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Biodiversity Defined

Biodiversity is a term applied all the biological capital occurring within a particular area. It captures both variety, in terms of genes and species, and processes, the complex and diverse interactions between different species, and between living organisms and the non-living environment. Biodiversity is not static; climate, soil chemistry and genetic constantly change, altering the balance between species. Competition for resources forces the evolution of new species as well as co-evolution between those already present. Species that are less well adapted to the environment, or unable to compete with others, may disappear, while others may take their place. So far taxonomists have named and described 1.4 million species. We know this is just a fraction of those in existence, estimates for which vary from 7 to 20 million species, with UNEP suggesting 13.6 million as a working estimate. While our knowledge of mammals, birds, reptiles and woody plants is reasonably complete, the vast mass of less visible species, the fungi and nematodes, bacteria and liverworts, deep-sea protozoans and terrestrial arthropods remain largely unknown. While some parts of the world have been well studied, others - and these are often the most remote and biologically rich - have been subject to little or no investigation.

Two examples of how priorities can change rapidly are the biodiversity of the deep seas and the changed view of the Caribbean as a biodiversity hotspot.

Recent research on deep-sea fauna suggest that it is more complex and more biodiverse even than comparable terrestrial fauna. Until the 1960s, the deep oceans were thought to be deserted for lack of light and food. With the introduction of new sampling techniques in the 1980s this was shown to be false and the deep oceans are known to be extremely biodiverse with high rates of endemism (Grassle 1991). The reasons for this are not entirely clear, although the patchiness of food resources and an absence of extreme environmental conditions are presumably important. From the Arctic to the tropics species diversity increases towards the equator, the same pattern seen on land, although again the reasons for this are still uncertain (Rex *et. al.* 1993). In the southern hemisphere, diversity is greatest at high latitudes particularly in the Indonesian archipelago, declining radially from there (Gray 1997).

Conservation International has recently devoted considerable research effort into fleshing out the hotspots concept, ranking different regions of the world in terms of diversity in different ranks of vertebrates (Mittermeier et al. 1999). Their first listing in this direction, in 1990, completely excluded the Caribbean, but

a decade later, the Caribbean was listed as one of the three highest ranking hotspots in the world. This illustrates the importance both of collating data in a co-ordinated way and mining the pre-existing scientific literature in a more systematic fashion.

As biodiversity is a multidimensional concept, describing both genes and species, which can be counted, and processes and relationships, which are less easy to quantify, measuring it is difficult. Species numbers are sometimes used as a proxy, but they tell us nothing about the difference between species in terms of their ecological, social and economic values. Species diversity is perhaps a better measure, as it reflects both the diversity of species and their individual abundance. But still, it tells us nothing about the relationships between them, nor about their significance in ecological or other terms.

Ecologists do not assign equal value to all species within particular ecosystems. Some of the concepts used to internally differentiate their assessments are endangered, endemic, keystone and rare species. These can be defined as follows;

Term	Comments
endangered	Species or taxa that face extinction unless the causal factors are eliminated
endemic	Species or taxa confined to a single bounded geographic region
keystone	Species whose presence is essential to the functioning of a particular ecosystem.
rare	Species or taxa with small world populations not at present endangered

IUCN has a number of other related categories, such as vulnerable as well as indeterminate and insufficiently known. The term 'threatened' is used as a cover term for all levels of endangerment.

Of these terms, 'keystone' is perhaps the most problematic to define and grasp. Many species within given ecosystems can be reduced or eliminated without causing the system itself to degrade. Fish that spawn in large numbers in markedly seasonal systems can recover from small-scale trapping operations. However, species that actually perform an operation on the environment are lost the whole ecology may be transformed. Typical are molluscs that filter water. The Chesapeake Bay oyster, for example, was reckoned to filter all the water in the bay once a week, ensuring a clean environment that supported a wide variety of aquatic life. Its numbers are presently so reduced that it filters the same volume of water every year and the deterioration of water quality has reduced the potential for other species to exist in the habitat.

An aspect of biodiversity that is problematic in terms of predictive models is that it is essentially chaotic; a system that has been static over a long period even when a large number of environmental variables change can suddenly flip into a new and potentially irreversible state following a small change. A classic example of this is coral reef system of the Caribbean. These reefs were historically protected from algae infestations by grass-eating species. The large herbivore fish were all removed from the reef by 1900, but the herbivore niche was filled by a species of urchin deemed inedible. Once a market developed for the urchin in Japan in the 1980s, the urchins were rapidly depleted as well. The consequence was that no species remained to keep the reefs clean of algae and they became overgrown and are now rapidly dying. The significant conclusion is that chaotic systems do not easily fit into the predictive mould required by economic valuation concepts. Moreover, and perhaps more importantly, small changes following activities of extractive industries can sometimes have major impacts, especially in poorly understood systems. This is turn may make offset theory difficult to implement in practice.

Biodiversity is a developed world concept, as indeed are 'nature', 'the environment' and 'ecosystem'. Indeed as a word, biodiversity dates only to the mid-1980s. We should thus be wary of attributing a conception of biodiversity to other cultures. There is a vast ethnoecological literature that describes both ethnobotanical and ethnozoological systems as well as helping to conceptualise others cultures' notions of the environment. However, this is rarely if ever cited in the biodiversity literature which tends to be driven by biologists for whom 'ethno-' approaches are anathema. The only generalisation that can be made is that the diversity of belief systems and conceptualisations parallels the diversity relate to in biology. Typically, tribal societies have classification systems that focus on the uses of plants and animals; plants and insects that have no uses may well have no names. Classes of birds with no use, such as sunbirds, may all be given a single name, while edible grasshoppers have a different name of each stage of their growth. This illustrates

well the contrast with Western aesthetico/scientific approaches, where each species of sunbird is differentiated by marked variety in colouring and is therefore named and described in great detail.

This is not a matter of perhaps quaint anthropological interest but highly relevant to the frameworks of resource-sharing agreements that are being commonly established across the world in relation to buffer zones around PAs and extractive industries. These generally assume that the parties to these agreements essentially have the same conceptualisation of natural resources and that hunting is undertaken to source protein and plants gathered for food or medicinal purposes. They also assume that the community with which the agreement is made is somehow homogeneous and views agreements of this type in the same light as the institution making the agreement. A short glance at the ethnoscientific literature would be enough to make clear how false these assumptions are. For example, a recent study of the Witoto of Colombia showed that they regarded some species of trees as essentially malevolent and emitting toxic perfumes. They therefore welcomed development plans that involved cutting down trees and ridding them of this source of sickness. All too often the assumption is made that the cultural system of other societies is similar to those in the developed world with a few differences in picturesque details. The complexity of understanding different world views has generally deterred all but a few biologists and social development 'experts' from making the effort. For the all the diversity in the natural world they celebrate they are unwilling to contemplate a similar diversity in human thought.

All published surveys of biodiversity reach the same gloomy conclusion; that almost everywhere in the world it is threatened and that the situation is deteriorating fast than resources can be mobilised to counteract these processes. The fossil record suggests a 'background extinction rate' of approximately one species per million per year. Anthropic extinctions in tropical regions are presently running at least a thousand times this rate (Wilson 1992). The reduction in biodiversity during the last ten thousand years has been on a scale that suggests human activity is precipitating a 'sixth extinction'. There have been five mass extinctions in the history of the planet, but the most spectacular of these was the Permian, some 250 million years ago, when 95% of the species on the planet died out. The causes of these extinctions are not known, but the effect on world biodiversity was drastic and took many millions of years to recover (see the case studies detailed in MacPhee 1999).

The endpoint of anthropic extinctions is being compared to these past episodes with the same dire predictions as to the eventual outcome. Occasional opponents have published indictments of 'environmental scaremongering' but these usually turn out to be the products of right-wing think tanks and to have a highly tenuous grasp of the statistical data that has now been amassed (see, for example, Simon and Wildavsky 1995).

It is important to emphasise that concern over biodiversity loss is largely external to politics, although arguments suggesting that biodiversity loss 'doesn't matter' or are 'grossly exaggerated' are typical of a certain type of right-wing thinker. One problem is that such writers can clearly point to dire environmental predictions in the past that have turned out not be fulfilled. Unfortunately this is part of the process; it may sometimes be necessary to over-dramatise descriptions of processes in order to gain public attention. Also, of course, predictions typically contain an 'if' clause; unless action is taken, the following dire consequences will occur. This is a poor reason for ignoring all the careful detailed work that has been done in many areas and continues be amended and expanded. It is also important to emphasise that large systemic descriptions and productions are not physic experiments; we make models and test them constantly. Hence the crucial importance of taking seriously the large body of scientific literature and turning it into practical policy.

Are indigenous peoples natural conservationists?

A key element in the psychology underlying attempts to conserve biodiversity is the notion that although we are destroying the environment in the present, in the past indigenous peoples lived in harmony with it. Hence the world was full of 'pristine' environments until the expansion of the West. Whether we like it or not, a powerful influence on thinking in this area is those sepia posters quoting the supposed statements of American Indians on our relation with the earth and our duty to conserve it. Whether these are fakes or not is often difficult to know, but their message is clear: indigenous peoples naturally tend to conserve their

environment. A more sophisticated version is often cited from anthropological texts concerning Amazonia: the shaman asks permission from the animal's spirit before killing it. The shaman becomes proto-conservationist, checking that hunters are only harvesting a sustainable yield from the forest. This idea lurks beneath the surface of all too many community conservation projects, especially in Africa: wildlands are rich sources of essential products valued by the community and only exceptional pressure causes their destruction. Hence, bolstering income from these areas will persuade individuals it is in their interest to conserve them.

This would be delightful if it were so: but since the 1980s evidence has mounted from many regions that Quaternary extinctions (the disappearance of megafauna in recent prehistory) in many parts of the world were in fact directly the result of human irruption. This was first proposed long ago for the New World by Darwin's rival, Alfred Russell Wallace (1911) and reprised again the 1980s (Martin 1984; Diamond 1989). It now seems likely that the Australian megafauna also disappeared coincidentally with primary human colonisation. In more recent times, the destruction of much of the fauna and flora of Madagascar and New Zealand followed the coming of the Malagasy and the Maori. Fossil evidence suggests that the Polynesians left a trail of destruction across the Pacific as they expanded (Pimm, Moulton & Justice 1995).

There is no reason why conservation should be a natural process: ethical arguments are plucked from scientists' wishlists rather than based in empirical reality. Indeed the drive for protected areas and environmental conservation usually follows panoramas of destruction and to be driven essentially by nostalgia and, more recently, recreational use. A considerable amount of evidence from Africa in the wake of community wildlife projects suggests that underlying attitudes are no different today. Especially where modern rifles have spread, game parks are more notable for their vegetation than their large mammals, except where policing has remained effective.

The value of biodiversity

In developing countries, rural people largely depend primarily on natural resources for subsistence, and biodiversity represents the biological core of that subsistence. Biodiversity is central to a whole range of ecosystem services - storing carbon and recycling freshwater, for example – that benefit all living organisms. Biodiversity is a shorthand for the range of genetic resources which underlie the diversity of crops and livestock on which we all depend. In economic terms, biodiversity matters: at a rough guess, 40% of the global economy is based on biological products and processes. Conserving species and genes is likely to yield benefits, presently unpredictable, for future generations. However, biodiversity is also ascribed less tangible values, ethical and aesthetic ones which exist in a feedback relationship with economics. The more we admire diversity and appreciate it, the more Protected Areas and ecotourism can realise direct benefits. The philosophically-minded have argued that biodiversity has an intrinsic value which transcends its financial and utilitarian worth and Edward Wilson, one of the key movers in giving a high profile to biodiversity, has named this worldview 'biophilia'.

Table 1 shows some of the key values attributed to biodiversity;

The sections below consider them in more detail.

Table 1. Values attributed to biodiversity

economic	1. The output from land is greater when biodiversity is conserved over long time-spans 2. Unknown biochemical and genetic resources of potentially considerable value 3. Outsiders will pay to preserve or to visit it
protection against evolving pathogens	Genetic uniformity may allow super-pathogens to evolve and cause sudden, catastrophic deficits in food, fuel etc.
ecosystem services	Biodiversity essential to ecological functioning of planetary system
aesthetic	diversity has a value in itself
ethical	Present society is a 'steward' of earth's biological resources and we have no right to destroy them

The economic value of biodiversity

The argument from economics is most commonly heard in the discourse of development. Broadly speaking, it has two elements; 'unmined riches' (i.e. undiscovered genetic resources of use to society) and relative outputs from land use systems. In the case of undiscovered potential, it is pointed out that 25-50% of the drugs in our pharmacopoeia were originally extracted from plants and thus we have the potential to discover new drugs to cure a disease such as AIDS in the unprospected rainforest. This is a very emotionally attractive, but dangerous argument, since it depends both on the probability of discoveries which cannot be transparently estimated.

More attractive is the relative output argument. Either a piece of land can be exploited by managing its existing resources sustainably (harvesting and then consuming and selling its products) or it can be ecologically transformed, for example, by turning rainforest into grassland grazed by domestic stock. In almost all tropical environments, the first option is more productive over the longer-term as cultivation has a short-term future without further inputs. However, exploiting wild or semi-cultivated resources demands a specific lifestyle and a taste for unusual, more toxic plants and animals and a willingness to accept dependence on patchy resources. This diversity and unpredictably is often unacceptable especially to migrant populations for whom such environments are unfamiliar. This argument thus depends on consumer preferences and their expression through markets. If people refuse to eat turtles, iguanas or palm-grubs, their overall biomass becomes largely irrelevant. The calculations of exploitable biomass can be made to work more convincingly in some environments than others; equatorial forest will always has an advantage over drylands.

In the case of metal mining, there is a specific aspect of biodiversity relevant to its overall value. Metal-rich sites all over the world have accelerated the evolution of metallophytes, plant (and probably animal) species or races resistant to levels of metals that would be toxic to most other plant species. This flora has been studied in relation to Cuba, New Caledonia and DRC, principally for copper and nickel, but is otherwise poorly known. Not only do metal-rich locations have high rates of endemism, but the very plants that make these sites attractive may have a higher potential economic value than a normal sample of plant species from the same region. This is because they are bio-accumulators, storing metals in their stems and leaves. This might be used a method of biomining, cultivating accumulators for their yield, or as tools in bioremediation, extracting toxic residues form the soil. In both cases, the potential economic value of these plants could be very high, suggesting that biodiversity surveys prior to mining pay particular attention to these possibilities.

Fisheries represents a rather different story. Almost everywhere in the world, fish stocks are collapsing and entire fisheries have disappeared following mismanagement by developed countries with access to high technology. A clichéd development tag has it that 'give a man a fish and you will feed him for a day, give him a net and you'll feed him for life'. In reality, spreading new fisheries technology had led to widespread overfishing, even in impoverished areas, and hence even worse protein shortages. At the same time, aquaculture has been considered a widespread strategy to increase protein and income but has almost everywhere generated further problems, most importantly the escape of domesticated breeds and outcrossing with wild species to reduce genetic diversity.

Biodiversity and protection against evolving pathogens

Curiously, it is less than certain why biodiversity occurs, in other words why organisms and genes speciate at such frantic rates in certain circumstances and why habitats evolve to support this diversity. One significant underlying cause may be the defence against pathogens; the more genetically uniform a population is, the more vulnerable it is to pandemic diseases. Pathogens evolve rapidly and plants and animals must adapt constantly to resist their attacks. Speciation is one obvious result; the more biodiverse a population is the less likely it is to be eliminated when a powerful pathogen evolves. Analogous arguments have been developed in relation to predation; the more effective the predator the greater the tempo of speciation.

In the case of domesticated plants and animals, food producers select cultivars and races that have desirable qualities and which retain those qualities by being reproduced in as genetically uniform a manner as possible. Modern techniques of propagation and selective breeding make possible a degree of homogeneity impossible until recently. As a result, extremely similar animals, trees and crops are found across much of the world.

This strategy is not without risks, as basic evolutionary theory suggests. In their home areas, organisms have co-evolved with pathogens and have more or less developed defences. However, when transplanted, the plants and animals face an alien array of pathogens they have not previously encountered. Many of these will be harmless, but it is possible for a 'super-pathogen' to evolve that will be extremely damaging to the imported plant. If such a pathogen is then carried back to the 'home' area of the organism (i.e. its centre of evolutionary diversity) it can have enormous destructive potential.

There is a potential for catastrophic effects on source-populations from super-pathogens. All the Eucalyptus plantations in the world derive from a relatively small genetic base in Australia. Guava rust (*Puccina psidii*), a pathogen of the native Myrtaceae in the New World has jumped to eucalyptus plantations there. Since the original Australian eucalyptuses have not co-evolved with the rust, should it spread back to Australia its impact on the wide range of native eucalyptuses may be devastating.

Similar patterns can show up in major cultivated plants, for example the potato. The potato blight, *Phytophora infestans*, was responsible for the Irish 'Great hunger' in the 1840s, but has never disappeared. A more virulent strain of the blight was identified in Switzerland in 1981. A series of smaller outbreaks were reported through to the early 1990s, when a change in the fungus dramatically increased its mutation rate and it was thus less susceptible to individual fungicides. It appears that some forms had 'swapped crops' and were now infesting tomatoes. By 1992, CIP estimated that yields in the developing world were down 30% as a result of infestation and, moreover, threatening to spread back to the high Andes, the original centre of domestication and still the major diversity reserve.

The aesthetic value of biodiversity

Another argument suggests that diversity has a value in itself, that it is aesthetically desirable. Of all the arguments for biodiversity, this is probably the most controversial. Although attractive to the middle-classes in the developed world, elsewhere it commands little support. In many places in the world, biodiversity *is* being destroyed either through habitat destruction or intentional pinpointing of resources such as large mammals by individuals too absorbed by financial gain to notice or households too poor to care. Demographic pressure will ensure that this process continues largely unabated; relentless burning of the Amazonian rain-forest sometimes drops slightly when political pressure is applied and rises again when it is relaxed. Because of this, economists and biologists have tended to advance economic and technical arguments for conserving biodiversity many of which contain large numbers of unknowns. In some ways, however, this approach too is naïve; aesthetics can drive significant financial and political processes. The large numbers of supporters of the major NGOs such as CI and IUCN are basically responding to aesthetics and in particular those that relate to headline species. The power of these NGOs in turn drives political processes and ensures their views are taken into account in regulatory negotiations.

Ethical aspects of biodiversity

Ethical approaches to nature and the environment have a long history in human society, especially in parts of Asia. Animals and plants are conserved because they are part of a larger spiritual web. The principle is to extend ethical precepts developed in relation to human culture to non-human entities. Just as human rights have been extended over time to slaves, and to children, the argument is that they should extended to animals and even the environment as a whole. From this perspective, human beings are 'stewards' of earth's biological resources and have no right to destroy them and deny future generations the opportunity to experience and interact with them.

Clashes of values

The systems of values described above are by no means always in harmony with one another. Analysis of conflicts between value systems can usually be reduced to two major categories;

a. Human-centred vs. environment-centred
b. Long-term vs. short-term perspectives

Much philosophical thinking is anthropocentric; 'man is the measure of all things'. The explicit statements in Genesis about humans being given 'dominion' over the natural world are replayed through many religions and humanistic systems of thought. In development speak, communities are often said to be the 'owners' of some tract of land and the biodiversity that it encompasses and this is said to give them the right to dispose of it. In contrast, some Asian religions, notably Buddhism, and many tribal systems of thought consider humans to be part of the natural world and their ritual systems reflect the importance of restituting damage to it, or asking the permission of animals to be killed.

In modern terms these conflicts are played out between 'social development' experts, administrators and economists opposing conservationists or biologists. For example, in much of the circum-polar world, 'native hunters' have made much of their rights to hunt sea-mammals, whales, walruses etc. There is no doubt that these animals were the base of subsistence in the pre-modern era and that they are of great cultural significance. In general, therefore, exceptions have been made for these groups in international fora such as the IWC, which has generally supported a moratorium on whaling by developed nations. Conservationists, however, say the question of tradition is irrelevant; what counts is the status of the species hunted; if these are threatened, then the moratorium should be exceptionless.

The status of 'native hunters' does seem to be fraught with ambiguity; many of these hunters have taken up hunting again after a long period of disengagement. Their transport and killing methods could hardly said to be traditional and the notion of quotas is generally paradoxical; hunters typically kill all they can in years of abundance. Their apparent conservationist ethic was simply a reflection of a technology which did not allow massive kills. At another level, we are perfectly ready to dispense with customary behaviours with a long tradition, such as fox-hunting and bear-baiting, where they offend modern sensibilities.

To look at these issues on a larger scale, policies on the siting of extractive industries in biodiversity reserves vary between nations according to their perspective on the importance of the potential benefits to society. The United States, for example, claims that it is essential to give permission for extractive industries to prospect in previously untouched wildlife areas because of the economic benefits they will return and the importance of maintaining pre-existing standards of living. Most other developed nations take the opposite view, namely that the biodiversity and environmental values represented by PAs takes precedence of any economic benefits that might accrue from opening them up to exploration.

The other set of issues concerns the weighing of benefits over time. This is particularly the case with agrobiodiversity where agronomists and agricultural economists oppose small farmers. There is little doubt that over a short time period, 'improved' crop and livestock varieties can give improved yields in comparison with the diverse portfolios maintained by small farmers. As a consequence, governments often

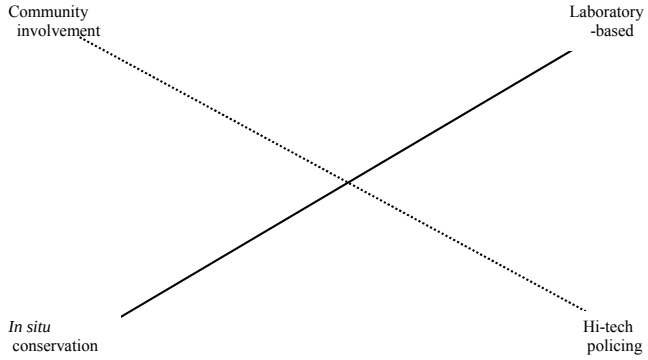
persuade farmers to exchange their stock for these new varieties. However, the new varieties inevitably make higher demands on inputs and labour and are more susceptible to pathogens. Often, the cash-flow of small farmers is such that they cannot afford the inputs in some years and their yields are ultimately lower than with their traditional varieties. Disease often sweeps through the farms leaving the rural householder more impoverished than at the beginning of the exercise. By this time, the expert has usually moved on and is not present to see the long-term failure of these strategies.

Historically, the value-systems espoused by the state and by large corporations have been those generally in use. Opponents of their actions have been too weak and dispersed and often too busy making a living to mount effective and critical opposition. However, a distinctive feature of the twentieth century was the rise of advocacy groups willing to challenge these value systems and to make use of scientific data to support their position. Improved communications have made possible the co-ordination of protest in a way that would have been impossible in previous eras. Clashes of value systems and the ability of niche groups to make their views known represent a permanent change in the relationship between citizens, corporations and the state.

Conservation and Protected Areas (PAs)

Any strategy for the conservation of biological resources can be plotted against two gradients, the social and the technological. Social aspects of conservation range from extreme policing strategies where access is controlled in quasi-military fashion, to situations where the integrity of the PA depends wholly on the goodwill of both the adjacent and international communities. Along the technological cline, conservation may be wholly laboratory based (*ex situ*), where germplasm is collected and stored against some future requirement (typical for agrobiodiversity) as against *in situ* conservation where all activities are sited within the PA or on the farm. Figure 1 illustrates these intersecting strategies;

Figure 1. Parameters situating conservation strategy



In reality of course, multiple strategies co-exist, both over time and place. Kenya is a good example of a country where policy on national parks has oscillated between extreme exclusionism[1] and community conservation, sometimes co-existing within the same region, but supported by different actors.

Broadly speaking there is a correlation between the value of the resource to be protected and the effectiveness of a given strategy. Where demographic pressure is high, the resource, whether, bushmeat, firewood, NTFPs etc.) becomes more valuable, and appealing to community conservation becomes proportionately more difficult. Where a resource has a high commercial value externally (rhino horn, ivory, tiger-bone) well-funded military-style raids will be mounted by outsiders to extract it. This can *only* be countered by well-instituted policing. Most of the problems with managing PAs arise from mismatches in dealing with these issues. Protecting PAs with ill-paid and badly supplied game guards will never work where poachers have both better resources and are willing to be more ruthless. Reserves that depend on community resource-sharing only function where the community is not under pressure.

[1] 'People don't come to game parks to see Maasai cattle' –Richard Leakey.

Protected areas have almost sacred status for NGOs and their institutionalisation depends heavily on a perceived dichotomy between 'wild' and 'domestic'. But such a division is hard to maintain from a scientific point of view. Although biodiversity reflects processes that were under way well before modern humans evolved, the biodiversity that can be measured today is virtually all the product of long-term interaction between the environment and human activity. Only the flora and fauna of the deep seabed is largely untouched and even this may not last.

To make rational policy involves an understanding of the main processes involved in human interaction with biodiversity over time. Such a historical understanding is essential to claims about the nature of 'historical', 'natural', 'pristine' or 'wild' environments. The processes identified as acting on biodiversity can be summarised as follows;

a. Habitat conversion
b. Plant and animal domestication
c. Chemical, microbiological and radiological contamination
d. Climate change
e. Conservation and management of 'wild' environments

Of these, habitat conversion is the oldest, with evidence for intentional burning of woodlands to create savanna for easier access to game at more than 400,000 BP. There was a major step upwards in intensity with the advent of plant and animal domestication, and many of the world's rangelands turn out to be created by farmers. Demographic increase in the twentieth century combined with urbanisation and industrialisation have converted a greater proportion of the earth's surface. Plant and animal domestication are typically associated with habitat conversion; transforming environments until they are suitable for the needs of particular species and eliminating natural biodiversity (weeds etc.).

Chemical, microbiological and radiological contamination typically begin in the sixteenth century with the earliest factories leaching waste into rivers. The growth of mining and industrialisation probably meant that the acme of this type of contamination was in the late nineteenth century in Europe and America, with Eastern Europe and Asia following later. Radiological contamination began in the 1940s and continues unabated. Climate change is indirect: human activities of various types, notably habitat conversion and chemical release cause poorly-understood and still controversial fluctuation in the world's weather. Managed environments go back the parks established by the Chinese emperors and the country estates created for hunting in medieval Europe. The growth of such Protected Areas in tropical regions typically goes back to the early years of the twentieth century.

All of these activities affect biodiversity; most are long-term and affect much or all of the planetary ecosystem. The perception of these activities as positive or negative is very much a reflection of the period. Until World War II, forests were largely perceived as negative, preventing farming and thus accelerating famine. Primary forests are now characterised as key planetary resource in biodiversity conservation. Mining and excavation often create complex micro-habitats which attract biodiversity; thus former quarry sites are often of particular scientific interest. Slash-and-burn agriculture in regions of low demographic pressure creates floral islands that preserve diverse fauna.

In the case of PAs, the impact of human activity on biodiversity is complex partly because management goals are highly diverse, even within one country, and because fashion and science move on. For example, Protected Areas in the tropics are very often old parks, reserves or forest areas that were established in the early twentieth century for a diversity of reasons, including hunting, logging and because they were marginal and the land could thus be easily and cheaply acquired. As tourism and biodiversity have become considerations in more recent times perceptions of their importance have changed. Game parks in tropical regions have high income potential and are thus most prone to manipulation, for example veterinary intervention, bringing in inconveniently absent species, preventing bushfires etc. As a consequence, PAs that are most commonly promoted on the basis of their 'wildness' usually have an entirely artificial floral and faunal architecture. Marine and freshwater areas are under-represented in terms of the total reserved area, despite their greater significance for biodiversity because of the low cost/benefit ratio in terms of visitor income.

Demographic increase and the movement of population out of PAs has the effect of creating a ring of predatory villages around them, often characterised by reduced access to resources. Their claims on the animals and NTFPs inside the PA may be legitimate, but there is considerable incentive to ramp up those claims. As a result, mediation and arbitration processes too often collapse in a welter of claim and counter-claim. The appeal to tradition is made in a situation where tradition has little role to play. The advent of guns, cash, vehicles, roads and the elimination of trypanosomosis have meant that the twentieth century is like no other, even for resident villagers. Advocacy groups function to make coherent the claims of resident populations on a rather selective basis. Resource-sharing agreements and community conservation have become commercial negotiations between two parties, with one side using ethical blackmail.

It is therefore unsurprising that mining companies and other industrial enterprises are thus somewhat sceptical about the rigid protectionist stance called for by major conservation bodies such as the IUCN. A widespread view is that PAs should be evaluated on their current merits, not on the historical conditions of their establishment. The catch with this is that if a government is strongly motivated to permit mining on revenue grounds, it will of course commission the consultancy company that produces that required result, namely that the environmental/biodiversity significance of a given PA is not sufficient to prohibit resource extraction, especially where the company promises remediation. Revisions of PA status can thus only be undertaken on a collaborative basis with external bodies to guarantee scientific objectivity.

Policy, planning and legislation issues

Extractive industries are usually highly profitable for national governments in relation to their impact and this makes those governments more willing to over-ride local objections than would be the case for other types of activity. Such industries are also often a subset of large multi-nationals who can make considerable expenditures in international lobbying. Biodiversity issues are sufficiently important that international processes should be in place to ensure that science-based decision making can oppose essentially political considerations.

The twentieth century has seen the promotion of many issues once considered local or national up to the category of global public goods. Biodiversity is one of these; we consider biodiversity losses or damage to ecosystem support services as having an impact on a global good. As a consequence, companies whose activities result in such impacts must consider that simple business models ('we pay our taxes') or national frameworks ('we have permission from the government') are no longer acceptable. The scale of large companies is such that they must be held responsible in proportion to the impact of their activities, as are governments. Although some companies continue to resist this view, advocacy groups for whom this is a fundamental assumption will oppose them.

In the long term it will therefore be better to be part of the process than to adopt a confrontational stance. Companies have a signal advantage over NGOs and government, their internal decision-making processes are less lethargic and their resources and infrastructure more rapid in response. They are therefore able to organise and fund the small and large-scale fora that can result in agreed guidelines and operating principles. At the same time, a key element is their acceptance of the principle of transparency, of making documentation and proposals accessible. In addition, as biodiversity theory evolves, so must policy; large companies can mobilise resources that will allow effective feedback processes to be put in place.

International agreements such as the CBD contain rather general principles that need to be fleshed out in national and local legislation. However, even ratifying international agreements is a glacially slow process, and turning them into practical legislation on the ground more dilatory still. NGOs have a key role to play in placing pressure on national governments to enact relevant laws and to ensure coherence both internationally and locally. One of weakest aspects of this type of legislative process is the potential for senior government figures to over-ride decisions made on environmental grounds by Environmental Protection Agencies or following tribunals and public enquiries. This is notably true in the construction and mining industries. The only protection against this can be a requirement to publish reasons for a decision on the web which would at least ensure that the argument is accessible to advocacy groups.

In a sense, all operations conducted by large enterprises are more subject to monitoring and legislative regulation than local-level operations. Some of the most dangerous activities for the conservation of biodiversity are uncontrolled mining by individuals or small groups with no official presence. Thus gold-mining in West Africa and the Amazon, reef-bombing in insular SE Asia and tantalum in the Congo are conducted by small groups who are quite prepared to use violent means to access and protect their patch. The is seen most clearly in the case of the 'blood-diamonds' in Angola and Sierra Leone, where the chain of corruption reaches from the small-scale struggles for territory on the ground to the hushed corridors of Antwerp. Sometimes these go ahead because of weak government, at other times, government is complicit. Where government has lost control, as in the DRC, there is a case for international action. Where government is actively profiting from such activities, as in West Africa, issues of national sovereignty come to the fore and the international community can only use diplomatic pressure. The problem is ensuring that such pressure is driven by the background science, not political convenience.

Environmental Impact Assessments

Environmental Impact Assessments (EIAs) are becoming one of the most troubling aspects of activities, whether mining, industry or construction, that have a major impact on the local environment. Although legally required for many types of impact operations in most countries, very little transparency exists in the award of contracts, the scientific refereeing of reports produced, while oversight of effective compliance is extremely limited. There is little doubt that some companies take advantage of poorly framed policies and lax regulation to reduce their commitment in this direction.

In the long term, this situation can only result in bad publicity for the companies in question, residual claims against them and further confrontation with advocacy groups. It is therefore imperative that a more effective international process be put in place. This must be done in conjunction with other aspects of capacity-building, notably in taxonomy –see below).

It is therefore recommended that in all aspects of the EIA process there be a 'presumption of transparency'. All requests, tenders and outputs should be made available internationally, primarily through the internet, but also on CD-ROM and via on-demand paper output. The standards an EIA should meet will either be those of the country in question or international standards, whichever is the more demanding. An alert list of stakeholders, including government, NGOs, donor agencies and scientific bodies, should be informed as new documents are posted to ensure that time for comment is adequate.

Ensuring compliance is more problematic, because mining is a long-term process and effective response to catastrophic and unexpected events is by definition hard to monitor. Companies should be required to post descriptions of compliance and accounts of response to disasters on the internet, and these should be subject to monitoring co-ordinated between an alliance of government, NGOs and international bodies. At present these types of disputes are played out a great length in the law-courts[2], with those organisations able to pay for the most astute lawyers reducing or delaying compensation for many years. A process that involves more consensus between those bodies charged with environmental protection and the mining companies and can produce more timely payments to the authorities who need to resource immediate remediation operations. This would involve less waste of resources and ultimately result in a better public image of extractive industries.

As other parts of this document suggest, all sections of the community are poorly informed about the scientific aspects of biodiversity and the processes that exist to update knowledge are very haphazard. Typically, when a new area is brought onto the agenda, governments begin an initiative intended to 'mainstream' topics such as environment, gender, desertification, climate change etc. After a few years, interest declines and it is thus deemed 'mainstreamed', an unsubtle code for 'forgotten'.

[2] As the case of the Exxon-Valdez illustrates.

In the case of the ephemeral enthusiasms of social development, this process is probably pragmatic, but for science-based topics it is highly undesirable. Policy-related decisions that depend on evolving science need to acquire institutional permanence as well as a tracer to the heart to government. Curiously, it is easier to get research funds to carry out new studies than to produce policy syntheses of current science and ensure they are read by decision-makers.

Governments change position slowly, especially when their own internal information systems have become centralised and rigid. External bodies, notably multi-lateral agencies, NGOs and companies have a better record of institutionalising new ideas, as the field of biodiversity shows. The supine nature of academia is underlined by its poor record of influencing government policy and challenging received wisdom. Sustained government interest and recurrent resourcing of biodiversity research will only happen as a result of persistent external pressure. UN-sponsored conventions such as the CBD have demonstrated their value in stimulating change in otherwise passive governments. The establishment of the WCMC as a formal UN body with its great emphasis on information, mapping and databases has had a similarly positive influence.

In the case of NGOs and advocacy groups, the problem is not usually lack of information but the imbalance created by their concentration on a single issue. A wildlife pressure group can campaign for total exclusion in a PA, but governments must balance issues of national finances, likely income from tourism and prospects for local employment. The advantage is that NGOs are highly motivated and will take considerable risks to elicit information other bodies are trying to keep hidden. The disadvantage is that they can wage sometimes elaborate and abusive campaigns against their perceived opponents with very little accountability. This is increasingly difficult to control; only the more authoritative dissemination of information by bodies perceived to be independent will outweigh such campaigns. NGOs have to raise funds as well, and sometimes the distortion follows from the potential of a given topic –it is easier to raise money for large photogenic mammals than small unattractive creatures, no matter how important these latter might be to an ecosystem.

In the case of biodiversity, therefore, NGOs also need a charter to which they can sign up to guarantee both a reasonable approach to advocacy and the consideration of related issues that other bodies must take into account. NGOs that refuse to affiliate cannot easily be halted but their credibility will be reduced. The charter needs to be such that large NGOs like IUCN will sign, otherwise the initiative will be useless.

Some large extractive industries have now established biodiversity units, although with highly variable resources and internal authority. Such units need to be mandatory, with coherence between enterprises an important element in their structure. The key tasks of such units would be;

a. Ensure that existing projects have conducted and reported biodiversity surveys
b. Provide terms of reference for new surveys and ensure quality of outputs and long-term compliance
c. Monitor relevant scientific and regulatory literature for its significance
d. Encourage publication of results in refereed journals
e. Ensure the quality of data disseminated via the web
f. Fund the preparation of accessible handbooks relevant to project areas
g. Support contributions to core funding of national and international bodies
h. Ensure coherence with other aspects of sustainable development

Such units would ideally also have a lobbying role, both within the companies in question and in the wider society.

Extractive industries presently spend a great deal on advertising, funds which are often wasted when a failure of transparency comes to the surface. The capacity to ‘leak’ information anonymously to large audiences has the consequence that such failures will be increasingly reported. This suggests that such money would be better diverted to the support of units which will have long-term beneficial results for the environment and will incidentally provide positive images without such expenditure.

Taxonomy –the heart of biodiversity assessment

At the heart of all biodiversity assessment is taxonomy- the capacity to identify and enumerate the species recorded in the field and link them with data from other regions to provide context for the findings. As estimates for the numbers of species on the planet climb relentlessly, and there are increasing requirements for biodiversity assessments, it might be thought that infrastructure, resources and trained personnel would increase at a similar rate. But in reality, the reverse is true. Institutions devoted to the classification and storage of biological specimens have seen their financial allocations reduced and the training of taxonomists everywhere is a declining priority. As Wheeler and Cracraft (1997:436) put it;

> 'The absence of adequate scientific infrastructure in most countries, especially in those that are species-rich, constitutes a major impediment to an international response by the scientific community. Even those countries with substantial scientific resources cannot meet their management needs. In these countries, for example, systematic collections are not funded to a level that is capable with keeping up with the existing rate of specimen acquisition, let alone at a level that is appropriate for the biodiversity crisis. Existing data in herbaria and museums remain largely inaccessible by modern technologies for data management. Funds available for investigating fundamental questions about biological diversity are severely limited to the task at hand And, finally, the numbers of students trained in systematics and organismal biology have diminished, contributing to what many, including ...UNESCO have called the "taxonomic impediment"'.

The reaction of industry could be that this is the responsibility of government. However, governments do *not* take this responsibility seriously, and indeed at times are openly sceptical about their role in this area. Increasingly, research and publication on biodiversity is in the hands of international NGOs, multilateral agencies, industry and the media[3]. But this is a tenuous coalition at best, not usually contributing to fundamental science and depending on fluctuating funding and the economic importance of particular sites. More importantly, such bodies cannot usually contribute to centralised infrastructure and long-term training needs. Museums and research collections are uncertainly funded even in the developed world[4]. Herbaria and zoological collections can easily be allowed to collapse in countries such as Indonesia, even though both biodiversity and scientific interest is extremely high. Long-term political instability, for example in the Horn of Africa, may mean that duplicate reference collections should be compiled.

As a consequence, mining companies, and a coalition of other bodies from related industries should be involved in a more comprehensive programme to revive and enhance skills in systematics and taxonomy. This should have a variety of elements;

a. Advocacy in the developed world to increase the profile of systematics
b. Core support to institutions and infrastructure involved in the storage of reference collections
c. Funding of new institutions in developing countries where a lacuna is identified
d. Support to training institutions in developing countries
e. Support to the publication and dissemination of data

Most of these activities fall into the category of public goods and will not be supported coherently within initiatives specific to individual companies. They can therefore only effectively operate through international bodies. Ideally, this would be managed through the UN, but UN spending priorities and internal over-regulation do not suggest this would be cost-effective. So the creation of a globally accountable body is recommended.

One of the problems of taxonomy from the point of view of developing countries is the concentration of resources in 'old' institutions in the developed world where most holotypes are stored. As the literature expands, access to journals and monographs become more problematic. Increasing access to specimens and literature through electronic means, DVDs and the internet should therefore be integral to any programme to support systematics. This should be supported at a global level; systematics based on administrative boundaries is of very limited value.

[3] Recent wildlife series, such as the 'Blue Planet' (BBC 2001) appear to be making a direct contribution to biodiversity assessment.

[4] See Mehrhoff (1997) for material on the evolution of systematics collections.

Reaching policy-makers

Biodiversity, even in the minds of many researchers, is still strongly associated with large land mammals or somewhat unrealistic representations of rainforests. The value of biodiversity is too often supported with examples of the use of individual species to humans. While these have great value in dramatising the importance of biodiversity to non-specialists they do not necessarily lead to rational policy-making. The reasons for not burning down the Amazon rainforest are not that we might find a cure for AIDs in its secondary phytochemistry; they are more fundamental, if more abstract.

Rational operating principles draw on a science base, recognising that in this area, science is constantly developing. For example, up to 1980, it was still thought that the deep seas were a desert of biodiversity; if this were so, the mining of manganese nodules would be considered to have little impact on the environment. However, it is now known that these regions are extremely biodiverse; therefore deep-sea mining regulations take on as much importance as they do in terrestrial zones.

However, governments and multilateral bodies have very inflexible processes for absorbing new knowledge and research results. Moreover, political imperatives can easily over-ride science-based decisions, as BSE, GM crops and the climate change negotiations show. It is striking that it takes a crisis, such as the recent foot-and-mouth epizootic, to stimulate the discussion of an environment-friendly tax regime for farms. United Nations bodies have generally developed some of the more advanced thinking in this area; the task is to press national governments to be aware and adopt the principles they espouse.

Media

Despite an abundance of popular natural history programmes, few deal with biodiversity, and even fewer deal with policy, social and conflict issues, preferring to present an almost entirely factitious image of pristine nature. Occasionally programmes presented by advocacy groups are aired but these are often disappointingly one-sided. Governments are much more responsive to media critiques than to academic publications or the output of think-tanks. Documentaries presenting these issues accessibly but seriously will be crucial in giving biodiversity issues and trade-offs a higher profile. All sides concerned with these issues should put more effort into ensuring the commissioning of radio and television broadcasts across the world.

Importance of field handbooks

Apart from taxonomy and systematic ecology, therefore, there is a considerable need for popular syntheses of current science in this area. This should take the form of field handbooks and other types of documents summarising new research. Handbooks are published and the standard is increasingly high, but they are highly selective; birds, butterflies, large mammals and wildflowers take priority and all other types of fauna and flora are poorly and irregularly covered. Similarly, geographic coverage reflects economics; insecure or marginal regions of the world are largely ignored or published handbooks allowed to out of print.

Field handbooks represent a cornerstone of effective biodiversity surveys and EIAs; their irregular coverage, uncertain availability, and sometimes their price, prevents credible identifications and reduces the value of all types of survey. Handbooks are also of particular importance in building the capacity of local consultancy companies in developing countries who may not have access to specialised taxonomic skills. They are also an easy guide to external evaluation and thus an aid to the process of transparency.

Another key element in the dissemination process is translation into vernaculars. Populous countries, such as those in SE Asia, where there is an established national script and a growing ecology movement, require access to these materials. Subsidised translation is part of creating a sense of ownership which will allow national scientists and advocacy groups. In Africa and the Americas, where the national languages are non-

indigenous, smaller-scale handbooks of vernacular terminology remain an important tool for biodiversity survey.

Ensuring equitable conditions across the industry

Writing a code of practice for the mining, or indeed other extractive and processing industries, is relatively easy; ensuring compliance is more difficult. Historically, large mining companies have relied on lobbying their government to support them in negotiations on international regulatory frameworks. They are increasingly aware that this approach is not acceptable and that they will have to meet international standards or face the well-organised campaigns and criticisms of advocacy groups. Hence, they are beginning to find it more effective to try and work with mediating bodies. But small groups can afford to simply ignore the strictures of such bodies, as they ignore other environmental and health and safety regulations. If such groups are allowed to escape regulation, larger players will be tempted to try and circumvent it on the grounds that the playing field should be level.

The Madrid Protocol is a subset of the 26-nation Antarctic Treaty intended to set environmental standards for research in Antarctica and to forbid all extractive industries for fifty years. As such it represents an early model for the evolution of an international regulatory framework. However, the experience of signing and ratifying the Protocol in January 1998 illuminates the role governments can play in delaying consensus on international accords. Despite the clear international support for the idea that Antarctica region is of planetary importance, the United States and Japan held up the treaty for five years before eventually ratifying it, principally at the instance of their mining lobbies.

The Madrid Protocol is relatively simple to establish and monitor because it consists principally of prohibitions and because no adjacent human communities are present. Moreover, mining operations are impossible to hide in such a landscape. Nonetheless, it provides a model at one level for the sort of international accords that must be developed and ratified both to promulgate new ground-rules and to ensure parity between countries. However, one aspect of the Protocol demonstrates an overall structural weakness that would need to be remedied. In this case, nation-states, following lobbying by commercial interests, take a position at the negotiating table that represents those interests. These lobby groups are wholly unelected and represent no more than a sophisticated bribe –funds to political parties in return for support in international negotiations. This is wholly unacceptable; global public goods should not be held to ransom by individual commercial interests.

There are some underlying axioms which it will be necessary to establish in such negotiations;

1. That biodiversity is a global public good
2. That some subsets of biodiversity are so important that only a total ban on incursions by extractive industries is acceptable
3. That some environments are so unique, the polar regions being one, that the same is true
4. That where an incursion is contemplated, international environmental regulatory frameworks supersede local, national or regional ones
5. That the same is true for compliance standards
6. That transparency applies to all negotiations including those of lobbying interests
7. That a compensatory mechanism needs to be developed to smooth out the inequities that follow from axioms 2 and 3.

Of these, the first principle underlies all the rest and will be the most difficult to get accepted in all its ramifications. If biodiversity is a global public good it follows that individual nation-states do not have the right to destroy or manipulate it simply because it occurs within their territorial boundaries. This would also imply acceptance of the principle that all governments must control local mining enterprises that may not be visible to international scrutiny and that, under such a framework, pleading poverty or demographics would not be permissible. In reality, biodiversity is being altered continuously on a small scale all the time, but the principle kicks in when axioms 2 and 3 are in question. This applies principally to ‘hotspots’ in biodiversity terms such as Madagascar, the Philippines or New Caledonia and unique environments such as the polar

regions. Conservation International's estimate suggest that their list of 25 identified hotspots cover 1.5% of the earth's surface but that their endemic plants include 44% of all known plants and their overall plant populations 67% of all plant species. Figures for vertebrates are slightly lower but similar. A second major consequence of principles 2 and 3 will be inequity; some regions of the world are of greater importance than others. Madagascar and Soqotra, with their high degree of endemism, are typical of biodiversity of global importance occurring in countries without the resources and possibly the political will to protect that biodiversity.

Part of the international regulatory process must be the synthesis of the results of current science to develop practical applications and judgments about the importance of particular sites, which may sometimes conflict with the historical siting of Protected Areas. The same process may be applied to offset decisions (to exchange an existing PA of limited biodiversity value for a larger one of greater value). Similarly, weighing the claims of different elements of biodiversity, such as endemism versus overall species richness, the relative uniqueness of particular habitats and determining whether management issues should be allowed to influence such decisions. These in turn will feed into compensatory mechanisms; deciding how to compensate individual nation-states for their obligations to protect biodiversity under the framework they have ratified.

Undersea mining in international waters represents a particular set of problems for biodiversity survey, compliance and equity. Yields of undersea mineral deposits such as those in the Southern Kermadec Arc or the Manus Basin are sufficiently high as to ensure that they will certainly be exploited in the next few years. Key issues are that the biodiversity of such regions is hardly known, and that surveys are expensive and can only be conducted with highly expensive ROVs available only in a few institutions. Similar problems apply to ensuring compliance. In addition, where minerals occur in international waters (and probably most fields occur partly in such waters and partly in national waters) who has the rights to exploit them and how should profits be distributed? Only a few companies have the resources to prospect for such minerals; it is clearly inequitable that the resources should accrue only to those nations where such companies are situated. Inadequate information makes it impossible to establish immediate ground-rules; but since this issue will be of increasing importance in the next decade all parties will need to begin discussions of a possible framework.

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