3. THE IDENTIFICATION OF KEY SPECIES FOR CONSERVATION

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3.1 Introduction

There is a diversity of arguments made to support conservation practice which ranges from an extremely nostalgic position (that any gain to or loss from the natural environment is a change in our heritage, and therefore to be resisted), to a purely economic argument that conservation retains species (and genes) that might in the future be found to be useful to man. There are further arguments that, in some way, the diversity of nature, or the persistence of natural communities, contributes to the stability of the earth as a long term habitat for humans. The arguments are very often intertwined. It is not the aim of this paper to enter into the discussion of when and how much conservation should be practised but rather to examine the types of species that it might be most important to conserve ('key species').

It is convenient first to consider the principles that might guide the choice of species that should be conserved because, although they are scarcely used, or not used at all by humans at present, might at some time prove useful and should not be lost. Although this paper is concerned with species that might warrant conservation it is important not to lose sight of the fact that it may sometimes be some of their genes rather than whole genomes that might become useful – even if transferred transgenically to other species.

3.2 Plant species that might become useful to man as food

Overwhelmingly the present provision of staple foods for man depends on plant species that concentrate carbohydrates, fats or proteins in large storage organs. This paper does not consider the very wide range of potential food crops that are not staple but may contribute important minerals and vitamins to diet (e.g. potential salad vegetables).

3.2.1 *Seeds*

It is annual plants with large seeds (almost entirely grasses and legumes) that provide the major staple seed food crops of the world. Among higher plant species the weight of individual seeds varies over 11 orders of magnitude (from 10^{-6} g in the orchids to more than 10^{5} g in the double coconut). Yet the range size of the seeds that are used as staple foods by most of mankind is only a narrow band, ca 3-4 orders of magnitude from this range. The limits on seed size for agronomically useful plants are placed by the difficulty of harvesting large crops of very small seeds and the

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apparently very limited habitat range of species with very large seeds. Rare exceptions occur when many small seeds are held in non-shattering capsules which are therefore harvestable e.g. the oil-seed poppy.

It is overwhelmingly annual plants that provide the world's bulk seed foods. This is presumably because annual plants allocate a very high proportion of their annual growth to seeds. The major grain crops (rice, maize, wheat, oats, barley, sorghum and rye) allocate 25-40% in this way. This contrasts with herbaceous perennials, and especially trees, in which the allocation appears always to be much lower (Harper 1977).

It seems likely that plants that might contribute significant staple foods in the future will continue to be annuals with large seeds, or (perhaps very important) that have the potential for the breeder to increase seed size or for the engineer to devise methods to harvest them efficiently. It is often argued that species that might become most useful as staple foods for man must be those capable of providing a bulk energy resource, i.e. species that store concentrated carbohydrate or oils. It may well be, however, that plants that store abundant reserve proteins may become increasingly important. In many diets a major protein component is provided by animals (meat and milk products) which convert carbohydrate (energy rich) plant material into a protein rich component of diet. Such animal protein is likely to remain an article of diet where the grazing animal is the only efficient harvester of land areas, but elsewhere it is on plant products that expanding populations are likely to depend for dietary protein. It is arguable that, in most parts of the world, protein famine will occur before energy famine. Key species are then likely to be those with efficient protein storage rather than those with efficient carbon fixation and storage. In the longer term, as fossil energy reserves are exploited and become more expensive, plants that store oils (in seeds or in latex) may become important sources of fuels for heating and cooking.

In summary, if we were to recognise key species for conservation that might become useful because they are potential sources of seed food crops, we would place special emphasis on annuals with large seeds and that store carbohydrates; proteins, fats and oils may become equally valuable.

The plant communities from which annual crops have been derived and from which new annual crops might be developed are of course primarily those of early successional stages and of semi-arid regions. These are likely to remain the source of 'key species' that may provide staple diets. Most staple food crops have come from the two families, Gramineae and Fabaceae. This may be because in species of these families the main defence against seed predators in nature is the physical hardness of their seed coats or pericarps or leachable secondary chemical compounds – this makes them easily accessible as a diet to man after milling and cooking. It may be that a much wider range of species could be potential food crops if they were bred to remove unpleasant flavours and toxins.

3.2.2 *Vegetative storage organs*

A wide variety of perennial plants store reserves in bulbs, corms or tubers. A few of these have become major contributors to diets (e.g. potato, yam, cassava, carrots) but, as with seed crops, the species that are used in significant quantities by humans are a tiny minority of those that might conceivably be used. There are three major problems with those sort of crops; (a) the product is usually bulky because of its high water content compared with seeds, (b) because the storage structures are almost always underground there are harvesting problems, and (c) the storage organs almost always contain defence compounds of one sort or another – e.g. alkaloids in Solanaceae, glucosinolates in Cruciferae, terpenes in Umbelliferae, raphides of oxalic acid in the bulbs of many Liliaceae. Such chemical defences appears to be very much rarer in potential crops for food from seed where the reserves are usually protected from predators and pathogens by physical defences (e.g. thick seed coats).

Chemical defences often make the vegetative storage organs of plants unpalatable or even toxic to man and restrict their use as food. However, they may be so desirable as contributors to diet that special cooking regimes have been developed to remove or inactivate the toxins. Pate & Dixon (1982) surveyed the bulb, tuber and corm flora of Western Australia and collected evidence of the use of the various species by aboriginals (see also Cribb & Cribb 1975). Of the ca. 7 000 species of flowering plant in the flora 304 bear fleshy underground storage organs and 36 of these species are eaten. Only 14 species are eaten raw, the majority are cooked, sometimes after prolonged soaking to remove toxins. For example, the storage organs of *Macrozamia riedlei* are soaked for a long period before cooking to remove cyanide and alleged carcinogens.

The choice here of the Australian example is made partly to illustrate how anthropological information may help in identifying possible 'key species' – it is not suggested that Western Australia is the likely source of the world's new food crops! However, among the Australian plants with vegetative storage organs there are 'potentials' of the sort that one might look for in a search for 'key species'. Pate & Dixon list four species in which the storage organs contain 16-18% storage protein, almost the equivalent of grain legumes (e.g. *Isoetes muelleri*, *Philydrella pygmaea* and *Stylidium petiolare* and seven species in which the storage organs contain 11-14% protein. Australasia has contributed no staple food crops to world agriculture and it would be foolish to imagine that there are, lurking in Pate & Dixon's list, new foods for the immediate future. What is more important for the conservationist argument is that there are clearly interesting qualities in some of the species that might, sometime in the future, be useful (though they might need to be transferred into other species).

In making any judgement of which native species in a flora might be worth conserving as potential future food crops it would be shortsighted to think only of those that already possess the qualities of a potential crop. Deliberate breeding programmes, e.g. to remove toxic principles, might easily release species from constraints that make them unacceptable at present. Recent advances in genetic technology – especially the possibilities of transgenic manipulation – may mean that genes, in species that are now unexploited, might usefully be transferred into other species – even if they are not exploitable in their present home. Virtually the whole effort in plant genetic engineering is at present concentrated on species that are already important crops. When genetic engineers widen their vision they will need to call on a much wider range of genetic resources.

This very brief consideration of conservation of species that might become 'key species' as potential food crops has concentrated on staple foods. Of course minor crops are not unimportant – especially as economies develop to provide rare and unusual plant delicacies for the ever more esoteric tastes of the wealthier nations. The ready acceptance of kiwi fruit, mangoes and star fruit in British markets implies that dietary tastes are not after all so very conservative and new industries may develop in the tropics and sub-tropics if they can offer novel delicacies for export. In this category of possible 'key species', plants bearing nuts or fleshy fruits are particularly interesting as the basis of possible new luxury export crops. There may be many such species that, freed of toxic or unpleasant tasting compounds and improved in size and keeping quality by the genetic engineer, might become important items in local economies.

The communities from which we might expect to recruit perennial 'key species' are of course quite different from those that might contain useful annuals. Lianas from forest communities commonly bear large fleshy storage organs (even the highly toxic *Tamus communis* of temperate communities forms a massive underground food reserve) and, as in the Western Australian species already mentioned, semi-arid regions also contain interesting plants with below ground food storage. Bulbous, cormous and rhizomatous plants extend into almost every community type in which there is a sharp alternation between seasonal conditions so that rapid regrowth from a large food reserve confers clear advantages. One would be hard put to define a plant community from which a potential food plant of this sort could not possibly be derived.

The communities from which potential new fruit and nut crops might be developed are more limited. Perhaps it is in tropical rain forest that such species are most likely to be found and developed – but needing to be freed of distasteful compounds or toxins. It is unrealistic wholly to write off fruit and nut crops as potential staple foods because we know that, even in Europe, *Castanea sativa* formed the staple diet over centuries in SW France and the walnut and olive were not unimportant! The reason why they appear less likely candidates for new staple diets is (as with fruits) the low yield per unit area of edible product; but such species may yet have a role in regions that are difficult of cultivation, too arid for traditional annual staple crops or if they produce a luxury food for export.

3.3 Plants potentially useful as pharmaceuticals, flavourings, etc

An immense variety of secondary chemical products are produced by higher plants – enough to make organic chemists deeply jealous. Almost all of these seem likely to have arisen as defence compounds in environments where protection from grazing or other forms of herbivory have been important. Among these, the species that are used by man for their volatile compounds (especially terpenes) seem most often to have come from grazed and over grazed communities – many from Mediterranean climates (e.g. thyme, sage, marjoram, eucalyptus, carrot, parsnip) though there are plenty of others from the tropics that have formed the basis of important spice trades (flower buds in cloves, nuts of nutmeg, bark of cinnamon, rhizomes of ginger, seed pods of vanilla, fruits of pepper and cardamom, etc.) It is not easy to predict what tastes might appeal to a new public and form the basis of export trades. Certainly tastes change as evidenced by the popularity of the tansy (*Tanacetum vulgare*) and even rue (*Ruta graveolens*) as flavourings in Elizabethan cuisine and their present distastefulness and the growing popularity of bergamot as the flavouring in Earl Grey tea.

Possibly more important is the range of potential pharmaceuticals that may lurk hidden in species yet unexplored and unexploited. There are hints of where we might expect to find the greatest diversity of plant chemical products and therefore 'key species' remaining to be exploited. Just as speciation itself (and outbreeding with its consequential accumulation of genetic variations) may have been strongly driven by selective pressures from pathogens and predators, so the evolution of chemical diversity may be expected to have been most intense where these same pressures were greatest – in tropical forests. We might expect to find the most interesting new pharmaceuticals in species that have evolved highly species-specific repellents and attractants and that form parts of specialised linear food chains. It can be argued that defences against generalist predators are less likely to have uniquely interesting properties. One might predict that interesting new chemicals (and so the 'key species' that produce them) are most likely to be discovered by looking for specialist herbivores and then tracing what plant it is that they eat. This would be an intelligent route to discovering new cardiac glycosides for example. It is likely that the most interesting specialist pharmaceuticals will be discovered by looking for plants that are eaten, but by only one predator, rather than by looking for plants that appear to escape predation altogether.

3.4 Plants to serve as fuel for cooking or as food without cooking

It has been estimated that by the end of the century 3 000 million people will face a shortage of fuel wood. Already 120 million people in the Sahelian and Himalayan regions face such shortage. Indeed it may well be that the retreat of forest margins as a result of the pressure from communities seeking fuel may be as or more important a cause of world deforestation that the commercial felling of tropical forests. The problem arises because man evolved as a species almost entirely dependent on plants that can be made acceptable as food only after being cooked (or processed by an animal into meat and milk products). Any definition of 'key species' ought therefore to consider both those that might be used to provide rapidly growing fuel and species that might form elements in staple diets but do not need to be cooked. If, in the course of their evolution, plants have been selected to be unacceptable to some predator or pathogen it is not surprising that most plants are unacceptable to humans until they have received some sort of treatment. Even the presence of cellulose cell walls makes plant cell contents difficult to digest by any large animal that lacks a rumen and has not learnt how to cook. An exciting discovery among 'key species' would be one that released its cell contents easily – perhaps after fermentation instead of cooking.

3.5 Key species for environmental protection

Key species could be those that can be used in protecting the environment because they are effective in special roles such as reducing soil erosion, colonising soils subject to creeping saline blight after irrigation, and the revegetation of industrial wastelands. Such species will usually have to be perennials with rhizomatous habit with or without specific tolerances of special soil conditions (heavy metals, salt, etc). They may therefore be found in rather unusual habitats (sand dunes, serpentine soils, metal quarry wastes, salt marshes). Many of these habitats are not those usually placed high on the list of those worthy of conservation but may become the source of useful species or of useful genes.

3.6 Key species for environmental conservation

Clearly a major argument for conserving the diversity of nature is that some of its species might become useful sometime. However, there are other forms to the argument for conservation e.g. that the variety of natural species transforms human values by the range of experience that natural diversity provides. There are arguments that it is the diversity (rather than just the biomass) of natural communities that in some way stabilises life on earth for man. If we are to identify which particular species are 'key species', because they play a special role in maintaining the diversity of nature, there seem to be only a few generalisations that might form useful guides. It can be argued that perennials and particularly trees contribute more to the earth's biota than short lived species because they provide a wider variety of resources for others (a tree is a more complex resource than an annual). Trees, especially in forests, create a wider variety of micro-habitats than short lived species and therefore control and permit greater potential diversity in their associated fauna. It can be argued that species (or other taxa) with a long evolutionary history in an area are more likely to have evolved a rich dependent fauna (contrast the rich insect fauna of the oak which has long been part of the British flora compared with the poor fauna of the sycamore which is a recent arrival). We might expect that species without specialised defences will support a greater variety of predators than those that possess such defences, because the latter may be parts of narrow relatively unbranched food chains which could disappear as a whole without drastic effect on the diversity of the whole community. But perhaps the relatively undefended species of plant will in general support large numbers of a few dominant consumers rather than a wide diversity of consumers.

Almost without question species that fix atmospheric nitrogen will be 'key species' in most communities. This is not only because nitrogen is so commonly a limiting resource, but because the activity of nitrogen fixers (the hosts of *Rhizobium, Frankia* and perhaps others) is to produce a patchy distribution of nitrogen in the soil and patchiness favours diversity. It may even be the case that plants that fix nitrogen are in a sense locally suicidal, making their nitrogen enriched environment suitable for others that will then replace them. Species that have life cycles or physiologies that initiate local patchworks of micro-successions may make an important contribution to natural diversity. Species that are efficient foragers of soil phosphorus may also act in this way (Bunting 1960).

3.7 General conclusions

There are very few clear generalisations that emerge from trying to define what species should be regarded as 'key species' – a species only becomes a 'key species' when some future role for it has been identified. The identification of 'key species' requires as much the art of the soothsayer and prophet as that of the professional biologist. I have argued that staple foods are most likely to be found among annual plants with large seeds that can be freed of toxins (and ideally do not require cooking). Species appropriate for staple diets at present may become quite unsuitable for a large part of mankind, if fuel for cooking becomes limiting as quickly as is forecast. The species that become 'key species' may then be those that can serve as quick growing fuel or can be eaten without being cooked. I have argued that plants that might produce new pharmaceuticals are most likely to be found in perennials – especially among tropical trees. But it could well be that new pharmaceuticals will be synthesised mainly by genetically engineered microorganisms, and that what will make a higher plant into a 'key species' is that it can be used as a source of bulk chemical feed stocks from which other compounds can be microbially synthesised in the laboratory or factory.

It could be that the definition of the sorts of species that are especially worth conserving will be completely altered by climatic changes (greenhouse effect or depletion of the ozone layer). The overwhelming need might then be for 'key species' (perhaps species of forest tree that could be planted extensively) that have especially great powers of fixing atmospheric carbon dioxide or special tolerance of high levels of incident ultraviolet radiation (the effect of ozone depletion). The latter might sensibly be looked for in the genomes of 'key species' from high alpine habitats. It might even be that the biggest influence on the stability of the terrestrial environment will come from the activities of 'key species' of microalgae in the ocean because of the overwhelming role that they are believed to play in regulating the concentration of atmospheric carbon dioxide so influencing the productivity of terrestrial life.

The main problem in trying to recognise what are 'key species' is that the world and its problems keep changing. When a new problem or opportunity arises the risk is that we did not foresee it; we might then have lost a species or gene because we had not foreseen the lock to which it was the key.

3.8 References

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