Part I General Issues

1 On the Value of Lakes

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1.1 INTRODUCTION

In Volume 1 of this book, we examined:

1 lake physical and chemical processes (the nature and origin of lakes themselves, the relationship between lakes and their surrounding water table and with their catchments, lake hydrodynamics and sedimentation);

2 limnetic ecology (the nature and role of the major classes of organisms found in freshwater lakes—phytoplankton, zooplankton, macrobenthos, pelagic microbes and fish—as well as whole lake communities).

In this volume, we discuss the general impact of human societies upon lakes, as well as that experienced by lakes of selected parts of the Earth—North America (and Lake Washington in particular), the Nordic and Alpine regions of Europe, Lake Baikal (by volume by far the world's largest lake), the arid zone in general, and Latin America. We then go on to examine the problems created by human use of various different kinds of lake—shallow bodies of both the temperate zone and the tropics, reservoirs and other artificial bodies.

The volume then continues with an examination of measures developed over the past 30 years in order to combat eutrophication (the most widespread 'environmental problem' created by human impact on lakes, on a catchment scale), especially the use of catchment models to predict nutrient loadings from the land upon lakes, and of steady state and dynamic models better to understand the problem itself. This is then followed by a discussion of the general measures currently available to reverse eutrophication, and of one of these in particular (biomanipulation), and also those employed in order to restore acidified lakes. Finally, we give various authors the opportunity to describe current and recent attempts to combat human impact on lakes, and to restore them to some state resembling stability, in various countries or regions (North America, Nordic Europe, East Africa, South Africa), in the hope that these experiences may prove useful, if not inspirational, to colleagues elsewhere.

In all of this, as also in Volume 1, the **value** of lakes—their immense scientific interest, their importance as threatened habitats, and for conservation of endangered species, their extreme importance to the human community as a resource—is implicitly accepted as a 'given', in that to us, as limnologists, the value and importance of lakes is so overwhelmingly and blindingly obvious as to need no further amplification. However, if we, as scientists, are to be accountable to the society which pays our salaries, and which funds our research (a function which is today increasingly demanded of us), and if we are to explain the value of what we do to a wider society which has never been exposed to the fascinations of limnetic ecology, we need to be able to state explicitly:

1 just what it is that we find so valuable (and indeed marvellous) about these beautiful but sometimes tantalising bodies of water;

2 just what it is we are restoring, when we propose that we restore lakes to some more desirable condition, and to spell this out in terms which involve using language with which we ourselves, as scientists, may be less comfortable.

This may be because

> *'Science, because of its desire for objectivity, is inadequate to teach us* ***all*** *we need to know about valuing nature. Yet value in nature, like value in human life, is something we can see and experience' (Rolston 1997, p. 61, my emphasis).*

Paradoxically, in attempting to do this, we may find ourselves reaching out beyond the laboratory, into the wider community, and enlisting the support of the growing number of our fellow citizens who may lack sophisticated limnological knowledge, but who share our concern for nature in general, and hence for lakes.

1.2 LAKES AS A RESOURCE

The human 'assault' upon lakes is discussed in detail in the next chapter. Here, in order to begin discussion of lakes as a resource in general, Table 1.1 depicts several of the major human uses of lakes, **as related to water quality**. It should be noted that the terms oligo- and eutrophic are used here according to their original meanings (i.e. in order to signify lake nutrient **status** or concentration [respectively, poorly and well-**nourished**; Hutchinson 1969, 1973; Rohde 1969; Edmondson 1991; O'Sullivan 1995], and not lake biological productivity). Thus, for drinking water, oligotrophic waters, which are normally, by definition, cooler and more oxygenated, and therefore potentially contain fewer pathogenic microorganisms, and fewer plankton, and thus require less treatment, therefore incurring fewer costs, are preferred. For bathing, mesotrophic waters are preferable to eutrophic, if not required, although it is sometimes possible to share the latter with blooms of benign phytoplankton, provided other distractions are available (e.g. the Wansee in August).

Non-bathing water sports are tolerable in eutrophic waters, but other recreational uses, particularly those where the aesthetic experience of lakes is as important, or more important, than their direct use, surely demand oligotrophic or mesotrophic waters, with their greater clarity, and general absence of water blooms and other nuisances. Fish culture (in the developed world, at least) depends on the species involved, with salmonids preferring those oligotrophic waters originally fished (in Britain, anyway) only by 'gentlemen'. Cyprinids, however, are tolerant of lowland, eutrophic waters, usually known (in that country) as 'coarse' fisheries, with all that the term implies regarding both nutrient and social status. The carp ponds of the Třeboň district of South Bohemia (Czech Republic) represent an early development of what is often nowadays thought of as a new idea (i.e. **permaculture**; Mollison 1988), but

Table 1.1 Lake and reservoir use according to trophic status (after Bernhardt 1981)

Use	Required/preferred water quality	Tolerable water quality
Drinking water	Oligotrophic	Mesotrophic
Bathing	Mesotrophic	Slightly eutrophic
Recreation (non-bathing)	Oligotrophic	Mesotrophic
Water sports (non-bathing)	Mesotrophic	Eutrophic
Fish culture:		
salmonids	Oligotrophic	Mesotrophic
cyprinids	Eutrophic	
Commercial fisheries	Mesotrophic, eutrophic	Eutrophic
Landscaping	Mesotrophic	Eutrophic
Irrigation	Eutrophic	Strongly eutrophic
Industrial processes	Mesotrophic	Eutrophic
Transport	Mesotrophic	Highly eutrophic
Energy (generation)	Oligotrophic	Mesotrophic
Energy (cooling)	Mesotrophic	Eutrophic

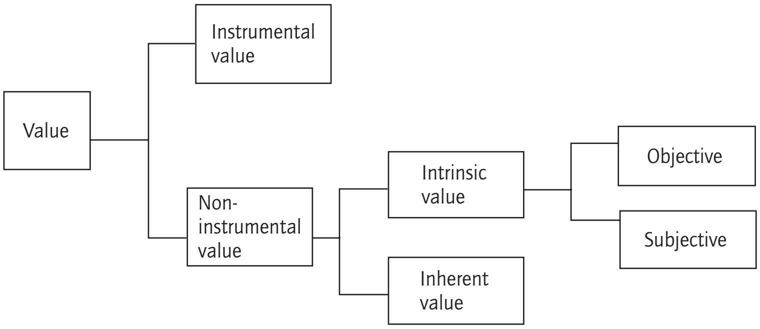


Fig. 1.1 Types of value in nature, according to sources cited in the text.

which in fact dates from the sixteenth century AD (Květ 1992).

Commercial fisheries, of necessity, rely on lakes of greater productivity, with nutrient status in the mesotrophic/eutrophic range (Sarvala *et al.* 2003). These are especially important in tropical countries, where other forms of protein are often expensive, and where, unfortunately, great damage to lakes is currently being done, both by eutrophication (Ogutu-Ohwayo *et al.* 1997), and by climate change (O'Reilly *et al.* 2003; Verburg *et al*. 2003). Landscaping is preferably carried out using mesotrophic waters, which are less valuable for drinking than the oligotrophic variety, but do not contain sufficient nutrients to support the growth of large, unsightly crops of macrophytes, filamentous algae or phytoplankton which would negate the purpose. Irrigation is one of the few economic activities which require water rich in nutrients, whilst many industrial processes demand only waters of moderate quality. Industry and transport are, of course, amongst the major factors which contribute to deterioration of water quality. Energy **generation** (hydropower) is preferable with oligotrophic waters, whereas cooling waters are usually abstracted from, and returned to, eutrophic lowland rivers, close to centres of population.

1.3 TYPES OF VALUE

1.3.1 Instrumental value

The uses to which lakes are put by human beings are therefore examples of their **instrumental value** (Figure 1.1), that is, in this case, their value **to humans**, either as the instrument of human needs or desires, or in some other way which contributes, directly or indirectly, to human welfare or human satisfaction. Instrumental value is therefore the value of an **item*** (in this case, a lake) to some other entity (in this case, and mainly, to humans), and so does not exist independently of that entity (whom we should call the **valuer**). Crucially (for the purposes of later argument), the instrumental value of an item may be reduced (e.g. if the quality of the water in a particular lake is allowed to deteriorate beyond a point where significant use is compromised), but may also be increased (e.g. if the quality of the water in the lake is restored, so that significant use may be resumed, or even enhanced). The instrumental value of lakes to much of humanity, as discussed above, is largely economic. As pointed out in the Introduction to Volume 1 (Reynolds 2003), lakes play a crucial role in the economies of many regions. They also contribute substantially to those biospheric 'services' which, it was recently shown, provide us with the equivalent of two to three times the gross product of the world human economy (Costanza *et al.* 1997).

* Environmental philosophers, a small sample of whose work we will shortly review, sometimes differentiate between natural 'objects' (plants, animals, bacteria, rocks), and natural 'items', a category which contains objects, but which also includes collections of objects arranged together as systems (e.g. a forest, lake or glacier). As most of what I have to say deals mainly with lakes as ecosystems, and with nature as a whole, I have chosen to use 'items' rather than 'objects' throughout, except where the latter is clearly signified.

Instrumental value need not be solely economic, however, and the recreational aspects of lakes, and their capacity to provide aesthetic experience, have already been mentioned. To go a stage further, we may say, that in common with other parts of nature in general, beyond their merely economic contribution to human welfare, lakes possess certain wider kinds of value, which Grey (1979) lists as part of his discussion of the general value (to humans) of wilderness.* Thus, Grey defines four types of wider value (of wilderness), three of which, as scientists, we would, presumably, easily recognise and subscribe to, and which, as limnologists, we could readily apply to lakes, the first of which has already been mentioned. They are (in a different order from that used by Grey):

1 the 'gymnasium' argument. This regards the preservation of wilderness in general, and thus lakes in particular, as important for athletic or recreational activities.

2 the 'laboratory' argument. Wilderness areas (and hence lakes) provide vital subject matter for scientific inquiry which furnishes us with an understanding of the intricate interdependencies of biological systems, their modes of change and development, their energy pathways and nutrient cycles, and the source of their stability. If we are to understand our own dependency on the rest of nature, we require natural systems as a norm, to inform us of ecological principles. Much of the subject matter of Volume 1 of this book falls into this category.

3 the 'silo' argument. One excellent reason for preserving areas of nature (including lakes) is that we thereby conserve genetic diversity (Sarvala *et al.* 2003). It is certainly prudent to maintain this as backup in case something should go wrong with the highly simplified biological systems which, in general, support human subsistence. Further, there is the related point that there is no way of anticipating future human needs, or the undiscovered applications of apparently useless organisms, some of which might turn out to be, for example, the source of some pharmacologically valuable drug. This might be called, perhaps, **the 'rare herb' argument**, and provides another persuasive (instrumental) justification for the preservation of wilderness, and hence (at least some) lakes.

4 the 'cathedral' view. Wilderness areas in general, and lakes in particular, provide a vital opportunity for human spiritual revival, moral regeneration, and aesthetic delight. Enjoyment of wilderness is often compared in this respect with religious or mystical experience. Preservation of wilderness areas for those who subscribe to this view is essential for human well-being, and its destruction conceived of as something akin to an act of vandalism, perhaps comparable to that of an important human edifice, such as the Great Wall, Angkor Wat, the Taj Mahal, the Pyramids, Stonehenge, Palenque or Macchu Picchu.

The 'cathedral' view of wilderness is, in fact, a fairly recent innovation, being largely introduced by the Romantics and Transcendentalists of the late eighteenth and nineteenth centuries, most of whom rejected the ethos of the Scientific Revolution and of the Enlightenment (Pepper 1996).† Nevertheless, as later writers (e.g. Leopold 1966) have shown, nature can also be marvelled at from a scientific as well as a philosophical or religious point of view, an attitude which may be **increased** by ecological understanding.

Lakes therefore clearly possess not only considerable economic, but also great recreational, scientific, spiritual and aesthetic value, as well as genetic potential, and as such, according to the instrumental argument, should, like other valuable resources, be protected and preserved, the better to promote not only the conservation of other species, and of the diversity of nature in general, but also the continued welfare of our own. However, some environmentalists find a definition of

* Although I have used 'wilderness' arguments throughout this article, it should not be construed that I am unaware of their past, present (e.g. the current removal of San people from the Kalahari 'game' reserve) and potential detrimental effects on indigenous peoples (Callicott & Nelson 1998; Woods 2001), or of the strong anti-human sentiments expressed in the past by some who advocate them (Devall & Sessions 1983).

† Not always completely, however, as witnessed by Henry David Thoreau's limnological studies of Walden Pond (Deevey 1942).

value which conceives of nature as being of value only to humans, and therefore to possess no value of its own, too limiting. Such definitions, they believe, offer only weak protection for nature, in that if nature possesses value only to us, then ultimately we will feel justified in using it for our own purposes, and in ignoring other aspects of the value of nature. Thus, Fox (1993, p. 100) writes

> *'(if) the nonhuman world is only considered to be instrumentally valuable, then people are permitted to use and otherwise interfere with any aspect of it for whatever reasons they wish (i.e. no justification for interference is required). If anyone objects to such interference then, within this framework of reference, the onus is clearly on the person who objects to justify why it is more useful to humans to leave that aspect of the nonhuman world alone' (quoted in Callicott 1995, p. 4).*

Similarly,

> *'A model in which nature (possesses) no value apart from human preferences will imply different conduct from one where nature projects fundamental value' (Rolston 1998, p. 144).*

There is also the 'rare butterfly' example, whereby, as species become increasingly rare, their economic value correspondingly increases* (Godfrey-Smith 1980; Rolston 1998), and the point that various human uses of nature may be conflicting (Grey 1979), and may also 'humanise' nature, taming it, and turning it into some kind of theme park.† Environmental philosophers of a more biocentric, or even ecocentric persuasion, therefore propose instead that we should regard nature (and hence lakes), as possessing some kind of value which exists independently of human beings, or of their use of nature (its 'non-instrumental' value, Figure 1.1), which therefore reflects much more accurately, the concept of nature as an entity possessing value of its own.

1.3.2 Intrinsic value

One such kind of value would be **intrinsic value** (Naess 1973). Unfortunately, this appears to be a concept about which philosophers themselves find it difficult to agree, and so, as a subject for non-philosophers, it represents a linguistic and intellectual minefield. However, as indicated earlier, it is at least arguable that, if scientists are to convey to the public at large what they feel about the importance of protecting nature, they first need to try to deal with such concepts. Of course, as this is my first (published) attempt, I may not have been as successful as I might have wished.

Various criteria are used to define the intrinsic value of natural items, not all of which apply, as we shall see, to every kind. Natural items are said, generally, to possess intrinsic value:

1 because they are able to exercise **preferences**, or are 'the subject of a life'. However, these criteria are used mainly by writers who see value in nature as confined mostly to animals, or even to higher animals (e.g. Singer 1976, 2001; Clark 1979; Regan 1984), and so, whilst they may clearly be important in that context, they are not of much relevance here.

2 owing to the realisation of the **interests**, or the (Aristotelian) **'good'** or well-being, of 'bearers of moral standing' (Attfield 1991, 1994). Again, this kind of criterion is used mainly by those writers (such as Attfield) who believe that value in nature is confined to individual organisms, as only these can be said to possess moral standing. It cannot therefore be said to be a property of species, of populations, of ecosystems, or of nature in general, and therefore will not be applicable to lakes.

3 when they are valued 'for their own sake', 'as an end in themselves' (Elliott 1980; O'Neill 1993; Callicott 1995; Rolston 1998), or for what they are 'in themselves' (Rolston 1980, 1998; Routley & Routley 1980; Des Jardins 2001), or when they possess 'a good of their own' (Taylor 1986; Rolston

* See, for example, reports of increased commercial fishing of previously little known stocks of the Patagonian toothfish (*Dissostichus eleginoides*); *The Guardian*, London, 19 August 2003, p. 11.

† A phenomenon whose origin is not as recent as one might think (see Orwell 1946).

1994a, 1998). It is also a controversial issue amongst philosophers as to whether non-sentient beings, or, more widely, non-animate nature in general, can ever possess a 'good' of their/its own (Rolston 1994a), so that, again, this argument will not be not taken further here.

4 when they are valuable solely in virtue of their intrinsic ('non-relational') properties (O'Neill 1993), or when they possess value which exists independently of the valuation of valuers (Godfrey-Smith 1980; O'Neill 1993), 'belonging to its essential nature or contribution' (Callicott 1995, p. 5), and therefore 'without (any) contributory human reference' (Rolston 1980, p. 158).

This last criterion (which is actually two separate criteria; O'Neill 1993, 2001) is also controversial, in that (again), since the Enlightenment (and especially since Descartes, Hume, and Kant), it has been a fundamental tenet of Western philosophy that 'objective' value of this kind cannot exist, independently of the valuation of valuers. This is because, unlike mass, volume or density, Enlightenment science does not conceive of value as an objective property (as neither does Enlightenment philosophy; Elliot 1980), but one which, instead, can only be attributed to other items by rational (i.e. human) beings (Midgley 1980), or by what Callicott (1995, p. 5) terms 'the intentional act of a Cartesian subject respecting an object'.

1.3.3 Objective and subjective intrinsic value

Essentially, then, environmental philosophers distinguish between two types of intrinsic value, namely,

1 'objective' intrinsic value, where items are **valuable** 'in themselves' (Routley & Routley 1980, p. 152);

2 'subjective' intrinsic value, where items are **valued** 'when an interest is taken in (them)' (Elliott 1980, p. 136).

The first is therefore the kind of value which exists entirely independently of human beings, and which requires no valuers in order for it to exist. Thus, in respect of lakes, we could say that, as natural items, lakes possess intrinsic value 'in themselves', as lakes, and that this intrinsic value exists beyond any value we ourselves may place upon them as resources of any kind, and even of their aesthetic or spiritual value to us.

Unlike instrumental value, intrinsic value of this kind surely cannot be increased, in that it exists as an attribute of the item itself, and therefore both independently of ourselves, **and of the item itself**. It is therefore likely that it also cannot be **reduced**, in that any damage to the item, or even modification of it, leads not to the reduction of its intrinsic value, but rather its destruction, in the form of its integrity. For example, some North American 'deep ecologists' (e.g. Devall & Sessions 1983) believe that wilderness, which for them clearly possesses intrinsic value, is somehow 'tainted' by **any** human encroachment.

Some radical philosophers (e.g. Naess 1973) have therefore adopted 'objective' intrinsic value as a main criterion for protecting nature, in that it is essentially the only one in which value is held to exist in nature itself, entirely separately from any valuation which human beings (or any other potential valuer) may place upon it. In this way, it is hoped that the problem of nature being vulnerable to the changing needs and interests of human beings (Godfrey-Smith 1980; Des Jardins 2001) may be avoided. Thus Fox (1993, p. 101) continues

> *'If, however, the nonhuman world is considered to be intrinsically valuable, then the onus shifts to the person who wants to interfere with it to justify why they should be allowed to do so' (quoted in Callicott 1995, p. 5).*

Intrinsic value of this kind therefore potentially offers much stronger protection for nature than instrumental value, in that it opposes any modification of natural items **beyond those necessary in order to satisfy vital needs** (Naess 1973, my emphasis).*

* This sanction is, indeed, so strong that it would, in effect, probably preclude all exploitation of nature for profit (Benton 1993)—a conclusion normally studiously ignored by most of the biocentric thinkers who advocate it (although **not** Naess (1973) or Routley & Routley (1980)).

However, it is also arguable that, as a philosophical construct, intrinsic value may not actually exist, outside the minds of human beings (see below). Conversely, there is the question that, if it does exist independently of us, why we should care about it at all (O'Neill 2001). There is also the further question as to why it should be reserved for natural items, in that many human artefacts (e.g. the Aztec calendar, the Mona Lisa, *Die Zauberflöte*) surely possess great (iconic?) value which is intrinsic to them, and which is clearly beyond any monetary value, or even instrumental value of the cathedral variety (see above, section 1.3.1, and also below, section 1.3.4).

Beyond this, there is the point that 'objective' intrinsic value clearly represents something of a moral absolute, in that either one subscribes to such a concept, or not. Whilst some philosophers may be comfortable with moral absolutes (though not all, as we shall shortly see), as scientists, we may find them unattractive, in that they cannot be easily falsified, and to use such arguments against those who adhere in all things to 'the bottom line', is often unproductive.

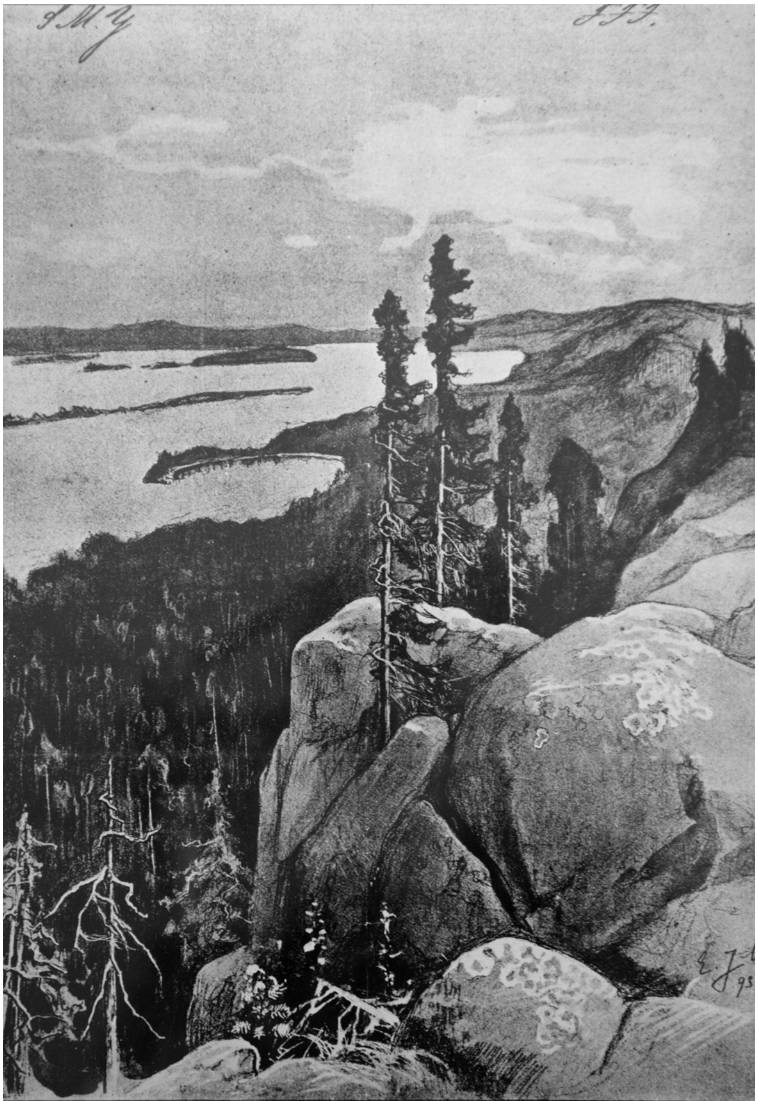
Others therefore suggest that whilst we can subscribe to the idea that intrinsic value in nature may exist, rather than existing independently of human beings, and therefore being 'discovered' by them, it is in fact 'generated' by human valuation of nature (Rolston 1994a), i.e. it is 'subjective' intrinsic value, 'allocated' rather than 'recognised' (Des Jardins 2001). This idea removes the problem of value only being generated 'by an intentional act of a subject' (Callicott 1995, pp. 5–6), but would still leave human beings as the ultimate judge of whether such value, in nature, actually exists. Basically, then, the problem with 'objective' intrinsic value is that it may not exist, whereas 'subjective' intrinsic value may not be strong enough to protect nature.

1.3.4 Inherent value

Some environmental philosophers (e.g. Frankena 1979; Taylor 1986, 1998; Attfield 1991) distinguish between intrinsic value, and **inherent** value (Figure 1.1). By this they mean '(the) ability (of an item) to contribute to human life' (Attfield 1991, p. 152) 'simply because it (possesses) beauty, historical importance, or cultural significance' (Taylor 1986, pp. 73–74 [quoted in Callicott 1995, p. 10]). Taylor (1986) appears to reserve this kind of value for human artefacts (see above), whereas Attfield (1991) also extends it to natural items, including rocks, rivers, ecosystems and wilderness* (i.e. to natural **systems**). We could therefore notionally apply this kind of value to lakes (Plate 1.1).

Grey (1979, p. 2) believes that 'Insofar as the "cathedral" view holds that value in nature derives solely from human satisfactions gained from its contemplation, it is clearly an instrumentalist attitude. It does, however, frequently approach an **intrinsic** attitude, insofar as the feeling arises that there is importance in the fact that it is there to be contemplated, **whether or not anyone actually takes advantage of this fact**' (my emphasis). However, what wilderness may also possess, in this context, is a value to humans which is neither intrinsic nor instrumental, but which is still clearly 'non-instrumental' (i.e. inherent value *sensu* Attfield 1991). This is also a type of value which can be decreased, in that the value of the item could easily be diminished by human (or other) agency (e.g. a 'natural' disaster), but it could conceivably also be **increased**, by careful management or other kinds of 'encouragement'. It still leaves us with 'human chauvinism' (Routley & Routley 1980) as the ultimate sanction as to whether natural systems possess anything other than instrumental value, however, and so may also offer only relatively weak protection.

* Confusingly, intrinsic value, 'intrinsic worth' (Godfrey-Smith 1980) and **inherent value**, are often used in the literature as synonyms (e.g. Regan 1981), which, on consulting a dictionary (Callicott 1995), they appear to be. Even more confusingly (I am afraid), Taylor (1986) uses 'inherent worth' to signify 'objective' intrinsic value as used here, and 'intrinsic value' to describe 'an event or condition in human lives which they consider enjoyable 'in and of itself' (Callicott 1995, p. 10). Similarly, Rolston (1980, p. 158) recognises value 'which may be found in human experiences which are **enjoyable in themselves**, not needing further instrumental reference' (my emphasis). Armstrong & Botzler (1993) suggest that we should use 'intrinsic value' to mean value which is independent of valuers, and 'inherent value' for the kind of non-instrumental value which is not.



Kolivaara. Eero Järnefeltin piirros Uudelle Kuvalehdelle 1893. Museovirasto, Helsinki.

Plate 1.1 Lithograph of the lake Pielinen (Pielisjärvi), North Karelia, eastern Finland (1893), from the Hill of Koli (347 m), by Eero Järnefelt, brother-in-law of the composer Jan Sibelius. Pielinen lies in an area rich in inherent value (as defined in this chapter), both geo-ecological, historical, anthropological and aesthetic, which provided inspiration for many Finnish National Romantic artists at the turn of the last century. During the early nineteenth century, poems of *Kalevala*, the Finnish National epic, were collected in this part of Finland. Since 1974, interdisciplinary studies of the palaeoecology and anthropology of the area have been conducted by the Karelian Institute, University of Joensuu, partly established on the initiative of the Finnish (palaeo)limnologist Jouko Meriläinen, who noted that records of swidden, the traditional Finnish method of cultivating the forests, were preserved not only in paintings by Järnefelt (e.g. *Under the Yoke (Burning the Brushwood)* (1893), and *Autumn Landscape of Lake Pielisjärvi* (1899), but also in the varved (annually laminated) sediments of many of the lakes of this region. The Koli National Park, presently extended to 3000 ha, was established in 1991 in order to include some of the most valuable local landscapes. (Copyright: Museovirasto (National Board of Antiquities), Helsinki, Finland. With thanks to Mr Kevin Given of the School of Architecture, University of Plymouth, for help with this illustration.)

1.3.5 Systemic value

The ecocentric philosopher Holmes Rolston III (1980; 1988; 1994a, b; 1997; 1998) has extensively explored the possibilities of developing ideas of other kinds of value in nature, especially as applied to species, to ecosystems, and to nature itself (as opposed to its individual components, see above). For example, he suggests that it is difficult to dissociate the idea of value from natural selection (Rolston 1994a), and that, as a product of this process, species (as opposed to the individual organisms of which they are composed; Attfield 1991) may themselves possess (intrinsic) value (Rolston 1980). Thus,

> *'We find no reason to say that value is an irreducible emergent at the human (or upper animal) level. We reallocate value across the whole continuum. It increases in the emergent climax, but it is continuously present in the composing precedents' (Rolston 1980, p. 157).*

Similarly,

> *'There is value (in nature) wherever there is positive creativity' (Rolston 1997, p. 62).*

Rolston (1998) also suggests that organisms possess value not just in themselves, or as the product of natural selection, but as part of the ecosystem, through which information flows, and that

> *'Every intrinsic value (is connected to) leading and trailing "ands" pointing to (other sources of value) from which it comes, and towards which it moves' (Rolston 1980, p. 159).*

> *'Systemically, value . . . fans out from the individual to its role and matrix. Things . . . face outward and co-fit into broader nature' (Rolston 1998, p. 143).*

Yet another way of expressing this would be to say that natural items possess value as 'knots in the biospheric net' (Naess 1973). Thus 'value seeps out into the system' (Rolston 1998, p. 143).

The existence of value in nature produced by the emergent, creative properties of ecological systems undergoing natural selection, resonates strongly with the concept of evolution developed by studies of complex systems (Goodwin 1994), and of 'Dynamical Systems Theory' in general (Capra 1997), although it would undoubtedly be rejected by NeoDarwinists. It is also supported by Warren (1980), who writes of the value of natural items **as parts of the natural whole**, and that

> *'It is impossible to determine the value of an organism simply by considering its individual moral (standing): we must also consider its relationships to other parts of the system' (Warren 1980, pp. 125–126).*

It is also (to me, anyway) reminiscent of a much more famous quote from the (earlier) environmental literature, with which some readers, at least, may be more familiar.

> *'One basic weakness in a conservation system based wholly on economic motives is that most members of the land community have no economic value. Of the 22,000 higher plants and animals native to Wisconsin, it is doubtful whether more than 5% can be sold, fed, eaten, or otherwise put to economic use. Yet these creatures are members of the biotic community, and if (as I believe) its stability depends on its integrity, they are entitled to continuance.' (Aldo Leopold,* A Sand County Almanac, with essays on conservation from Round River. *Oxford University Press, Oxford, 1966, p. 221).*

Finally, Rolston (1994a, 1998) has also developed the concept of the **systemic** value of ecosystems, by which he means

> *'a spontaneous order (which) envelops and produces the richness, beauty, integrity and dynamic stability of the component parts' (Rolston 1994a, p. 23).*

As well as organisms, species and ecosystems, for Rolston, nature as a whole possesses emergent properties which confer upon it, at the ecosystem level and beyond, value which is both intrinsic and completely independent of any which we, as humans, may place upon it. Thus creativity is both the impetus and the outcome of the evolutionary play (Hutchinson 1965).

These ideas are more fully explored in other, lengthier publications (Rolston 1988, 1994b), neither of which was I able to consult during preparation of this article. However, there are certain problems with the 'value' approach, which we should now therefore discuss.

1.3.6 Problems with intrinsic value

The first of these is that intrinsic value, despite the above fairly lengthy discussion, may not actually exist, but may instead be merely a human construct. Thus Rolston (1994a) himself writes that

> *'The* **attributes** *under consideration are objectively there before humans come, but the* **attribution** *of value is subjective. The object . . . affects the subject, who . . . translates this as value' (Rolston 1994a, p. 15, original emphasis).*

Similarly,

> *'Even if we somehow manage to value wild nature per se, without making any utilitarian use of it, perhaps this valuing project will prove to be a human construction. Such value will have been projected onto nature, constituted by us and our set of social forces; other peoples in other cultures might not share our views' (Rolston 1997, pp. 40–41).*

In fact, according to several of the writers cited here (e.g. Callicott 1995), it is the case that intrinsic value **must** actually exist somewhere, owing to the very existence of instrumental value. This is because those items which possess only instrumental value, do not exist 'as ends in themselves', but only as 'means' to other ends, whereas, apparently, the existence of means implies the existence of ends. Items which do exist as 'ends in themselves' therefore possess intrinsic value, because they also possess 'a good of their own' (see section 1.3.3). This 'teleological proof' of the existence of intrinsic value apparently dates back to the *Nichomachaean Ethics* of Aristotle (Callicott 1995), but, as already mentioned, since the Enlightenment, Western philosophy has rejected the existence of intrinsic value in all but rational beings (i.e. [until recently, anyway] sane, adult, white, male, property-owning human beings).

Enlightenment science, and the atomistic modern economics based upon it, also find it difficult to accept teleological concepts, which means that as well as amongst some philosophers (e.g. Attfield 1991), the concept of the intrinsic value of nature may be difficult to accept on the part of scientists. Instead, they may reject objectivism, and fall back upon the subjective view, which is that value only exists in natural items insofar as there are human valuers present. This is difficult to argue against. For example

> *'Resolute subjectivists cannot, however, be defeated by argument. . . . One can always hang on to the claim that value, like a tickle, or a remorse, must be felt to be there. It is impossible by argument to dislodge anyone firmly entrenched in this belief. That there is retreat to definition, is difficult to expose, because they seem to cling too closely to inner experience. . . . At this point, the discussion can go no further' (Rolston 1980, p. 157).**

> *'. . . there is no way of rationally persuading someone to adopt a new ethic or new values . . . if someone is 'value-blind' to the intrinsic worth (*sic*) of natural systems, I could not expect (them) to manifest anything but indifference to their destruction in the interests of what (they) took to be matters of importance' (Godfrey-Smith 1980, p. 46).*

Finally,

> *'. . . persons with different moral intuitions belong to a different moral world. Value systems, more clearly than empirical theories, may simply be incommensurable. Within our society . . . we*

* I am afraid I cannot help find it amusing that those who, over the past 30 years, have repeatedly told me that I do not live 'in the real world', have demanded of me nothing but 'facts', and who (mainly since 1979), have told me that I, and the rest of humanity must, from now on, live by 'the bottom line', should be correctly called, in this context, 'subjectivists'.

(encounter) competing moral systems; and the competing moral injunctions are concerned to promote the welfare of human beings, treating the welfare of anything else with moral indifference.' (Godfrey-Smith 1980, p. 45).

1.4 NATURALNESS

At the risk of taking the long route to come full circle, I therefore conclude that, in order to protect nature (and hence lakes) from further depredation, and to identify reasons why they should be rehabilitated, it may be necessary to find a criterion (or some criteria) stronger than instrumental value (or even inherent value), which can, however, be accepted by 'resolute subjectivists'. It (or they) will therefore need to be empirical, quantifiable, and free of any connotations of non-falsifiability. One such concept, I believe, is **naturalness**.

This is one of a number of criteria used historically in order to evaluate sites and areas for nature conservation (Table 1.2). Of these, area and population size are clearly 'objective' criteria, in that they can be quantified independently. They can also be described as 'non-relational properties' (O'Neill 1993, p. 16), in that unlike richness, rarity, representativity, potential value, uniqueness, and all subsequent criteria in Table 1.2, they can be determined 'independently of the existence or non-existence of other objects' (weak interpretation), or 'without reference to other objects' (strong interpretation). Naturalness, however, at least of an ecosystem, is possibly also a non-relational property, in that it can be assessed, and even quantified, independently of other natural items (see below).

Previously employed by Ratcliffe (1977) in order to designate nature reserves, and also currently in several methods for assessing the conservation value of rivers* (Boon & Howell 1997), the concept of naturalness has been extensively explored by Peterken (1981, 1996). His key ideas regarding the concepts of original-, past-, present-, future- and potential-naturalness, as modified in order to apply to lakes, are outlined (accurately, I hope) in Table 1.3.

* Some of which recognise the importance of intrinsic value, and of 'non-instrumental utility' (e.g. O'Keefe 1997).

Table 1.2 Criteria used internationally for nature reserve evaluation (after Usher 1997)

Area (or size, extent)
Population size
Richness (of habitat and/or species)
Naturalness, rarity (of habitat and/or species)
Representativity ('representativeness', 'typicalness')
Ecological fragility, position in ecological unit, potential value, uniqueness
Threat of human influence
Amenity, scientific or educational value
Recorded history
Archaeological/ethnographic interest, availability, importance for migratory, intrinsic appeal, management factors, replaceability, gene bank, successional stage, wildlife reservoir potential

Naturalness refers to an ecosystem 'unmodified by human influence' (Ratcliffe 1977, p. 7), a concept which is difficult to apply (Birks 1996 [citedin Battarbee 1997]), owing to the problem of judging accurately the degree of modification it has experienced. Original naturalness and past naturalness are clearly linked, in that they are based on features of the present ecosystem which are descended from the period before human impact. Few existing features of contemporary ecosystems can be described as 'original natural', however, as almost all parts of the Earth have been modified from their original state by some agency or other, either natural or human (Peterken 1981). Given that present and potential naturalness are hypothetical states, the two forms which actually exist are therefore past naturalness (in lakes, the 'memory' of lake **ontogeny** ['development thorough time'; Deevey 1984] to date), and future naturalness, the capacity for the present lake to follow its own future ontogeny undisturbed, in the absence of further human impact.

Naturalness is therefore precise as a concept, but imprecise as a descriptor of particular ecosystems (Peterken 1996). Rather than there being a single state of naturalness, different states may ac-

Table 1.3 Types of naturalness as applied to lakes (adapted from Peterken 1996)

Type	Characteristics
Original naturalness	The physical, chemical and biological state in which lakes in any region existed before humans became a significant ecological and biogeochemical factor (i.e. mostly before the arrival of agriculture). Sometimes referred to as 'pristine' (but not *sensu* Moss *et al.* 1997)
Present naturalness	The physical, chemical and biological state in which lakes in any region would now exist had humans not become a significant ecological factor. Sometimes also referred to as 'pristine' (but not *sensu* Moss *et al.* 1997). As present conditions in many areas are quite different from those of pre-agricultural times, present naturalness (a hypothetical present state) differs from original naturalness (a previous but now non-existent condition)
Past naturalness	Those physical, chemical and biological characteristics of present day lakes (e.g. 'relict' species, population structure) inherited from original natural times. May be thought of as surviving 'memory' of past processes, states and conditions. Therefore combines elements of original and present naturalness
Potential naturalness	The hypothetical physical, chemical and biological condition into which a lake would develop if • human influence was completely removed • the resulting successional adjustment took place instantly Thus, potential naturalness expresses the potential of the present system to revert (instantly) to natural conditions
Future naturalness	The physical, chemical and biological state into which a lake would eventually develop over time, were significant human influence to be removed. This concept takes account of possible future climatic, edaphic and other successional changes, as well as potential extinctions, introductions and colonisation, and current past naturalness. Not a return to original naturalness

tually be applicable to each component of the system. Thus we might imagine lake **physics** (except perhaps the heat budget, or where **meromixis** develops) being little disturbed by all but the most radical of human impacts, whereas lake **chemistry** will almost certainly be changed (Stumm 2003), but probably at least partially recover, once the impact is reduced or removed (Edmondson 1991). In terms of lake **biology**, the effects may be the most extensive, and also the most prolonged (e.g. the 'memory' frequently attached to fish populations in eutrophicated lakes). In employing this concept, there is therefore a need to identify those features of past naturalness descended from original naturalness, and which contribute to future naturalness, and perhaps express these for lakes in general along a continuum similar to that used by Peterken (1996) for forests and woods (Table 1.4).

For the north temperate zone, this list looks remarkably similar to that of Moss (1988), who related mean annual total phosphorus (TP) concentration (in $\mu g\,L^{-1}$ TP yr^{-1}) to degree of human impact (i.e. broadly, to past naturalness), although the similarity breaks down in the tropics, where lakes are characteristically much richer in phosphorus. Suggested characteristic mean annual phosphorus concentrations are therefore added to Table 1.4. for certain lake categories only.* Lakes possessing the greatest degree of naturalness are therefore those which are most free from human influence (Margules & Usher 1981) except that of traditional cultures (Smith & Theberge 1986), in which natural ecological regimes are present, in which natural processes operate to the greatest extent unmodified by human impact, and in which natural lake ontogeny has therefore been most closely followed.

As discussed by Stumm (2003), those catchments with the least human impact generally produce the most pristine waters, and vice versa. However, lakes also change according to natural factors, and those processes most often affecting lakes during their ontogeny, both natural and artificial, are listed in Table 1.5. Thus we can see that succession, infilling, paludification and siltation

* A similar scale could perhaps be developed for tropical lakes, but using mean annual total nitrogen concentration.

Table 1.4 Categories of forests and woods, and notional categories of lakes, exhibiting different kinds of naturalness (after Peterken 1996; Moss 1988)

Forests/woods	Lakes
Virgin forest	'Pristine' lakes possessing many features descended from original-naturalness (1–10 $\mu g\ L^{-1}\ TP\ yr^{-1}$)
Primary, ancient near-natural forests and woodlands*	Near–natural lakes possessing considerable past naturalness, only once or recently 'disturbed', and probably only in a limited sense, and/or receiving only limited human influence (e.g. from traditional human cultures) (10–20 $\mu g\ L^{-1}\ TP\ yr^{-1}$)
Primary, ancient near-natural and semi-natural forests and woodlands	Lakes still possessing considerable past naturalness, but experiencing frequent significant or prolonged human influence (20–100 $\mu g\ L^{-1}\ TP\ yr^{-1}$)
Secondary, disturbed primary, semi-natural woodland	Lakes with substantial recent and/or prolonged human impact (100–1000 $\mu g\ L^{-1}\ TP\ yr^{-1}$)
Secondary, semi-natural woodland	Lakes of recent natural origin
Plantations	Reservoirs

* For definitions of virgin, primary, secondary, ancient and semi-natural, and their relationship to North American 'old-growth', and/or European *Urwald/prales*, see Peterken (1981 1996).

(under natural catchment regime) are part of natural lake ontogeny, whereas eutrophication* (*pace* most of the North American literature; O'Sullivan 1995) and acidification, except in certain rather particular circumstances (i.e. catchment regimes characterised by nutrient mobilisation, or by prolonged podsolisation), are not. Those lakes which have been affected by the least number of artificial processes, and which have most closely followed the natural ontogenic pathway peculiar to their own particular locality, are clearly those which have received the least human impact, and those which therefore posses the greatest (past) naturalness.

As mentioned earlier, one problem with the naturalness approach is identifying the degree of past human impact. Interestingly, environmental philosophers such as Rolston (1997, 1998) have also highlighted this problem, in that 'unlike higher animals, ecosystems have no experiences' (Rolston 1998, p. 138), and that

> *'Often the problem of scale becomes that of time, which makes much invisible to our myopic eyes. We cannot see mountains move, or the hydrological cycle, or species evolve, though sometimes one scale zooms into another. Water flows, mountains quake, rarely: and we can see incremental differences between parents and offspring. We can see occasions of mutualism and of competition, though we have no estimates of their force. We can examine the fossil record and conclude that there was a Permian period and a catastrophic extinction at the end of it' (Rolston 1997, p. 52).*

However, as pointed out in Volume 1 (O'Sullivan 2003), lakes offer a unique framework for studying the above problem, in that they are one of the few ecosystems which continuously accumulate and store a record of their own ontogeny, in the form of information stored in their sediments. What is more, this information precisely bridges the gap identified by Rolston (i.e. that between geological, 'deep', evolutionary time, and the everyday, observational and instrumental record). Two main

* Except, of course, for that (surely, by now) unfortunate term 'morphometric eutrophication' (Deevey 1955, 1984), which is clearly a misnomer for that part of the succession which involves reduction of lake volume as a result of infilling, deoxygenation of the sediment water interface, release of buried phosphorus from the sediments, and a speeding up of internal nutrient cycling, but **not** an overall increase in nutrient **loading** above and beyond background (Edmondson 1991), and which is therefore not, *sensu stricto*, eutrophication.

Table 1.5 Processes characterising lake ontogeny (after Deevey 1984; Edmondson 1991; Oldfield 1983; O'Sullivan 1995)

Process	Characteristics
Succession	Internally driven process Community controlled Involves change in community structure, and increasing biomass and productivity (the 'sigmoid phase') up to 'trophic equilibrium' (Deevey 1984) No increase in productivity thereafter unless external nutrient loadings increase Inorganic nutrients converted to biomass (i.e. leads to overall **decline** in lake inorganic nutrient concentrations) No overall increase in total nutrient stock Process of 'self organisation' leading to 'self stabilisation' (Oldfield 1983) In 'large' lakes, stable state may persist indefinitely In 'small' lakes, leads eventually to infilling (see below) and 'death' of lake ('senescence', dystrophy) 'Natural process'
Infilling	Internally driven process Community controlled Mainly affects 'small' lakes of north temperate zone (Edmondson 1991) Involves infilling with autochthonous organic material leading eventually to infilling and 'obliteration' of the hypolimnion (Deevey 1955), and thence to ombrogenous peat formation or terrestrial habitat (hydroseral succession; Walker 1970) and 'death' of lake ('senescence', dystrophy) No increase in productivity, or overall increase in total nutrient stock necessarily involved, and yet (confusingly) sometimes termed 'morphometric eutrophication' (Deevey 1984) 'Self organisation' leading to 'self stabilisation' (Oldfield 1983) 'Natural process'
Paludification	Related to influx of allochthonous humic organic matter (Deevey 1984) Confined mostly to northern hemisphere peatlands External forcing Leads to decline in productivity (owing to lack of nutrients and increased chemical demand for oxygen), and eventually to dystrophy Forced self organisation to new stable state (Oldfield 1983) Maintained by external factors (existence of peatlands in catchment)
Siltation	Related to influx of allochthonous mineral matter Confined mostly to grassland, semi-arid, or arid zone (Chapter 8), or to agricultural regions External forcing May lead to increase in lake nutrient concentration owing to inwash of soil material (**edaphic** eutrophication; Deevey 1984) Forced self organisation to new stable state (Oldfield 1983) Maintained by external factors (existence of unstable soils, or farmland in catchment) May therefore be 'natural' or artificial process
Eutrophication	Influx of allochthonous nutrients and/or non-humic organic matter 'above and beyond natural background' (Edmondson 1991) External forcing Increase in the proportion of lake nutrients present in the inorganic form Leads to increased biomass and productivity, and to changes in community structure Leads to instability so long as external forcing continues Attempted 'self organisation' to a new stable state (Oldfield 1983) May be 'natural process' (edaphic eutrophication, see above) but more often artificial (**cultural** eutrophication; Likens 1972)

Table 1.5 *Continued*

Process	Characteristics
Acidification	Influx of allochthonous hydrogen ions associated with anthropogenic emissions of NO_x and SO_4^-
	External forcing
	Increase in proportion of major ions present as H^+, reduction in bases (Na^+, K^+, Ca^{2+}, Mg^{2+})
	Leads to reduced biomass and productivity, and to changes in community structure
	Leads to instability so long as external forcing continues
	'Self organisation' to a new stable state (Oldfield 1983)
	May be 'natural process' ('edaphic oligotrophication'; Pennington 1991) but more often anthropogenic
Other forms of pollution (heavy metals, hydrocarbons, persistent organic compounds)	Influx of allochthonous material mainly associated with anthropogenic emissions
	External forcing
	May lead to reduced biomass and productivity, and to changes in community structure owing to toxicological effects
	Leads to instability so long as external forcing continues
	'Self organisation' to a new stable state (Oldfield 1983)
	May be 'natural process' (e.g. due to influx of natural materials) but overwhelmingly anthropogenic (Stumm 2003)

approaches have been adopted, namely 'hindcasting' of export coefficient models (Moss *et al.* 1997; see also Wilson, Chapter 15), and, as intimated above, palaeolimnology.

1.5 LIMNOLOGY, PALAEOLIMNOLOGY AND NATURALNESS

1.5.1 'Hindcasting'

Moss *et al.* (1997) describe a 'state changed' (or even 'value changed', [*sic*], p. 124) approach to assessing change in lakes from an original, 'baseline' state. The objective is to identify a condition to which lakes may be restored, using 'hindcasting' of current nutrient loadings based on export coefficients, and historical data on land use, livestock density and human population. Restoration to pre-settlement conditions (i.e. to a state of **original naturalness**) is considered unrealistic, whereas a pragmatic approach, involving standards for drinking water or industrial abstraction (i.e. applying standards which take into account **instrumental value** only), might not give sufficient protection. Instead, a third (functional) approach is adopted, whereby a state is identified 'which reflects the highest possible quality, consonant with (the) maintenance of current (human) populations and or agricultural use of the catchment' (p. 126). The authors consider that this approach is likely to generate the maximum conservation value (habitat and species diversity), to preserve functional values (fisheries, natural flood storage, traditional uses), and to maintain high amenity. In effect, what this approach will maximise, is **future naturalness**.

For the UK, Moss *et al.* (1997) choose AD 1931 as their 'baseline' state, on the grounds that this date clearly precedes the intensification of British agriculture which took place mainly after 1940. It also mostly pre-dates the widespread use of synthetic nitrate fertilisers, a point which is obviously not coincidental. Restoration of nutrient loadings to values characteristic of this period would also not be expensive.

Whether this would actually restore some UK lakes to a stable condition, and therefore maximise future naturalness, is an interesting point, however, as there is some evidence (developed both from hindcasting, and from palaeolimnological studies) that eutrophication (for example) of certain bodies began as early as c. AD 1900, with the final connection of many outlying regions to the railway network, and hence the national market in agricultural produce (O'Sullivan 1992, 1998). Similarly, the commercialisation of agriculture in England and Wales (i.e. production for more than a limited, mainly static, local market) was a process which took several centuries (Overton 1996). Nutrient loadings from agriculture may therefore have begun to rise in some localities as early as AD 1500 (Wharton *et al.* 1993).

Nevertheless, out of a sample of 90 lakes in England and Wales, 75% had suffered more than 50% change, with only 4.4% being insignificantly perturbed (Moss *et al*. 1997). The state-changed method also identified as significantly perturbed a subset of upland lakes in unproductive catchments which the OECD spatial-state approach (see Rast, Chapter 14) would classify as oligotrophic.

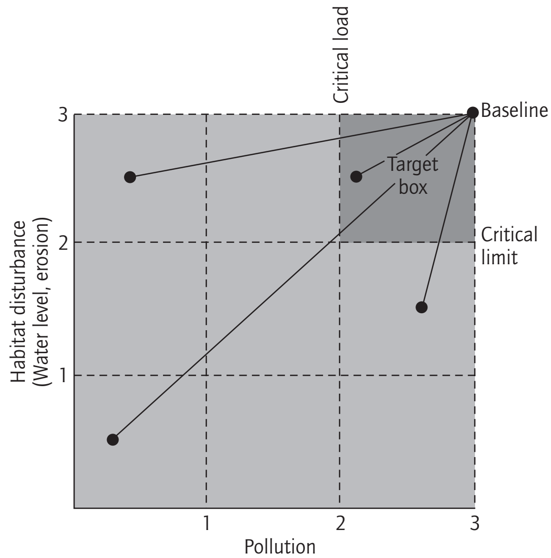


Fig. 1.2 Naturalness matrix for lakes (from Battarbee 1997). Vectors represent hypothetical lake time trajectories. For other explanation, see text.

1.5.2 Palaeolimnology

A couple of years ago, when I first thought of applying palaeolimnology to George Peterken's idea of naturalness, I was quite pleased with myself. After all, it is just the kind of interdisciplinary connection I have spent my career trying to make. However, not for the first time (and probably not the last), when I consulted the literature, I found that my old colleague Rick Battarbee (1997) had been there before me. Battarbee describes an ingenious use of palaeolimnology, historical and instrumental records to develop a naturalness index for lakes (Figure 1.2), based on reconstructed habitat change ('disturbance') versus critical loadings of pH, nutrients, or other inputs (e.g. heavy metals, persistent organic pollutants (POPs), radionuclides). Again, the objective is to assess and quantify the degree to which a lake has departed from a **natural** state (i.e. as defined here, its **past** naturalness), and to identify ways in which best to restore it (i.e. to maximise **future** naturalness).

In Figure 1.2, the horizontal axis can represent any chemical change which leads to biological change, as defined above in terms of variations in critical load (Vollenweider 1975). On the vertical axis is plotted 'habitat disturbance', a variable which is more difficult to define, but which might include physical factors such as shoreline and water level changes, and inwash of catchment soils and/or other eroded material, and biological change, such as introduction of exotic species, or overfishing. Some of these will have had no discernible effect on lake ecology, whilst others will have exceeded some 'critical limit', and therefore produced changes in species composition and/or abundance. Ideally, a third axis should represent direct biological influences, such as introduction of exotic species, stocking of lakes for angling, or commercial fishing. For simplicity, however, these are included on the vertical axis.

Baseline conditions (original naturalness) are reconstructed using palaeolimnological methods, especially the 'transfer function' approach (Battarbee *et al.* 2001; O'Sullivan 2003). To date, these have mainly been developed for organisms characteristic of lower trophic levels (e.g. diatoms, chrysophytes, cladocera, chironomid midges, ostracods; O'Sullivan 2003). Direct (and indirect) reconstructions of changes at higher trophic levels, or of community structure

(Gregory-Eaves *et al.* 2003; Leavitt *et al.* 1994; Schindler *et al*. 2001), are also being developed, however. The severity of change over baseline, in terms of biological consequences, is (provisionally) expressed using **species turnover** (Gauch 1982; cited in Battarbee 1997).

The pristine or baseline state of the lake is then one which ideally combines absence of pollution and habitat disturbance with maximisation of diversity of indigenous taxa. Desirable future chemical and biological conditions are defined in terms of the target box, in which lake ecology approaches 'pristine' (i.e. original naturalness). Lakes may then be classified into three broad categories, one of which is subdivided, namely:

1 Undisturbed lakes (Category 3 in Figure 1.2), including all completely undisturbed sites, or where known physical change has not caused any (biological) impact upon the lake (i.e. where no critical limit has been exceeded). These lakes are then subdivided into Category 3A (Pristine—i.e. completely unaffected by human impact), and 3B (Lakes in which known physical change has not produced a biological response). The first group (in the UK) includes only a few lakes in remote mountain areas, but the second contains some major lakes (e.g. Loch Ness).* Both of these subcategories therefore contain lakes which possess both considerable past naturalness, and substantial memory of original naturalness (compare Table 1.4).

2 Lakes in which catchment or other change has led to variations in composition and/or abundance of lake biota (Category 2, Figure 1.2). Such events include water level changes and reworking of marginal sediments into the profundal, and accelerated soil erosion, as well as influx of exotic species, or commercial fishing. Such lakes, whilst clearly no longer pristine, may still possess substantial past naturalness, however, and also significant future naturalness (Table 1.4).

3 Lakes in which major impact has led to significant changes in lake ecology (Category 1, Figure 1.2). In such lakes, not only have there been changes in community structure, but also in the ecological functioning of the ecosystem. These lakes therefore possess little past or future naturalness, in that their condition has departed furthest from the course of natural ontogeny.

Figure 1.3 illustrates how the naturalness matrix can be applied to a set of seven UK lakes, four affected by acidification, and three by eutrophication. Distance from the target box depicts severity of change over baseline, and the degree to which loadings would need to be reduced in order to restore these lakes to that condition. In Figure 1.3c, biological effects of pollution, in the form of species turnover, are also shown, whilst in Figure 1.3d, scores on both axes are neatly combined to generate a state-changed classification scheme, in which 10 indicates pristine (3A above), 9 Category 3B, 4–6 perhaps Category 2, and 1–4 Category 1. Hence the baseline sediment record can be used to define some of the key biological characteristics of the restored lake. Whilst values on the *y* axis are subjective, those on the *x* axis are objective, and therefore offer the possibility of a quantitative approach to the 'reconstruction' of past naturalness, or more correctly, the enhancement of future naturalness. Battarbee's (1997) matrix is therefore potentially a more than useful addition to lake management.†

1.6 CONCLUSIONS—WHAT EXACTLY ARE WE RESTORING?

To paraphrase Grey (1979), suppose, for example, that a lake in a remote region of no economic importance was found to be so precariously balanced that *any* human intervention or contact would inevitably bring about its destruction. Those who maintained that the lake should, nevertheless, be

* Here, Battarbee (1997) cites building of the Caledonian Canal through the Loch during the early nineteenth century as one such event, but it now seems that the earlier 'Clearance' (i.e. eviction) of native highlanders from Glen Moriston, a valley which drains into the northern side of the Loch, did produce some effects upon its ecosystem which are detectable via palaeolimnology (O'Sullivan *et al.* 2000 a, b).

† Although not 'ecocentric' lake management (Battarbee 1997, p. 157), either as defined here, or, as originally, by O'Riordan (1981).

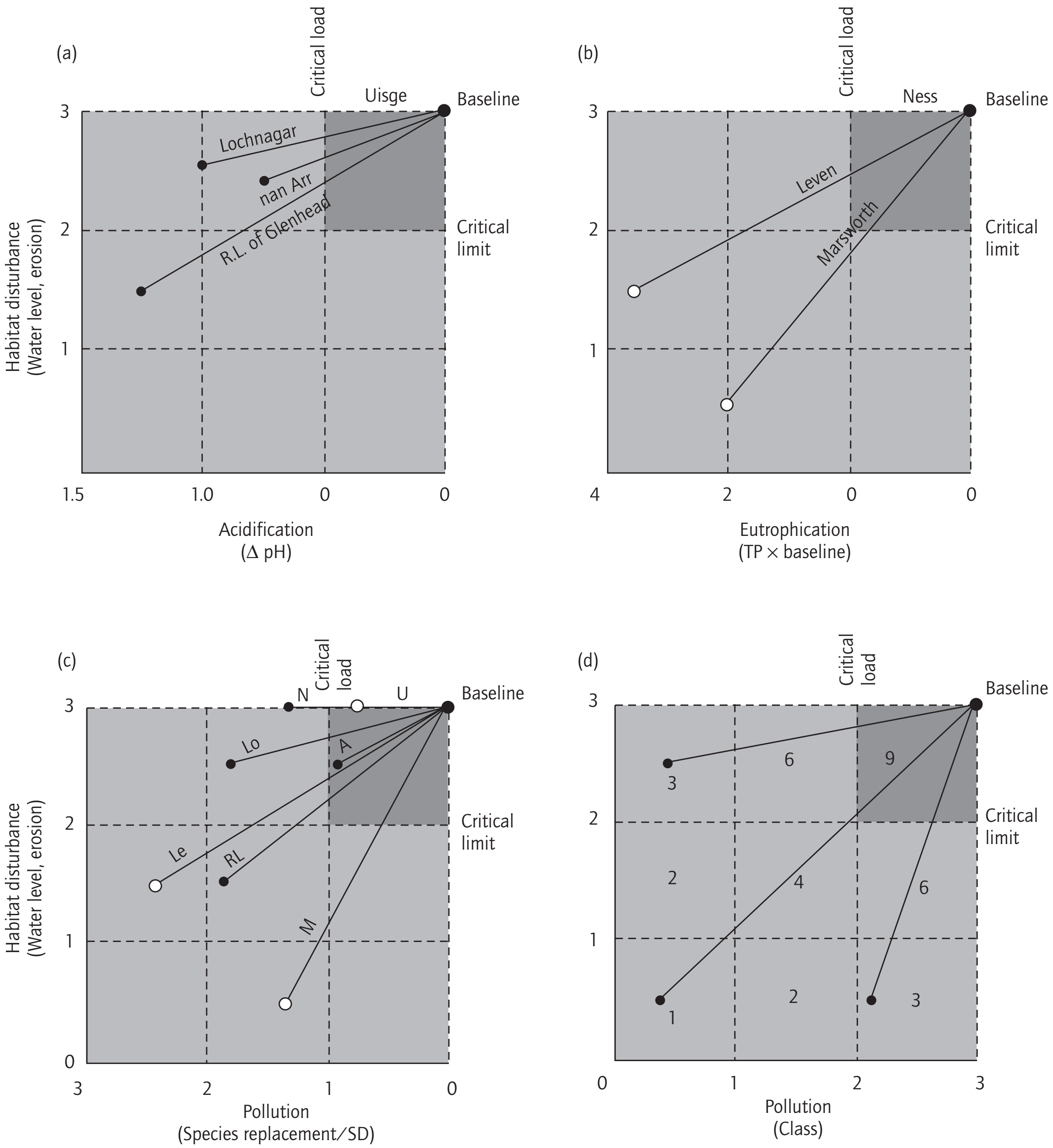


Fig. 1.3 Naturalness matrix applied to specific case studies of seven UK lakes. Note that in (a), acidification is expressed in pH units, whereas in (b), eutrophication is cited as multiples of baseline TP concentration. For other explanation, see text.

preserved, unexperienced and unenjoyed by humans, would certainly be ascribing to it some kind of value, independent of any use to which human beings might, or could put it. Those who think it should not be preserved intact, but should not be destroyed, also presuppose that it possesses some similar kind of value. Those who think that if it was destroyed, then 'something' would be missing, must surely subscribe to the idea that this 'something' is clearly greater than the lake's economic value, or even its wider instrumental and/or inherent value (as defined above).

We could, of course, try to ague that what would be removed is the lake's inherent value (its capacity to please **us**) or even its intrinsic value (as variously defined above), but an alternative approach is to say that what is really being destroyed is its **naturalness**, a property which exists along a continuum, and which (as we have seen) can therefore be both 'hindcast', reconstructed, and quantified. The goal of lake rehabilitation would then be not to enhance the lake's instrumental value, or even its inherent value, nor even yet its intrinsic value (always assuming that this **can** be increased, which is at least questionable).

Instead, what we would be trying to enhance is its **future** naturalness (that is, its capacity to return, unaided, to its natural ontogenic pathway), by restoring the present condition of the lake to a state most closely resembling its original naturalness. In order to achieve this goal, we would need to identify those aspects of the present lake ecosystem which are most directly descended from its past naturalness, and those which stem from subsequent perturbation, using hindcasting and palaeolimnology, as outlined above. As the lake will then continue to change, under the impact of both internal and external natural factors, we cannot predict this future state, except to say that it will not be the same as its present state, or its past natural state, nor its original natural condition.

Interestingly (again!), a few environmental philosophers have identified naturalness as a source of value in nature. For example, Elliott (1994, p. 36) believes that it is the 'otherness' of nature which underwrites its value, and that this naturalness is achieved without intentional design. Similarly, Routley & Routley (1980) write

> *'Value is not subjective, but neither is it an objective feature entirely detached from nature' (p. 154). 'In simple terms, objective value is 'located' in (nature) entirely independent of valuers' (p. 151),*

where it resides in

> *'diversity of systems and creatures, naturalness (*sic*), integrity of systems, stability of systems, harmony of systems' (p. 170)*

Thus it would appear that naturalness, as modified by the palaeolimnological approach, offers us what we have so far lacked, that is, **a quantifiable measure of environmental value** (as applied to lakes, at any rate). If we also take into account that lake sediments collect information not only from lakes themselves, but from their catchment/watershed, and from their wider region (their 'airshed'; Likens 1979), we may eventually be able to apply it to ecosystems in general, or at least, wherever there are lakes.

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