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Biosubsistence – a powerful aid to rare plant conservation?

Abstract

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The concepts biodiversity and biosubsistence are discussed. The significance of patterns and structures that enable organisms to survive in nature is illustrated by examples, and the importance of such knowledge for the purpose of conserving endangered species is pointed out.

Introduction

Biodiversity is a term frequently used in conjunction with taxonomy and chorology. Biosubsistence is a less well known word. It refers to how an organism behaves and what it needs in order to ensure its continued existence in nature. As defined by Greuter (1991), the term encompasses a broad spectrum of biological notions such as survival capability, seed dormancy and viability, formation of roots and shoots (the study of growth forms), flower biology, seed dispersal, ecological demands, plant diseases, population size and structure (demography), symbiosis with other organisms, interactions between parasites and their hosts, and so on. Research teams with representatives from various, related disciplines are needed to develop strategies for the study and documentation of the many aspects of the biology (biosubsistence) of endangered plants, under various angles. Only through more exact knowledge of the biodiversity and biosubsistence properties of a species may we hope to understand the sources of its endangerment and may, on this basis, take successful, specific conservation measures.

One might believe that by now all relevant aspects have been exhaustively investigated and that one is just to tap the appropriate source to obtain the needed information. However, when one searches for pertinent information on this or that species it soon becomes apparent that secure, detailed data most often are plainly missing, or if they exist they are either not yet published or so widely scattered in the literature as to be almost impossible to locate. Relevant studies are indeed conducted in diverse scientific domains, but their results are often published with other than conservational goals in mind, which makes them of little value from the conservationists' point of view. Therefore, I feel that the study of individual species under several different angles, and the assembling and processing of extant data, are both extremely important. I shall briefly discuss several different approaches and their significance for species conservation.

Biodiversity

Taxonomy

Taxonomic research is concerned with organismic diversity. It is the prerequisite for the identification of individual species and creates a system for accessing the corresponding literature. The definition of taxa at the species and infraspecific levels and their differentiation from related taxa by means of their characters is the obvious foundation upon which further studies may then be based. International committees either already exist or should be formed for the purpose of generating universally accepted criteria for the definition and naming of taxa.

Chorology

It is important to know the geographical range of a species as precisely as possible and to use this knowledge for conservation purposes. The information in existing distribution maps and floras usually pertains to large areas and is therefore not very detailed. Field work and herbarium studies lead to more precise statements on the whereabouts of the populations of a species. The definition of international standards for distribution data and maps would be welcome. Herbarium studies can help to reconstruct the previous distribution of an extinct or endangered species and document its present decline.

The study of herbaria has the added benefit of providing an overview of infraspecific variability. The knowledge of local botanists often results in remarkably accurate statements on, e.g., population decline, showing whether they must be categorized as endangered and whether protective measures should be initiated. Local botanical expertise is extremely important in the compilation of endangered species lists, or “red data lists”, which are most valuable tools for species conservation.

Vegetation science, the domain of plant geography that deals with the relation between plant associations and their environment, is very significant for reintroduction programmes, especially when, as a last resort, a substitute location for a destroyed habitat must be found.

Biosubsistence

Morphology and growth form analysis

Morphology has a long tradition as a science that deals with the structure and shape of plant organs. Structure is being increasingly analysed with regard to the function of organs, placed in their natural context, so as to better understand a plant’s way of life.

Proceeding from morphological observation, the analysis of growth forms has developed into a substantial contribution to the understanding of “behaviour” of plant species through their life cycle. It assesses the development of plants in space and time within a framework of ecological and morphological parameters. Recent studies in different plant groups (e.g. Meusel & Kästner 1990, Hagemann 1989) show that plant architecture results from a plant's life history and ecosystem function. These studies must start at germination and continue through the complete life cycle. Excellent opportunities for such observations exist in botanic gardens, where all stages from seedling to adult plant can be studied the year round, including rooting, branching, time of flowering and fruiting, number of seeds produced, and seed viability. Experiments conducted during critical phases of development can throw light upon a plant's requirements and perhaps on hidden reasons for its decline in natural settings. It is ideal when observations in the garden can be complemented by studies in the field in different seasons, although these are usually, by necessity, quite limited in time.

Growth form studies in the natural environment must always take into account the climatic and edaphic conditions as well as all other relevant local factors, which are essential for a proper understanding of growth processes and rhythms, and also of anatomical structures. Pertinent investigations have shown that, depending on its eco-character, each taxon has evolved its peculiar, eco-geographically relevant features like branching system, anatomical structure, and growth rhythm – its so called growth strategy. This type of research leads on to ecosystem studies that can provide important cues on the nature of existential threats.

Demography (population analysis)

Plant demography, which provides information on populations and their dynamics in their natural habitats, is another aspect of biosubsistence that has practical relevance for the protection of endangered species. In contrast to growth form analysis, demography is mainly involved with the statistical study of the age structure and growth of a population, of which the rates of seedling production, juvenile plant constituency, reproduction and death are considered. Studies of population dynamics and the factors that bring about demographic changes also belong to demographic research.

The predominance of young over dying individuals, or vice versa, determines a population's tendency to grow or decline. Only when rejuvenation and mortality are balanced is a population assured of maintaining itself safely in a biotope. When a population falls below a critical size it loses its ability to survive and reproduce, so that recovery may become impossible. This is especially true for open-pollinating species. It is therefore important for conservation projects to know the minimum size of a population, or "minimum viable population". A number of recent contributions (Gilpin & Soule 1986, Menges 1991, Shaffer 1981, 1987) discuss the minimum viable population concept and demonstrate that population size is inversely correlated to the probability of extinction. This means that smaller populations are more susceptible than larger ones to threatening events. Efforts aiming to preserve small populations must address all stages of the life cycle, and protective measures in such instances should combine in-situ and ex-situ conservation.

During their development, individuals pass through various stages, some of which have greater significance than others for the population's survival. If individuals predominate that are either too young or too old to reproduce, the existence especially of perennial species may be threatened.

Site destruction also plays a substantial role, as does habitat shrinkage when it reaches the point when populations become isolated. Then the population size may become too small for maintaining a sufficient level of genetic diversity. If the different areas where a species grows are too far apart, the possibility of its spreading further through seeds is reduced to nil (Franklin 1980).

The space freed by extinction of a species is often quickly filled by some opportunistic annual, which may result in a rapid succession of extinction and repopulation events.

Genetic, ecological, and historical factors play a major role in demography and are referred to as gene-environment interactions. The probability that a population succeeds in adapting itself to radically changed site conditions is very small. Up to now, however, there have been few comprehensive studies to consider this topic.

Demography must be distinguished from population genetics, a complementary discipline which investigates the genetic diversity within and among populations. According to Ritland (1990) there are extremely few studies to date of quantitative allelic variation in populations. Usually only single-gene character frequencies or electrophoretically marked gene block frequencies have been investigated.

Reproduction biology

The biology of reproduction, which in plants is remarkably varied, sometimes even within a single species, is perhaps the single most important feature for a conservationist to know. In contrast to most animals, plants have different ploidy levels, diploid or polyploid, and several different possibilities of reproductive and vegetative multiplication.

Chromosome and genome mutations, as well as hybridization, play an important role in plant speciation. Polyploidy is of particular significance, resulting in the multiplication of DNA quantity, the enlargement of cells, a raise of genetic diversity, enhanced gene interactions, and increased phenotypic plasticity through gene recombination. It further leads to physiological changes that may modify environmental requirements and increase the potential for area expansion. Conversely, diploid taxa tend to have narrower environmental preferences and, therefore, smaller distributional areas.

Polyploids have been shown to have longer biological cycles, extended vegetative and reproductive phases, more effective types of reproduction, improved resistance to stress, increased competitivity, and better fitness for colonizing new habitats. The higher genetic diversity and better physiological balance of polyploids are the reasons why they are less frequently endangered and can more successfully compete with their progenitors, outgrowing them eventually (Clegg & Brown 1983).

Many polyploids only reproduce vegetatively and are called agamic. Many are apomicts that do not reproduce sexually. Usually apomixis reflects an imbalance in the chromosome complements that makes regular meiosis impossible.

Knowing the respective distributions of sexual populations and vegetatively reproducing strains, and the ecological requirements of both, is important for devising sound conservation strategies. One must bear in mind that non-sexual multiplication leads to complete uniformity, and that the ability of an asexually propagating clone to adapt to changed conditions is severely limited.

Up to now it was not clear whether it is possible and, if so, how long it will take, for a clone such as may result from multiplication by cuttings over several years, to develop into a viable population once the plants start flowering and resume propagating generatively. Observations in the botanic garden show that the first new generation of *Freylinia visseri* Van Jaarsv. raised from seed already exhibits marked differences in leaf form. One may conclude that a certain degree of allelic variability must have existed, that became manifest through recombination in the first meiosis.

Self-fertilization (autogamy) is frequent in plants. On one hand, inbreeding may result in reduced rates of genic recombination and loss of variability (Selander 1983). On the other hand, autogamy enables single individuals to propagate when cross-pollination would fail, which is highly important for pioneer plants and weeds and may allow small populations to survive. Numerous cases of new populations getting established from a single individual ("population founding") have been observed in nature (Carson 1983).

Seed dispersal and seed banks

Plants, while otherwise stationary, are capable of changing their location and expanding to new areas by way of seeds. In so doing they adopt different strategies, including wide-range dispersal and conversely, especially in arid and semiarid areas like the Mediterranean region, retention of diaspores near the mother plant where site characteristics have proven to be suitable. The latter strategy is particularly frequent in annuals. Information on propagation strategy is valuable for plant population management.

Seeds may be crucial for the survival of species, being that stage in life cycle that can outlast periods of stress such as drought. Also, seeds are carriers of genetic diversity. Seeds in the soil form a natural seed bank and can survive for several years or even decades.

The green belts along streets and highways bear witness of such seed reserves in the soil surviving through unfavourable periods. These strips of land may have been treated with herbicides for many years, and all "weeds" eliminated, but no sooner are the herbicide applications stopped, the same "weeds" spring up again.

However, the supply of viable seeds in the ground decreases with time unless the stock is continually replenished. To date little is known on the conditions that favour the survival of seeds in the soil. Factors affecting dormancy, such as temperature, moisture, or chemical bonds, still pose many unanswered questions.

Seed banks offer the possibility to store dormant seeds at low temperatures, under laboratory conditions, for many years. In several such banks the seeds of endangered species are being stored, and much useful experience has accumulated (Gómez-Campo 1985). Germination tests on banked seeds, made at regular intervals, have yielded data on seed viability and its dependence on dormancy time, but have still left many questions unanswered.

The role of botanic gardens

Botanic gardens are invaluable "germplasm collections". Some species extinct in the wild survive in botanic gardens. However, plants kept in cultivation often lack essential information such as data on wild origin. They often stem from a single ancestor and may be the product of cloning, so that their genetic diversity is limited. Details of culture conditions have seldom been recorded. The Botanic Gardens Conservation International has for many years supported efforts to improve the value of scientific plant collections and the quality of their documentation.

Botanic gardens play a role similar to laboratories, where studies on the biology of species can be carried out, even though their potentialities in this respect are often under-utilized. There is hardly another type of institution in which so much expertise and so many resources are available to explore the "behaviour" of plant species, to understand their biosubsistence, and thus to gain knowledge of tremendous value for protecting threatened species in situ at comparatively small expense. Knowing the smallest population size capable of survival is just one of many such essentials for conservation management.

The ex-situ conservation of endangered species as cultures in botanic gardens can be a valuable complement to conservation efforts at field sites (in-situ conservation), but not in the long term a safe alternative for the latter. This is now a widely held opinion.

In the future, restoration of natural habitats and concomitant reintroduction programs will play a prominent role in ensuring the survival of threatened plants. Guidelines now exist for the introduction of plants from a botanic garden into the wild. A recent handbook on that very subject (Akeroyd & Wyse Jackson 1995) addresses relevant issues.

To ensure the success of a reintroduction programme, parallel studies of the plants in cultivation and of the potential natural sites should be conducted. The habitat requirements of a species regarding soil quality, exposure, or water availability, to name just a few factors, are very important to know. When considering reintroduction of a species into sites from which it had previously disappeared, one must ascertain and eliminate or minimize the causes of disappearance; otherwise, reintroduction makes little sense.

Reintroduction programmes typically use plants previously multiplied in cultivation in botanic gardens. Both the gardeners and scientists responsible for multiplying endangered plants will thus have become intimately acquainted with the biology of the relevant species, and their knowledge will be of immense help to the reintroduction programme. The same holds true when depleted populations are bulked up, a procedure more frequently used than actual reintroduction or introduction into new natural or artificially created sites.

When selecting reintroduction sites, e.g. restored habitats, one should compare all ecological parameters with the previously known requirements of the plant; otherwise, reintroduction efforts may well be vain. Different kinds of problems may arise in this context, which should be recognized and dealt with in advance whenever possible. For example, the presence of pollinators may be crucial for the establishment of a plant population. If plants are reintroduced into their previous sites but their pollinators are no longer present, then facultatively autogamous species are at an advantage. The majority of plants, however, are self-sterile, and in planning their reintroductions it is essential to identify their pollinators, particularly when they are highly specific, and include them in the management plan.

The Berlin Botanic Garden took part in a conservation project for species endangered in the Land of Berlin, including *Silene chlorantha* (Willd.) Ehrh., *Euphorbia palustris* L., *Iris sibirica* L. and *Dianthus superbus* L. The results were in part quite positive. In the case of *Silene chlorantha*, for example, o135135nly ten individual plants were left at the original site by the time when the cause of decline had been removed, to which hundreds of young plants raised in the botanic garden were then added to bolster the population. Two years later hundreds of self-seeded plantlets were observed, so that one may hope that the population at this site is again firmly established (Hagemann & Bley 1991, Hagemann & al. 1991).

Conclusions

Knowledge about as many separate biological factors as possible is valuable in the devising of strategies for species conservation, both in situ and ex situ. Some of these factors have been mentioned and expanded upon here. They include the inventorying of plant taxa and their geographical distribution (biodiversity), and the whole field of biosubsistence, "everything that an organism does, and requires, to ensure that it, its descendants and the population of which it forms part can survive in a natural form" (Greuter 1991). It is obvious that the more information we have on the cycle of a plant's development, its critical phases, and all other biosubsistence factors, the sooner and better will it be possible to provide appropriate assistance.

Only by pulling together the data from as many fields of knowledge as possible may we hope to succeed in pursuing comprehensive species and environmental protection. In order to speed up progress, data banks should be created. Information on research on the biology of threatened species in the Mediterranean region was collected in a database by Iriondo & al. (1994). This should now be expanded into a more comprehensive database from which a fact file for every endangered species could be generated. Such data summaries would undoubtedly be of immense help to those involved in the practical work of conserving threatened species. It would certainly be advantageous for the compilation and interpretation of these data if the data categories were suitably standardized, perhaps by apposite working groups representing various disciplines and building on such fact files from their respective areas of expertise as may already exist.

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