ed.) 1976. *Theoretical ecology. Principles and applications*. Blackwell, London, UK. (2nd. ed. 1981 Sinauer Associates, Sunderland, MA, US.)
11. Harper, J.L. 1977. *The population biology of plants*. Academic Press, London, UK.
12. Pielou, E.C. 1977. *Mathematical ecology*. Wiley and Sons, New York, NY, US.
13. Grime, P. 1979. *Plant strategies and vegetation processes*. Wiley and Sons, Chichester, UK. (2nd. ed. 2001 *Plant strategies, vegetation processes and ecosystem properties*.)
14. Boucher, D.H. (ed.) 1985. *The biology of mutualism: Ecology and evolution*. Oxford University Press, New York, NY, US.
15. Pickett, S.T.A. & White, P.S. (eds.) 1985. *The ecology of natural disturbance and patch dynamics*. Academic Press, Orlando, FL, US.
16. Keddy, P.A. 1989. *Competition*. Chapman and Hall, London, UK. (2nd. ed. 2001 Kluwer Academic Publishers, Dordrecht, NL.)
17. Leck, M.A., Parker, V.T. & Simpson, R.L. (eds.) 1989. *Ecology of soil seed banks*. Academic Press, San Diego, CA, US.
18. Aber, J.D. & Melillo, J.M.. 1991. *Terrestrial ecosystems*. Saunders, Philadelphia, PA, US (2nd. ed. 2001, Academic Press, San Diego, CA, US.)
19. de Groot, R.S. 1992. *Functions of nature*. Wolters-Noordhoff, Groningen, NL.
20. Archibold, O.W. 1995. *Ecology of world vegetation*. Chapman and Hall, London, UK.

References

Bormann, F.H. & Likens, G.E. 1981. *Pattern and process in a forested ecosystem*, 2nd. corrected printing. Springer-Verlag, New York, NY, US.

Connell, J.H. 1978. Diversity in tropical rain forests and coral reefs. *Science* 199: 1302-1310.

Connell, J.H. & Slatyer, R.O. 1977. Mechanisms of succession in natural communities and their role in community stability and organization. *Am. Nat.* 111: 1119-1144.

Crocker, R.L. & Major, J. 1955. Soil development in relation to vegetation and surface age at Glacier Bay, Alaska. *J. Ecol.* 43: 427-448.

Denslow, J.L. 1987. Tropical rain forest gaps and tree species diversity. *Annu. Rev. Ecol. Syst.* 18: 431-451.

Ehrlich, A. & Ehrlich, P. 1981. *Extinction: The causes and consequences of the disappearance of species*. Random House, New York, NY, US.

Elton, C. 1927. *Animal ecology*. Sidgwick & Jackson, London, UK.

Groombridge, B. 1992. *Global biodiversity: Status of the Earth's living resources*. Chapman and Hall, London, UK.

Grubb, P.J. 1977. The maintenance of species-richness in plant communities: The importance of the regeneration niche. *Biol. Rev.* 52: 107-145.

Harper, J.L. 1967. A Darwinian approach to plant ecology. *J. Ecol.* 55: 247-270.

Harper, J.L. 1977. *The population biology of plants*. Academic Press, London, UK.

Hazen, W.E. 1970. *Readings in population and community ecology,* 2nd. ed. W.B. Saunders Company, Philadelphia, PA, US.

Holden, C. (ed.) 2003. Data overload. *Science* 302: 1325.

Huston, M.A. 1979. A general hypothesis of species diversity. *Am. Nat.* 113: 81-101.

Hutchinson, G. E. 1959. Homage to Santa Rosalia or Why are there so many kinds of animals? *Am. Nat.* 93: 145-159.

Jordan III, W.R., Gilpin, M.E. & Aber, J.D. 1987. *Restoration ecology: A synthetic approach to ecological research*. Cambridge University Press, Cambridge, UK.

Keddy, P.A. 1991. Working with heterogeneity: an operator's guide to environmental gradients. In: Kolasa, J. & Pickett, S.T.A. (eds.) *Ecological heterogeneity*, pp. 181-201. Springer-Verlag, New York, NY, US.

Kershaw, K.A. 1973. *Quantitative and dynamic plant ecology*, 2nd. ed. Edward Arnold, London, UK.

Kolasa, J. & Pickett, S.T.A. (eds.) 1991. *Ecological heterogeneity*. Springer-Verlag, New York, NY, US.

Likens, G.E., Bormann, F.H., Pierce, R.S., Eaton, J.S. & Johnson, N.M. 1977. *Biogeochemistry of a forested ecosystem*. Springer-Verlag, New York, NY, US.

Mackay, C. 1841. *Memoirs of extraordinary popular delusions*. Reprinted in 1980 as *Extraordinary popular delusions and the madness of crowds*. With a forword by A. Tobias, Harmony Books, New York, NY, US.

Moore, D.R.J., Keddy, P.A., Gaudet, C.L. & Wisheu, I.C. 1989. Conservation of wetlands: Do infertile wetlands deserve a higher priority? *Biol. Conserv.* 47: 203-217.

Myers, N. 1988. Threatened biotas: 'Hotspots' in tropical forests. *Environmentalist* 8: 1-20.

Pielou, E.C. 1975. *Ecological diversity*. John Wiley and Sons, New York, NY, US.

Pitman, N.C.A. & Jörgensen, P.M. 2002. Estimating the size of the world's threatened flora. *Science* 298: 989.

Ricklefs, R.E. & Schluter, D. (eds.) 1993. *Species diversity: Historical and geographical perspectives*. University of Chicago Press, Chicago, IL, US.

Rosen, C. 2003. Culture on the market. *The New York Review of Books* (6 November 2003): 70-73.

Salo, J., Kalliola, R., Hakkinen, I., Makinen, Y., Niemela, P., Puhakka, M. & Coley, P.D. 1986. River dynamics and the diversity of Amazon lowland forest. *Nature* 322: 254-258.

Schindler, D.W. 1977. Evolution of phosphorus limitation in lakes. *Science* 195: 260-262.

Silvertown, J. 1980. The dynamics of a grassland ecosystem: botanical equilibrium in the Park Grass Experiment. *J. Appl. Ecol.* 17: 491-504.

Skellam, J.G. 1951. Random dispersal in theoretical populations. *Biometrika* 38: 196-218.

Sousa, W.P. 1984. The role of disturbance in natural communities. *Annu. Rev. Ecol. Syst.* 15: 353-391.

Spence, D.H.N. 1982. The zonation of plants in freshwater lakes. *Adv. Ecol. Res.* 12: 37-125.

Strong Jr., D. R., Simberloff, D., Abele, L.G. & Thistle, A.B. (eds.) 1984. *Ecological communities. Conceptual issues and the evidence*. Princeton University Press, Princeton, NJ, US.

Takhtajan, A. 1969. *Flowering plants: Origin and dispersal*. Oliver and Boyd, Edinburgh, UK. (Translated and revised from a Russian 2nd. ed. published in Moscow in 1961.)

Tilman, D. 1982. *Resource competition and community structure*. Princeton University Press, Princeton, NJ, US.

Tilman, D. & Pacala, S. 1993. The maintenance of species richness in plant communities. In: Ricklefs, R.E. & Schluter, D. (eds.) *Species diversity in ecological communities*, pp. 13-25. University of Chicago Press, Chicago, IL, US.

Watt, A.S. 1923. On the ecology of British beechwoods with special reference to their regeneration. Part I. The causes of failure of natural regeneration of the beech. *J. Ecol.* 11: 1-48.

West, D.C., Shugart, H.H. & Botkin, D.B. (eds.) 1981. *Forest succession. Concepts and application*. Springer-Verlag, New York, NY, US.

White, P.S. 1979. Pattern, process and natural disturbance in vegetation. *Bot. Rev.* 45: 229-299.

Whittaker, R.H. 1975. *Communities and ecosystems*. MacMillan, New York, NY, US.

Woodwell, G.M. 1962. Effects of ionizing radiation on terrestrial ecosystems. *Science* 138: 572-577.

Woodwell, G.M. & Whittaker, R.H. 1968. Effects of chronic gamma irradiation on plant communities. *Q. Rev. Biol.* 43: 42-55.

App. 1. Complementary readings.

In addition to the short canon as essential for a young professional's library on plant ecology, here are 22 complementary readings for a total of 42 books. These fall into three categories: the origin and evolution of plants, historical context (books out of date but valuable for historical perspective), and popular/environmental (books that provide the social container for the technical works). They are listed in chronological order of first editions, with subsequent editions noted.

The origin and evolution of plants

1. Takhtajan, A. 1969. *Flowering plants: Origin and dispersal*. Oliver and Boyd, Edinburgh, UK. (Translated and revised from a Russian 2nd. ed. from 1961.)
2. Raven, P.H. & Curtis, H. 1970. *Biology of plants*. Worth Publishers, New York, NY, US. (Six editions 1976-1999.)
3. Willams, G.C. 1975. *Sex and evolution*. Monographs in Population Biology. No. 8. Princeton University Press, Princeton, NJ, US.
4. Dawkins, R. 1976. *The selfish gene*. Oxford University Press, Oxford, UK. (New ed. 1989.)
5. Levin, H.L. 1978. *The Earth through time*. Saunders College Publishing, Philadelphia, PA, US. (Six editions 1983-2003.)
6. Mayr, E. 1982. *The growth of biological thought. Diversity, evolution and inheritance*. Belknap Press of Harvard University Press, Cambridge, MA.
7. Stewart, W.N. 1983. *Paleobotany and the evolution of plants*. Cambridge University Press, Cambridge, UK. (2nd. ed. 1993 with G.W. Rothwell.)
8. Delcourt, H.R. & Delcourt, P.A. 1991. *Quaternary ecology: A paleoecological perspective*. Chapman and Hall, London, UK.

Historical context

1. Lavoisier, A.L. 1789. Elements of chemistry. Translated by R. Kerr and reprinted in: Adler, M.J. (ed.) 1990. *Great books of the Western World*, 2nd. ed., Vol. 42, pp. xii & 1-60. Encyclopaedia Britannica, Chicago, IL, US.
2. von Humboldt, A. 1845. *Kosmos: Entwurf einer physischen Weltbeschreibung*. Translated by E.C. Otté. Reprinted 1997 as *Cosmos: A sketch of the physical description of the Universe. Volume I*. The Johns Hopkins University Press, Baltimore, MD, US.
3. Warming, E. 1909. *Oecology of plants: An Introduction to the study of plant communities*. Clarendon Press, Oxford, UK. (2nd. ed. 1925.)
4. Tansley, A.G. 1923. *Practical plant ecology; A guide for beginners in the field study of plant communities*. Allen & Unwin, London, UK. (2nd. ed. 1946.)
5. Clements, F.E., Weaver, J.E. & Hanson, H.C. 1929. *Plant competition*. Carnegie Institution of Washington, Washington, DC, US.

Popular/Environmental

1. Leopold, A. 1949. *A Sand County almanac*. Oxford University Press, London, UK.
2. Carson, R. 1962. *Silent spring*. Houghton Mifflin, Boston, MA, US.
3. Meadows, D. H., Meadows, D.L., Randers, J. & Behrens III, W.W. 1972. *The limits to growth: A report for the Club of Rome's Project on the Predicament of Mankind*. Universe Books, New York, NY, US. (2nd. ed. 1974.)
4. Schumacher, E.F. 1973. *Small is beautiful*. Blond & Biggs, London, UK.
5. Colinvaux, P. 1978. *Why big fierce animals are rare: An ecologist's perspective*. Princeton University Press, Princeton, NJ, US.
6. Ehrlich, A. & Ehrlich, P. 1981. *Extinction: The causes and consequences of the disappearance of species*. Random House, New York, NY, US.
7. Botkin, D.B. 1990. *Discordant harmonies: A new ecology for the twenty-first Century*. Oxford University Press, New York, NY, US.
8. Wilson, E.O. 1993. *The diversity of life*. W.W. Norton, New York, NY, US.
9. Noss, R.F. & Cooperrider, A. 1994. *Saving nature's legacy: Protecting and restoring biodiversity*: Defenders of Wildlife and Island Press, Washington, DC, US.