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.

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Genetic stocks: Current resources and recent losses

ALMOST ALL OF THE GENETIC STOCKS of chicken, turkey, Japanese quail, and other domesticated birds that have been used in research in the US and Canada were developed and conserved by public sector universities and federal government research organizations in these two countries. Many in the research community have been aware of the gradual attrition, and occasional dramatic losses, of these specialized stocks over the years. Some important genetic resources were discarded before relocation plans could be developed or because a new stock curator could not be located. Current threats to additional abandonment of existing genetic stocks gave impetus for a study of the true situation of existing genetic stocks, where such stocks are located, and their status for conservation and use. The situation is dynamic, for not only are established genetic resources at risk, but new genetic stocks are also being developed in current research programs that will in turn require preservation or conservation in the years to come. SOMES (1988) provided a benchmark with his comprehensive, but not exhaustive, summary of the state of genetic stocks up to 1988. Hence the Task Force undertook an assessment of the current situation with the goal of producing a complete database inventory of extant genetic stocks, along with a summary of the genetic stocks that had been discontinued, abandoned, or lost since 1984. This information constitutes the basis for the proposal of a comprehensive strategy geared towards the conservation of avian genetic stocks important to basic biological research and education. (See Chapter 6).

Survey methods

The study was conducted by Jacqueline Pisenti during 1995–97 at the UC Genetic Resources Conservation Program, with additional financial support from the National Science Foundation and the USDA Agricultural Research Service. In 1998 each curator was contacted again to produce an updated report. A survey instrument (Appendix 1) was sent to all of the curators mentioned in SOMES (1988) and the participants in the CSREES Regional Research Project NE-60 on genetic basis for resistance and immunity to avian diseases. Individuals listed in the Poultry Science Association 1995–96 membership directory who indicated a focus on genetics or immunology, and individuals on the 1997 Poultry Science Resource List prepared by the Poultry Science Association and R.D. Reynells (USDA/CSREES) were also contacted (usually via email or telephone) and queried. In all, survey forms were sent to 37 curators (11 in Canada and 26 in the US) at 27 institutions listed in the SOMES (1988) registry and 72 additional individuals were contacted by phone or email. All curators were asked to report on the status of stocks that had been included in the 1988 registry (i.e., which of these stocks had been retained, transferred, or eliminated), and to list any new stocks acquired since1988. They were also asked to indicate the prognosis for long-term security of each stock. Finally, respondents were asked to send the names of any poultry genetic stock curators they were aware of, either at their institutions or elsewhere, and these individuals not already contacted were also asked to respond to the survey.

Results from the survey

According to the survey, 361 genetic stocks are currently maintained (Table 1 and Appendix 2). Of the 36 curators at 27 institutions listed in the 1988 registry (SOMES 1988), 31 of them (or their successors) responded; four no longer maintained stocks, and 27 still had at least some of

the stocks listed in the 1988 registry. Of the 72 other persons queried, 44 responded and 13 reported that they curated poultry genetic stocks.

By species, there are 268 chicken stocks (with 38 existing only as cryopreserved material), 65 Japanese quail, 20 turkey, six waterfowl, and two gamebird. Table 1 shows the categorization of the existing genetic stocks. The detailed database in Appendix 2, Table 2.1, lists the characteristics of every genetic stock that was identified in the survey. These were grouped into ten main categories. The largest category is single-gene mutants, with 107 stocks that display color variations or defects in developmental, immunologi-

Table 1. Summary by category of existing poultry genetic stocks (live and cryopreserved).

Category	Chicken	Japanese quail	Turkey	Waterfowl, Gamebird	Total
			Number of stocks		
Bloodtype-Gene pool	6	0	0	2	8
Bloodtype-Major Histocompatibility Complex (MHC)	13	0	0	0	13
Bloodtype-MHC-Inbred	51	0	0	0	51
subtotal	*70*	*0*	*0*	*2*	*72*
Chromosomal variant	5	0	0	0	5
Endogenous virus	1	0	0	0	1
Endogenous virus-Inbred	4	0	0	0	4
subtotal	*5*	*0*	*0*	*0*	*5*
Inbred	27	1	0	0	28
Mutant-Color, eggshell	0	2	0	0	2
Mutant-Color, feather	1	12	0	0	13
Mutant-Developmental defect-Eye	5	0	1	0	6
Mutant-Developmental defect-Face/limb	28	0	0	0	28
Mutant-Developmental defect-Skin/feather	8	6	0	0	14
Mutant-Developmental defect-Spine/tail	3	0	0	0	3
Mutant-Gene pool	7	1	0	0	8
Mutant-Immunological defect	5	0	0	0	5
Mutant-Neurological defect	3	0	0	0	3
Mutant-Physiological defect	12	0	0	0	12
Mutant-Reproductive defect	3	0	1	0	4
Mutant-Uncategorized	8	1	0	0	9
subtotal	*83*	*22*	*2*	*0*	*107*
Pure breed	12	0	5	6	23
Randombred	18	14	8	0	40
Selected-Behavioral trait	2	1	0	0	3
Selected-Egg trait	11	0	2	0	13
Selected-Growth trait	14	18	3	0	35
Selected-Immune trait	11	1	0	0	12
Selected-Physiological trait	2	8	0	0	10
subtotal	*40*	*28*	*5*	*0*	*73*
Transgenic	2	0	0	0	2
Uncategorized	6	0	0	0	6
Total	**268**	**65**	**20**	**8**	**361**

cal, neurological, physiological, or reproductive characteristics. The selected stocks category, with 73 stocks, are products of long-term selective breeding and are characterized by above- or below-normal performance in defined behavioral, growth, egg production, immunological, or physiological traits. The next largest category with 72 stocks consists of the bloodtype variants, representing most of the known forms of chicken erythrocyte and leukocyte alloantigens. The inbred category, with 28 stocks, consists of stocks approaching genetic homogeneity as a result of crossing full sibs or other close relatives for many generations. In addition to the inbred category, highly inbred stocks can be found in the bloodtype-MHC-inbred and endogenous virus-inbred categories. A few highly inbred stocks are also found among the mutant-developmental defect-face/limb category. The randombred category with 40 stocks and the pure breed category with 23 stocks are important as control or reference populations and represent gene pools from which many of the selected and mutant stocks were derived. The uncategorized group with six stocks are those stocks for which no description was available.

Forty-one researchers at 27 institutions (24 in the US and 3 in Canada) maintain 323 genetic stocks as living birds (Table 2). Six of these institutions maintain 20 or more stocks (University of Arkansas, University of British Columbia–Vancouver, University of Connecticut–Storrs, University of California–Davis, University of Wisconsin–Madison, USDA/ADOL East Lansing, Michigan). Six maintained between ten and 19, four had six to nine, and 11 had five or fewer genetic stocks. Two institutions in the US and four in Canada no longer keep such stocks.

In addition to the living bird collections, 87 genetic stocks are maintained under semen or blastodisc cryopreservation at five institutions. Such frozen reserves are kept at the University of Guelph (Guelph, Ontario) (33), the University of California–Davis (31), the USDA Avian Disease and Oncology Laboratory at East Lansing, Michigan (17), Pennsylvania State University (4), and the University of Wisconsin–Madison (2). Five of the cryopreserved stocks at University of California–Davis are no longer maintained as live birds. The 33 cryopreserved stocks at the University of Guelph are from the Canadian Food Animal Research collection and also are no longer maintained as live birds. Thus, 51 stocks maintained as live birds are also backed up by cryopreservation, while 38 stocks now exist only under cryopreservation.

At the time this report went to press, approximately one-third of the stocks kept as live birds were considered by their curators to be at high risk of elimination within the next few years (30% of the chicken, 35% of the turkey, and 49% of the Japanese quail stocks). Just over 40% were considered to be in a secure situation, including 42% of the chicken, 45% of the turkey, and 37% of the Japanese quail stocks. The remainder of the stocks (about 30%) were considered to be only moderately at risk.

Lost stocks

In the last 15 years, some 238 avian genetic stocks were reported as lost or eliminated by research institutions in the US and Canada (Table 3; this also includes those few stocks reported as transferred to private individuals or organizations). The actual number of lost stocks is probably much higher. The data in Table 1 show the numbers and percentages of genetic stocks lost, based on the current number of existing stocks and documented numbers of lost stocks. Some new stocks have been developed since the last survey, specifically in the MHC-defined endogenous virus and selected categories. These recent additions inflate the total numbers of existing stocks and bias downwards the estimated percentage of stocks lost. Even so, stock losses have been substantial: close to 40% of the reported living US stocks and over 60% of the Canadian stocks were discontinued since 1984, 42% of all stocks (Table 2). Most notable was the discontinuation of more than 30 genetic stocks by Agriculture and Agri-Food Canada at its facility in Ottawa. This clearly reflects a disturbing trend in avian genetic resources conservation.

Of all lost stocks, 75% were chickens, 11% were turkeys, 11% were Japanese quail, and 4% were gamebirds or waterfowl. Ironically, more than one-third of these stocks were reported lost between 1995 and 1998 while this survey was in progress, including 50 chicken stocks, 19 turkey stocks, 10 Japanese quail stocks, and four of the waterfowl stocks. The losses were heaviest (35% of all lost stocks) among the mutant and chromosomal variant categories, although the selected (25%) and the bloodtype-MHC-inbred (21%) categories were not far behind. Some of these lost stocks, such as the bloodtype-MHC specialized stocks, included genes that can be recovered by breeding and selection from existing genetic resources, but at a great cost of money and time. The now-extinct lethal and

Table 2. Number of poultry genetic stocks kept as live birds in institutions in the USA and Canada in 1998 and the number lost since 1984.

	Kept as living birds[†]					Lost since 1984[†]					
Curating institution	**C**	**JQ**	**T**	**W,G**	**Total**	**C**	**JQ**	**T**	**W,G**	**Total**	**% all[‡]**
USA					Number of stocks						
Alabama: Auburn University	10	0	0	0	10	17	0	0	0	17	63
Arkansas: University of Arkansas	12	9	0	0	21	1	2	0	0	3	13
Arizona: University of Arizona	0	0	0	0	0	1	0	0	0	1	100
California: University of California	46	1	0	0	47	15	7	1	4G	27	36
Connecticut: University of Connecticut	20	0	0	0	20	8	1	1	0	9	31
Delaware: University of Delaware	1	0	0	0	1	0	0	0	0	0	0
Georgia: University of Georgia	4	9	0	0	13	2	6	0	0	8	38
Illinois: Northern Illinois University	7	0	0	2G	9	0	0	0	0	0	0
Illinois: University of Illinois	2	0	0	0	2	0	0	0	0	0	0
Indiana: Purdue University	2	1	0	0	3	6	0	0	0	6	67
Iowa: Iowa State University	17	0	0	0	17	5	0	0	0	5	23
Iowa: USDA National Animal Disease Center	0	0	1	0	1	0	0	0	0	0	0
Louisiana: Louisiana State University	0	3	0	0	3	2	0	0	0	2	40
Maryland: University of Maryland	0	1	0	0	1	0	0	0	0	0	0
Massachusetts: University of Massachusetts	4	0	1	0	5	10	0	1	0	11	69
Michigan: USDA Avian Disease & Oncology Lab.	37	0	0	1W	38	2	0	0	0	2	5
Minnesota: University of Minnesota	0	0	0	0	0	5	0	0	0	5	100
Nebraska: University of Nebraska	1	1	0	0	2	0	0	0	0	0	0
New Hampshire: University of New Hampshire	14	0	0	0	14	14	0	0	0	14	50
New York: Cornell University	7	0	0	1W	8	7	1	0	0	8	50
North Carolina: North Carolina State University	5	0	7	2W	14	0	0	2	0	2	13
Ohio: Ohio State University	2	7	6	0	15	15	0	2	0	17	53
Oregon: Oregon State University	1	0	0	0	1	0	0	17	0	17	94
Pennsylvania: Pennsylvania State University	6	0	0	0	6	0	0	0	0	0	0
Virginia: Virginia Polytechnic Inst. & State Univ.	4	0	0	0	4	0	3	0	0	3	43
Wisconsin: University of Wisconsin	19	1	3	0	23	6	0	0	0	6	21
Total in USA	**221**	**33**	**18**	**4W 2G**	**278**	**116**	**20**	**23**	**4G**	**163**	**37**
Canada											
British Columbia: Univ. of British Columbia	3	32	0	0	35	0	5	0	0	5	13
Ontario: University of Guelph	3	0	1	0	4	10	0	0	0	10	71
Ontario: AA-FC Center for Food Animal Research	0	0	0	0	0	30	0	0	6W	36	100
Quebec: McGill University	0	0	0	0	0	4	0	0	0	4	100
Quebec: University of Lavale	0	0	0	0	0	1	0	0	0	1	100
Quebec: Deschambault Research Station	0	0	0	0	0	4	0	3	0	7	100
Saskatchewan: University of Saskatchewan	3	0	1	2W	6	11	0	1	0	12	67
Total in Canada	**9**	**32**	**2**	**2W**	**45**	**60**	**5**	**4**	**6W**	**75**	**63**
Total	**230**	**65**	**20**	**6W 2G**	**323**	**176**	**25**	**27**	**6W 4G**	**238**	**42**

[†]C = chicken, JQ = Japanese quail, T = turkeys, W = waterfowl, G = gamebird.
[‡]"% all" indicates the proportion of total stocks at that institution that were lost since 1984.

subvital mutant stocks, along with the large number of discontinued translocation stocks, appear rarely, are difficult to detect, and are often discovered serendipitously. A number of the viable mutations that were kept in gene pools or as specialized stocks in research collections can still be found among hobbyist breeds or exhibition stocks, but they present problems in use because there is a risk of transferring diseases or they have background genotypes that may be inappropriate for use in research.

Individual stocks and whole collections that have been lost in recent years include:

- Inbred, specialty, and historical commercial stocks once maintained by Agriculture and Agri-Food Canada in Ottawa that were dispersed or eliminated in 1997, due to loss of government support. While some of these specialized stocks were sent to other institutions or private companies, 33 were retained only as cryopreserved blastodisc cells kept at the University of Guelph, (Ontario, Canada) (Box 20) and 30 were eliminated. However, one-half of these 30 were bloodtype stocks that are still available elsewhere.
- Five stocks (long-term inbred lines and one gene pool of dominant mutations) maintained at the University of Minnesota, were eliminated in 1996, although two (the dominant marker stock and the inbred Rhode Island Reds) had been transferred to the University of British Columbia a few years earlier.
- The collection of stocks at the University of Massachusetts went into dispersal in 1997, due to the retirement of its curator. While several important mutant stocks have found new curators, including the auto-immune vitiligo (DAM) chickens and their normal controls, the feather color and comb-type gene pool and tester stocks have been eliminated.
- At Oregon State University (Corvallis), a large and unique collection of 17 stocks carrying feather-color and embryo-lethal turkey mutations was eliminated in 1995, due to funding difficulties. A similar problem contributed to the loss of another collection of turkey stocks in the 1960s, this one held at the University of California–Davis.
- Fires at bird-care facilities have killed off at least two turkey stocks at the Deschambault Research Station and one Japanese quail mutation at University of California–Davis. Five other quail mutations salvaged from that fire at Davis (three unique to University of California–Davis) were subsequently eliminated due to funding difficulties.
- At the University of California–Davis, the retirement of two researchers with large collections of research stocks has put over 40 stocks in jeopardy (Box 3); these include over 20 mutations and an array of MHC-defined inbred lines, many of which are found nowhere else.

Table 3. Summary by category and species of poultry genetic stocks reported lost since 1984.

Category	Chicken		Japanese quail		Turkey		Waterfowl, Gamebird[†]		Total	
	No.	%[‡]	No.	%[‡]	No.	%[‡]	No.	%[‡]	No.	%[‡]
Bloodtype-MHC-Inbred	49	28	0	0	0	0	0	0	49	21
Chromosomal variant	33	19	0	0	0	0	0	0	33	19
Inbred	6	3	0	0	0	0	3G	30	9	4
Mutant	25	14	11	42	19	70	0	0	55	23
Pure breed	18	10	0	0	3	11	4W	40	25	10
Randombred	3	2	3	12	0	0	1W	10	7	4
Selected	42	24	11	46	5	19	1W,1G	20	60	5
Total	**176**	**74[§]**	**25**	**11[§]**	**27**	**11[§]**	**6W,4G**	**4[§]**	**238**	**100[§]**

[†]W=waterfowl; G=gamebird.

[‡]This column indicates the percentage of lost stocks in a category out of the total of lost stocks for that species.

[§]This value is the percentage of total lost stocks over all species accounted for by the total lost stocks for a given species.

Trends in poultry genetic stock development and conservation

Only a few large collections of vertebrate genetic stocks have been assembled, including the mouse (*Mus musculus*) collection that is currently kept at the Jackson Laboratory in Bar Harbor, Maine (Box 21) and the Japanese quail collection at the University of British Columbia (Box 22). But it is the chicken mutant collections that probably have the longest history, starting in the 1920s with Landauer and Dunn at the University of Connecticut, Storrs Agricultural Experiment Station (a collection that still exists, in part). These early researchers in vertebrate embryology used classical embryological techniques to study mutant gene expression, the effect of background genes on mutant phenotype, and the production of environmentally induced phenocopies (genetically normal embryos that resemble mutants) of specific mutant syndromes (LANDAUER 1973). Ironically, it is these areas of study that attract the attention of researchers today, just as the remaining academic avian genetic stock collections have become threatened. This underscores the need for preserving these unique gene pools and identified single-gene mutations for the benefit of future researchers. Similar arguments can be made for other research stocks, particularly inbred and selected strains. Both require many years and large, pedigreed populations during their development; factors that place formidable barriers to the regeneration of such stocks because of short-term and limited funding commitments.

Traditionally, poultry stocks were maintained at the research institutions where they were developed and studied. These institutions, frequently in states with a large or growing poultry industry, often had poultry or avian science departments that were independent of the larger animal science departments. This served to encourage research on the different poultry species and the development and maintenance of unique poultry genetic stocks. In the early 1960s, some 45 poultry science departments existed in the US; since that time and in spite of the tremendous growth in economic value of the the poultry industry and great consumer interest in poultry products, most departments have been eliminated or merged with other departments, leaving only eight poultry science departments today (PARDUE 1997; DELANY and PISENTI 1998). With reorganization of these departments and their resources, genetic stock losses were inevitable as a result of loss of long-term support funds, reallocation of funding and resources to other areas, condemnation of poultry housing facilities without construction of adequate replacement housing, retirement of researchers who served as curator of stocks, shifts in research interests, and new research on exotic avian species as research models or companion birds.

The number of genetic stocks reported by SOMES (1988) is nearly the same as that detected in the present survey. However, the present survey documented the loss of nearly 200 chicken stocks, 23 turkey stocks, and at least 8 Japanese quail stocks, so it is evident that a considerable number of new stocks have been produced during the past decade, possibly displacing some of the older ones. Most curators faced with the need to reduce or disperse inventory try to find alternate conservators for stocks that are slated for elimination (Boxes 2, 3, 4), although this is not always successful (Box 8). Informal networking for new curators has worked well enough with single-gene mutation stocks when curating researchers had funding to support a number of these unique stocks, but this is often no longer an option.

Clearly, planned and unplanned stock losses are impacting the availability of specialized genetic resources to researchers. Stock eliminations are increasingly driven by funding problems, more will be lost. Particularly at risk are the selected lines and mutant stocks, which require either larger numbers or special handling to propagate.

Box 21. The Jackson Laboratory model for vertebrate genetic stocks

A GOOD EXAMPLE OF A SUCCESSFUL genetic stocks conservation program is the Jackson Laboratory, a non-profit, independant research institution, in Bar Harbor, Maine. Along with research and training, its third mission is the maintenance and distribution of a huge inventory of mouse genetic stocks. They are maintained as either live animals or frozen embryos and are distributed either as live animals or DNA preparations. Annually, the Laboratory supplies about two million mice from over 1,700 stocks to universities, medical schools, and research laboratories worldwide. In addition to providing the genetic stocks, the Jackson Laboratory also maintains and serves a computerized database system available anywhere in the world that enables fast, efficient access to a single comprehensive archive on the mouse. Supported partly by government grants and partly by user fees, the Jackson Laboratory is a good model for long-term preservation of avian genetic stocks. Further information on the Laboratory and the databases can be accessed from their web site (URL: http://www.jax.org/).

Box 22. Japanese quail at the University of British Columbia

PRIOR TO 1980, A JAPANESE quail colony was maintained at the Department of Animal Science, University of British Columbia (UBC) for research and teaching in genetics. In 1980, the goal was set to expand this colony and manage it as a genetic resource collection, and to make it available to users outside the department. In 1982, the Quail Genetic Resource Centre was formally established with the support of the department and the Natural Sciences and Engineering Research Council of Canada (NSERC). In the last 14 years, many new mutations and strains have been incorporated into the collection. At present, the quail populations at the Centre harbor 27 morphological and physiological mutations, close to 50% of all the mutations (not including isozyme variants) ever reported in the literature for this species. Detailed descriptions of the mode of inheritance, the phenotype, and possible applications of these mutations can be found in CHENG and KIMURA (1990). In addition, they also maintain 12 random-bred populations and specially developed strains that are useful for biological research or as breeding stocks for meat and egg production. Stocks from the Centre have been widely utilized for research, teaching, and extension.

Areas of research include genetics, physiology, developmental biology, cancer, atherosclerosis, eye defects, neurology, animal behavior, and animal ecology. In the past three years, the Centre assisted or collaborated in more than 35 research projects. Currently, there are two on-going research projects using quail as a model to study atherosclerosis and another project using quail to study age-related macular degeneration (AMD). Except for monkeys, the quail is the only suitable model to study this disease which is the most common cause of blindness in humans over the age of 65. The Centre has also started screening chicken microsatellite DNA primers obtained from Hans Cheng to detect polymorphism in quail.

Teaching uses include courses in biology, genetics, poultry management, and animal behavior at University of British Columbia and other universities and colleges in the province. These stocks have also been used by students from local secondary schools for their senior science projects. The Centre staff also provides consultation for researchers and teachers on managing quail as a laboratory animal, and consultation for local producers and raptor rehabilitation centers on management of the flocks and/or marketing. In the latter cases, birds from the Centre were sometimes provided as breeding stocks. With the increase in consumption of quail products in metropolitan areas in Canada and also in the southern US, there has been a significant increase in requests for information from other parts of Canada and from the US.

The Centre has been partially supported by an infrastructure grant from NSERC, which provided the salary for the full-time technician. This grant covered 25% of the operating costs. Besides capital investments, the University provided 40% of the operating costs through department funds. The remaining 35% of the operating costs were covered by income from sales of products and users' fees. The NSERC support was terminated in 1995, and income generated from egg sales and research contracts are not sufficient to sustain the operation. An endowment will be sought to generate Canada $30,000 Cdn a year to keep the operation going.