The publications which will emerge from IUCN in the next two years generated by the Caracas Congress will provide a cornucopia of ideas, information, guidelines and practical assistance which will provide a springboard for improving the world's national parks and protected areas.

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Bias and biodiversity

W. F. Ponder

Australian Museum, Sydney

It is well known that the greatest threat to biodiversity is due to the rapidly expanding human population with its insatiable appetite for the Earth's resources. The human plague and all its catastrophic side effects are perpetrating a major extinction event. And yet what efforts are being made to understand the real nature of the diversity that is being lost and the actual cost to us as living organisms? With around only 5.2 per cent of our planet's land protected (Groombridge 1992), and an estimated 140 species in the tropics alone becoming extinct every day (Ryan 1992), where do our priorities lie? Should we be more concerned about diminishing koala numbers, destruction of rainforests, threats to the Great Barrier Reef, or soil erosion?

Before attempting any such prioritization we should ask a basic question — what organisms play key roles in the fundamental processes in ecosystems? We may then be able to assess the kinds of losses that would cause the most serious impacts. Much of the conservation literature is dominated by work on vertebrates and higher plants. Whereas higher plants play an enormously important part in terrestrial ecosystems, in the marine sphere this is clearly not so. Vertebrates are usually conspicuous, for example fishes in marine ecosystems, and birds, reptiles and mammals in most terrestrial systems. But are they significantly involved in any of the processes that might be called "fundamental"? To answer this question we must go back to basic ecological principles.

The key to animal life is autotrophy — the conversion of inorganic substances into organic. The most essential autotrophic process, as we all know, is photosynthesis — in which living organisms are able to use the energy of sunlight to convert inorganic material (carbon dioxide), into organic material. It occurs not only in plants but also in many bacteria. Algae, higher plants and some bacteria produce oxygen as a byproduct. Another, but less well known, autotrophic process is chemosynthesis, the production of organic matter from inorganic by means of chemical energy, which is limited to certain groups of bacteria. Photosynthesis and chemosynthesis are an essential part of the cycling of elements and compounds upon which the entire biosphere depends.

Because as little as 1–15 per cent of plant material is actually harvested by animals (Whittaker 1975), the other side of the autotrophic coin is the vital necessity to decompose dead organic material to make it once again available to the autotrophs, otherwise all nutrients would be locked up in dead bodies. Bacterial and fungal activity is responsible for most decompostion, although some is non-biotic (e.g., fire). Thus the popular notion that ecosystems can be understood with food chains starting with plants, followed by herbivores, and ending with carnivorous animals is excessively simplistic, ignoring the huge, necessary contribution by micro-organisms. In fact without their intestinal symbiont fauna and flora most metazoans would be unable to function. Other vital activities such as soil formation and maintenance are also largely due to micro-organisms.

Vertebrates are either not involved in, or not essential for, any of these fundamental processes. In fact, bacteria have been in existence for about 3 400 million years whereas the first animals are only 700 million years old. Thus life has been maintained on earth for nearly five times longer than higher plants and animals have been in existence.

Not only are most of the species and numbers of animals "invertebrates" (e.g., Beattie *et al.* 1992) in most terrestrial communities animal biomass is concentrated in "invertebrates", not vertebrates, and in the sea most of the biomass is in planktonic animals, not fish (Whittaker 1975). Tiny animals can be found in very high numbers, for example as many as 20 million nematodes per m^2 (Overgaard-Nielsen 1949, 1949a).

Is our preoccupation with vertebrates in ecological and conservation priorities out of all proportion to their ecological importance? Vertebrates actually make up less than 1 per cent of living species (Groombridge 1992) and yet, by definition, only terrestrial vertebrates (amphibians, reptiles, birds and mammals) are recognized as "fauna" in New South Wales government legislation dealing with conservation and endangered species. The total number of species of living organisms is thought to lie somewhere in the range of 5–30 million (Wilson 1988; Groombridge, 1992), although even the higher number is possibly conservative (e.g., Stork, 1988). We do not know the number even to the nearest order of magnitude because many large groups (protozoans, bacteria, mites, nematodes, fungi etc.) are extremely poorly known. Erwin (1988) suggests that there could be more than 50 million species of insects alone whereas Stork (1988) has an upper estimate of 80 million species. On Wilson's estimates of species numbers, only about 42 000 (0.14–0.84%) are vertebrates.

Why is it then, when most of us think of "animals" or "biodiversity", we think of vertebrate examples. This preoccupation with megafauna is not just a problem with the general public — many zoologists and conservationists also appear to think this way. There is a similar perception that "plants" comprise angiosperms, gymnosperms and ferns, because they are the most conspicuous. Nevertheless other plants and plant-like groups (including fungi, algae, mosses, lichens) are also ecologically and numerically very important.

The most abundant organisms are "microbes", which loosely include bacteria, viruses, single-celled "algae" and protozoans. Although there are only about 4 000 named bacteria and 5 000 named viruses (including plasmids, phages etc.), estimates (e.g., Groombridge 1992) suggest there may be three million species of bacteria alone. As I have attempted to show above, these organisms play crucial roles in our ecosystems — like the photosynthetic Cyanobacteria (commonly called blue-green "algae") which have a history reaching back 2 500 million years and comprise thousands of living species. Cyanobacteria were probably responsible for changing the atmosphere and making it possible for the "higher" life forms to evolve and are one of many groups that comprise the "Bacteria" (Kingdom Prokaryotae or Monera). This diverse grouping of immensely important organisms exist in every environment capable of sustaining life. A spoonful of soil is said to contain some 10^{10} bacteria and the number of bacteria in your mouth is more than the number of people that have ever lived (Margulis and Schwartz 1988).

Organisms as different as protozoans and algae make up another enormous group sometimes considered to be a separate kingdom, the Protista or Protoctista, comprising 27 (Margulis and Schwartz 1988), 37 (Margulis 1992), or as many as 45 phyla (Corliss 1984). This extremely heterogeneous group is so diverse that one author proposed 20 separate kingdoms to accommodate them (Leedale 1974). All are aquatic, although many live internally in other organisms as symbionts, commensals or parasites. Probably every species of multicellular organism has protoctist associates. The number of species there are is unknown but estimates range from 65 000 to 260 000 (Margulis and Schwartz 1988; May 1991).

Most animal species are "invertebrates". This unfortunate term is used to cover about eight major phyla, a number of minor phyla and some of the phylum Chordata which includes the vertebrates. Most named taxa are insects with about 800 000 described species with estimates of several million to tens of millions remaining to be described (May 1988; Erwin 1988, 1991; Stork 1988; Groombridge, 1992). Other groups may be much larger than generally recognized. For example the Mollusca, for which Wilson (1988) and Barnes (1989) give a figure of 50 000 living species, which was presumably based on the flawed estimate by Boss (1971), actually comprises about 80 000 named and probably 200 000 extant species (pers. data). Another often cited example are the nematodes, of which about 15 000 are named (Groombridge 1992), but recent estimates of living species range from 12 000 to a million or more (May 1991; Ehrlich and Wilson 1991). Despite the obvious importance of "invertebrates", much of our knowledge of many groups of these animals is centred on the minuscule proportion that are pest species or taxa involved in human or livestock diseases. And yet these animals are crucial in maintaining the structure and function of ecosystems (Wilson 1987, 1988).

Only about 1.7 million species of living organisms are actually named (Groombridge 1992), and of these vertebrates comprise 2.7 per cent of the total. The majority (>95%) of the vertebrate fauna has been named, compared with only 3–20 per cent of invertebrates, in part a reflection of the relatively much greater effort (and resources) expended on vertebrate work. Of the systematists in the USA, 33 per cent work on vertebrates, 28 per cent are botanists and the remaining 39 per cent work on invertebrates (Barrowclough 1992).

The smaller, largely microscopic invertebrates are the most poorly known. In a study on "selected" soil invertebrates (arthropods only) in jarrah forests in south Western Australia, 290 species were listed (about one third of which were mites) and only 6 per cent identified to species (Postle *et al.* 1991). Clearing of native vegetation for farming results in loss of some of the soil fauna (Abbott *et al.* 1979; Greenslade and Greenslade 1983) and the consequent deterioration of the soil (Parker 1989).

In plants, too, the real diversity is not reflected in the numbers actually described. There are about 220 500 described flowering plants and gymnosperms compared with only about 101 000 species of the other plant and "plant-like" groups (algae, fungi, ferns etc.) (Wilson 1988), although one estimate suggests that there are about 1.6 million species in the Kingdom Fungi alone (Hawksworth 1991) with, perhaps, 200 000 species in Australia, 80 per cent of which are unnamed (Walker 1992).

Clearly there has been relatively much more taxonomic work on vertebrates and higher plants than other life forms and this mega-biota bias is also reflected in most other areas of biological research. For example there are only a few studies (Campbell and Tanton 1981; Majer 1984, and references therein) on the impact of fire on litter and soil organisms involved in the crucial processes of litter breakdown and recycling, and soil formation. Instead the impact of fire is largely being looked at in terms of how it affects higher plants and, to a lesser extent, vertebrates (e.g., Gill *et al.* 1981).

If we lose rainforests it is not just the trees and vertebrates that are lost. Vast numbers of other organisms — most of them still unknown (e.g., Richardson 1984) — are found in our forests, and other terrestrial habitats (Wilson 1988; Ehrlich and Wilson 1991; Erwin 1988, 1991; Stork 1988). Until we understand more about the processes in which these organisms are involved and their relationships to the larger animals and plants in the community we cannot say that we understand these systems. Most organisms, and most of the fundamentally important ones (as discussed above), are very small — many microscopic. They are the foundation of most communities but are largely ignored by taxonomic, ecological and conservation programmes. For example, in a recent work entitled "Conservation of Australia's forest fauna" (Lunney 1991) only one of 34 chapters dealt with invertebrates. Conservation organizations are similarly biased. For example, of the IUCN Species Survival Commission Specialist Groups (IUCN 1990), only five of 82 (6%) deal with invertebrates. Of these, 58 (71%) deal with vertebrates, 56 per cent with mammals and birds!

Recorded extinctions are also heavily biased towards the mega-biota. Despite this, of animals, there are more molluscs recorded as having become extinct than any other group [191 species, compared with 115 species of birds and 58 mammals (Groombridge 1992)]. The data for molluscs are better than most other invertebrate groups because terrestrial and freshwater molluscs are relatively well known. They can also occupy very limited ranges, sometimes being confined to single valleys, small islands, or a single river or spring (e.g., Solem 1988, 1990; Ponder and Clark 1990) making them very vulnerable and yet they barely rate a mention on the conservation agenda.

One of the greatest challenges for the 90s is the need to reassess our priorities. The mega-biota bias in the study of life on earth has dominated biology to the present day. It must change to allow a much sharper focus on the major diversity of life. There have been some moves in this direction. For example a workshop (Majer 1987) was held on "the role of invertebrates in conservation and biological survey" and, more recently, Australian National Parks have contracted a report on invertebrate conservation (see Yen and Butcher, 1992). In addition some papers in the Conservation

Biology in Australia and Oceania at the University of Queensland in 1991 dealt with invertebrates and a symposium on invertebrate biodiversity will be held this year in Brisbane.

Yes, we should be concerned about koalas but our concerns should be put in perspective. It is ironic that we are primarily concerned with conserving *Homo sapiens* itself — by far the single most destructive biological agent on the planet. Perhaps we wish to ease our collective conscience by saving "endangered species" with programmes such as captive breeding. This Noah's Ark mentality is, in my view, misplaced and is only delaying inevitable extinction. Our limited resources would be better utilized in increasing our knowledge of ecosystems and using this information to maintain the health of those systems, rather than waiting until the taxa unique to that system are "endangered" (e.g., Reid 1992). Clearly it is also crucial to "conserve" additional habitats and, given limited resources, it is important that those habitats be carefully prioritized and not chosen on an *ad hoc* basis (e.g., Vane-Wright *et al.* 1991; Georgiadis and Balmford 1992).

Virtually all known human-induced extinctions are occurring in terrestrial and freshwater habitats and it is here that our priorities should be placed, there being only one authenticated report of an extinction of a marine invertebrate in historical times (Carlton *et al.* 1991). Moreover, when prioritizing, it is not always appropriate to use the threat of extinction of a single species as the primary motivation to conserve a particular habitat unless there is a good chance of the long-term survival of not only the species but the habitat itself.

We will not be able to effectively gauge the health of ecosystems until we better understand at least a subsample of the vast majority of the currently largely neglected organisms that comprise them. The use of key indicator groups of micro-organisms and invertebrates should make it possible to effectively monitor environments in a statistically powerful way. Large sample sizes and rapid generation times should enable, much more precisely (and more cost effectively?), the detection of changes and potential problems than is possible by counting birds or trapping mammals. Perhaps conservation science will ultimately be better served by a microscope or an agar plate than by a pair of binoculars.

Scientific administrators may perceive that the public is more interested in kangaroos and cockatoos than nematode worms and therefore studying mammals and birds might be easier to justify politically. But what are the costs if we continue to largely ignore the other 99 per cent of life on earth?

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