The conservation of brackish-water systems: priorities for the 21st century

R.S.K. BARNES*

Department of Zoology, University of Cambridge, Cambridge, UK

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There is a marked contrast between the theory and the practice of conservation in terrestrial environments on one hand and in most aquatic environments, including those of the coastal marine zone, on the other. It is effectively axiomatic in the terrestrial sphere that conservation requires active management. It is not sufficient simply to safeguard an area from external threats, although that could also be important. Without active intervention, a given terrestrial system is likely to change into another, almost certainly of lesser conservation interest. The habitat must be manipulated so as to maintain it in a form suitable for the species and the communities of interest, and the populations of certain species—most especially various potentially superior competitors and often significant consumers—must be controlled in order to favour others. Burning, grazing and many other tools are routinely used to prevent natural changes. To a degree, the same is also true of freshwater habitats: control of water tables, of water quality, of fringing stands of vegetation and of submerged aquatics are all well-known and much practised measures.

Marine and brackish-water systems are treated differently, however. Through much of the past, these have been conserved only insofar as they lay within the boundaries of conservation areas declared—and managed—for other purposes, whether these have been botanical or ornithological. More recently, however, they have become the focus of conservation interest in their own right with the declaration of Marine Nature Reserves, or Special Areas of Conservation as a consequence of the ‘Habitats Directive’ (Council Directive 92/43/EEC; Anon., 1992), etc. In these, in contrast to terrestrial conservation practice, management measures have largely been restricted to preventing human activities that might impinge adversely on them, with no attempt being made to manipulate the contained populations.

In part this could be a consequence of the recency of their designation, but it also reflects divergent philosophical approaches. In essence, it is necessary to interfere in terrestrial systems because most of them are anthropogenic in origin and are naturally subject to successional changes. In contrast, the sea is supposed to be a natural system and is thought to be able to maintain itself in the desired state provided that human interference can be removed or at least controlled. It is essential to prevent natural succession from occurring on land but the aquatic coastal system is already in its climax state and it is this status quo that must be maintained, not a degraded version of it. This may (or may not) be true of much of the coastal sea, but is it also the case in coastal brackish waters including lagoons?

Here the argument is rendered more complex by another system of divergent philosophical approaches. Some habitats are perceived as being under physical control whilst others are structured by biotic...
interactions, such as competition and predation. If the nature of the physical environment is such as to cause periodic heavy mortality, which will serve to depress populations, then those populations will be below carrying capacity and potential competitive interactions will be unlikely to cause the disappearance of species of conservation interest. In other words, preserve the natural physically hostile environmental regime and that regime will manage the habitat.

Brackish waters have traditionally been regarded as being physically hostile. They are, after all, a sort of no-man’s-land between the major biotic assemblages of the sea and freshwaters. In the first extensive review of the habitat, Remane (1958), who did much to establish brackish-water biology as an acceptable discipline, described its ‘special ecological features’ in the form of a series of perjoratives, using section-heading words such as ‘poverty’, ‘reduction’, ‘depauperization’, ‘deviation’, ‘anomalies’ (i.e. malformations and reproductive sterility), etc. Other authors have since repeated the tenor of these attributes. In comparison with freshwaters and the sea, brackish waters are usually portrayed as species poor, ‘unsaturated’ habitats (Arndt, 1989), and received wisdom, dating back to Lovén’s 1863 lecture to the first Public Meeting of the Scandinavian Association of Natural Scientists, implicates salinity as the cause of this under-saturation. Such is implicit in the oft-quoted diagram, first published by Remane (1934), that shows a species minimum in the brackish-water range of the salinity gradient (Figure 1). The essential question is therefore: is this evidence of environmental hostility and physical structuring?

Clearly it is the case that very few marine species (mainly a few fish and even fewer decapod crustaceans) can also inhabit freshwaters, and vice versa. Where the two environments abut, it is only to be expected that one biota largely ceases and another starts. If, however, one was to produce a Remane-type graph along a transect starting in, e.g. a microtidal sea and finishing on land via a mangrove swamp, no one would be surprised at its equivalent shape, and it would be unlikely that this interface would be labelled as hostile per se. (Microtidal sea was carefully chosen here in order to avoid problems relating to the potential hostility of the intertidal zone.) Thus, while most marine species are stenohaline and have had no evolutionary reason to become euryhaline, it is only to be expected that their distributions cease on encountering diluted sea water.

There are, however, other classic explanations for the species poverty of brackish-water habitats besides the environmental hostility hypothesis (Barnes, 1984), such as: (i) because the habitat contains little

![Figure 1. The classic diagram showing relative numbers of species present along a gradient in salinity from freshwater to fully marine conditions (after Remane, 1934).](image-url)
heterogeneity, being largely a monotonous expanse of soft sediment (the low habitat diversity hypothesis); (ii) because of the geologically short life of any given brackish-water system and its isolation from other such systems by expanses of marine environment (the short timescale/isolation hypothesis); and (iii) because of biological interactions.

Several observations suggest the general falsity of the hostility hypothesis. First, osmoregulation is energetically much more economic than was once thought (Schmidt-Nielsen, 1975): euryhaline animals appear to expend only some 1% or less of their metabolic rate in regulating the constancy of their body fluids, even in the face of a large gradient. Second, the classic reduction in maximum size of, e.g. bivalve molluscs in estuaries, as documented by Remane (1934), that has been taken to indicate metabolic stress, includes a powerful confounding variable: age. Reise (1985) and others have shown that as a result of predation by shore birds, fish, etc.—brackish waters being extensively used as feeding grounds by migratory crustaceans, fish and birds—bivalve molluscs and other invertebrates in estuaries seldom achieve old age and hence large size. Thus, e.g. in 1971 the maximum size of cockles *Cerastoderma edule* at Hythe in Southampton Water was 24 mm, compared with nearly 40 mm outside the mouth (Barnes, 1973). However, the cause was not decreased growth rate, but simply differing life expectancy; the cockles at Hythe were no more than 2 years old, whereas the largest ones at the mouth were 9 years old (Barnes, 1973). Third, the large majority of the euryhaline members of the brackish-water fauna that have been tested can all survive and breed successfully in considerably lower (and higher) salinities than those in which they have usually been observed to inhabit in the field (Barnes, 1989). Their realised niches are much smaller than their potential ones, with respect to physical environmental variables.

Nevertheless, a convincing argument can be made for physical structuring of communities near the heads of estuaries. For example, the discharge of considerably more than the usual quantity of freshwater into a brackish-water system by the river or rivers entering it (see, e.g. Boesch *et al*., 1976; Thomason and Bennett, 1997) will create temporary freshwater conditions near the head and can wipe out the essentially marine component of the fauna there. These then recolonize after the event, when ‘normal’ salinities have returned, but their speed of recolonization may well be such that the ground lost is not recovered before the next local mass mortality occurs. Recovery times of several species has been shown to be slow (e.g. Simon and Dauer, 1977). In other words, they are continually recolonizing (i.e. advancing) and continually being killed off (i.e. retreating). How far upstream they happen to have advanced at any particular point in time (when perhaps someone happens to be mapping their distribution) is purely a matter of chance, and the only limit to their distribution, other than the fact that they cannot withstand pure freshwater, is lack of time since the last period of mortality (Barnes, 1994a). This section of the estuarine salinity gradient inhabited by any given species is labile and will only be in equilibrium when the gradient itself is unchanging; however, such a state rarely occurs in interface environments. Estuarine distributions near the freshwater end of the spectrum are, therefore, dynamic and are not explicable in terms of the precise nature of the physical or biotic variables of the system at any particular point in time. For all of these species, their distributions with respect to ambient salinity vary from location to location and from time to time (e.g. Boyden and Little, 1973).

Otherwise, and particularly in non-estuarine brackish waters, the evidence for physical structuring is much less convincing. Many species are characteristically to be found in greatest abundance or with greatest frequency in brackish waters (the ‘brackish-water species’, *sensu* Zenkevitch, 1959 and see Remane, 1969; Wolff, 1973 and Day, 1981), although virtually all are also known to occur in either freshwater or the sea (see Barnes, 1989). It has been argued that this is probably a consequence of interspecific competition: ecologically they may be restricted to brackish habitats in many areas but none is really restricted (i.e. physiologically) to brackish water. These species also occur in systems that have all the environmental characteristics of brackish waters except the lowered salinity (i.e. in sheltered, shallow, detritus- and nutrient-rich areas of soft sediments that support benthic photosynthetic production). This observation that it is not salinity that restricts the species to brackish waters is the reasoning behind the
renaming of the biota as ‘paralic’ in recent francophone literature (following Perthuisot, 1975, Guèlorget and Perthuisot, 1982, etc.). The characteristic brackish-water fauna is a suite of marine species of differing degrees of euryhalinity, that penetrate into dilute media to varying degrees, together with a few freshwater species than can withstand more saline waters.

Near the mouths of some estuaries, circumstantial evidence suggests that the ability of characteristically estuarine species to withstand low salinities has provided them with an environmental refugium lying outside the range of potential but more stenohaline competitors. However, in the absence of such competitors they are as characteristic of full-strength sea water as they are of more dilute media (Barnes, 1994a). There is also concrete evidence of interspecific competitive interactions in brackish-water lagoons: one possible reason for the rarity of the lagoonal mudsnail Hydrobia neglecta could be competition with the more abundant and widespread H. ulvae (Barnes and Gandolfi, 1998). The role of predation in reducing the abundance (and species-richness) of the soft-sediment macrofauna, including through the agency of the species using these areas as nursery grounds, was referred to above. Indeed, a glance through the non-conservation literature reviewing the processes likely to structure most estuarine, lagoonal and equivalent expanses of soft sediment (e.g. Peterson, 1979; Reise, 1985; Barnes, 1994b; Olafsson et al., 1994) soon discloses that the debate is not between physical versus biotic control, but between various possible types of biological controlling process, particularly top–down predator action versus bottom–up competition.

Leaving aside those brackish-water communities found in areas adjacent to inflowing freshwaters, there is then abundant evidence that they are not physically structured by salinity, but are instead governed by biotic processes. In this they are like most terrestrial systems. Therefore, if brackish-water habitats and their contained organisms are to be conserved, it will not be sufficient simply to prevent adverse human impact. Dominant competitors and certain types of predator will have to be manipulated, just as they are on land. Management plans in the 21st century will have to be based on detailed knowledge of the ecological processes structuring the individual systems. Most of this information remains to be collected, and if conservation is to succeed much less emphasis will have to be placed on the mapping, recording and monitoring of the health of existing brackish-water populations and much more emphasis put on understanding why those populations fluctuate and why certain species are restricted to only a few individual habitats. Only then can we begin to ask how we can manipulate them to achieve desired aims. This is especially true in the coastal lagoons that are designated for priority treatment by the ‘Habitats Directive’, and that contain a suite of rare species scheduled by the British Wildlife and Countryside Act 1981 for statutory protection. A requirement of the ‘Habitats Directive’ is that EU member states shall replace lagoonal habitat which was lost during the last 50 years and is expected to be lost in the immediate future. Creation of such new habitats is not the problem. The problem is whether any of the organisms of interest, if introduced, will survive in the newly created locations. This we as yet have no means of telling. Until research and associated funding emphasis are placed on establishing how these communities work, conservation attempts will be little more than trial and error, with few opportunities to learn from failed attempts. Aquatic conservation knowledge, at least in respect to lagoonal and other brackish-water habitats, has a long way to go before its base is equivalent to that for terrestrial management plans. And we do not have all that much time in which to catch up if these habitats are to be safeguarded through the century, let alone the next millennium.

REFERENCES


Barnes, R.S.K. and Gandolfi, S.M. 1998. ‘Is the lagoonal mudsnail Hydrobia neglecta rare because of competitively-induced reproductive depression and, if so, what are the implications for its conservation?’, Aquatic Conservation, 8, 737–744.