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Conservation of Wetlands: Do Infertile Wetlands Deserve a Higher Priority?

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ABSTRACT

In this study we evaluate whether infertile wetlands had higher conservation value than fertile wetlands based on three criteria commonly used in ecological site evaluations: species richness, number of rare species and species composition. The data consisted of species composition in $n = 401$ $0{\cdot}25\,m^2$ quadrats from a wide range of wetland types in eastern Canada.

Infertile wetlands had higher species richness and many more rare species than did fertile wetlands. Further, infertile wetlands had a greater range of vegetation types than did fertile wetlands. It is also probable that infertile wetlands are more sensitive to human disturbances. These results indicate that infertile wetlands are more desirable for conservation than presently accounted for in wetland evaluation systems. In addition, because of greater variation in vegetation types, relatively more ecological reserves are needed to adequately represent the variation in infertile wetlands.

INTRODUCTION

Wetland losses due to human exploitation have been extensive in the last century. In spite of their many ecological, economic and social values, more than 50% of original wetland areas have been lost in the United States (Frayer *et al.*, 1983) and Southern Canada (Lynch-Stewart, 1983; Bardecki, 1984; van Patter & Hilts, 1985). Though attitudes have shifted to conservation rather than exploitation of wetlands, conflicts with agriculture,

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TABLE 1
Variation in Life Form and Life History Type in Various Wetlands with Low Standing Crop[a]

Low standing crop wetlands	*Annual species*	*Reeds*[g]	*Isoetids*[h]	*Insectivorous species*[i]
Nova Scotia Gillfillan L.[b]		*Eleocharis smallii* Britt. *E. tenuis* *Equisetum arvense* *E. fluviatile* *Juncus filiformis*	*Eleocharis acicularis* *Eriocaulon septangulare* *Gratiola aurea* *Isoetes acadiensis* Kott. *Juncus pelocarpus* *Lobelia dortmanna* *Lycopodium inundatum*° *Ranunculus reptans* L. *Sabatia kennedyana* *Xyris difformis* Chapm.°	*Drosera intermedia* *D. rotundifolia* *Sarracenia purpurea* *Utricularia cornuta* *U. geminiscapa* *U. subulata* *U. vulgaris*
Wilsons L.[c]	*Elatine minima*	*Eleocharis robbinsii* *E. smallii* Britt. *E. tenuis* *Equisetum fluviatile* *Juncus filiformis* *Scirpus validus*	*Eleocharis acicularis* *Eriocaulon septangulare* *Isoetes tuckermani* A. Br. *Juncus pelocarpus* *Lobelia dortmanna* *Lycopodium inundatum*° *Myriophyllum tenellum* *Ranunculus reptans* L. *Sabatia kennedyana* *Xyris difformis* Chapm.°	*Drosera intermedia* *D. rotundifolia** *Utricularia cornuta* *U. purpurea** *U. resupinata* *U. vulgaris**
Ontario Axe L.[d]	*Bidens* sp.	*Eleocharis smallii* Britt. *Juncus filiformis* *Scirpus torreyi*	*Eriocaulon septangulare* *Juncus pelocarpus* *Lobelia dortmanna* *Lycopodium inundatum*° *Myriophyllum tenellum*	*Drosera intermedia* *D. rotundifolia** *Utricularia cornuta* *U. gibba* *U. intermedia*

			Xyris difformis Chapm.[o]	*U. purpurea* *U. resupinata* *U. vulgaris*
Ottawa R[e]		*Eleocharis erythropoda* *E. smallii* Britt. *Equisetum fluviatile* *Scirpus acutus* *S. americanus*	*Eleocharis acicularis* *Eriocaulon septangulare* *Isoetes echinospora* *Juncus pelocarpus* *Myriophyllum tenellum* *Potamogeton gramineus* *Ranunculus reptans* L. *Sagittaria graminea*	
Presqu'ile[f]	*Aristida longespica* *Bidens cernua* *B. frondosa* *Panicum flexile* *Scleria verticillata* *Sporobolus vaginiflorus*	*Eleocharis elliptica* Kunth. *Equisetum fluviatile* *E. variegatum* *Juncus alpinoarticulatus* Choix. ex. Vill. *J. balticus* *Rhynchospora capillacea* *Scirpus americanus*	*Carex aurea*[o] *Parnassia glauca*[o]	*Utricularia minor*
Westmeath[f]	*Bidens cernua* *B. frondosa* *Fimbristylis autumnalis* *Gratiola neglecta* *Impatiens capensis* Meerb. *Ludwigia palustris* *Polygonum lapathifolium* *P. neglectum* Bess. *P. persicaria* *Sporobolus vaginiflorus*	*Eleocharis elliptica* Kunth. *E. smallii* Britt. *Equisetum fluviatile* *Scirpus acutus* *S. americanus*	*Eleocharis acicularis* *Eriocaulon septangulare* *Juncus pelocarpus* *Ranunculus reptans* L.	*Drosera intermedia*** *Utricularia cornuta*** *U. vulgaris***

(continued)

TABLE 1—*contd.*

Low standing crop wetlands	*Annual species*	*Reeds*[g]	*Isoetids*[h]	*Insectivorous species*[i]
Quebec				
Luskville[f]	*Bidens cernua*	*Eleocharis acicularis*	*Eleocharis acicularis*	
	B. frondosa	*E. erythropoda*		
	Callitriche deflexa	*E. smallii* Britt.		
	Cyperus aristatus	*Equisetum fluviatile*		
	C. diandrus	*Juncus bufonius*		
	C. rivularis	*J. effusus*		
	Eleocharis obtusa Sch.	*J. nodosus*		
	Gnaphalium uliginosum	*Scirpus acutus*		
	Juncus bufonius	*S. americanus*		
	Lindernia dubia			
	Panicum capillare			
	Xanthium strumarium			

[a] Species nomenclature follows Gleason & Cronquist (1963) except where authorities are given.
[b] Unpublished data analysed in Keddy (1984).
[c] Wisheu (1987); see also Keddy (1985).
[d] Keddy (1981); see also Keddy (1983).
[e] Day *et al.* (1988).
[f] C. Gaudet, D. Moore & P. Keddy (unpublished data).
[g] As defined in Day *et al.* (1988); 'leafless' shoots.
[h] From Table 1 in Boston & Adams (1987); ° similar species.
[i] * personal observations; ** unpublished reports.

industry and urban sprawl are inevitable. Therefore, it is of primary importance that we utilize clear scientific criteria for setting priorities in selecting wetlands for conservation (McCormick, 1978).

Much research into the functioning of wetlands has focussed on cyclical disturbance (van der Valk & Davis, 1976, 1978; van der Valk, 1981; Keddy & Reznicek, 1982; Pederson & van der Valk, 1984; Keddy, 1986) which permits regeneration from buried seeds. Most work has been done in prairie potholes (Pederson & van der Valk, 1984). As a consequence, current wetland evaluation and management practices are often based on principles derived from this rather narrow range of wetland systems (e.g. Weller, 1978; Pederson & van der Valk, 1984). However, there is another class of wetlands typified by chronically low productivity, which may be the result of any number of factors (e.g. soil infertility, exposure to waves or ice scour, sand deposition). In general, these wetlands are characterized by plants of small stature and communities with low standing crop (e.g. Keddy, 1981, 1983, 1985; Boston & Adams, 1987; Day *et al.*, 1988; see examples in Table 1). Soil nutrient analyses of a wide variety of eastern Canadian wetlands have demonstrated a positive relationship between macronutrient levels (with the possible exception of nitrates) and standing crop (Table 2). Therefore, in this study we term low standing crop wetlands 'infertile wetlands'. However, it should be noted that this generalization may not extend to other wetland systems.

Infertile wetlands have been found to contain a wide array of species morphologies (e.g. reeds, isoetids, insectivorous species) and life history types (annuals and perennials) (Table 1). Table 1 shows that many low standing crop wetlands in eastern Canada contain isoetid and insectivorous plant species, both of which may be an indicator of poor soil fertility (Givnish *et al.*, 1984; Boston & Adams, 1987). In addition, infertile wetland species are characterized by low growth rates (Shipley & Keddy, in press) and poor competitive ability (Wilson & Keddy, 1986).

If the ultimate goal of nature conservation is to preserve genetic diversity as stated in the World Conservation Strategy (International Union for the Conservation of Nature and Natural Resources, 1980), then the most efficient means of reaching this goal is to conserve systems with high species richness and numerous rare species. In fact, traditional methods of ecological site evaluations have included these parameters as important selection criteria (Margules & Usher, 1981). More recent studies have emphasized community species composition as an important selection criterion, the goal being to preserve the maximum range of vegetation types (Nilsson, 1986). The purpose of this study was to compare a large number of wetlands in eastern Canada which vary in standing crop and fertility and represent much of the variation in Temperate zone wetlands. We use the

TABLE 2
Mean Macronutrient Levels (ppm) and Mean Above-ground Standing Crop ($g\,0{\cdot}25\,m^{-2}$) ($n = 15$) in Each of Five Wetland Sites Sampled at Each of Three Study Locations (Presqu'ile, Westmeath and Luskville)[a]

Location	*Standing crop*	NO_3	*P*	*K*	*Mg*
Presqu'ile					
1	17·8	7·33	1·13	17·3	43·3
2	67·0	9·07	1·33	34·5	69·9
3	86·8	7·80	1·00	35·2	53·9
4	173·1	8·93	1·00	52·7	63·1
5	421·6	9·20	4·20	15·5	32·9
Westmeath					
1	4·0	18·00	3·27	36·7	74·3
2	54·5	7·07	5·27	38·3	130·5
3	131·9	7·87	19·40	62·5	243·7
4	163·0	16·40	10·93	59·0	345·0
5	315·8	27·33	25·73	93·4	236·9
Luskville					
1	32·7	6·93	6·80	56·9	191·2
2	40·0	4·93	8·73	62·0	187.3
3	92·3	5·07	5·27	132·3	326·6
4	124·6	11·60	9·67	150·3	383·0
5	277·7	15·73	15·67	159·4	386·9

[a] The data from the three study locations were collected at different points in the growing season and in different years; caution should therefore be exercised when comparing the three locations.

dependent variables of (1) species richness, (2) number of rare species, and (3) species composition to determine the relative value of infertile wetlands in wetland conservation.

METHODS

Study locations

Three primary study locations were chosen in Eastern Ontario, Canada (Westmeath and Presqu'ile) and Western Quebec (Luskville). The Presqu'ile study location (44° 0′ N, 77° 43′ W) is a peninsula located on the north Lake Ontario shoreline within Presqu'ile Provincial Park. The sites surveyed included low standing crop (1–400 $g\,m^{-2}$) infertile wet meadows, a moderate standing crop (200–500 $g\,m^{-2}$) fen, a high standing crop (400–900 $g\,m^{-2}$) marsh and a very high standing crop (800–2500 $g\,m^{-2}$) *Typha* marsh. The Westmeath study location (45° 47′ N, 76° 50′ W) is a riverine shoreline located on the Ottawa River 22 km southwest of the city of Pembroke. At this location, we surveyed low standing crop open beach sites and moderate to high standing crop sheltered marshes located in Bellows Bay. A very high standing crop *Typha* marsh located 15 km south of Westmeath was also surveyed. The Luskville study location (45° 31′ N, 76° 6′ W) is also a riverine shoreline located 5 km west of Luskville, Quebec on the Ottawa River. The survey included low standing crop open beach sites, moderate and high standing crop sheltered bay marshes, and a very high standing crop *Typha* marsh.

Additional wetlands were surveyed at Wilsons Lake in the Tusket River valley of Nova Scotia (43° 55′ N, 65° 53′ W) (Wisheu, 1987) and in 22 sites on the Canadian Shield in the Georgian Bay area of Ontario. These wetlands are found along lake shorelines and are also characterized by low standing crop. Corresponding high standing crop wetlands were not surveyed at these locations.

Wetland surveys

The descriptive surveys described below were done at Presqu'ile (12–14 September 1986), Westmeath (25–26 August 1987) and Luskville (18–19 August 1987). At each study location, five sites of varying standing crop were selected. In each site, fifteen quadrats were randomly chosen and the vegetation sampled using a 0·5 m × 0·5 m quadrat with nine equivalent subdivisions. The presence of each species in each subdivision was recorded and the vegetation clipped at ground level, dried to constant biomass at 60°C, and weighed.

At Wilsons Lake, the species present in each of 119 quadrats (0·25 m × 1·0 m) arranged along a standing crop gradient were determined during 1–26 August 1984. Quadrat standing crop was then determined as above.

A total of 57 0·5 m × 0·5 m quadrats were randomly located and sampled from 22 lakes in the Georgian Bay area during 19–27 August 1987. In each quadrat, the species present within each of nine equivalent subdivisions were recorded. Quadrat standing crop was then determined as above.

All voucher specimens were deposited at the Agriculture Canada herbarium (DAO) except those from the Georgian Bay locations which were deposited at the University of Toronto herbarium (TRT).

Species richness and number of rare species

Species richness was calculated as the number of species per 0·25 m^2 quadrat and the results plotted against quadrat standing crop for all 401 quadrats.

Nationally rare plant species were determined by reference to *The Rare Vascular Plants of Canada* (Argus, G. W. & Pryer, K. M., unpublished). The number of rare plant species per 0·25 m^2 quadrat was then calculated and the results plotted against quadrat standing crop for all 401 quadrats.

Vegetation types

Wetlands were qualitatively assigned to vegetation types on the basis of the one to three most abundant species present, and major habitat features noted for each wetland. The number of vegetation types as a function of standing crop was then determined.

RESULTS

Species richness

At very low standing crop (1–25 g m^{-2}) species richness varied from 2–12 species (Fig. 1). As standing crop increased, species richness rapidly increased to a maximum of 12–20 species between 60–400 g m^{-2}. Above 400 g m^{-2} species richness gradually declined to 2–6 species at high standing crop (>600 g m^{-2}).

Number of rare species

Figure 2 indicates that low standing crop wetlands often have many nationally rare species while high standing crop wetlands do not (>600 g m^{-2}). Further, several of the rare species encountered are not only nationally rare but are nationally threatened (e.g. *Sabatia kennedyana*

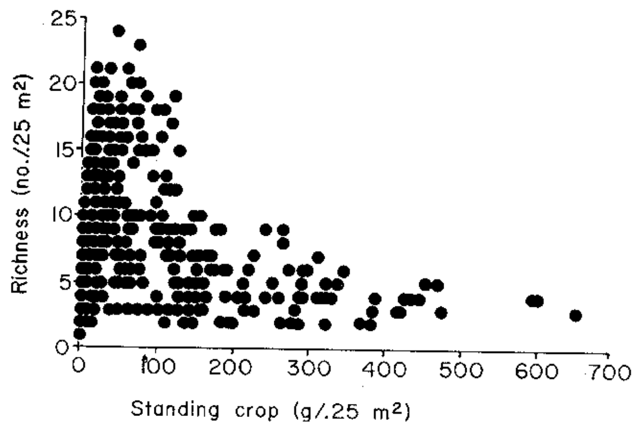

Fig. 1. Species richness versus standing crop in 401 0·25 m^2 quadrats from wetlands located in Ontario (Presqu'ile Provincial Park, Westmeath and near Georgian Bay), in Quebec (Luskville marshes) and in Nova Scotia (Wilsons Lake).

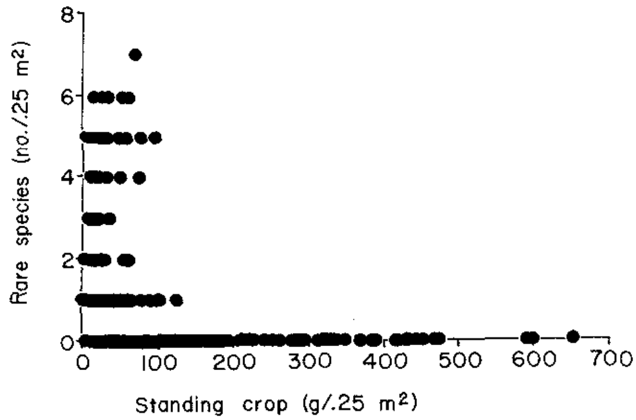

Fig. 2. Number of nationally rare species versus standing crop in each of 401 quadrats from wetlands located in Ontario, Quebec and Nova Scotia.

TABLE 3
The Current Status of Rare Species from over Twenty Wetlands Sampled in Ontario, Quebec and Nova Scotia

Location	*Species*[a]	*Status*
Nova Scotia		
Wilsons Lake	*Coreopsis rosea*	c
	Solidago galetorum	a
	Habenaria flava	a
	Hydrocotyle umbellata	c
	Panicum longifolium	a
	Rhexia virginica	a
	Sabatia kennedyana	b
	Xyris difformis Chapm.	a
Ontario		
Georgian Bay area	*Panicum rigidulum* Nees. var. *rigidulum*	a
	Rhexia virginica	a
	Xyris difformis Chapm.	a
Presqu'ile	*Aristida longespica*	a
	Scleria verticillata	a
Westmeath	—	—
Quebec		
Luskville	*Lindernia dubia*	a

[a] Species nomenclature follows Gleason & Cronquist (1963) except where authorities are given.
a = Nationally rare.
b = Nationally threatened.
c = Nationally endangered.

Fernald) or endangered (e.g. *Coreopsis rosea* Nutt.) in Canada (Argus, G. W. & Pryer, K. M., unpublished). The rare species encountered in this study are listed in Table 3 along with their current national status.

Vegetation types

In low standing crop wetlands, almost every wetland observed had a unique vegetation type. That is, the most abundant species in each low standing

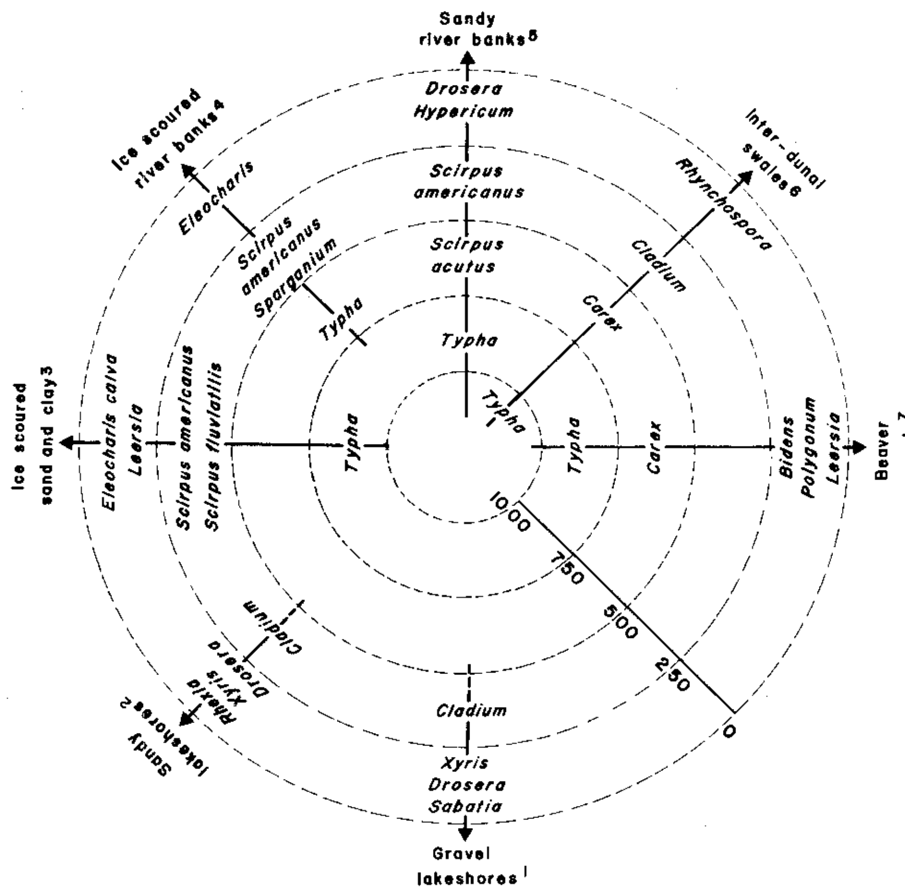

Fig. 3. Centrifugal organization model showing the relationship between vegetation type, habitat and standing crop. Standing crop (g m^{-2}) increases from the exterior (0 g m^{-2}) to the interior of the circle (> 1000 g m^{-2}). Habitats located on the exterior of the circle and at low standing crop have different vegetation types. At high (>750 g m^{-2}) standing crop, similar vegetation types are found. 1, Wilsons Lake (Wisheu, 1987); 2, Axe Lake (Keddy, 1983); 3, Luskville, Ottawa River (this study); 4, Ottawa River, 4 locations (Day *et al.*, 1988); 5, Westmeath, Ottawa River (this study); 6, Presqu'ile Park, Lake Ontario (this study); 7, Beaver Ponds, Lanark County, Ontario (Keddy, field observations).

crop wetland were not found in other low standing crop wetlands. However, as standing crop increased the number of vegetation types encountered declined until at very high standing crop only one vegetation type, *Typha* marshes, was observed in the wetlands we sampled (Fig. 3).

DISCUSSION

Species richness and number of rare species

The results indicate that, in general, species richness was higher in infertile than in fertile wetlands although richness was reduced in very infertile wetlands (Fig. 1). This relationship between species richness and standing crop has also been found in many other wetland systems (Wheeler & Giller, 1982; Vermeer & Berendse, 1983; Wisheu, 1987; Day *et al.*, 1988) and is likely a general trend in herbaceous plant systems (Grime, 1977; Tilman, 1982).

Similarly, nationally rare species were only found in infertile wetlands (Fig. 2). These results clearly indicate that infertile wetlands have a much higher conservation value than do fertile wetlands. Therefore, if we are to realize the goal of preserving genetic diversity (International Union for the Conservation of Nature and Natural Resources, 1980), infertile wetlands must be given high conservation priority.

Vegetation types

Another major goal of conservation is to ensure protection of all representative vegetation types (Marsh, 1978; Nilsson, 1986). A frequent observation in our surveys of eastern Canadian wetlands is that very fertile wetlands are almost always dominated by *Typha* spp. As fertility decreases, a wider array of vegetation types are observed (Fig. 3) (also see Day *et al.*, 1988). Thus, in order to ensure an adequate representation of the variation in infertile wetlands, more should be protected.

Sensitivity of infertile wetlands

While plant species of infertile wetlands are found in a wide variety of habitats, they share a number of characteristics important in their response to human disturbances. For instance, infertile wetland species are sometimes evergreen (Wisheu, 1987), have relatively low growth rates (Shipley & Keddy, in press), and have low competitive ability (Wilson & Keddy, 1986). They can therefore be categorized as stress-tolerators (*sensu* Grime, 1977;

Boston & Adams, 1987). In general, systems dominated by stress tolerators recover very slowly from disturbance events (Thorhaug, 1980) and infertile wetlands will therefore likely be slow to recover from human disturbances such as trampling and all-terrain vehicles (Wisheu & Keddy, in press).

Many infertile wetlands are also being subjected to increasing eutrophication pressures (Hines, 1973; Owen, 1980) as a result of pollution or management practices. Previous studies have indicated that nutrient loading in previously infertile systems has the effect of reducing species richness (Tilman, 1987) and converting unique vegetation types to those more commonly observed (Ehrenfeld, 1983; Morgan & Phillipp, 1986; Tilman, 1987). Many rare species which are usually of small stature will also be competitively eliminated by large, rapidly growing species capable of surviving in more fertile areas (Grime, 1977; Wilson & Keddy, 1986). The 'radial organization' model of wetlands shown in Fig. 3 illustrates these points. As fertility and standing crop increase, vegetation types converge on the central region of *Typha* dominance. Because *Typha* is a large clonal perennial, it competitively eliminates the smaller, less agressive infertile wetland species (Table 3). Therefore, species typical of infertile wetlands will progressively disappear from the landscape as eutrophication continues.

Planning for conservation of infertile wetlands

Present wetland evaluation systems tend to be skewed in favour of fertile rather than infertile wetlands (e.g. Ontario Ministry of Natural Resources, 1983). This is especially true in the case of infertile wetlands which do not have rare species, even when they have high species richness or unusual vegetation types. Similarly, management strategies often favour fertile wetlands as a means of maximizing wildlife productivity (e.g. Weller, 1978).

The results of this study clearly indicate that wetland evaluation systems, conservation priorities and management strategies need to be adjusted to reflect more effectively the inherent conservation values of infertile wetlands. The following steps are suggested as part of this re-evaluation.

(1) *Research:* Further research is required for a better understanding of the functioning of infertile wetlands and their likely responses to perturbations.

(2) *Site selection and evaluation:* Wetland evaluation systems need to be modified to place greater emphasis on high species richness and the presence of unusual vegetation types rather than productivity.

(3) *Management:* The current tendency of managing wetlands as if they all require cyclical disturbance (dyking and manipulation of water-levels) needs to be replaced by a pluralistic approach where different kinds of wetlands receive different management.

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