CONSERVATION OF GENETIC RESOURCES: A PROPOSAL FOR SHARING THE RESPONSIBILITY

Calvin O. Qualset

Abstract: *Genetic resources include (1) populations of organisms in their native habitats and wild types maintained in zoological and botanical gardens, in seed or gamete banks, or microbial cultures; (2) plants, animals, and microorganisms that evolved through direct and indirect genetic manipulation; and (3) highly defined stocks arising as the result of genetic research. Genetic resources must be conserved indefinitely for future scientific, technological, and evolutionary advances. Those who benefit from conserved genetic resources are many and diverse. It is not always clear where the responsibility for protection of genetic resources lies; however, both governmental and nongovernmental, national and international consortia should establish criteria, develop genetic resources management plans and priorities, and arrange funding. Funding is the most crucial step. Multiple sources of funds are desired, and wide-scale public involvement is essential. Major successful efforts can be cited for parks, reserves, seedbanks, and botanical and zoological gardens. Special genetic stock collections of many species have been encouraged and developed by short-term research funding, and therafter orphaned. A secure base-level funding system should be developed in the US as a national endowment or trust fund derived from both public and private funding sources. A portion of research funding should be assessed for genetic resources maintenance. For the US, a National Biological Resources Agency should be organized to ensure the permanent security of biological resources for future generations to use and enjoy. This concept can be extended internationally for all types of genetic resources.*

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There are rapid economic, social, and agricultural changes throughout the world that are impacting greatly on availability of genetic resources to meet the needs of a rapidly expanding human population. Throughout this symposium there has been emphasis placed on availability and accessibility of genetic resources for research and for development of new products, such as antibiotics or crop varieties. Genetic resources are extremely vulnerable to loss at the present time, and it was the intent of this symposium to call attention to this vulnerability and then to offer suggestions for overcoming this alarming situation. It is the intent of the following discussion to summarize some of the major points about genetic resource conservation. Underlying this discussion will be an emphasis on the commonalities that exist between the practices of conservation of specific genetic resources and the practices of conservation of biological diversity in its wild state. Finally, a coordinated action and funding plan is proposed which considers biological resources in the broadest sense as the target of conservation.

Types of genetic resources:
...natural populations

One class of genetic resources consists of the natural populations of wild species of organisms that have evolved, and are still evolving, over a long period of time. They can be maintained by habitat preservation. As a last resort, small samples can be saved by *ex situ* conservation in gardens, zoos, and microbial cultures, but samples of most species from the natural populations are necessarily small and do not adequately represent the genetic diversity within the species.

...landraces

A second type of genetic resources are the landraces of agriculturally important species of plants and animals. Landraces have been developed without serious or conscious plant or animal breeding, but they have been modified over millennia by farmers. Possibly these can be retained *in situ* in natural or native farming systems. However, Dr. Rick (p. 12) has pointed out, in certain cases, *in situ* conservation of these landraces is not very secure. Thus, *ex situ* conservation in seed banks, plantations, botanical gardens, or zoos is the primary method.

A third type consists of germplasm stocks and genetic stocks. These can be roughly considered as "manipulated genetic resources." These are products of breeding, selection, and creation of special gene combinations by induced mutation or molecular manipulation.

...germplasm stocks

Germplasm stocks are breeders' lines that come from the manipulation of populations. They appear in various forms as livestock breeds, plant cultivars, or microbial strains. These are primarily retained by *ex situ* conservation. But some of them in fact, are not endangered as breeds or strains because they are so widely grown throughout the world, as is, for example, the Holstein dairy cow or the Leghorn chicken.

...genetic stocks

Genetic stocks are very special genetic resources that are well defined and almost always must be maintained by *ex situ* conservation methods. They are expensive to maintain. Most of the collections of

defined genetic stocks do require special study or manipulation when they are regenerated, for example, to verify their chromosomal status or to select specific mutant gene combinations.

From a utilitarian point of view, one issue is conserving genetic resources of species used for food, fiber, and energy as they may be needed in the future. From the scientific point of view, conservation permits evolution to proceed (in contrast to preservation which retains static gene combinations), so that evolution and interrelationships of species and genes can be studied. From the environmental point of view, biological conservation is a vital component in maintaining the quality of water, soil, and atmosphere. Finally, conservation is important for sustaining agricultural systems and for aesthetic qualities.

Why conserve genetic resources?

The conservation of all of these forms of genetic resources requires careful analysis in terms of numbers of species, amount of genetic variability within species, and native habitat — all of which are subject to government policy (or lack of it), individual commitment to conservation, available trained human resources, and, of course, financial resources.

Since these types of genetic resources are interrelated, the conservation of biological diversity, *i.e.*, conservation of genetic resources, should be approached in an integrated way. Operationally, genetic resource conservation programs have the following components: The first is to develop scientific principles for genetic resource conservation. This means applying genetic and biological principles to conservation in a sensible way. The second is to establish criteria for conservation of the various types of genetic resources. For example, what are the criteria for conservation of natural populations? These must be cognizant of the specific requirements for species and its environment. The third step is to develop a workable strategy to conserve a specific group of genetic resources. The fourth step is to create an implementation plan. This is where the rub begins. The first three steps can be done on the basis of prior knowledge, research, and good sense. Implementation, however, requires interaction among people who have responsibility for the genetic resources that are objects of conservation. Institutional requirements and arrangements, including legal aspects of ownership, have to be dealt with. The availability of human, physical, and financial resources are often limiting.

Components of genetic resource conservation

Another point of emphasis is that the conservation of genetic resources of tropical forests, for example, is fundamentally no different than conservation of genetic stocks of maize or mice. The planning and implementation phases are different, but it is still the same basic problem. Both ends of that spectrum must be given proper attention. Comprehensive genetic resource conservation plans are needed in which the interrelationships of *ex situ* and *in situ* requirements for conservation are included. These plans must also establish responsibility of organizations or individuals for the conservation of the targeted genetic resources.

One of the problems is that conservation is forever. In other words, a conservation program cannot be started one year with the possibility it will be changed on the whim of the next administrator or government agency a year or so later. Continuous, permanent attention is required. It must be stable over time and must have a degree of independence from politics, both domestic and international. The latter is especially important because of the global aspects of genetic resources conservation.

Current conservation efforts What is happening now? Most of the present effort and attention is given to natural populations and habitat preservation. There are certain limitations that need to be urgently addressed by the scientific community. What information is available or needed in terms of the biosystematics and genetic diversity in natural populations? That certainly has a bearing on the strategy of conservation to be adopted. There has typically been insufficient planning. There is a time factor problem because of rapid urban development and environmental effects induced by agricultural, forestry, and industrial activities. Spontaneous decisions must be made about conservation that may or may not be correct. Currently, there are insufficient human, physical, institutional, and financial resources marshalled to deal properly with preservation of the genetic variability in natural populations and in habitat preservation.

In terms of *ex situ* conservation of plants and animals, there are many species represented in collections in botanical gardens, zoos, seed banks, and so forth. However, they do not really represent the range of genetic variability as it occurred in nature. Of course, many such collections were not brought together for that purpose. They were brought together as demonstration materials for teaching purposes or for research, truly representative collections exist for only a very few species.

In terms of the manipulated genetic resources, *i.e.*, the germplasm and genetic stocks, permanent funding and organization networks are really not well established. There is essentially none for domestic animals. There is a fragmented one for microorganisms. For cultivated plants, organized conservation activities are much more developed than for other organisms. For example, there is a rather comprehensive National Plant Germplasm System in the United States, and there is a large international activity by the International Board for Plant Genetic Resources; but the primary attention is given to domesticated rather than wild species. The Center for Plant Conservation is evolving a network for *ex situ* conservation of rare plants.

Genetic stocks are practically left out of the general conservation issue. That is partly because they are usually developed by very specific research programs funded by specific research grants. These grants may be awarded on a competitive, peer-reviewed basis. If a proposal is not funded or a continuation grant is denied, the genetic materials cannot be maintained. Thus, the process which successfully advances

scientific knowledge is a direct contributor to the loss of genetic stocks that are needed for further advancement of science. Clearly, a mechanism is needed for long-term funding for the maintenance of collections.

The conservation of wild and domesticated genetic resources is a matter of national importance in the US, even to the extent of impacting national security for food and natural resources. At the federal level there is no single agency having responsibility for monitoring or managing genetic resources. This could be provided by a Biological Resources Conservation Agency in federal government which would have direct oversight and management responsibility for biological materials held in the public domain. It would monitor and provide financial assistance for the conservation and distribution of genetic materials held by public nonfederal organizations. This national system could be modeled after the present National Plant Germplasm System operated by the US Department of Agriculture in its Agricultural Research Service and Cooperative State Research Service. It would be broadened to include units for conservation of biological diversity of naturally occurring species, including rare and endangered ones, and additional units or systems for livestock, including fisheries, and microbial species. This unified concept for management of biological diversity in the US is attractive from the point of view of providing clear responsibility to a federal agency, somewhat analogous to the Soil Conservation Service in the USDA, for biological resource conservation.

Integrating conservation efforts

a National Biological Conservation Agency...

Most important from an operational point of view is that mechanisms for providing operational funds for the Biological Resources Conservation Agency could be devised. Here it is clear that multiple funding sources are needed. Much biological conservation activity, as for example in the zoos and botanical gardens, is done with a mixture of private and public funds. This should be encouraged, with federal funds being provided for special needs. Line-item funding is required, but additional funds could be attracted to a National Endowment for Genetic Resources — a "social security" system for genetic resources. This endowment fund could be developed by direct ear-marked donations and by private-federal matching to encourage substantial donations. The endowment funds would provide operational funds for conservation programs from the interest earned and would ensure the permanence that is essential for conservation of items of importance for the national security. The US has a good, but not outstanding, record in biological conservation. A unified approach would provide a model for other nations to follow. At the same time, we could learn from other countries, Great Britain, for example, where some elements of this proposal are already functional.

a National Endowment for Genetic Resources...

DISCUSSION

Comment (from audience): *Groups like the Sierra Club and other groups with political bases might be useful in creating an issue of this tie between genetic resources and our long-term national security.*

Qualset: I agree. I think we have to articulate the conservation issues more broadly in a biological and scientific sense. The action of setting aside more land or waters in preservation reserves is important, but I think we must know what is the biological content in those places. We must be sure that we have a total program, one that is going to involve both *in situ* and *ex situ* conservation.

We have had many examples of industrial or urban development which impinge upon endangered species. There are examples of impacted populations of such species being moved to other, secure places. This is an operation of last resort to mitigate the impact. It is the developer who must pay for this mitigation cost and for the maintenance of the populations in the new sites forever. The developers establish a trust fund to finance this perpetual maintenance. The actual moving and maintenance is done by an organization with established expertise. For example, with funding from developers, the Rancho Santa Ana Botanical Garden in California has accepted responsibility for mitigating development impact in this way in at least one instance. This procedure could be a model for funding other aspects of conservation. We have to deal with the practicalities of the human population pressure.

Question: *Could you identify the areas you feel are most under pressure in terms of loss of diversity, areas either in terms of species or in terms of actual geographic areas in California?*

Qualset: For example, there are wild species of *Fragaria* related to the commercial strawberry in California, and many of their populations have been threatened and destroyed by development in coastal areas. There are other plants that are endangered by development aspects. An example is the native annual meadowfoam (*Limnanthes*) which grows near vernal pools. This plant produces seed which contains industrially useful oils. There is also the matter of overgrazing that threatens certain species.

Question: *Where is the major concentration of funding in California? Is it for conservation of wild species or for economic species?*

Qualset: I cannot give you a precise answer on that. We are doing some survey work of what portion of public funds and grants for research are spent on actual genetic resource conservation practices, but we do not have answers yet.

Most of the deliberate conservation is directed toward rare and endangered species. There are government agencies and private voluntary organizations working directly on that problem. We have a state environmental fund which is developed by charging a fee for car license plates with personalized messages. Those funds are used almost entirely for conservation of rare and endangered species, including land acquisition. What we are seeking is a way to raise the more general consciousness of conservation. Certainly, in California and other states, rare and endangered species raise the general awareness of the conservation issue. For example, the impact of agricultural practices on biological diversity is now surfacing. The use of pesticides that could harm an endangered species is being curtailed. In the last few years, there have been model programs set up in counties across the country. Merced County in California is an example. First, the species there were inventoried and the number of rare and endangered species of insects, plants, or animals, was determined. Then a list of pesticides that might affect these species was drawn up. The idea is to eliminate the use of those pesticides. At this point, the farmers are impacted. A lot of questions are raised. Was the biological survey adequate? How precisely known is the distribution of these taxa? Was the toxicological data adequate? If there is an insect endangered there, is its habitat so well defined that pesticides could be judiciously used? These are very troublesome issues for agriculture. They are also troublesome from the endangered species point of view. More effort on research and on biological surveys is required. There are many conservation issues that impact on agricultural species. It is not only endangered species that are impacted by agricultural activities.

Comment: *Endangered species will always be with us. You have suggested that we have perhaps a fairly adequate system at the present time for agricultural plant species. In general, it has been tough to implement new projects with limited resources. I like very much your idea of an endowment. But how an endowment is set up, of course, becomes somewhat of a problem. It seems that with the success of the biotechnology industry, there could be a source of money there, if for no other reason than as a tax write-off.*

Qualset: The genes are free, basically. We have wanted the resources to be distributed freely so people could have access to them and not be required to provide a certain amount of money to use them.

Comment: *I am not suggesting a fee for samples, though, that may be what you have to come to. But with respect to plants, Pioneer Hi-Bred International made a monetary commitment to conservation over periods of time. If that could be put into an endowment instead of something that is spent next year, next year, and next year, then your "forever" becomes realistic.*

Qualset: That is a good point. What I meant by the genes being free is that paying for them has not been a part of any business plan of a biotech company or any other company. The seed companies know that the genetic resources are available to them. They budget for other issues, such as getting enough money to operate labs, but they do not have to allocate any part of their money to get their initial stocks to work with. We are going to pursue this endowment idea with the University of California Tomato Genetics Stock Center. This Center was reviewed and a report* was prepared showing how valuable the Genetic Stocks Center is, what it contributes, and how there has been a considerable industry interest in it. We are hoping that between the public and private sectors, an endowment fund could be established. If it can be done for tomatoes, it will be a good model for other species.

Comment: *If genetic resources literally represent financially immeasurable value in terms of the world's future, it seems that this idea of the endowment could be modeled after The National Endowment for the Arts created in the 1930s in America. The way Congressional and Presidential powers were brought to bear to create it would be instructive to study. There must be a grassroots understanding of why these things really have an actual future value.*

Comment (Allard): *When one considers maintenance of diversity at the level of the genotype, it becomes quickly obvious that any ex situ facility would easily be swamped by the numbers of genotypes of just one species. I would suggest making alleles the criterion of selection rather than these incredible numbers of genotypes. The question becomes whether one can reconstitute populations of genotypes from stocks maintaining alleles. As a matter of fact, in the particular case of barley, it turns out that it is very easy to reconstitute the population. At least one can obtain the alleles that are favorable in a local environment. It turns out that worldwide there are only about half a dozen major environments for barley to be concerned about. The procedure would be to make up an arbitrary population of individuals containing identified alleles. That is, one would put them together and grow them in large numbers. It has to be in large numbers, but there would be only one population. Within 15 or 20 generations of growing that population in a given environment, the desired alleles are expected to be in fairly high frequency.*

Qualset: This is an excellent point which illustrates how a genetic resource conservation strategy can be developed for a crop plant or species. Clearly, Noah's ark would be full very quickly if everything were to be brought into *ex situ* conservation status.

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* **Evaluation of the University of California Tomato Genetics Stock Center: Recommendations for its Long-term Management, Funding, and Facilities. 1988.** Tomato Genetics Stock Center Task Force. Report No. 2, University of California Genetic Resources Conservation Program.