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COMMENT

Biodiversity in fresh waters – an issue of species preservation or system functioning?

Introduction

Fresh waters offer intricate diversity, from small hot springs to huge floodplain systems, from temporary pools to big lakes, each containing significant proportions of the world's stock of inland water. In this collection is a great diversity of organisms, and of interesting relationships amongst them and with traditional peoples. There is thus every reason to value the diversity of freshwater systems and reasons for conserving them, from the ethical to the economic, can be listed no less than for terrestrial systems.

The approaches currently used to conserve the diversity of terrestrial systems, however, may be counter-productive for the conservation of freshwater systems. These approaches include emphasis on individual, often charismatic species, or on areas of high quality that can be boundaried and protected (fortress conservation) and rest on arguments that all species must be maintained for the system to function. The current decline in world biodiversity under our increasing impact suggests that these are failing approaches even for terrestrial systems. They may be disastrous for freshwater ones.

Contrasts between fresh waters and biodiversity icon habitats

Freshwater systems differ greatly from the biodiversity icons of tropical moist forests and coral reefs, which shape much of the philosophy of nature conservation. They have had long periods of minimal disturbance for niche differentiation to have produced many very specialist species. Removal of just a few species from them potentially could have major general consequences. Their internal biological relationships are intricate and the organisms themselves, trees or corals, dominate the structure of the system. Conservation objectives directed to particular organisms (say jaguars or mahogany trees) are likely to be effective because inevitably they mean preservation of substantial parts of a highly interlinked system.

Fresh waters differ. The medium, rather than the organisms, determines the structure of freshwater ecosystems and though it changes in distribution, it is indestructible. But freshwater is also a medium that is always changing. Ice ages, droughts, vulcanism and earth movements mean that no freshwater system is very old, that disturbance is frequent. Considerable turnover in biodiversity must be normal. There are exceptions of course. In the tropics, in particular, are well-known diverse, indeed strongly endemic, communities of fish and invertebrates in for example, the African Great Lakes, but they are dependent on the unusually great age of the basins.

Keystone species and groups

In freshwater systems, the specific nature of the biota has a minor effect on the processing of nutrients or the flow of energy. The system is predominantly bottom-up controlled (with reference to the orientation of the food webs). This means that in the recovery of deep lakes from eutrophication, for example, restoration depends on nutrient control (Bjork 1972). In engineered river systems, restoration of channel complexity by re-meandering and reconnecting the main channel with its floodplain is the successful approach (Brookes 1995). There is little point in attempting to conserve particular species without paying attention first to the whole system.

However, there may still be a structuring role for particular organisms or life forms. A typical floodplain wetland (Dugan 1994) includes emergent and submerged plants in a strongly disturbed system which is valuable in providing flood storage, in denitrifying nitrate, withholding silt, providing wet grasslands for sympathetic agriculture or pasturage, and attracting charismatic birds and mammals, which add to its conservation and amenity significance. The existence of substantial plant biomass is very important, but it probably does not matter a great deal if the dominant plants are *Phragmites*, *Typha*, *Scirpus*, *Cladium* or *Papyrus*, provided they can grow in the area. The wetland will continue to maintain the functions listed above.

Similarly, a case can be made that in shallow lakes, dominated by aquatic plants, the nature of the system is determined to a large degree by the plant structures rather than their specific nature. The community responds to bottom-up processes such as nutrient loading, but a system of plant beds, growing in clear water, with a diversity of associated algae, invertebrates and fish, can be maintained over a huge range of nutrient loading by buffer mechanisms created by the community structure. The system can be destroyed, however, by any mechanism which removes the plants, or otherwise interferes with the buffer mechanisms (Moss *et al.* 1996), but the structure may be relatively easily re-created, because a great deal of possible species substitution is possible.

There are certainly examples of keystone species as well as keystone groups; the alligator, which excavates pools which remain wet in the dry season and on which many other organisms depend, is one. But overall in freshwater systems, maintenance of particular species, as opposed to general life forms, is probably not important. The system is more crucial. The problem that we have is that maintaining the aquatic system is more difficult than the maintenance of, say, a functioning area of forest or grassland as an island of diversity amid a sea of damaged landscape. It is not possible to draw a boundary around a freshwater system, as is frequently done around a patch of terrestrial habitat to preserve it, with reasonable success, at least in the medium term.

Maintaining the system

The unit of freshwater systems is not defined by the wetted perimeter of the lake or river but by the limits of the catchment area from which the water is drawn. This may be huge, and may even straddle international boundaries. Conservation of functional values, including the conservation of biodiversity, is thus not possible without control of the way that the catchment is managed.

For example, stable restoration of a damaged floodplain lake is not possible without maintenance of the water regime of the whole floodplain (Klinge *et al.* 1995). Similarly, maintenance of migratory salmonid stocks may require major moderation of forestry operations around the spawning river (Cederholm & Peterson 1985) and conditions in estuaries or on the open sea will affect the recruitment and survival of the stock and have impacts on the remainder of the freshwater system.

Managing the whole system clearly means enormous practical, political and legislative problems but nonetheless, conservation of functional value, rather than of particular species arrays, should be the crucial goal in fresh waters. It is probably also a more tangible commodity to 'sell' to policymakers. The exhaustive recording of existing biodiversity, on the grounds that what has not been documented cannot therefore be protected, is worthy, but such an approach will not halt the decline in biodiversity. Worse, it has the political effect of giving the impression that all is being done that needs to be done, when in fact there is a significant net decline in world diversity. Its scope is too long term to meet immediate problems. It is equivalent to treating the symptom rather than the cause of the problem; an analogy would be with administration of aspirin rather than the establishment of orderly public health systems.

Selling the concept of conserving the functional value of whole systems, on the other hand, means also compromise from the conservation as well as from the exploitative lobbies. Maintenance of function in freshwater systems, perhaps in all ecosystems, is not synonymous with absolute preservation of all species. It is inconceivable that the totality of species that was extant when the human population was small can be maintained now that it is large. Attempts to preserve all species, though laudable, are probably futile; worse, through their high publicity profile they may undermine ultimately more valuable attempts to preserve functioning systems, albeit sometimes without some of their former rare or charismatic components.

Valuing the system

Intact floodplain wetland systems provide valuable services as well as a diversity of renewable resources. The cost of replacing these by engineered flood defences or water treatment works can be considerable (Maltby 1986). This gives a basis for justifying maintenance of these systems at a period of history when monetary values have become the currency of much decision-making. Such an approach has been taken by Costanza *et al.* (1997) to value the biosphere as a whole following determination of a set of functional values (Tables 1 & 2).

Table 1 Average annual global value (US$ ha^{-1}) of ecosystem services. From Costanza *et al.* (1997).

Service	*Terrestrial*	*Wetland*	*Lake/river*
Gas & climate regulation	141	133	?
Hazard protection	2	4539	?
Water regulation	5	3815	7562
Erosion control	106	?	?
Nutrient cycling	361	?	?
Waste treatment	87	4177	665
Biological control	23	?	?
Refugia	?	304	?
Resource production	181	362	41
Recreation/culture	68	1455	230

Table 2 Total global value per year of ecosystem services. From Costanza *et al.* (1997).

Ecosystem	*Area (10^6 ha)*	*Value (US$ ha^{-1})*	*Total (10^9 US$)*
Open ocean	36 302	252	8381
Coastal marine	3102	4052	12 568
Forest	4855	969	4706
Grassland	3989	232	906
Cropland	1400	92	128
Urban	332	0	0
Desert etc.	4308	0	0
Wetland	330	14 785	4879
Lakes and rivers	200	8498	1700
Total	*51 625*		*33 268*

Table 1 values these services per hectare of all terrestrial habitat, wetlands, including coastal wetlands, and freshwater rivers and lakes. Notable is the much greater value placed on aquatic habitats than on the terrestrial and although there may be many uncertainties in the valuations given, it seems likely that this distinction, being so prominent, is valid. Table 2 gives the total value of the functions provided by different ecosystems and again a proportionately high value of freshwater habitats emerges. It provides a strong argument for conservation of functional values in aquatic systems through whole-system reconstruction rather than through following the philosophy of terrestrial species-orientated and fortress conservation.

Nonetheless, examination of current freshwater biodiversity conservation usually reveals that it is species-orientated or involves the scheduling of particular bodies of water or wetlands without reference to the source of the water on which the site crucially depends (European Commission 1992). This sort of protection is, of course, better than nothing, but it falls far short of what is needed for indefinite conservation. Common sense suggests that the high costs incurred in the individual conservation of a particular species or isolated area are probably wasted, for any measures taken will be vulnerable to change in the greater catchment system. Measures taken to preserve the system, even if unusual species are lost for lack of specific attention, will be far more useful for they will give a better ultimate basis for the conservation of the unusual species.

Cost/benefit analysis of ecosystem use

However, whole-system conservation is costly in the short term and usually effective only in the long term compared with concentrated local campaigns to preserve species. The need to give cash values, as illustrated above, to justify it is thus understandable and these values can be used as a basis for cost-benefit analysis of the effects of system destruction, damage or restoration. They can point up immense value but sometimes the process can backfire. The techniques for valuation are often crude and therefore challengeable (Abramovitz 1997). An example comes from the UK (Environmental Data Services 1998), where the benefits of maintaining river flow in a southern

English river, the River Kennet, were very differently valued by the Environment Agency, a statutory body, opposing further water abstraction, and by a private water company, Thames Water, wishing to maintain at least its current abstractions for provision of domestic water supply. There was evidence that low flows, following abstraction in dry summers, were severely damaging the invertebrate and plant communities of this chalk stream and devaluing the trout fishery.

The British Environment Agency must, by law, consider costs and benefits in exercising its powers and a standard procedure for cost/benefit analysis was used which valued the river, based on 'willingness to pay' for use-related benefits (such as recreation and angling) and on non-use related benefits such as aesthetic and cultural values. The ecosystem function values considered by Costanza *et al.* (1997) are not recognized in this technique and consequently the total value that could be placed on the river was much lower than that of the river as a water supply and the abstraction was allowed to proceed. It seems likely that this approach to valuation will leave similar systems vulnerable. Perhaps a wider view of functional value, as taken by Costanza *et al.* (1997) will be more valid, but the stumbling block to this is acceptance of the functional values that such systems provide.

Ultimate reasons

Though I have taken a very hard-headed view of conservation in fresh waters, it is not because I do not value the intricacies of freshwater biodiversity but because I do so very much, and see the functional approach as being the better way to achieve such species conservation as part of a greater goal. The way in which we treat other organisms, and the respect which we afford them, is a reflection of how we treat diversity in our own societies. Our collective record on this is poor; the ways of life of hundreds of traditional peoples have been obliterated by the bulldozers of western economics. How we treat other organisms is a measure of how much we are valued as individuals within our own society. The future of a society which loses this respect for the individual is very bleak indeed.

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