Wetland management and conservation of rare species

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Abstract: The value of wetland is now widely recognized; some legislation requires "no net loss" of wetlands, although economic incentives still exist for wetland conversion. Rare plants may be protected by law; however, wetlands are rarely managed specifically to conserve rare species. Furthermore, it is not always clear how the environment should be manipulated to increase the abundance of such species, since necessary autecological details are rarely available. Species conservation involves demographic and genetic elements, as well as ethical decisions about the merits of transplanting or importing genes through controlled pollinations. Rare species may serve as indicators of habitat quality, although this will depend on the reasons behind the species' rarity. There is a need for multiple-use management plans that incorporate species- and habitat-conservation goals and that implement overall strategies to maintain or enhance the total quantity and quality of wetlands.

Key words: rare plants, management, wetland conservation, habitat conservation.

Résumé : L'importance des terres humides est maintenant généralement reconnue; certaines législations exigent qu'il n'y ait pas de "perte nette" de terres humides, bien que les pressions économiques favorisant la conversion de ces habitats existent toujours. Les plantes rares peuvent recevoir la protection de la loi; cependant les terres humides sont rarement aménagées de manière à conserver les espèces rares. De plus, les façons d'intervenir dans le milieu pour augmenter l'abondance de ces espèce ne sont pas toujours évidentes parce que les détails autécologiques nécessaires sont rarement disponibles. La conservation des espèces implique des éléments démographiques et génétiques, ainsi que des décisions éthiques sur les mérites de la transplantation ou de l'importation de gènes par des pollinisations contrôlées. Les espèces rares peuvent servir d' "indicateurs" de la qualité des habitats, bien que ceci dépende des raisons qui justifient le caractère rare des espèces. Il est nécessaire de mettre en place des plans d'aménagement qui incluent à la fois les objectifs de conservation des espèces et de conservation des habitats et qui comportent des stratégies d'ensemble pour augmenter la quantité et la qualité des espaces humides.

Mots clés : plantes rares, gestion, conservation des terres humides, conservation des habitats.
[Traduit par la rédaction]

Introduction

A linkage is needed among aspects of several ecological subdisciplines, including population ecology, conservation biology, and environmental policy and planning, to achieve conservation of rare wetland species. Successful progress in conserving rare wetland species is most likely if we can unify the goals and understanding provided by each of these fields.

Defining wetlands

Quantity and quality

Wetlands are transitional ecosystems, between upland and open water, and therefore they are difficult to delineate precisely (Tiner 1993). However, it is often necessary to identify the physical extent of wetlands, especially for regulatory purposes (Adams et al. 1987; Mitsch and Gosselink 1993; Kusler 1992). Wetland borders are in flux, at time scales of weeks, seasons, years, centuries, and millenia, and attempts to delineate particular wetlands for protection may be problematic if regulations and policies are made on the basis of a single survey (Botts and McCoy 1993). They do not, therefore, map consistently to particular spatial coordinates but rather are defined by the prevalent conditions. These conditions can be readily altered by the activities of humans and other biota, including plants and microorganisms. Formally, the defining features of wetlands are specific combinations of (*i*) hydrogeological conditions; (*ii*) physical, chemical, and microbiological properties of the substrate; and (*iii*) specialized plant communities. Wetlands normally have (*i*) at least temporarily waterlogged or saturated substrata; (*ii*) dominance of plants adapted to saturated soils (hydrophytes and helophytes, sensu Raunkiaer); and, reciprocally, (*iii*) scarcity of flood-intolerant plants.

The widely used Cowardin system for wetland classification focuses on identification of dominant plant or animal communities as indicators of the hydrologic and substrate conditions (Cowardin et al. 1979); this classification system

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Table 1. Abbreviated aspects of the scoring system for the Ontario Ministry of Natural Resources (1993) habitat evaluation system for southern Ontario wetlands.

Class	Component	Maximum no. of points
1	Biological	
	Productivity	80
	Diversity	120
	Size	50
	Total	250
2	Social	
	Resource cash value	60
	Recreational value	70
	Aesthetic value	25
	Education − public awareness	35
	Proximity to urban areas	20
	Ownership−accessibility	20
	Size	20
	Total	250
3	Hydrologic	
	Flow-stabilization value	190
	Water-quality value	35
	Erosion-control value	25
	Total	250
4	Special features	
	Rarity−scarcity value	250
	Significant features and (or) fish wildlife habitat	250
	Ecological age value	15
	Total (not to exceed)	250

is frequently used in mapping and in preparing environmental impact statements. It is also possible to devise botanically based criteria of environmental quality (see Boutin and Keddy 1993), in the sense that changes in species composition, diversity, and abundance as well as net primary production and overall productivity may signal environmental impairment or improvement from a degraded state.

A considerable area of wetlands has already been lost in North America (Bildstein et al. 1991; Mitsch and Gosselink 1993). More than half of the wetland area present in the mainland United States in the 17th century has been lost, that is about 70 million hectares, mostly as a result of human activities (Dahl 1990; National Research Council 1992). In Canada, wetlands have already been reduced by 15% since European settlement. National data for Canada belie the severity of wetland loss in highly populated areas: 68% of wetlands in southwestern Ontario have gone, over half the potholes in the central Prairies have been lost, and 70% of the Pacific estuary marshes are gone or degraded (Shrubsole 1989, 1990; North American Wetlands Conservation Council of Canada 1992, 1993). There is, therefore, intense pressure on the wetlands in our most populated areas.

Several schemes have been established to assess wetland quality. The objective is generally to give each wetland a score that will allow prioritization of protection of particular wetlands from development. One comprehensive scheme is that elaborated by the Ontario Ministry of Natural Resources (OMNR; 1993). However, some criticisms have been made of that scheme on the basis that the assessment and classification framework is not sufficiently open-ended and flexible (McKee et al. 1990). Wetlands that earn a low score are less likely to be purchased by regional conservation authorities or granted protected status such as being designated ecologically significant areas (ESAs) or provincially significant wetlands (PSWs). In the OMNR classification system, wetlands receive a score based on such properties as social value (including the dollar income from the use of its resources and recreational value); a hydrologic component, which includes water quality and erosion control value; and a biological component (Table 1). There is also a special features component that allows for the regional scarcity of wetlands, the representation of different wetland types, and the particular species present. More specifically, the number of provincially significant plant species in a wetland is tallied; the more species there are (of 524 upland and wetland species listed in Argus et al. 1982−1987), the greater the additional score for special features.

The ecological importance of wetlands is now widely recognized. Many authors have emphasized and demonstrated the fundamental contribution of wetlands to the health of adjacent ecosystems; wetlands have been called nature's lungs and nature's kidneys (Catallo 1993); along the same analogy, they could also be described as nature's womb (nursery areas for aquatic organisms) and liver (detoxification centre for pollutants and excess nutrients; see, e.g., Mitsch and Gosselink 1993). Although they constitute only 1% of the planet's surface area, 6% of global land surface, and 14% of Canada's land area, they are critical to the productivity of adjacent ecosystems, particularly fisheries. For example, significantly decreased fish landings and wildlife production have been associated with wetland loss and deterioration (Chambers 1992; Harris 1988). As in many ecological situations, the greatest species diversity is observed in ecotones between wetlands and other ecosystems.

Wetland protection and legislation

Wetlands were until recently only very weakly protected in Canada. In Ontario, until 1988, wetlands were taxed twice as heavily when left in a natural state than if they were drained and planted with crops. They were viewed as underutilized swamps, recreational land at best (McCullough 1985). Grants and other financial incentives were also given for the draining and diking of wetlands, whether or not they were put into agricultural production (Lynch-Stewart et al. 1993). Since 1981, concerted attempts have been undertaken to inventory existing wetlands in Ontario (see Smith et al. 1991).

The Canadian Fisheries Protection Act of 1986 called for "no net loss of fish spawning habitat;" thus a development that destroys wetland must replace it with an equivalent area. However, there have been very few prosecutions under the act. This simply illustrates the point that laws are only as good as the extent of their enforcement. The 1988 Conservation Lands Act provided tax rebates on some wetlands (and other critical habitats) in exchange for their protection from development by landowners in Ontario. Areas of natural and scientific interest (ANSIS) receive a 100% rebate. Unfortunately the standards for minimal area (>0.2 ha) and high

OMNR wetland quality scores mean that few privately held wetlands qualify for this rebate.

Federal responsibilities for wetland habitat protection in Canada are mentioned in the *Great Lakes water quality agreement* (International Joint Commission 1988) and the *North American waterfowl management plan* (Environment Canada and the United States Department of the Interior 1986), but these are only agreed goals and guidelines, not laws. While much is made of the principle of no net loss (e.g., see North American Wetlands Conservation Council of Canada 1992), the idea has been somewhat weakened and modified in recent policies of the Ontario government. For example, Ontario policy goals under the 1983 planning act are to ensure "no loss of provincially significant wetlands." Provincially significant wetlands (PSWs) are those that fall into class 1, 2, or 3 of the OMNR (1993) evaluation system. Some of the lands owned by regional conservation authorities did fall into the protected category, but unfortunately these conservation authorities have recently lost their exemption from property tax, forcing some to sell off land they had been given or had purchased expressly for protection! One encouraging step is that, recently, Agriculture Canada has put forth objectives to conserve wetlands; this is an important change of policy, since, in the past, Agriculture Canada provided much of the impetus for wetland conversion (McCullough 1985).

A difficulty with respect to wetland protection in Canada is that it is essentially nonregulatory: it is overseen by a layered mosaic of agency policies, and portions of a few laws, set by several different levels of government, not all of which are pushing in the same direction. We endorse the proposition that distinct, federal legislation for the protection of wetlands in Canada would be the most effective means of protecting this vital and undervalued habitat.

Management

Management techniques, and the fate of rare species

The goals of wetland management are usually dictated by a single, resource-based objective, such as flood control, wildlife management, or fisheries enhancement. Only very occasionally is wetland managed to enhance a particular rare species. At most, in terms of botanical goals, wetland may be managed to enhance the abundance of plants that are valuable resources for wildlife, or towards the objective of controlling nuisance species (Keddy 1988). Since these policies affect abundant resource plants and nuisance plants, they will inevitably also have effects on rare plants in the wetland; it is therefore useful to outline the kinds of management activity that may be undertaken, and to assess any known or anticipated effects of these practices on rare species.

A common technique in wetland management involves diking to enhance habitat for waterbirds. Ducks Unlimited has financed a large number of diking ventures across the country. There are arguments in the literature as to whether this enhances or reduces the diversity of vegetation; typically there are fewer emergents but more floating-leaved macrophytes in open wetlands, and although standing biomass is greater in diked wetlands, productivity and export of primary production to the lake may be greater from open wetland (Stuckey 1975, 1989). Diking therefore changes the nutrient dynamics of wetlands and their adjacent ecosystems.

Weed control

Much of the research that has occurred on emergent and aquatic macrophytes has been (at least initially) stimulated by the need to control nuisance species such as purple loosestrife (*Lythrum salicaria*), Eurasian water milfoil (*Myriophyllum spicatum*), elodea (*Elodea canadensis*), coontail (*Ceratophyllum demersum*), curlyleaf pondweed (*Potamogeton crispus*), water hyacinth (*Eichhornia crassipes*), and chinese water chestnut (*Trapa natans*) (Nichols 1991). We can postulate a reciprocal relationship between the abundance of weedy species and that of native species, since invaders frequently invade the niches of native components of the vegetation (Mills et al. 1993). For demographic reasons, it would seem reasonable to suggest that rare species would suffer the impact of invaders more than other native species do, but this needs to be documented directly.

Carpenter (1983) suggested that we should exploit our understanding of the phenology of turnover of plant structures in order to control nuisance algal blooms; he proposed (not, perhaps, very practically!) that replacing a species such as milfoil, which is constantly recycling nutrients, with a species like *Vallisneria* that has low summer mortality might provide an interesting way of limiting internal nutrient loading during the phytoplankton growing season; this would be a kind of biological control mediated through regulation of nutrient availability.

Nutrient input controls

Only rarely have water resource managers established a program where nutrient input controls have been imposed. One of the most large-scale nutrient-control programs was driven by Annex 12 of the *Great Lakes water quality agreement* between the United States and Canada (International Joint Commission 1988). This set very specific goals and schedules for the reduction of phosphorus inputs to the Great Lakes, calculated on a lake by lake basis. It had been concluded that cultural eutrophication through phosphorus enrichment was driving excessive algal growth in many regions of the Great Lakes basin, and in particular that it was responsible for the seriously eutrophic state of Lake Erie in the 1960s. Much has been achieved through the control of phosphorus inputs. Ironically, however, phosphate controls are now being cited as being possibly responsible for the decline of some desirable fisheries in the lake (Makarewicz and Bertram 1993). Wetlands provide a buffer from high inputs of nitrogen and phosphorus and other contaminants (U.S. Environmental Protection Agency 1984), but their capacity to absorb pollutants is not infinite. They can, over time, rerelease the materials (both nutrients and persistent toxic substances) that they have absorbed. In the Great Lakes system, the release of contaminants from "historic" sediment deposits sometimes exceeds current industrial discharges to the water, and this will become more widely the case if input controls ("end-of-pipe" releases) are brought under legislative or self-regulatory control.

Herbicides

Herbicides are often applied to control nuisance macrophytes; the release of systemic herbicides in a wetland ecosystem has numerous undesirable side effects, including damage to nontarget species (Clark et al. 1993). Furthermore, plant decay reduces dissolved oxygen, stressing fish and other animals. Broad-spectrum herbicides are particularly problematic in that they eliminate most plant species and open up this niche to opportunistic weeds, which may be introduced taxa. Indeed, when herbicide treatment has been used to alter plant community structure the results have proved to be highly unpredictable (Miller and Trout 1985). Outcomes included (*i*) regrowth of the target species in dense monospecific stands; (*ii*) development of a community dominated by species resistant to the herbicide that had been applied; and (*iii*) development of a rich, diverse, macrophyte community containing the target species, resistant species, and others.

The unpredictability of the outcome of herbicide treatment, in addition to the collateral damage that herbicides may do, makes them unattractive as management tools, particularly if there are rare species present.

Drawdown

A common treatment to control nuisance emergents and floating macrophytes has been drawdown, that is, artificially lowering the water level so that plant parts that are normally submerged are dried out and die in the open sun (Cooke et al. 1986). Generally, the response of vegetation to drawdown is species specific, season specific, and repeatable. However, if drawdown is carried out on a regular basis, it favours species that are tolerant of such variations in water level, and this may disrupt the plant community.

For example, our experiments with *Typha angustifolia* and the invasive alien, *Lythrum salicaria*, grown in plots in contrasting water tables, indicate that the amplitude of desiccation tolerance for *Lythrum* is significantly greater than that of *Typha*, one of its major competitors in North America (T. Mal, unpublished observations). In other words, the alien's physiological niche seems to be broader than that of the native species, with respect to water table, and therefore manipulations of water level would, if anything, favour the weed.

Given the uncertainty about the outcome of most environmental manipulations, we may not be ready to expose the natural environment to large-scale experiments involving nutrient controls, manipulation of lake levels, the application of herbicides, etc., until well-designed microcosm or mesocosm studies have been carried out (see, e.g., Pratt et al. 1987; Pratt and Bowers 1990; Taub et al. 1986). It would be fair to say that research biologists have so far not made sufficient contribution to the understanding of the functional population ecology of aquatic species in a way that can be exploited by managers of wetlands. Partly, this is because of the technical difficulties of carrying out demographic investigations in aquatic systems, and in part it is because of the challenge of turning ecological observations and conclusions into concrete recommendations that managers can put into practice. (It could also be argued that population studies are not capable of answering questions of ecosystem management, although many management goals are expressed in terms of desired population size and structure for harvested species.)

A major problem with most of the prevalent management techniques outlined so far is that none of them can be viewed as directed at, or even necessarily as potentially favourable to, rare species. In fact it is quite possible that environmental manipulations such as water-level control, plant harvesting, herbicides, and nutrient manipulation will have more severe effects on rare species than on abundant natives or nuisance species. We could reasonably ask if any of these traditional wetland-management activities are even compatible with conservation measures. One possible fallback is that such manipulations may be followed by reintroduction of species that were previously in decline. However, this is, at best, restoration, rather than conservation or management of the natural ecosystem, and it certainly hasn't worked very well with the fish species, such as lake trout and walleye, that have been reintroduced to Lake Erie.

Restoration of aquatic plant communities

Plant communities can be enhanced by reintroducing native species. However, transplants can often fail, for a variety of reasons. The habitat may have already been sufficiently degraded that the species cannot tolerate the changed conditions, or it may be necessary to use the forester's approach of introducing plants of a particular ecotype or provenance to ensure their success. Various studies of reciprocal transplants between locally specialized populations indicate that survivorship, fecundity, clonal growth, etc. are invariably superior when plants are returned to the microhabitat in which they were collected (Lovett Doust 1981; McGraw and Antonovics 1983). It may also be necessary to harvest existing vegetation before new materials can establish (Les 1989). Nichols (1991) suggested that principles of landscape architecture should be applied to new (macrophyte) plantings in terms of plant size, diversity, and the provision of open space. In addition, weeding and replanting may be needed to establish a successful stand.

Rarity

Rarity is not a monolithic property; a species may be described as rare for a variety of reasons. Rabinowitz (1981) tried to tie all these together by recognizing "seven forms of rarity," each of which had distinct ecological and evolutionary consequences (Table 2). Categories were constructed on the basis of three sets of criteria: geographic range, habitat specificity, and local population size. The various forms of rarity may also have different implications in terms of appropriate conservation strategies.

In Canada, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has developed a list of endangered, threatened, and vulnerable organisms, including some 60 plants (COSEWIC 1993). The distribution of these species is interesting in that most cluster along the Canada–U.S. border. One might ask whether this is because human pressures impact more on plants there, driving them towards extinction, or if it is simply a reflection of the fact that there are more botanists and herbaria available to notice rare species along the border! For comparison, in the well-studied flora of California, 209 native plants have been recognized as rare, threatened, or endangered by the Fish and Game Commission (Holsinger and Gottlieb 1991).

According to COSEWIC (1993), 18 plants are endangered, 26 are threatened, and 22 are vulnerable. Many of the species listed by COSEWIC are wetland species or are found

Table 2. "Seven forms of rarity" according to Rabinowitz (1981).

Geographic range:	Large		Small	
Habitat specificity:	Wide	Narrow	Wide	Narrow
Local population size				
Large, dominant somewhere	Locally abundant over a large range in several habitats	Locally abundant over a large range in a specific habitat	Locally abundant in several habitats but restricted geographically	Locally abundant in a specific habitat but restricted geographically
Small, nondominant	Constantly sparse over a large range and in several habitats	Constantly sparse in a specific habitat but over a large range	Constantly sparse and geographically restricted in several habitats	Constantly sparse and geographically restricted in a specific habitat

in wet woodland soils where the water table is close to the surface. In Lake Ontario's coastal wetlands, for example, 19 species are described as provincially rare (Argus et al. 1982–1987; Smith et al. 1991). Wetlands are therefore home to a large number of recognized rare species, but, of course, this is partly because the wetland habitats themselves are rare and possibly because of bias in reportage.

As Rabinowitz (1981) recognized, the abundance matrix she constructed did not take account of another category, species that are "pseudo-rare," that is, species on the margin as opposed to in the middle of their range. When we give account to national or provincial boundaries, many of the species listed as rare in Canada fall into this category, i.e., they are rare in Canada or provincially rare, but, on the other side of a political boundary, they may be more abundant or even widespread.

For example, green dragon, *Arisaema dracontium*, is classified as threatened by COSEWIC (Keddy 1984), and a recovery plan is being developed for its protection. On an international scale, it could be argued that there is less need for concern about the loss of green dragon than there would be for species that are restricted to Canada, since the species is widely distributed in the eastern United States (Huttleston 1953). However, in Canada green dragon is present in only a limited number of sites in Ontario and Quebec, and Canadian conservationists have no control over the species' protection elsewhere. The decision to make efforts for conservation of green dragon is driven by concern about the rarity of suitable habitat combined with observations of the species' decline over the past 20 years in Canada, as well as a concern for the species' continued presence in Canada, whatever its distribution and abundance may be on a continental scale. It may be important to distinguish the category of rarity for each listed species in order to rank priorities for conservation.

It seems reasonable to ask whether some rare species may be more important than others, and might deserve different ranking for the triage of conservation effort. From the perspective of community energetics, it may be argued that some rare species could be lost without noticeable effect on community function. In contrast, loss of, for example, a canopy dominant might radically alter ecological function (Pratt and Cairns 1992). Does this provide a criterion for ranking rare species for conservation efforts? Such an approach would be very dependent on the quality of survey of local communities, and on a good understanding of the role of each species in the community. This kind of information is, unfortunately, often lacking.

Conservation biology

Conservation biology has been described as a "crisis-oriented science" in that conservationists have to be willing to make guesses about the long-term behaviour of complex systems without knowing much about their dynamics (Soulé 1991). In this respect, conservation biology is not all that different from environmental management as a whole. Much has been written over the past decade about the concept of sustainable development (which some critics describe as an oxymoron, amounting to sustained development). If the term is to be useful, it is important that conservation strategies be an intrinsic component of all management plans; indeed, conservation strategies and management strategies for optimization of resource yield and sustainability need to be fully integrated if either is to succeed.

Typically, in the classification of terrestrial vegetation types, rare species are used as indicators of the particular conditions at a site that are attributable to subtle variations in the environment. If we assume that rare species are rare because they are more sensitive than the other members of the community to slightly changed conditions, then, by extension, the presence or abundance of the rare species may also provide an assessment of site quality. It is not clear whether rare species are the best indicators of stress impacts in a wetland ecosystem, but for demographic reasons alone they are most likely to disappear first in the face of stress. Many species have already been reduced to one or two populations with few individuals, so it is important to determine what kind of conservation program is most appropriate, what biological information is needed to implement those programs, and what criteria should be used to set the priority ranking of species for conservation.

Conservation can target many levels of variation; alleles, allele frequencies, heterozygotes, subspecies, ecotypes, varieties and species, communities and ecosystems (Noss 1990). Some rather different philosophies seem to exist within the community of conservationists: there are those whose goal is the conservation of diversity in communities (Davis et al. 1990), and those who are particularly concerned about the preservation of particular rare or endangered species, and the appropriate management choices for the two goals do not necessarily coincide (Harper 1981). Those concerned with particular species can be further clustered into those who place primary emphasis on population genetics, and those who are concerned with issues of population dynamics.

Genetic aspects

Broadly speaking, we probably know more about the genetic properties of rare species than we know about their demography, particularly in terms of theory. There are clear genetic consequences to rarity that increase the probability of extinction; the most obvious of these are the risks of genetic bottlenecks (Barrett and Kohn 1991), and problems for outbreeders in terms of finding compatible mates. However, Goodnight (1988; and see Falk and Holsinger 1991) has suggested that additive genetic variance, the portion of genotypic variance among individuals that can respond to selection, may actually *increase* as a result of bottlenecks if there are significant interactions among loci in determining phenotypic characters.

Species abundance per se is presently the major (and often the only) criterion used for listing species as rare. Unfortunately, simple results of a census showing low numbers is an inadequate basis for a conservation plan. Strong arguments exist for considering other biological properties as well (Holsinger and Gottlieb 1991). A hierarchy of concern, with taxonomic distinctiveness being one of the most decisive factors, seems more appropriate. Holsinger and Gottlieb (1991) proposed that monotypic genera or families deserve the highest priority and stipulate that endangered species are of more direct concern than endangered intraspecific taxa. This is sort of a sophisticated Noah's Ark approach: keep at least some of everything presently in existence.

Holsinger and Gottlieb (1991) gave little weight to asexual mutants and sterile hybrids. In contrast, the *British red data books* of endangered species (Perring and Farrell 1977), possibly due to the particular, idiosyncratic, taxonomic expertise of contributors, gave much attention to agamospecies of *Sorbus* and *Taraxacum*, for example. Similarly, locally adapted races of contaminant-tolerant grasses (Antonovics 1984) would not be a matter of note. One may argue, therefore, that Holsinger and Gottlieb's criteria of taxonomic diversity will not necessarily reflect losses of biological diversity and interesting variation of (intraspecific) evolutionary importance.

This suggests a special responsibility for systematists. If the criteria of Holsinger and Gottlieb (1991) are followed, then decisions made by systematists with regard to delimination of genera, and measures of relatedness between taxa will be very important components of the argument that is constructed to conserve any given taxon.

An obvious strategy based on the population genetics approach would be to target the effective population size, N_e, through management activities. Such a strategy would involve maintaining population size, encouraging outcrossing, and enabling migration between populations. For example, in a sexually monomorphic species, N_e can be doubled by equalizing the contribution of each adult to the population, through setting up a controlled-crossing program. It is probably too complex an issue to attempt to directly manage or design the genetic structure of a population, but with a knowledge of the existing genetic structure, it may be "improved upon" assuming there is, indeed, something inherently superior about a greater level of genetic diversity. Obviously this is a very labour-intensive approach that would only be justifiable for significant species in imminent danger of extinction. A related issue concerns the long-distance importation of genes through transplantation or artificial pollinations, in that the unique nature of local genetic diversity and adaptation may be irrevocably altered. If projects of this kind are undertaken, they should certainly be well documented and records should be kept so that future researchers will be able to understand the origin of patterns of genetic diversity that result.

Although some studies of allozyme diversity have been made comparing rare species with congeners, it has long been argued that allozyme diversity may bear little relationship to genes determining ecologically important properties that will largely dictate the success of conservation efforts (Holsinger and Gottlieb 1991; Trieste 1991). Frequency-dependent selection may be an important feature of such populations, particularly as the population becomes smaller (Menges 1991).

From the genetic perspective then, Holsinger and Gottlieb (1991) argue that conservation strategies need to be species specific. They propose that conservationists should proceed as follows: (*i*) collect seeds or other propagules for off-site conservation; (*ii*) establish new populations at a distant site; (*iii*) display representatives in parks and botanic gardens (to pique public interest), (*iv*) rank the species that are at risk, nationally, so that we first preserve those most at risk (this is tantamount to figuring out a plan for triage, identifying which species will be rescued, and which will not); (*v*) have clearly stated goals for each plant; and (*vi*) goals might include dependence on the life-form, attractiveness, nature of the native habitat, degree of scientific interest, etc.

According to this scheme, the plant community and habitat are regarded essentially as a backdrop to the interesting, rare species that are deserving of attention.

Census studies

A census is a record of abundance, where the fates of individuals are not tracked. There is, therefore, no information on the turnover, birth, and death rates of individuals; only their standing numbers are recorded. Several case studies of rare species have allowed post hoc explanations of their low numbers. Most usually, the status of rarity has been assigned by knowledgeable local botanists; in their travels they have noticed rarities and kept track of sites where rare species occur. Herbarium samples provide a nonsystematic record of sites where rare species have occurred or continue to occur. At present tremendous effort is underway to identify new and endangered species in tropical ecosystems (before they disappear), but comparable efforts do not seem to be underway in temperate and boreal zones. It is therefore reasonable to ask if we have yet sampled sufficiently to detect all the rare species that may require our conservation efforts. Green and Young (1993) examined the design of sampling procedures and the amount of sampling effort required for detection of a rare species and concluded that sample size would have to be determined on the basis of a Poisson distribution, since the chance of collecting an individual in any given sample is low. To design the sampling program, therefore, it will be necessary to decide at the outset how rare a species one wants to detect, i.e., the target density. However, very few rare species have been detected on the basis of random sampling procedures; usually it is simply the result of reports from observant field botanists. Statistically based sampling procedures may, however, be appropriate for sampling of "invisible" organisms such as phytoplankton and zooplankton, and soil microfauna, where samples will be processed in the laboratory rather than directly in the field.

Caughley (1994) has argued that declining populations, rather than small populations are the ones that need attention from ecologists and conservationists. He argues that population ecologists should seek to develop a theory of what drives population declines, so we can break away from the limitations of case by case (post facto) explanations of extinctions. Although population genetics may be a very important interpretative tool in maintaining and assessing sheltered zoo and garden populations, Caughley (1994) argued that it is not the key to identifying priorities for conservation. Similarly, although genetic diversity is likely to affect the long-term prospects of the species, Caughley concluded that it is not clear how reduced genetic diversity will affect their short-term prospects for conservation.

Demographic approach

Byers and Meagher (1992) modelled seed set in small populations of self-incompatible plants and concluded that, in general, there would be (*i*) diminished seed set per individual because of limited numbers of mates; and (*ii*) increased variance in seed set among individuals, because of increased variance in available mates. Both effects would increase the chances of extinction of the population.

Rarity is a phenomenon in space and time; it is important to recognize the transient nature of many plant populations, particularly biennials or early successional species (Harper 1981). As a result, rarity or extinction from a particular site may be irrelevant; rather the species' status should be assessed on a wider geographic scale. Species may be rare because the window of opportunity for colonization is small, and this will be more of a problem if propagules are few in number or are poorly dispersed. The population dynamics of rare species may best be measured in terms of the following components (Harper 1981): (*i*) the frequency of disturbance, (*ii*) the potential for recovery in terms of the reproductive capacity of the plants, (*iii*) the longevity of the seed bank, and (*iv*) the rate at which the carrying capacity of the environment itself changes. That is, it is useful to ask how often these species will be "on the move." From the point of view of assessing rarity in space, habitable sites that are available generally greatly exceed the number that are actually occupied by a particular rare species. Problems of dispersal and fecundity may restrict the species from colonizing otherwise suitable locations, and the problem becomes more acute as the geographic distribution of the species contracts. According to our field studies (Boles et al. 1993), the green dragon, for example, is absent from most of the suitable riverbanks in southwestern Ontario, and it has been lost from several sites where, according to old herbarium records, it used to grow.

Cairns (1991) speculated that cosmopolitan species may also be at risk of extinction; many of them are in fact perpetual fugitives, moving from one ecological island (or reprieve, perhaps, from intense competition) to another, as colonizing and dispersal conditions permit. For this kind of species to persist, it would be necessary, Pratt and Cairns (1992) speculate, for occupied sites to be linked by a number of "stepping stones," or suitable areas in between. A critical factor will of course be the viability and durability of propagules. In the case of wetland species, riparian corridors represent a critical source of plant diversity and recolonization of disturbed areas (see, e.g., Naiman et al. 1993).

Wetland management and conservation of rare species

In reconciling an integrated conservation strategy for rare wetland species, we support a nested approach, setting conservation goals simultaneously at the levels of landscape and habitat (Mitsch 1992) as well as at the levels of species and genotypes, as follows.

(1) Habitat conservation in terms of both quantity and quality is a first priority. This is best done through federal legislation. It is in the mutual interests of resource managers and conservationists to take this action, so it would not be hard to build a coalition of stakeholders including resource management agencies and conservationists, as well as plant ecologists, to lobby for the drafting of a federal wetland protection act.

(2) Differences may exist between central and peripheral populations; this may be reason enough to conserve the pseudo-rare species that make up a high proportion of Canada's rare species. In any event, this is an obvious situation that calls upon international aspects of conservation; at a minimum, conservationists in Canada and the United States should cooperate to examine their lists of rare and endangered species. Given limited resources available for conservation, we need to decide whether we will place higher priority on the conservation of species that are endangered on a global scale, perhaps giving less attention to the pseudo-rare species. This begs the question of whether conservation biology has a global or a national scope. At present, legislation, management, and policy are restricted to jurisdictional boundaries, but conservation scientists may be expected to set their priorities on a global basis, particularly as economic linkages such as the North American Free Trade Agreement, the General Agreement on Tariffs and Trade, and the European Union, which incorporate environmental standards and arrangements, are becoming the rule rather than the exception. Several theoretical explorations have been made of rare species, where authors have tried to find common properties (e.g., Schwartz 1993; Hodgson 1986), but it is important to remember that rarity is a consequence of ecological factors, not a cause.

(3) Species conservation, particularly for those species that are in danger of extirpation, calls for application of the genetic approaches and the demographic approaches mentioned earlier. This includes developing theory to explain driven population declines, as well as examination of the ethics and justification of artificial pollinations, interpopulation matings, and heroic measures such as plantings of samples in botanic gardens, and seed storage. We must hope to be able to show that there are inherent ecosystem-level

benefits to maintaining species diversity which will persuade resource managers to incorporate conservation in their resource-management plans. This question deserves the serious attention of those concerned with species conservation, because without the support of resource managers, conservation plans are likely to continue to be at odds with other resource-management goals.

(4) Rare species may be used as symbols of site recovery, or their absence may be used as evidence of impairment. However, species used in this regard must be selected with care, because a given species may be absent for reasons of dispersal or other ecological factors, independent of site quality.

In conclusion, the problems facing rare species in wetlands are, in principle, similar to those for rare species in other habitats, but they are made more urgent because of the exponential rate of loss of wetland to development, and the increasing diversity and intensity of stakeholder pressures on the wetlands that remain. Although it is unlikely that most wetlands will ever be managed directly to conserve particular rare plants, botanists, and particularly plant ecologists, should participate in multiple-use planning teams to ensure that conservation of the habitat and plant community also entails conservation of its rare members. Supported by data on environmental tolerance of species (and norms of reaction for individuals), rare species may be nominated as indicators of environmental quality or degradation, and therefore their sustained abundance can be used as an indicator, and set as a goal, of management of the resource.

It is therefore important that botanists become directly involved in the resource planning process and contribute the demographic, genetic, systematic, and physiological data that will allow effective environmental assessment and tracking of environmental quality and, not at all incidentally, will allow preservation of rare species in wetland habitats.

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References

Adams, D.A., Buford, M.A., and Dumond, D.M. 1987. In search of the wetland boundary. Wetlands, **7**: 59–70.

Antonovics, J. 1984. Genetic variation within populations. *In* Perspectives on plant population ecology. *Edited by* R. Dirzo and J. Sarukhan. Sinauer Associates, Sunderland, Mass. pp. 229–241.

Argus, G.W., Pryer, K.M., White, D.J., and Keddy, C.J. 1982–1987. Atlas of the rare vascular plants of Ontario. Botany Division, National Museum of Natural Sciences, Ottawa.

Barrett, S.C.H., and Kohn, J.R. 1991. Genetics and evolutionary consequences of small population size in plants: implications for conservation. *In* Genetics and conservation of rare plants. *Edited by* D.A. Falk and K.E. Holsinger. Oxford University Press, New York. pp. 3–30.

Bildstein, K.L., Bancroft, G.T., Dugan, P.J., Gordon, D.H., Erwin, R.M., Nol, E., Payne, L.X., and Senner, S.E. 1991. Approaches to the conservation of coastal wetlands in the western hemisphere. Wilson Bull. **103**: 218–254.

Boles, R., Lovett Doust, J., and Lovett Doust, L. 1993. Population biology of *Arisaema dracontium* (green dragon) a rare plant in Ontario. *In* Proceedings of the Ontario Ecology and Ethology Colloquium, 6–8 May 1993, Windsor, Ontario. pp. 3–4.

Botts, P.S., and McCoy, E.D. 1993. Delineation of spatial boundaries in a wetland habitat. Biodiversity Conserv. **2**: 351–358.

Boutin, C., and Keddy, P.A. 1993. A functional classification of wetland plants. J. Veg. Sci. **4**: 591–600.

Byers, D.L., and Meagher, T.R. 1992. Mate availability in small populations of plant species with homomorphic sporophytic self-incompatibility. Heredity, **68**: 353–359.

Cairns, J., Jr. 1991. Probable consequences of a cosmopolitan distribution. Speculations Sci. Technol. **14**(1): 41–50.

Carpenter, S.R. 1983. Submersed macrophyte community structure and internal loading: relationship to lake ecosystem productivity and succession. *In* Lake restoration, protection and management. U.S. Environmental Protection Agency, EPA 440/5-83-001, Washington, D.C. pp. 105–111.

Catallo, W.J. 1993. Ecotoxicology and wetland ecosystems: current understanding and future needs. Environ. Toxicol. Chem. **12**: 2209–2224.

Caughley, G. 1994. Directions in conservation biology. J. Anim. Ecol. **63**: 215–244.

Chambers, J.R. 1992. Habitat degradation and fishery declines in the U.S. *In* Coastal wetlands. *Edited by* S. Bolton. American Society of Civil Engineers, New York. pp. 46–60.

Clark, J.R., Lewis, M.A., and Pait, A.S. 1993. Pesticide inputs and risks in coastal wetlands. Environ. Toxicol. Chem. **12**: 2225–2233.

Committee on the Status of Endangered Wildlife in Canada. 1993. Canadian species at risk. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario.

Cooke, G.D., Welsh, E.B., Peterson, S.A., and Newroth, P.R. 1986. Lake and reservoir restoration. Butterworth Publishers, Boston.

Cowardin, L.M., Carter, V., Golet, F.C., and LaRoe, E.T. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish Wildl. Serv. FWS–OBS-79/31.

Dahl, T.E. 1990. Wetland losses in the United States, 1780s and 1980s. U.S. Department of the Interior, U.S. Fish and Wildlife Service, Washington, D.C.

Davis, F.W., Stoms, D.M., Estes, J.E., Sapan, J., and Scott, J.M. 1990. An information systems approach to the preservation of biological diversity. Int. Geogr. Inf. Syst. **4**: 55–78.

Environment Canada and the United States Department of the Interior. 1986. The North American waterfowl management plan. Environment Canada, Ottawa, and U.S. Department of the Interior, Washington, D.C.

Falk, D.A., and Holsinger, K.E. (*Editors*). 1991. Genetics and conservation of rare plants. Oxford University Press, New York.

Goodnight, C.J. 1988. Epistasis and the effects of founder events on epistatic genetic variance. Evolution, **42**: 441–454.

Green, R.H., and Younger, R.C. 1993. Sampling to detect rare species. Ecol. Appl. **3**: 351–356.

Harper, J.L. 1981. The meaning of rarity. *In* The biological aspects of rare plant conservation. *Edited by* H. Synge. John Wiley & Sons Ltd., Chichester, United Kingdom. pp. 189–204.

Harris, L.D. 1988. The nature of cumulative impacts on biotic diversity of wetland vertebrates. Environ. Manage. **12**: 675–693.

Hodgson, J.G. 1986. Commonness and rarity in plants with special reference to the Sheffield flora. Part III. Taxonomic and evolutionary aspects. Biol. Conserv. **36**: 297–305.

Holsinger, K.E., and Gottlieb, L.D. 1991. Conservation of rare and endangered plants: principles and prospects. *In* Genetics and conservation of rare plants. *Edited by* D.A. Falk and K.E. Holsinger. Oxford University Press, New York. pp. 195–208.

Huttleston, D.G. 1953. A taxonomic study of the temperate North American Araceae. Ph.D. thesis, Cornell University, Ithaca, N.Y.

International Joint Commission. 1988. Great Lakes Water Quality Agreement, amendment to protocol. International Joint Commission, Windsor, Ontario.

Keddy, C.J. 1984. *Arisaema dracontium*. *In* Atlas of the rare vascular plants of Ontario. *Edited by* G.W. Argus, K.M. Pryer, D.J. White, and C.J. Keddy. 1982–1987. Botany Division, National Museum of Natural Sciences, Ottawa.

Keddy, C.J. 1988. A review of *Lythrum salicaria* (purple loosestrife) ecology and management: the urgency for management in Ontario. Report to the Natural Heritage League, sponsored by the Ontario Heritage Foundation, Toronto, Ontario.

Kusler, J. 1992. Wetlands delineation: an issue of science or politics? Environment, **34**: 7–36.

Les, D. 1989. Feasibility of increasing aquatic plant diversity in Lac LaBelle and Okauchee lakes, Waukesha County, Wisconsin, U.S.A. Final report of the 1988 field season. Department of Biological Science, University of Wisconsin, Milwaukee.

Lovett Doust, L. 1981. Population dynamics and local specialization in a clonal perennial (*Ranunculus repens*). II. The dynamics of leaves and a reciprocal transplant–replant experiment. J. Ecol. **69**: 757–768.

Lynch-Stewart, P., Rubec, C.D.A., Cox, K.W., and Patterson, J.H. 1993. A coming of age: policy for wetland conservation in Canada. Sponsored by the North American Wetlands Conservation Council (Canada). Ottawa, Ontario. Rep. No. 93-1.

Makarewicz, J.C., and Bertram, P.E. (*Editors*). 1993. Special issue on evidence for the restoration of Lake Erie. J. Gt. Lakes Res. **19**.

McCullough, G.B. 1985. Wetland threats and losses in Lake St. Clair. *In* Coastal wetlands. *Edited by* H.H. Prince and F.M. D'Itri. Lewis Publishers, Inc., Chelsea, Mich. pp. 201–208.

McGraw, J.B., and Antonovics, J. 1983. Experimental ecology of *Dryas ocapetala* ecotypes. I. Ecotypic differentiation and life-cycle stages of selection. J. Ecol. **71**: 879–897.

McKee, P.M., Batterson, T.R., Dahl, T.E., Glooshenko, V., Jaworski, E., Pearce, J.B., Raphael, C.N., Whillans, T.H., and LaRoe, E.T. (*Editors*). 1990. Great Lakes aquatic habitat classification based on wetland classification systems. Chapter 4.

Menges, E.S. 1991. The application of minimum viable population theory to plants. *In* Genetics and conservation of rare plants. *Edited by* D.A. Falk and K.E. Holsinger. Oxford University Press, New York. pp. 45–61.

Miller, G.L., and Trout, M.A. 1985. Changes in the aquatic plant community following treatment with the herbicide 2,4-D in Cayuga Lake, New York. *In* Proceedings of the 1st International Symposium on Watermilfoil (*Myriophyllum spicatum*) and related Haloragaceae species, Victoria, B.C. *Edited by* L. Anderson. pp. 126–138.

Mills, E.L., Leach, J.H., Carlton, J.T., and Secor, C.L. 1993. Exotic species in the Great Lakes: a history of biotic crises and anthropogenic introductions. J. Gt. Lakes Res. **19**: 1–54.

Mitsch, W.J. 1992. Combining ecosystem and landscape approaches to Great Lakes wetlands. J. Gt. Lakes Res. **18**: 552–570.

Mitsch, W.J., and Gosselink, J.G. 1993. Wetlands. 2nd ed. Van Nostrand Reinhold, New York.

Naiman, R.J., Decamps, H., and Pollock, M. 1993. The role of riparian corridors in maintaining regional biodiversity. Ecol. Appl. **3**: 209–212.

National Research Council. 1992. Restoration of aquatic ecosystems: science, technology and public policy. National Academy Press, Washington, D.C.

Nichols, S.A. 1991. The interaction between biology and the management of aquatic macrophytes. Aquat. Bot. **41**: 225–252.

North American Wetlands Conservation Council of Canada. 1992. No net loss: implementing "no net loss" goals to conserve wetlands in Canada. Environment Canada and the Canadian Wildlife Service, Ottawa, Ont. Issues Paper No. 92-2.

North American Wetlands Conservation Council of Canada. 1993. Wetlands: a celebration of life. Final report of the Canadian Wetlands Conservation Task Force. Environment Canada and the Canadian Wildlife Service, Ottawa, Ont. Issues Paper No. 93-1.

Noss, R.F. 1990. Indicators for monitoring biodiversity: a hierarchical approach. Conserv. Biol. **4**: 355–364.

Ontario Ministry of Natural Resources. 1993. Ontario Wetland Evaluation System, southern manual. NEST Technical Manual No. TM-002, MNR warehouse No. 50254-1. Ontario Ministry of Natural Resources, Toronto.

Perring, F.H., and Farrell, L. 1977. British red data books: I. Vascular plants. Society for the Promotion of Nature Conservation, Lincoln, United Kingdom.

Pratt, J.R., and Bowers, N.J. 1990. A microcosm procedure for estimating ecological effects of chemicals and mixtures. Toxicol. Assess. **5**: 189–205.

Pratt, J.R., and Cairns, J., Jr. 1992. Ecological risks associated with the extinction of species. *In* Predicting ecosystem risk. *Edited by* J. Cairns, Jr., B.R. Niederlehner, and D.R. Orvos. Adv. Mod. Environ. Toxicol. **20**: 93–117.

Pratt, J.R., Niederlehner, B.R., Bowers, N.J., and Cairns, J., Jr. 1987. Effects of zinc on freshwater microbial communities. *In* International Conference on Heavy Metals in the Environment. *Edited by* S.E. Lindberg and T.S. Hutchinson. CEP Consultants Ltd., Edinburgh, Scotland. pp. 324–326.

Rabinowitz, D. 1981. Seven forms of rarity. *In* The biological aspects of rare plant conservation. *Edited by* H. Synge. John Wiley & Sons Ltd., Chichester, United Kingdom.

Schwartz, M.W. 1993. The search for pattern among rare plants: are primitive species more likely to be rare? Biol. Conserv. **64**: 121–127.

Shrubsole, D. 1989. Integrated water management strategies in Canada. *In* Integrated water management. Chap. 4. *Edited by* B. Mitchell. Bellhaven Press, London, United Kingdom.

Shrubsole, D. 1990. The evolution of public water management agencies in Ontario: 1946–1988. Can. Water Resour. J. **15**: 49–66.

Smith, P.G.R., Glooschenko, V., and Hagen, D.A. 1991. Coastal wetlands of three Canadian Great Lakes: inventory, current conservation initiatives, and patterns of variation. Can. J. Fish. Aquat. Sci. **48**: 1581–1594.

Soulé, M.E. 1991. Conservation: tactics for a constant crisis. Science (Washington, D.C.), **253**: 744–750.

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

Stuckey, R.L. 1989. Western Lake Erie aquatic and wetland vascular plant flora: its origin and change. *In* Lake Erie estuarine systems: issues, resources, status and management. *Edited by* K.A. Krieger. NOAA Estuary-of-the-month Seminar Series, Vol. 14. U.S. Department of Commerce, Washington, D.C. pp. 205–256.

Taub, F.B., Kindig, A.C., and Conquest, L.L. 1986. Preliminary results of interlaboratory testing of a standardized aquatic microcosm. *In* Community toxicity testing. *Edited by* J. Cairns, Jr. Am. Soc. Test. Mat. Spec. Tech. Publ. No. STP-920. pp. 93–120.

Tiner, R.W. 1993. Using plants as indicators of wetland. Proc. Acad. Nat. Sci. Phila. **144**: 240–253.

Trieste, L. (*Editor*). 1991. Isozymes in water plants. Opera Botanica Belgica 4. National Botanic Garden of Belgium, Meise, Belgium.

U.S. Environmental Protection Agency. 1984. The ecological impacts of wastewater on wetlands. An annotated bibliography. EPA-905/3-84-002. U.S. Environmental Protection Agency, Chicago, Ill.