FORUM

Freshwater Wetlands Human-Induced Changes: Indirect Effects Must Also Be Considered

PAUL A. KEDDY
Department of Biology
University of Ottawa
Ottawa, Ontario K1N 6N5

ABSTRACT / Two recent studies have documented changes in wetland ecosystems in New England by examining changes in wetland vegetation over time. Both documented shifts in vegetation towards shrub and forest dominated wetlands. Both then concluded that natural succession has changed more wetlands than human impact has. The last conclusion does not necessarily follow from the data provided.

There are three important points that emerge from re-considering these studies: 1) indirect human impact (for example, water level changes, eutrophication, sedimentation) must be considered when assessing human impact on wetlands, particularly given that subtle indirect impact affects larger areas than direct impact from drainage and infilling; 2) when discussing indirect effects of human activity, it is important to carefully define which indirect effects are being considered, since there is a continuum ranging from infilling through to alteration of global CO_2 levels; and 3) given the complexity of indirect effects, it is unlikely that most can be recognized in the field.

With the rapid disappearance of North American wetlands, there is a great need for long-term data documenting changes in wetland ecosystems over time. Two recent studies have examined changes in wetland vegetation over time in Maine and Rhode Island (Larson and others 1980; Golet and Parkhurst 1981). They documented change in wetland vegetation and concluded that natural succession was the major cause of these changes. These conclusions may have considerable implications for resource management policy, yet, in my opinion, they are not demonstrated by the data provided. I will summarize the data from these studies, and then show that they are open to different interpretation. I will emphasize the difficulty of recognizing human-induced change, and stress the need for studies to clearly define the terms natural and human-induced.

Larson and others (1980) studied changes in freshwater wetland ecosystems on the Massachusetts Coastal Plain over a 20-year period (1951–1971), while Golet and Parkhurst (1980) studied Rhode Island wetlands over a 33-year period (1939–1972). Both studies used vegetation types recognized from vertical aerial photographs to classify wetland ecosystems into different classes such as deep marsh, shallow marsh, meadow, and shrub swamp. By comparing classifications from the two sets of aerial photographs they determined the relative abundance of wetland ecosystems at each time and documented the direction of change over the time interval studied. Larson and others examined 8 classes of open freshwater wetlands and reported that over the 20 years studied, nearly one-half of these wetlands changed vegetation class. Golet and Parkhurst also examined 8 classes of freshwater wetlands and reported that over the 33 years, 17 percent of the wetlands changed class. Both papers show that changes were strongly unidirectional from open water through marsh to shrub swamps and finally to wooded wetland. Both studies attempt to interpret these changes and separate human-induced changes from natural changes. Both conclude that changes caused by humans are insignificant compared to natural changes.

KEY WORDS: Wetlands ecosystems; Human environmental impact; Resource management

The Importance of Indirect Effects

Larson and others included effects of agriculture, highways, and impoundments as human-caused changes in wetlands. They state that "Succession was deemed to be the responsible agent of change in areas 1) where woody vegetation in wetlands had grown to trees . . . , 2) where woody shrubs had invaded previously open wetland areas, 3) where floating or submerged vegetation had become established in open water or, 4) one instance of natural migration of a sand dune into a marsh" (p. 670). Golet and Parkhurst do not explain how they recognized natural succession, although they do state that 92 percent of all natural changes were progressive, that is, moving toward an ultimately forested state.

There are alternate hypotheses for the observed changes apart from natural succession. Many of the examples of succession could also be human-induced change, and thus the human impact was probably underestimated. Assume that there are three main factors influencing wetland ecosystems (Figure 1): water level, nutrient status, and natural disturbance (Keddy 1982). By modifying any one of these factors, human activity could induce vegetation change that would duplicate the unidirectional natural succession observed in the above studies.

First, consider water levels. It is well-known that in wetlands, water depth has an important influence on species composition (see Pearsall 1920, Dansereau 1959, Spence 1967, Walker and Wehrhahn 1971, Hutchinson 1975). If the depth of water (or depth to the water table) were reduced, all of the

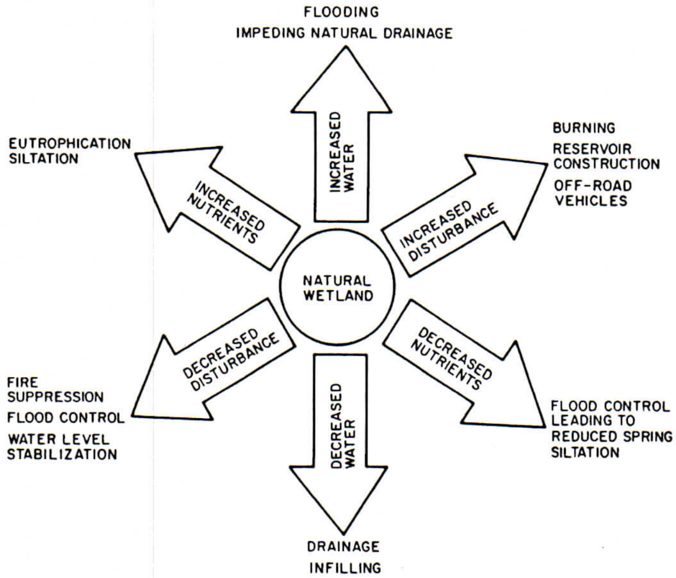

Figure 1. Some human impacts on the major ecological factors influencing wetlands (after Keddy 1982). Increased nutrients, decreased disturbance, or decreased water could all produce unidirectional vegetation change towards shrub and forest wetlands.

above described changes (for example, open water to deep marsh, shallow marsh to shrub swamp) could be duplicated. Any human activity that lowered the water table (for example, agricultural drainage pumping for municipal wells), or caused increased sedimentation (for example, erosion from highway construction) could therefore cause these unidirectional changes from open water to forest. Both lowering the water table and increasing sedimentation are human-induced impacts, not natural succession.

Secondly, consider nutrients. Aquatic plant growth is often greater in nutrient-rich sites (Swindale and Curtis 1957, Auclair and others 1976a, 1976b) and thus eutrophication from agricultural activities or sewage could induce changes from open water to deep marsh. More importantly, we have little or no data to demonstrate how many wetlands naturally remain open marshes because nutrient shortages prevent (or at least greatly hinder) succession to shrubs and trees. If this were an important factor in wetlands, any increases in nutrient status would be expected to cause unidirectional vegetation changes.

Third, consider the role of natural disturbances. Many wetlands experience cyclical vegetation changes associated with fluctuations in water level (Harris and Marshall 1963, Stuckey 1975, van der Valk and Davis 1978, van der Valk 1981, Keddy and Reznicek 1982) and shrubs might dominate many wetlands were they not eliminated by occasional high water periods. Thus any human impact that tends to reduce the amplitude or frequency of water level fluctuations (for example, flood control) could cause unidirectional changes from shallow marsh to swamp wetland.

It may be that natural succession always causes wetlands to converge upon shrub and forest vegetation; and therefore, that many open shallow-water wetlands exist only because of recent natural disturbances such as peat fires or beaver dams. The proportion of wetlands in each successional stage would then reflect a dynamic equilibrium between natural disturbance (creating open water wetlands) and succession (converting open water wetlands to forested wetlands). There is much data consistent with this view in the general ecological literature (Connell 1978, Huston 1979, White 1979) as well as in the wetlands literature (Harris and Marshall 1963, Salisbury 1970, van der Valk and Davis 1978, van der Valk 1981, Keddy and Reznicek 1982). Human intervention in this scheme might not be reflected in increased or decreased rates of succession as in earlier examples, but rather by decreased rates of disturbance. Fire suppression, or beaver trapping might all reduce natural disturbance, thereby producing the same pattern: a unidirectional succession from open water to wetland. In this case, human impact would be even more indirect than in the previous examples.

Note that I am not claiming that all, or any, of these three factors explain the data presented, but simply that they are alternate hypotheses that could produce the same patterns, and that all are indirect human-induced impacts.

How Do We Define Indirect Effects?

The preceeding examples illustrate how numerous and subtle indirect human impacts could be. Yet neither Golet and Parkhurst, nor Larson and others define natural or human-induced changes. Defining human-induced changes is difficult, since there is a continuum of effects. At one extreme there are direct and obvious human-induced effects, such as drainage and infilling. The observed changes are rapid, major changes in species composition occur, and there are usually nearby unaffected areas that serve as controls. Contrast this with the more subtle human-induced effects such as rising atmospheric CO_2 levels, acid rain, or low-level radioactive fallout. The resulting changes in wetlands might be slow, and there would be no adjacent unaffected areas to serve as controls. In between these extremes lie all other human impacts on wetlands just discussed. Should the term human-induced impact include all of the above? Workers may disagree on the limits of the definition, but should clearly state where along this continuum they have decided to stop.

How Do We Recognize Indirect Effects?

Given that there is a continuum of indirect effects, any study that deals with human-induced change in wetlands should also state how indirect effects were recognized. Neither Larson and others nor Golet and Parkhurst provide such details in their methods sections. I suggest that it is virtually impossible to recognize many human-induced effects, even with careful field observation. This will be particularly true for the more subtle human-induced effects such as atmospheric CO_2 or acid rain.

Consider another example, a small Ottawa valley wetland, which I have observed for over a decade. It appears that open, shallow pools of water over limestone bedrock on a floodplain are gradually being replaced by *Onoclea sensibilis, Scirpus cyperinus,* and *Lythrum salicaria* meadows. Noticing that this change has occurred, how are we to interpret it? Natural autogenic succession is one possibility. Organic matter from these species may be accumulating over time, gradually filling in the pools, and providing more substrate for plants, which in turn increases the rate of primary production in the pools. Natural allogenic succession may also be involved. There are steep wooded banks sloping into the pools, and detritus from neighboring forests may be accumulating. The area is part of a floodplain, as well, and considerable amounts of debris are deposited by receding floodwaters in the spring. There are, however, many other possibilities that cannot be easily separated from the above, such as the following examples of human-induced autogenic succession. Nutrient loading from sewage facilities upstream may have stimulated primary production sufficiently to allow rates of production to exceed rates of decomposition, thereby causing organic matter to accumulate. Alternatively, heavy metals from sewage, or herbicides from nearby cornfields might be inhibiting bacterial decomposition; primary production may have been unaffected, but the lower rate of decomposition may thus cause an accumulation of organic matter. The introduced herbaceous weed *Lythrum salicaria* has only recently invaded the area, and if *L. salicaria* is using sites previously vacant, or otherwise raising primary production, this simple floristic change may have led to organic matter accumulation. Small dams upstream from this area may be reducing spring ice scouring. If ice scouring removes excess primary production, reduced ice scouring could be causing organic matter accumulation. Lastly, human-induced allogenic succession must also be considered. For example, sedimentation resulting from erosion upstream could be filling in the pools. No doubt many other hypotheses could be suggested. Without a detailed study, it would be impossible to distinguish among these hypotheses. Thus while the wetlands change might be a fact, the interpretation of these changes would be speculative.

In conclusion, the two papers cited illustrate a problem that faces resource managers. Studies that attempt to recognize human-induced effects on ecosystems must consider indirect human-induced effects. Otherwise, because indirect human impact may greatly exceed direct human impact, it is entirely possible that human-induced effects will be underestimated. If indirect human-induced effects are considered, then one is faced with the difficulty of defining which human-induced effects one includes, and of recognizing these effects in the field. At very least, it is important to clearly define indirect human-induced effects and to clearly explain the methods of recognizing such effects. It is essential that other scientists be able to evaluate and repeat the methods used.

Returning to the two papers on New England wetlands, the data clearly show that the wetlands of New England are dynamic and that wooded swamp is growing in abundance. One possible interpretation is that natural succession is towards wooded swamp, and that these natural changes exceed human-induced changes. Another interpretation is that indirect human-induced effects often simulate or enhance natural succession. Given the inherent difficulties in such studies, it may be some time before these (or other) hypotheses can be rejected.

Acknowledgments

Thanks to H. M. Dale, and the reviewers, J. G. Gosselink, C. S. Hopkinson, Jr., and R. E. Turner for constructive criticisms of earlier drafts of this manuscript. I also thank F. C. Golet and J. S. Larson for their correspondence, and for clarifying several items raised in an earlier draft. The above, of course, are not responsible for the opinions expressed here.

Literature Cited

Auclair, A. N. D., A. Bouchard, and J. Pajaczkowski. 1976a. Plant standing crop and productivity relations in a *Scirpus-equisetum* wetland. *Ecology* 57:941–952.

Auclair, A. N. D., A. Bouchard, and J. Pajaczkowski. 1976b. Productivity relations in a *Carex*-dominated ecosystem. *Oecologia* 26:9–31.

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

Dansereau, P. 1959. Vascular aquatic plant communities of southern Quebec. A preliminary analysis. Pages 27–54 in Trans. Northeast Wildl. Conf., 4–7 June 1958, Montreal, Quebec. Department of Game and Fisheries, University of Montreal, Montreal, PQ.

Golet, F. C., and J. A. Parkhurst. 1981. Freshwater wetland dynamics in South Kingston, Rhode Island, 1939–1972. *Environ. Manage.* 5:245–251.

Harris, S. W., and W. H. Marshall. 1963. Ecology of water-level manipulations on a northern marsh. *Ecology* 44:331–343.

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

Hutchinson, G. E. 1975. A Treatise on Limnology. Vol. III. Limnological Botany. John Wiley and Sons, New York, NY. 660 p.

Keddy, P. A. 1982. Biological considerations in wetlands management. Pages 183–189 in Proceedings of the Ontario Wetlands Conference, September 18–19, Toronto. Federation of Ontario Naturalists, Toronto, Ont. 193 p.

Keddy, P. A., and A. A. Reznicek. 1982. The role of seed banks in the persistence of Ontario's coastal plan flora. *Am. J. Bot.* 69:13–22.

Larson, J. S., A. J. Mueller, and W. P. MacConnell. 1980. A model of natural and man-induced changes in open freshwater wetlands on the Massachusetts coastal plain. *J. Appl. Ecol.* 17:667–673.

Pearsall, W. H. 1920. The aquatic vegetation in the English Lakes. *J. Ecol.* 8:163–201.

Salisbury, E. 1970. The pioneer vegetation of exposed muds and its biological features. Philosophical Transactions of the Royal Society of London, Series B, 259:207–255.

Spence, D. H. N. 1967. Factors controlling the distribution of freshwater macrophytes with particular reference to the lochs of Scotland. *J. Ecol.* 55:147–170.

Stuckey, R. L. 1975. A floristic analysis of the vascular plants of a marsh at Perry's Victory Monument, Lake Erie. Mich. Botan. 14:144–166.

Swindale, D. N., and J. T. Curtis. 1957. Phytosociology of the larger submerged plants in Wisconsin Lakes. *Ecology* 38:397–407.

van der Valk, A. G. 1981. Succession in wetlands: A Gleasonian approach. *Ecology* 62:688–696.

van der Valk, A. G., and C. B. Davis. 1978. The role of seed banks in the vegetation dynamics of prairie glacial marshes. *Ecology* 59:322–335.

Walker, B. H., and C. F. Wehrhahn. 1971. Relationships between derived vegetation gradients and measured environmental variables in Saskatchewan wetlands. *Ecology* 52:85–95.

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