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Approaches to conservation

F. Thomas Ledig, Deborah L. Rogers, and workshop participants

It is as if man had been suddenly appointed managing director of the biggest business of all, the business of evolution—appointed without being asked if he wanted it, and without proper warning and preparation. What is more, he can't refuse the job. Whether he wants it or not, whether he is conscious of what he is doing or not, he is in point of fact determining the future direction of evolution on this earth. That is his inescapable destiny, and the sooner he realizes it and starts believing in it, the better for all concerned.

—Julian Huxley (Anderson 1987)

The overall objective of genetic resource conservation, as expressed by workshop participants, is "to conserve the adaptive, evolutionary, commercial, and amenity potential of trees and the ecosystems in which they exist". A secondary stated objective was "to ensure access to genetic resources".

The approach(es) taken to genetic resource conservation will depend upon a variety of biological and social factors (Figure 12). Levels and patterns of biological variation, including phylogenetic relationships, may be useful in determining priorities for conservation of genetic resources. The spatial distribution of a species is a contributing factor to its degree of vulnerability and determines the scale available and appropriate to conservation activities. The reproductive biology of species (mating system, etc.) determines the means by which they respond to new environments, migrate, become domesticated, and thrive or falter under various conservation methods. The complexity of relationships among species and with the physical environment underlies, in particular, the success of *in situ* versus *ex situ* conservation methods. The patterns and rates of environmental

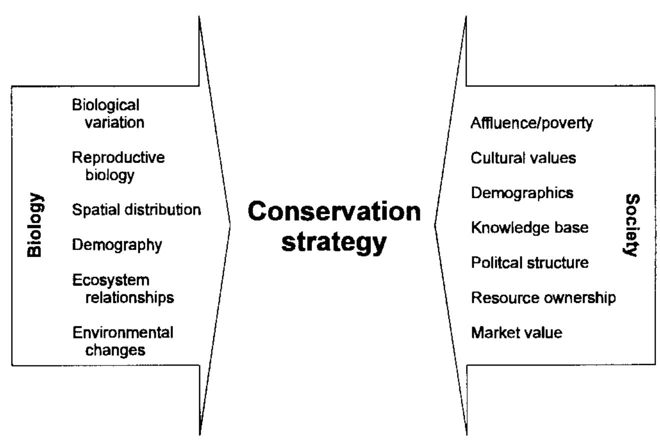

Figure 12. Biological and social factors affecting the approach to conservation

change determine the temporal and spatial scales that are necessary for conservation efforts. Finally, the demography of specific populations will influence the choice of conservation methods.

Social factors also affect the opportunities for conservation and help determine the most effective approach. Underlying the social factors is a tension between the drives to utilize and to preserve resources. The relative levels of societal affluence and poverty may provide or deny opportunities for conservation. The market value of a particular species is an important influence on its perceived social value. The resident political and administrative structures, their stability, and their level of accountability will influence the capacity to conserve and the efficacy of any conservation efforts. Similarly, the pattern of resource ownership will directly impact conservation options. Cultural values, independent of affluence or politics, may shape attitudes towards genetic resources. The sense of stewardship will determine the social will for conservation investment. Finally, the knowledge base available, including information from local to global levels, and from scientific to cultural realms, will determine the tools available for conservation.

We **recommend** *that conservation of forest genetic resources be addressed by multiple approaches, and that, whenever possible, they should include ecosystem reserves. We recognize, that for noncommercial species, ecosystem reserves may be the only economically practical method of conservation. We recognize that while biotechnology can be useful in many ways, it is not a substitute for an adequately funded, field-oriented genetic conservation program.* (Rec. no. 2)

Conservation methods

In situ conservation is dynamic and provides for coevolution of the target species, its predators and pests, its symbionts, and its competitors. For passive *in situ* conservation, viable populations must be maintained, which will invariably mean large numbers distributed over sufficient area to accommodate spatial and temporal dynamics of all the key elements of the ecosystem. Participants generally accepted the argument that conservation of species by conserving ecosystems was desirable because it offered the least expensive means for conserving large numbers of species and, perhaps, the only economically feasible method for noncommercial species. However, strict preserves are problematic because the requirements of conservation must be balanced with the needs of local people to use forests.

Management of reserves is often passive. National parks and designated wilderness areas in the United States are examples of reserves largely under passive management. The policy in these areas can be described as 'letting nature take its course', formally known as the philosophy of natural regulation (see Bonnicksen 1989). Ecological processes are allowed full sway, but individual species are not actively protected. (National parks and wilderness areas are only one component of the lands that could be considered 'reserves' in the United States: other federal, state, and private lands are managed under a variety of stewardship philosophies.)

In fact, strict reserves, such as the national parks in the United States, may be of limited value for conservation of genetic resources unless they are very large. Active management of forests may be a better form of *in situ* genetic resource conservation than passively managed, strict reserves, though this is not to say that strict reserves do not have their own values. Many species are typical of early stages in succession, form even-aged stands, and will not replace themselves except in the wake of catastrophic disturbance; e.g., aspens (*Populus* spp.). Generations migrate across the landscape. The current term for the migration of species in time and space is patch dynamics. Management can create conditions that reduce the element of chance and encourage the replacement of targeted species.

Forest management must be part of any solution to the conservation of biodiversity in general and genetic resources in particular. Passive management will become ever more ineffective as fragmentation of habitat continues. Development outside reserve boundaries affects populations within the reserves (Schonewald-Cox 1988, Dasmann 1988) and these influences will continue or increase in intensity. Because private lands are subject to changes in management goals and philosophy, it imposes a responsibility on federal, provincial, and state governments to actively manage the resources on public lands to counterbalance influences originating beyond their boundaries. Management on public lands, it is hoped, will be consistent and stable over time, as contrasted to the vagaries of private tenure.

> *Recognizing that forest management practices may have positive or negative impacts on genetic diversity and population viability and, in fact, that some form of management will be necessary to maintain genetic resources, we* **recommend** *a research emphasis on the consequences of forest management practices. We encourage the use of reference populations within long-term ecological research sites, 'model forests', and research natural areas for studies on the effects of forest management.*
> (Rec. no. 6)

In the future, effective conservation of genetic resources will depend increasingly on a better understanding of the impacts of human activities and management practices on the resource. Research is needed to prescribe the best management procedures to maintain and optimize genetic diversity. Conservation should not, and cannot, be considered in isolation from any aspect of forest management or culture. As Teobaldo Eguiluz Piedra said: "Conservation should not be an isolated tree in the great woods of forestry" (Notes from the Tenth World Forestry Congress, Paris, 1991).

Timber harvest is not incompatible with conservation of genetic resources as long as stands are logged in such a way that protection and perpetuation of the genetic resource is the primary consideration. In California, Constance I. Millar and Robert D. Westfall are working with the national forests to establish Genetic Conservation Areas (GCAs). GCAs are open to timber harvest (see Box 24). The shelterwood system employs a method of harvest and regeneration that, in theory, should have negligible effects on the genetic resource. Conservation of genetic resources can be effective even when artificial regeneration is used, if forest managers use one standard rule: replant with the local seed source. Local seed could mean seed from the stand being harvested, or it could have a broader definition (Ledig 1988).

For *ex situ* conservation, one of the first questions to address is the goal—whether to save genes or genotypes. If the objective is to restore populations *in situ*, (i.e., 'salvation collections'), then the goal is to save genotypes; fitness is important. In this case, a great number of populations should be conserved. National forest seedbanks in the U.S. store tons of seeds to restore sites that have burned or been logged (Figure 13). If the objective is to obtain or preserve genes for breeding, through either conventional hybridization or through biotechnology, then the goal is to save genes. In this case, far fewer populations are required.

Provenance and progeny tests, if properly maintained and protected, are also a mechanism for the *ex situ* conservation of genetic resources. They may be a means to store germplasm for a century or more, and in some cases (species with 'recalcitrant' seed, seed that does not maintain viability in storage for long periods of time), they are the **only** method of *ex situ* conservation presently available.

As the practice of forestry becomes more sophisticated and species become domesticated, conservationists will have to decide what to conserve among the array of materials assembled during the domestication and breeding process. Should provenance samples be preserved? Early progeny tests? Clonal archives of early selections? Interspecific and intraspecific hybrids?

One criterion might be to consider the difficulty of replacing the material in question. It could require decades to reconstitute hybrids in tree species (Figure 14), which argues that they should be included in conservation schemes. Selections from an early stage of a breeding program, and their progeny, on the other hand, could be easily replaced from *in situ* reserves.

Economics and long-term conservation

Effective conservation of genetic resources requires long-term commitment. How can short-term economic needs be reconciled with the long-term commitment to genetic conservation? Workshop participants expressed the view that three groups, in general, are best suited to this long-term endeavor: 1) National governments—under the philosophy that governments at this level are best equipped, and have the responsibility, to carry and administer this type of 'social burden'; 2) Nongovernmental organizations, including land trusts and partnerships between private and public groups; and 3) User consortia—wherein the 'user' of genetic resources pays for them accordingly.

Box 24
Integrated management and monitoring of Genetic Conservation Areas on National Forests in California

Maintenance of genetic diversity in designated Genetic Conservation Areas (GCAs) is increasingly being promoted as a supplement to resource protection practices in timber management programs. GCAs are parcels of land chosen to encompass representative genetic diversity in target species and designated for long-term genetic management. In addition to their conservation function, GCAs play important monitoring roles. They provide opportunities both for monitoring long-term trends in natural genetic diversity and as control sites for monitoring effects of timber management on genetic diversity.

In the western United States, GCA networks exist for Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) in Washington state and are being developed for Pacific yew (*Taxus brevifolia* Nutt.) and Port-Orford-cedar (*Chamaecyparis lawsoniana* (A. Murr.) Parl.) in the Pacific Northwest. On the Placerville Ranger District of the Eldorado National Forest in California, a research demonstration project has proposed seven GCAs for the mixed forest type of the District. The Sierra mixed-conifer type includes five conifer species. This GCA project is unique not only in taking a multi-species approach to conservation, but in developing management approaches in which timber harvest and genetic conservation are compatible. Whereas established and proposed GCA networks elsewhere are managed as strict set-asides, the Placerville District would develop GCA management standards that achieve genetic conservation standards while allowing for timber harvest and artificial regeneration.

The proposed GCAs have been located in pairs, with members of a pair spaced along two transects 4 to 6 minutes of latitude apart. Each pair is located approximately 1000 feet (approx. 300 m) in elevation apart, starting at 3000 feet (approx. 910 m). There is a single GCA at the highest elevation, 6000 feet (approx. 1830 m). The spacing of locations was determined using a measure of transfer risk (Campbell 1986) applied to available data from allozyme and common garden studies. Sizes of the GCAs (including a buffer) were determined using dispersal distance estimates (see Wright 1978).

Phases in the development of the Placerville District GCA network included: (1) Genetic analysis—Geneticists developed a potential set of GCAs based on analysis of genetic diversity in Douglas-fir, sugar pine (*Pinus lambertiana* Dougl.), ponderosa pine (*Pinus ponderosa* Laws.), incense-cedar (*Calocedrus decurrens* (Torr.) Florin), and white fir (*Abies concolor* (Gord. et Glend.) Lindl.); (2) Gap analysis and site nomination—A candidate set of areas with defined boundaries was determined by integrating the genetically based maps delimiting practical opportunities with constraints. Candidate sites included the proper mix of species and desired ecological conditions and were acceptable from the standpoint of land-use allocations; (3) Ecological data collection—Candidate GCAs were inventoried for ecological data. This effort will be coordinated with Eldorado National Forest and Pacific Southwest Regional inventory and classification approaches; (4) Development of GCA management and monitoring plans—Integrated management plans for GCAs that take a bioregional perspective will be developed. These will be coordinated with working groups for surrounding areas and resources. Included in this effort will be a focus on developing objectives for GCA management, desired future conditions, and management of adjacent as well as GCA lands. Silvicultural and regeneration standards and fire management plans will be developed that provide for maintenance of genetic diversity. Seed collection plans will be developed, with the joint purposes of genebanking (Institute of Forest Genetics seedbank), providing material for monitoring the genetic status, and preparing for artificial regeneration; (5) Implementation of management and monitoring plans—Coordinated with other activities in the area, management and monitoring actions will be carried out and information from monitoring would feed back to management of the individual GCA and other GCAs in the network. The initial focus of management is to develop management objectives and compatible silvicultural standards, and to collect seeds for genebanking and monitoring.

This project is still in the implementation phase, and the efficacy of this approach (relative to others) as a management tool is constantly being reviewed in light of new genetic information. However, the value of Genetic Conservation Areas for studying the impact of *in situ* genetic management systems remains.

Constance I. Millar and
Robert D. Westfall

Workshop participants were adamant in their views that effective conservation requires solutions that consider all stakeholders, including landowners, governments, lobbyists, forest industries, and the scientific community. In particular, penalties and regulations requiring conservation on private land are less effective than the provision of positive incentives. Workshop participants expressed the view that much more could be done to promote a conservation ethic and reward conservation practices through public education and recognition, respectively.

> *Recognizing that private-sector owners and managers play an important role in* in situ *conservation of forest genetic resources, we* **recommend** *that the FAO and conservation agencies explore a range of incentives and agreements (e.g., tax incentives, easements, and land trusts) to foster conservation of forest genetic resources by the private sector.*
> (Rec. no. 9)

Institutionalizing gene pool reserves

A quandry exists in the conservation of forest genetic resources: the time-frame for conservation is the indefinite future, while the threat of loss is immediate. Here we will address the first need—how to ensure long-term conservation. By 'institutionalization' we refer to the means of maintaining or stabilizing conservation activities. The social stage is a dynamic one: land ownership, political leadership, legal requirements, and social values change over time. How can we incorporate genetic conservation into social processes and norms such that it is an abiding institution, and not a momentary fad?

Currently existing methods range from the 'passive' (i.e., incidental set-asides of land) to the 'active' (i.e., dedicated genetic reserves that are selected and maintained for that purpose). *In situ* reserves could be passive, such as many national monuments and parks in the U.S.A. and private reserves. When genetic considerations are integrated into management policy and practice, the reserves can be classified as active (Figure 15). Examples of the latter are 'Genetic Conservation Areas' (GCAs)—a new designation within the U.S. Forest Service, proposed in California; some Canadian reserves, with a similar philosophy to GCAs; and some reserves of The Nature Conservancy, a nongovernmental organization.

Ex situ genetic reserves are by nature active, having been established with genetic characteristics in mind. They are collections designed to maintain genetic parameters in population samples, and are intensively managed.

The requirements or mechanisms to implement or enforce conservation over time are numerous and include: subsidies and endowed funds; contractual obligations; volunteer efforts; land management policies; legislation, international treaties, and conventions; research on ecosystem management; development of a networking structure for conservation;

Figure 13. Interior of the U.S. Forest Service's Pacific Southwest regional seedbank on the Eldorado National Forest, California, U.S.A. Over 100,000 pounds (45,400 kg) of conifer seed are stored at 0°F (-18°C) for use in reforesting national forests in California in the wake of catastrophe or timber harvest. Identity of seed origin is maintained by species, seed zone, 500 ft (approx. 150 m) elevational band, national forest district, and national geodetic survey coordinates.

Recognizing that effective genetic conservation programs are very long term in nature, we **recommend** *that the FAO encourage and assist in the education of natural resource professionals and the lay public to foster a conservation ethic.*
(Rec. no. 10)

cultural commitment (e.g., religion); influencing social values; and education.

The 'social machinery' or organizations vested with the ability to make use of these mechanisms currently include: foundations and conservancies; concerned citizens; government agencies (federal, state, provincial, local); private industry (forest industries, banks, etc.); international agencies (e.g., FAO, IUFRO, CAMCORE, CGIAR); academic institutions; and collaborations of the foregoing.

In conclusion, long-term conservation of gene pools requires that a conservation ethic, suitable conservation mechanisms, and the acquisition and incorporation of knowledge be embraced by society. More specifically:

1. For any given species, multiple approaches to conservation are necessary, preferably including passive and active;
2. Success and stability of conservation measures require the incorporation of a conservation ethic into cultural values;
3. Sound and comprehensive methods for data acquisition and management are required;
4. Genetic resource management should be a part of all approaches to conservation.

The role of national governments in genetic conservation

The role that can be effectively played by national governments in conservation of forest genetic resources depends on the constitutional organization and social history of each country. This role typically includes passing legislation (e.g., import/export laws on traffic in endangered species), funding programs and projects (e.g., research), maintaining inventories (documentation of reserves), and providing leadership (determining guidelines for regional governments).

We **recommend** *the development of national programs to address issues in the conservation of forest genetic resources. Due to the complexity of land ownership patterns and land management objectives within and among Canada, México, and the United States of America, coordination on the national level is necessary. All of those directly involved with forest land ownership and/or management should be actively involved with the national program—contributing to databases, participating in conservation planning, and implementing action plans for conservation of forest genetic resources. These programs should include the exploration, inventory, documentation, and monitoring of forest genetic resources, both in situ and ex situ. Both exotic species growing in North America and native North American species growing elsewhere should be considered in national programs. Furthermore, because species cross national borders, coordination and cooperation among nations will be required.*
(Rec. no. 1)

Some components of a national genetic conservation program would typically, although not necessarily, include the following:

1. Monitoring of resources—i.e., the level of diversity
2. Research (in particular, examining the relationship between conservation objectives and forestry practices)
3. *In situ* programs
4. Genebanks
5. Databanks
6. Documentation
7. Public education

The role of international organizations in genetic conservation

International organizations, such as the North American Forestry Commission (NAFC) can play an important role in conservation of forest genetic resources. Workshop participants expressed the view that the NAFC could provide leadership in the realm of conservation of genetic resources. Some of the roles this organization could play include:

1. Coordinating working groups to assess the nature of impacts on individual species;
2. Monitoring and documenting the status of genetic resources, conservation goals, and programs among countries.

An international conservation organization in Europe, EuForGen, plays such a role for participating countries in Europe. Based on a voluntary agreement, EuForGen works towards the conservation of genetic resources in Norway spruce (*Picea abies* (L.) Karst.), cork oak (*Quercus suber* L.), black poplar (*Populus nigra* L.), and the noble hardwoods.

We **recommend** *that member countries request FAO, through their Regional Forestry Commissions, to promote and coordinate national forest genetic resource conservaton programs, and their integration into forestry practices.* (Rec. no. 8)

Figure 14. A test of knobcone × Monterey pine (*Pinus attenuata* × *P. radiata*) hybrids at City Creek, San Bernardino National Forest, California, U.S.A.

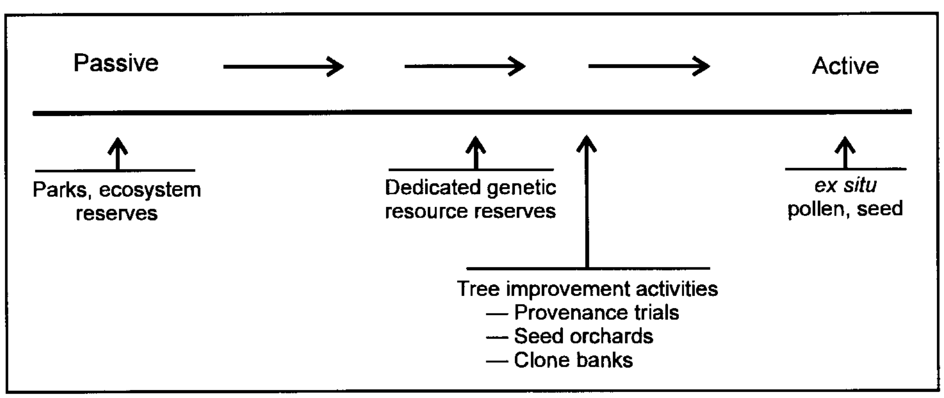

Figure 15. Conservation methods on the passive to active scale