Excerpt from "Avian Genetic Resources at Risk: An Assessment and Proposal for Conservation of Genetic Stocks in the USA and Canada". 1999. J.M. Pisenti, M.E. Delany, R.L. Taylor, Jr., U.K. Abbott, H. Abplanalp, J.A. Arthur, M.R. Bakst, C. Baxter-Jones, J.J. Bitgood, F.A. Bradley, K.M. Cheng, R.R. Dietert, J.B. Dodgson, A.M. Donoghue, A.B. Emsley, R.J. Etches, R.R. Frahm, R.J. Gerrits, P.F. Goetinck, A.A. Grunder, D.E. Harry, S.J. Lamont, G.R. Martin, P.E. McGuire, G.P. Moberg, L.J. Pierro, C.O. Qualset, M.A. Qureshi, F.T. Shultz, and B.W. Wilson. Report No. 20. University of California Division of Agriculture and Natural Resources, Genetic Resources Conservation Program, Davis CA USA. 120 p.

Preface

IN 1984, AN INTERNATIONAL SYMPOSIUM and Workshop on Genetic Resources Conservation for California made the recommendations that precipitated the establishment of the Genetic Resources Conservation Program within the University of California (UC/GRCP). These recommendations recognized that the avian genetic stocks developed in California, primarily chicken and coturnix quail, had been valuable in research and the commercial poultry industry and that continued conservation of such stocks depended upon long-term support for live-bird maintenance and further research on cryopreservation technology. At that time, there was no national-level program, comparable to the National Plant Germplasm System, directed to animal genetic resources. By the early 1990s, the California situation was fast approaching a crisis with the imminent retirement of the two primary developers and curators of poultry research genetic stocks at the University of California–Davis, Ursula Abbott and Hans Abplanalp. No plan was in place for the continued support and maintenance of the important and widely used genetic stocks developed and acquired by them. Nationally, other collections were at risk as the poultry and avian science departments in the US were losing faculty (to retirements) and financial resources that had supported collection maintenance in the past. The UC Davis campus recently followed this trend, with the merging of its Avian Sciences Department into the Animal Science Department in 1997. Avian genetic stocks in Canada are likewise imperiled.

Recognizing the drastic reductions in human and financial resources for avian genetic resources management in the US and Canada, UC/GRCP, in cooperation with two agencies of the US Dept. of Agriculture (USDA), the Agricultural Research Service (ARS) and the Cooperative State Research, Education, and Extension Service (CSREES), convened a binational Task Force in 1995 to address the problem. The Task Force included representatives from the many public institutions that have or had poultry research programs, from private companies, and from research programs that have utilized poultry genetic stocks.

In support of the Task Force's work, UC/GRCP conducted a survey of existing genetic stocks in the US and Canada to provide an inventory for analysis. This new inventory is presented in this document. The most recent prior inventory was published in 1988 (R.G. Somes, Jr. 1988. *International Registry of Poultry Genetic Stocks*. Storrs Agr. Exp. Sta. Bull. 476. The University of Connecticut, Storrs). It was not surprising to find that many stocks had been lost in the interval. Indeed, numerous stocks have been lost over the course of this Task Force effort.

The majority of the Task Force convened at an initial meeting in Davis in October 1995 and a subgroup met in Washington DC in May 1996. Results of the survey and progress of the Task Force have been presented and discussed at several meetings including the annual NE–60 Regional Research Project meetings and the annual meetings of the Poultry Science Association and the Society for Developmental Biology. An interim review of the issues was presented by M.E. Delany, co-chair of the Task Force, and J.M. Pisenti, UC/GRCP's facilitator for the Task Force (M.E. Delany and J.M. Pisenti. 1998. Conservation of poultry genetic research resources: Consideration of the past, present, and future. *Poultry and Avian Biol. Rev.* **9**:25–42).

We thank Mary Delany (University of California–Davis) and Robert L. Taylor, Jr. (University of New Hampshire) for serving as co-chairs of the Task Force and all the members for their contributions of information and editing of this report. We especially acknowledge Jacqueline Pisenti, a

poultry developmental geneticist, who facilitated this effort in every way. Her great familiarity with poultry stocks and expertise in maintaining the genetic stocks at UC Davis was a definite asset in carrying out the charge to the Task Force. Her persistence in pursuit of information for the survey made it a successful venture. Her work in pulling together this report from components submitted by many different individuals has produced what we think is a document that speaks in a uniform, strong voice for the value of these genetic stocks and for the imperative of their continued conservation.

The work of the Task Force could not have been accomplished without financial support from UC/GRCP and from grants from the National Science Foundation and the Agricultural Research Service. These grants both supported the activities of the Task Force and contributed to the maintenance of at-risk poultry genetic resource collections at the University of California–Davis.

The Task Force has defined the types of genetic stocks, made an excellent summary of the extent of the use of avian genetic resources in many different research disciplines, analyzed the inventory for trends in stock development and conservation, and finally made recommendations designed to ensure the continued availability of existing genetic resources and support the further development of new genetic resources.

While Congress authorized the US National Genetic Resources Program with the Food, Agriculture, Conservation and Trade Act of 1990, there still is no plan for ensuring the conservation of poultry and other livestock genetic resources critical to the US. In Canada there has been a loss of federal support for poultry genetic resources and now most of their important genetic resources exist only as frozen embryo blastodisc cells. With these uncertainties, it is doubtful if new genetic stocks from current research will be conserved. This is a direct deterrent to new research on critical issues in avian biology. At the same time, we recognize that emerging technologies of molecular biology and genomics have increased the value of existing genetic stocks and provided the impetus to develop new ones which will need conservation attention. The Task Force has made well considered and reasonable recommendations. UC/GRCP and the USDA will work to make these recommendations known and will support their adoption into a viable Avian Genetic Resources System to protect and make available to all researchers extant avian genetic stocks and, importantly, to encourage new research in biomedicine, biology, and agriculture.

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Executive Summary

Background

AMONG THE DOMESTICATED AVIAN species, traditional breeds developed for meat or egg production are a tremendous source of genetic diversity. Such breeds result from hundreds of years of selection by farmers and breeders, incorporating a variety of unique genes and gene combinations. Likewise, intense selection for odd and interesting traits resulted in the array of fancy breeds treasured by hobbyists. The relatively small size of most poultry species (particularly the chicken and Japanese quail), along with their phenomenal reproductive capacity and genetic variability, make them particularly well suited to multi-generational studies with rigorous selection or high levels of inbreeding. This has stimulated the development of many important genetic stocks of chicken, turkey, and quail by researchers in agricultural departments at public universities or in federal agricultural research organizations. These specialized genetic stocks have contributed widely to research in basic, biomedical, and agricultural sciences.

To date, no formal conservation plan exists for these stocks at any organizational level. Instead, conservation of these important avian genetic resources is largely dependent upon individuals, sometimes connected through breed associations or academic circles, but largely as independent efforts. This lack of a formal conservation plan is particularly perilous for research genetic stocks. Unlike the more widely dispersed traditional or hobby breeds, specialized research stocks are often kept at only one location, which makes them far more vulnerable to extinction. In particular, when such stocks can no longer be maintained by their curating researcher, they are often perceived as an unnecessary drain on dwindling financial resources at that institution, and may be eliminated at very short notice.

Findings

This study documented the loss of more than 200 stocks since 1984. A detailed database was prepared for all extant stocks in the US and Canada, including 268 chicken, 20 turkey, 65 Japanese quail, and 8 waterfowl or gamebird accessions.

1. The continuing loss of avian research stocks is a significant concern, as in the past 15 years more than 200 mutant, inbred, and selected avian genetic stocks were destroyed. More than one-third of the remaining stocks are at risk of elimination within the next few years.

2. While several research institutions in the US and Canada still maintain collections, they are at capacity and will likely face reduction in resources in the near future. There is no facility currently available that can accommodate the needs of all currently at-risk stocks.

3. Without stock conservation facilities, there will be little incentive for investment in lines of research that would produce new genetic stocks, particularly highly inbred and selected stocks. This is a direct deterrent to research on critical issues in avian biology.

4. Many research stocks have unique genetic properties which would be impossible or very costly to recreate. Some of these have high potential value for future genetic research in the basic, biomedical, and agricultural sciences, for example:

    - Uniform selected and inbred stocks are genetically well suited for studies of the

immune system and other complex functional systems.

- Strains that carry a wide variety of mutations affecting specific developmental or metabolic processes provide a starting point for research exploring the tissue or cellular source of defects in embryonic development and metabolic function, leading to a better understanding of the control of the normal processes.
- Mutations that closely mimic certain human congenital defects or disorders provide animal models for detailed experimental analysis of such conditions.

5. Information regarding the properties and availability of research stocks is not readily accessible to researchers who could effectively use them.
6. Many researchers who utilize genetic stocks, especially in basic biological and medical research areas, do not have facilities for maintaining stocks and require consistent and reliable sources for live birds, tissues, or eggs.
7. Avian genetic stocks can be conserved as live animals or cryopreserved germplasm (specifically as embryonic cells, semen, or embryos).
   - Live bird maintenance is expensive and labor intensive, as many research stocks require rigorous disease control measures with specialized rearing and adult bird housing conditions, yearly monitoring of specific performance traits for selected stocks, and genetic testing for chromosomal-abnormality and mutant-carrier stocks.
   - Although the annual storage cost for cryopreserved germplasm is relatively low, very little germplasm from avian genetic stocks is currently cryopreserved, and recovery of live birds from the cryopreserved semen can be quite difficult. An additional disadvantage of semen cryopreservation is that only the male genome is conserved. This eliminates or severely limits the usefulness of this conservation technique with inbred or selected stocks.
   - Promising new methods for conservation of diploid germplasm, cryopreservation of dissociated early blastodiscs and primordial germ cells, are the subject of recent research in Canada, Japan, and the US. These methods allow the recovery of intact genomes in the first generation.
8. Funding is difficult to secure for conservation-related research and for the maintenance of live animal collections and germplasm repositories.
9. It is difficult to predict which stocks will be of value to commercial or academic researchers at some future time. So, despite the uniqueness and potential usefulness of the existing avian genetic stocks, the tenuous nature of the "value" of many stocks has precluded sustained financial support for their preservation from any single agency.
10. There is currently no organization in the US or Canada to monitor conservation status and availability of avian genetic stocks and set priorities for their conservation on a national or binational level.

Recommendation

An avian genetic resources management system, with strong leadership, but shared responsibility, is proposed as the most efficient and secure way to conserve genetic stocks and address issues of risk and loss. The proposed Avian Genetic Resources System (AVGRS) would be comprehensive and would require the cooperation and collaboration of scientists, funding agencies, and research institutions. The System must be oriented toward research objectives, but it could also support the needs of breeders, breed hobbyists, and breed historians.

Rationale

Historic long-term collaboration between Canadian and US scientists provides a basis for collaboration in the formation and operation of an Avian Genetic Resources System. The US National Plant Germplasm System and its counterpart in Canada serve as excellent models for the proposed Avian Genetic Resources System. A system on this binational level is necessary because no dependable regional or local solution exists.

Components of an Avian Genetic Resources System

The Avian Genetic Resources System is envisioned as a multilocational organization that would serve the avian genetic resources needs for the US and Canada. The AVGRS would feature a central facility as a focal point for many of the activities of the System. The functional components are outlined in Executive Summary Figure 1 and are briefly discussed here.

Avian Genetic Resources Advisory Committee (AVGRAC)

The AVGRS would be advised by this binational committee comprised of representatives of national and state/provincial agencies, stock curators, and researchers. It would consist of 12 to 15 individuals who have worked with avian genetic resource issues, drawn from government, industry, and academic institutions in the US and Canada. Specifically, they should have worked in close association with national, international and private research-oriented organizations, and be familiar with avian genetic stock conservation issues. The members should meet at least once a year and be in regular communication during the year. The Committee would review reports and recommendations for conservation of stocks received from species-oriented committees. It would make recommendations to the management unit of the AVGRS.

Coordination

The various government and research institutions involved in avian research and conservation would use the AVGRS for coordination of information about genetic resources and the AVGRS would in turn be responsible for maintaining and distributing this information. This function would also include strategic planning for conservation of particular stocks, based on advice from advisory groups established for each species. For example, imperiled stocks would be identified to the AVGRS and a plan for their conservation would be developed through coordinated analysis. International relationships would be coordinated through the AVGRS, including conservation of stocks in other countries, import and export of genetic stocks, data sharing, and development of conservation plans for landraces, wild species, and breeding populations.

Conservation

This is the cornerstone activity of the AVGRS and of critical importance. A central facility is needed for conservation and distribution of genetic materials. The central facility would house those living genetic stocks that could not be maintained elsewhere and would serve as a backup site for important stocks that are maintained elsewhere. This would include a secure backup repository for privately owned lines or populations, either as live birds or cryopreserved germplasm at the central or secondary centers on a fee basis. The central facility would also physically maintain the various types of preserved genetic resources and would coordinate those maintained elsewhere. The cryopreservation capabilities of the central facility would be supplemented by a specialized cryopreservation center, presently unused, at the USDA site in Beltsville, Maryland. No site for the central facility is identified at this time.

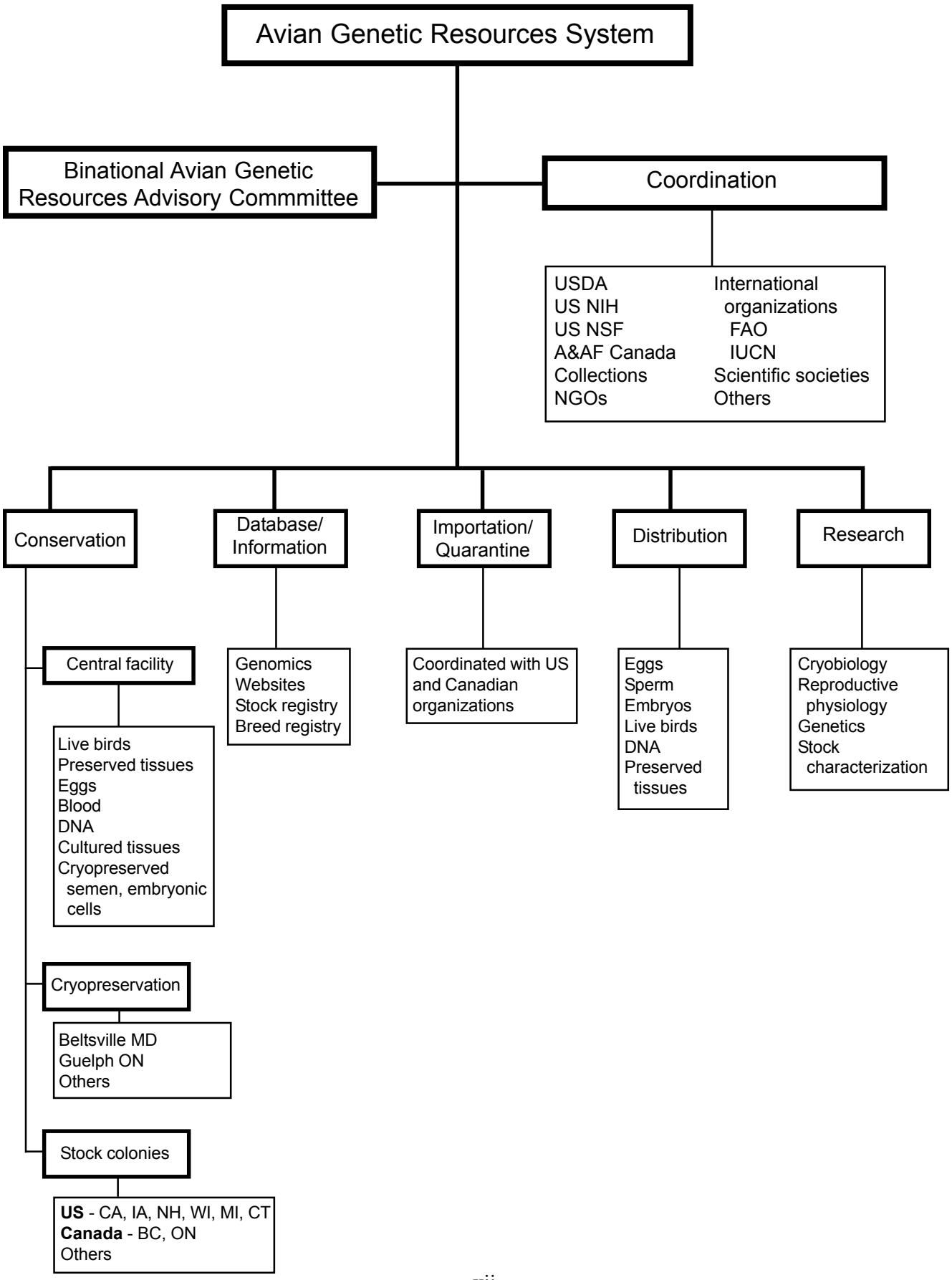
The central facility would support and be linked to secondary facilities located at active research centers which have the capability of maintaining genetic stocks for their own research needs. Several locations in the US and Canada would qualify as secondary sites.

Methods of conservation. Conservation methods employed in the AVGRS would be live-bird maintenance and cryopreservation.

Targets for conservation. Conservation emphasis of the AVGRS should be on live birds, embryonic cells, gametes, DNA, and tissues. The target species for the system will be those of interest in agriculture for food production and for basic biological and biomedical research. Thus, the focus will be on chicken, turkey, and Japanese quail genetic stocks. However, this system could also consider wild turkey, jungle fowl, and game birds, as well as species commonly raised in captivity. The AVGRS will emphasize:

- Genetic stocks having traits and genetic characteristics useful in research, such as inbred lines, single-gene mutations, chromosome aneuploidy, and DNA marker sequences.
- Lines and populations developed by private and public breeders by hybridization and selection for important production-related traits.
- Domesticated mid-level production and fancy breeds held by small producers

Figure ES1. Components of the Avian Genetic Resources System.



and hobbyists in North America and Europe.

- Domesticated, but primitive, landraces existing in Asia, Central and South America, and elsewhere, primarily as scavenger birds.

Archival preserved specimens of birds, organs, skeletons, eggs, feathers, and tissues that have been preserved as museum specimens are also a component of the genetic resources system, since these materials provide for baseline observations and time-course monitoring of factors such as environmental toxicants.

An informal *in situ* system of conservation of landraces and breeds is well established in North America. A monitoring and database system may be the most important need for those genetic resources. This could become an activity of this proposed system.

Databases

Detailed information about all genetic stocks in the US and Canada should be maintained and updated by the AVGRS in a genetic resources information system, similar to the Genetic Resources Information Network (GRIN) developed for the US National Plant Germplasm System and housed with the USDA National Agriculture Library. Additionally, database service would be offered to the various breed conservancies and hobbyists groups for inventory and location of conserved breeds, landraces, and specialty stocks. It would also be logical for the AVGRS database to include DNA sequence data as they are developed.

While GRIN currently focuses on plant information, its goal is to include information on all of the common and endangered breeds of farm animals, including the avian genetic stocks used primarily in research. Collaboration with the AVGRS database would facilitate this goal.

Outreach

Researchers can also be informed of the wide variety of available genetic stocks at the annual meetings of a variety of organizations, including the Poultry Science Association, the Pacific Egg and Poultry Association, the Poultry Breeders Roundtable, the Society for Developmental Biology, the American Association for the Advancement of Science, and the American Medical Association. Presentations at the commercially oriented meetings could be used to showcase the benefits the different companies could derive from supporting an avian genetic stocks conservation program, while the basic research or disease model aspect of genetic stocks could be emphasized for organizations promoting basic and biomedical research. Thus, the underlying goals of presenting genetic stocks information at such meetings is not only to attract the attention of researchers, but to engage the interest and promote funding from commercial sectors that can benefit directly from research using avian genetic stocks.

Another outreach option for the AVGRS would be an independent website that would promote the available avian genetic stocks to the scientific community by advertising what is available, and indicating those that are slated for elimination. The effectiveness of such a site could be multiplied by linking it with websites: the animal genetic map (Angen), the chicken map (ChickMap), various research organization sites (*e.g.,* Poultry Science Association, Society for Developmental Biology, various commercial poultry sites, and sites for academic institutions).

The AVGRS website information could be further promoted by a series of clearly written review articles in several of the major biological science journals. In each case, a specific area of research would be targeted, such as animal models for human diseases, limb pattern defects, craniofacial defects, integumentary defects, or immunogenetic research.

The outreach activity would also involve international contacts through FAO or various countries with respect to avian genetic resources. For example, there are genetic stocks at risk in other countries that should be considered for rescue in the AVGRS because of their value for research.

Bird care and housing

The housing and care of the live birds at all centers will follow American Association for Laboratory Animal Care standards for a breeding colony. Essentially, the breeding stock should be kept in a facility that approximates that of a well-run commercial poultry breeding farm. The highest degree of automation for feeding, cleaning, watering and climate control is recommended. With most of the chicken genetic stocks, the adult birds will be housed in single-bird cages, and bred by artificial insemination. Other features of the facility may include: floor pens, with or without trap nests, to maintain stocks that do not perform well in cages; and separation of males and the females (in different

rooms or cage rows), so that appropriate, sex-specific breeder diets, lighting, and feeding regimens can be provided for each group.

Importation and quarantine

Movement of animals introduces risks of spreading contagious diseases, obviously of great concern in long-term conservation of live birds. Movement of genetic resources as fertile eggs or semen reduces disease transmission risk and are preferred procedures. Importation of stocks to the central facility will be done through on-site isolation and through national facilities under the direction of USDA Animal and Plant Health Inspection Service. The central facility will have appropriate isolation and sanitation capabilities.

Distribution

A major function of the AVGRS will be to provide genetic materials to users in the research community, breeders, and others. The genetic stocks may be transferred as live birds, semen, or eggs. These will be distributed on a cost-recovery basis. Some users require a continuing supply of genetic stocks and these needs would be supplied by contractual stock reproduction programs. The distribution function would supply well-documented stocks to researchers, thus contributing to the integrity of research projects. This functional component of the AVGRS is analogous to services provided by the Jackson Laboratories for mouse genetic stocks.

Research

The AVGRS should have a research capability within the central facility, especially for developing cryopreservation technologies. Research would also be done on methods for documenting genetic integrity or diagnostics with DNA markers. Other research would be done as needed and appropriate. The research activities would be networked with research laboratories in the US and Canada for collaborative work.

Facilities and organizational aspects of AVGRS

The central facility

Ideally, the primary AVGRS facility would be constructed *de novo* near or part of a major agricultural institution (land-grant university) with a veterinary school that has a good avian medicine program, but reasonably isolated from commercial poultry stocks. The connection with a land-grant institution would give the center close ties to active research laboratories and faculty, who could benefit from such a resource and be drawn upon in support of the center. Access to state-of-the-art poultry disease diagnostics and veterinary care is critical, along with good, off-site quarantine facilities for newly acquired genetic stocks. Locating in a strong poultry producing state would also provide an existing poultry-oriented political and commercial infrastructure that could be mobilized to help support the conservation center.

This facility would include a hatchery, brooding and growing areas, adult bird housing, an isolation area, a cryopreservation laboratory and storage facility, a database center, staff and administrative offices, and a laboratory to support research and analytical services.

Network of secondary genetic stock centers

Secondary stock centers would be designated as part of the AVGRS at land-grant universities and other institutions across the US and Canada that fulfilled two criteria: (1) had adequate facilities and support for the genetic stocks used in its own research programs and (2) had a long-term interest in conserving genetic stocks. Such centers, approved as part of the AVGRS, would receive funding from AVGRS for maintenance of stocks. These secondary centers would maintain live birds and would provide backup for at-risk stocks held in the central facility. As with the central facility, the secondary stock colonies would also have a distribution function on a fee basis. Researchers could also, on a fee basis, arrange to keep research flocks at the central facility or one of the secondary centers, since they may find it difficult or impossible to keep such stocks at their own institutions. Secondary centers could specialize on one or a few classes of genetic stocks.

Management

The central facility and the secondary centers would be administered by the research institutions with which they are located. The central facility would have, at a minimum, a director or manager (research scientist), curator, an administrative assistant, database manager, cryopreservation research scientist, and three or four

laboratory and animal care technicians. The AVGRS would be guided by the advisory committee on all management aspects.

Stock evaluation guidelines

One of the more important activities of the AVGRAC would be the evaluation of stocks for conservation, cryopreservation, or elimination. Guidelines for assessing the value of genetic stocks should be consulted.

Financing the Avian Genetic Resources System

Multiple sources of funding will be necessary to meet all of the needs of the AVGRS. Initial costs are those to construct the central facility and upgrade the secondary stock centers. Annual costs of the central facility would be for its personnel and operations. It would also be necessary to support the annual activities of the AVGRAC. The central facility could also divert funding for specific needs to the secondary centers by means of annual grants.

From the US side, the biological resource programs of the National Science Foundation and the National Institutes of Health would be expected to provide operational funds through direct grants and through grants to investigators who use the avian genetic resources in their research. The USDA's National Genetic Resources System should participate in the AVGRS through the Agricultural Research Service and the Cooperative State Research, Extension, and Education Service. The various State Agricultural Experiment Stations and land-grant and other Universities should also participate. Canadian support and participation should be forthcoming to the extent that the AVGRS provides support to its research and development programs.

The AVGRS will be the major provider of genetic materials to researchers throughout the public and private sectors. For the most part, researchers do not have capacity to maintain live bird colonies and depend upon stock colonies for their research. User-fees are an appropriate means to recoup costs of stock maintenance.

Donation funds can be expected to support the perpetual maintenance of particular genetic stocks. These funds may be provided as annual grants or through income derived from interest on endowment accounts.

Funding should be sought from the US government for construction of the central facility and for personnel support for operations as a part of the US National Animal Genetic Resources System.

Long-term funding would be the most secure from endowment funds. Contributors could be encouraged from the private sector, from large integrated commercial poultry companies to private individuals with interests in preserving poultry stocks or willing to promote the conservation of stocks that can be used to study human diseases.

Construction, personnel, and operational costs have not been established, pending further analysis of potential sites for the central facility and other considerations. For illustrative purposes, rough order-of-magnitude estimates are given in Executive Summary Table 1.

Table ES1. Estimated costs of Avian Genetic Resources System.

Startup costs	
Constructing and equipping central facility	$15,000,000
Upgrading and renovating secondary centers	2,000,000
Total	**$17,000,000**
Annual costs	
Personnel at central facility	$400,000
Operating costs at central facility	100,000
Grants to secondary centers (8 x $25,000)	200,000
Advisory Committee	25,000
Total	**$725,000**

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Charge to the Task Force

EVALUATE THE CURRENT STATUS of avian genetic stocks maintained in the US and Canada. The assessment should include the following aspects:

Origin and history of avian genetic stocks.
How avian genetic stocks have been utilized.
Value of avian genetic stocks in agriculture, biomedical, and basic biological research.
Strategies and techniques for long-term conservation.

Produce a report documenting these findings and include recommendations for organizational, fiscal, and administrative steps and personnel necessary to ensure the long-term security of avian genetic stocks for the US and Canada.