The Crumbling Infrastructure of Biodiversity: The Avian Example

KEVIN WINKER

National Museum of Natural History, MSC MRC 534, Smithsonian Institution, Washington, D.C. 20560, U.S.A., email winker@onyx.si.edu

Abstract: *The successful conservation of biodiversity depends in part upon an accurate assessment of the diversity to be preserved. This assessment is in the domain of systematics, taxonomy, and general comparative biology. Specimens play a central role in this science, and research collections thus represent the touchstone of biodiversity. The massive job of describing and understanding avian diversity is far from complete, yet the specimen basis for much-needed work is not being added to our collections; current holdings are inadequate. The dwindling influx of specimens is due primarily to opposition to collecting, which is fueled by (1) focusing conservation at the level of the individual; (2) unfamiliarity with population biology; (3) misunderstanding of scientific research; (4) typological thinking; and (5) misplaced morality. Specimen-based avian research has a long and scientifically strong history, and the benefits of this research have been extensive. Our research collections must serve as functional biological libraries. The majority of avian populations can easily withstand the relatively tiny levels of collecting required to keep this science vigorous. Insofar as avian conservation necessarily includes the preservation of a myriad of species comprising the ecosystems upon which birds rely, this problem has broad implications for the conservation of biodiversity.*

El Desmoronamiento de la Infraestructura de la Biodiversidad: El Ejemplo de las Aves.

Resumen: *La conservación exitosa de la biodiversidad depende en parte de la adecuada evaluación de la diversidad que se pretende preservar. Esta tarea es del dominio de la sistemática, la taxonomía y la biología general comparada. Los especímenes juegan un papel medular en estas ciencias y las colecciones por lo tanto representan una estimación de la biodiversidad. El trabajo masivo de describir y entender la diversidad de las aves se encuentra aún lejos de estar completo y los especímenes base de este tan necesitado trabajo de continuidad no han sido agregados a nuestras colecciones; lo colectado a la fecha es aún inadecuado. La decreciente entrada de especímenes se debe principalmente a una oposición a llevar a cabo colectas, esto es alimentado por: 1) enfocar la conservación a nivel de individuo; 2) no estar familiarizados con la biología poblacional; 3) malentendidos sobre la investigación científica; 4) pensamiento tipológico; y 5) desubicación moral. La investigación de aves basada en especímenes tiene una historia larga y científicamente bien fundada. Los beneficios de este tipo de investigación han sido extensos. Nuestras colecciones de investigación deben servir como bibliotecas biológicas funcionales. La mayoría de las poblaciones de aves pueden soportar fácilmente los relativamente pequeños niveles de colecta requeridos para mantener vigorosa a esta ciencia. Puesto que la conservación de aves necesariamente incluye la preservación de una miríada de especies involucrando a los ecosistemas de los que las especies dependen, este problema conlleva implicaciones para la conservación de la biodiversidad.*

An insidious malaise threatens the quality of comparative avian biology, and, as a direct consequence, the successful conservation of biodiversity. The causes are diverse, but the symptom is plain: few specimens are being added to systematics collections. The diversity of life is known to us only through the efforts of taxonomists and systematists and the reference specimens they have preserved. The specimen record is of incalculable importance because it allows repeated examination for scientific verification and further study. The touchstone of biodiversity *is* the world's systematics collections. In

Paper submitted June 9, 1995; revised manuscript accepted September 26, 1995.

birds, at least, this touchstone is getting old, and in its old age it is becoming less capable of serving modern researchers. At the same time, few new specimens are replacing this aging resource.

The science emanating from avian specimens has a long, strong record (see Darwin 1871; Mayr 1942, 1969, 1988; Parkes 1963; Remsen 1984; Graves 1991; Dumbacher et al. 1992; Parsons et al. 1993). Conservation efforts have benefited immensely from this science and its associated specimens, from plates in field guides (most are based on specimens) and the detailed avian monographs that serve as the basis for any work in Aves, to modern biodiversity surveys (e.g., Ridgway & Friedmann 1901–1950; Cory et al. 1918–1949; Peters et al. 1931–1986; International Council for Bird Preservation 1992). These important contributions, clearly far from finished, will continue only with further collection growth. Collections exist to help scientists understand diversity and distribution. If collecting stops, collections will represent old and incomplete documentation of a historic condition of a dynamic process. Instead, our research collections should serve as functional, biological libraries. How informative is a library that stops acquiring books?

Although the historic value of collections is immense, that value is realized largely through comparison with modern material. Old specimens generally have few or no data on their labels, making them useless for many types of research—including investigations most important for conservation decisions (examples in Remsen 1995). Modern specimens (generally those taken after about 1960) are both rare and prized; they have better, more complete data (e.g., date, specific locality, sex, skull and gonad development, molt, etc.), which enables them to be used to answer more questions. Because older specimens have fewer data, modern collection studies quickly run out of useful material (Remsen 1995 and references therein). The average and median collection date of (computerized) specimens in the U.S. National Museum of Natural History is 1926 (n = 174,285; Fig. 1). The average date of specimens found useful over the past few years in my studies of external phenotype and geographic variation is 1958 (n = 3283).

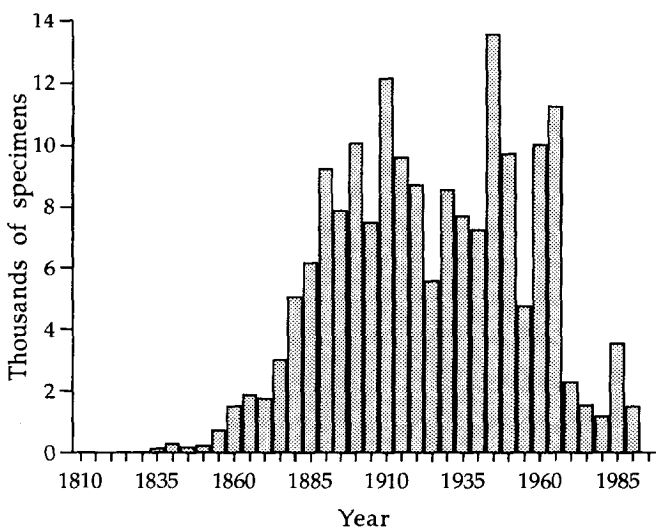

Figure 1. Temporal distribution of the 174,285 computerized bird specimens in the U.S. National Museum of Natural History.

As each year passes, the U.S. national bird collection becomes less useful and less capable of answering today's questions. For attacking modern problems this collection can only supply ammunition that is on average 70 years old. With the average specimen so far removed from the present, the ability of this world-class collection to continue to make what have historically been monumental contributions is seriously jeopardized by the severe decline in recent acquisitions. The situation is no better at other major North American collections: The average date of specimens in the Field Museum of Natural History (Chicago) is 1935 (median 1932; n = 377,608) and in the Academy of Natural Sciences of Philadelphia, 1927 (median 1931; n = 109,636).

Do we know it all? Should we view the study of avian variation (and its necessary adjunct, the description and resolution of forms) as a quaint, historic job now finished? Hardly. The massive job of describing and understanding avian diversity is far from complete. Comparison of standard monographic references (e.g, Ridgway & Friedmann 1901–1950; Cory et al. 1918–1949; Peters et al. 1931–1986) with more recent treatments (e.g., Phillips 1986, 1991), and comparison among treatments of ostensibly well-known areas (Friedmann et al. 1950; Miller et al. 1957; American Ornithologists' Union 1957, 1983; Sibley & Monroe 1990), demonstrate a considerable level of fluidity in nomenclature and the recognition of avian taxa. Substantial disagreement among authoritative works is the hallmark of a vigorous science in which much remains unknown. When our ignorance is coupled with the strong role that birds have played in major societal conservation issues (e.g., *Silent Spring* and the Spotted Owl) and the fact that global change is accelerating, *specimen collection has never been more important than now,* yet it has nearly stopped. Given past contributions and an ongoing need for similar work, this is a serious problem.

Efforts to understand and preserve biodiversity must take into account the central role of systematics and taxonomy in demarcating biological units (Brooks et al. 1992; Systematics Agenda 2000 1994) and, concomitantly, the central role of specimens in this endeavor. This important work is far from complete in birds, and the existing specimen base is inadequate to the task. It has recently been estimated (generously) that for the average species of bird in the world, research collections (accumulated over 150 years) contain approximately 21

of each age and sex class for each month of the year, or about three individuals of all classes per 1000 km^2 of their range (Goodman & Lanyon 1994). Goodman and Lanyon (1994) conclude that fewer than 0.5% of the worlds' species are adequately represented in museum collections for thorough studies of geographic variation. A recent effort to examine all useful traditional specimen material for many North American taxa makes it clear that gap-filling specimens alter our perceptions of avian diversity and that there are many gaps to fill (Phillips 1986, 1991).

The shrinking influx of specimens is caused primarily by an opposition to collecting, fueled by

(1) focusing conservation at the level of the individual;
(2) unfamiliarity with population biology;
(3) misunderstanding of scientific research;
(4) typological thinking;
(5) misplaced morality.

Most of these obstacles to collecting are fallacious, and all are needless.

Confusing the welfare of the individual with the welfare of the population or species is a common error made by would-be conservationists. Individuals cannot be conserved; every one dies eventually. Only populations and species can be conserved. A related problem is an unfamiliarity with the basic principles of population biology. In a given year animal populations undergo fluctuations in abundance caused by natality (birth) and mortality (death). Birds generally have rather high mortality rates. Wood-warblers (Parulinae), for example, have about a 38% annual adult mortality rate (Hann 1948; Mayfield 1960; Roberts 1971; Nolan 1978; Karr et al. 1990), offset, of course, by accordingly high levels of natality. The vast majority of avian populations can easily withstand the relatively tiny levels of loss to scientific collecting needed to keep our science active and our collections useful for the study of current and future problems. Stopping (or severely retarding) the collection of birds, an activity known to be inconsequential in relation to natural mortality factors (King & Bock 1978; Banks 1979), will have no positive effect on conservation efforts. On the contrary, stemming the collection and preservation of specimens hampers our abilities to promulgate effective conservation strategies by prolonging our ignorance of the populations and species we wish to conserve.

A misunderstanding of scientific method is one of the largest problems that has arisen between agencies that grant collecting permits and specimen-based avian researchers. Agencies generally require that a year's collecting effort be requested and justified (as to the species and number of individuals) at the start of that year. This policy assumes that everything is known about the avian diversity of an area before research begins (frequently untrue), and, in effect, that the experimental approach is the only legitimate method of scientific inquiry. The latter view completely ignores the comparative method, the other major method of scientific inquiry in biology; observations give rise to questions, which in turn generate hypotheses (tentative answers), which may then be tested through experimentation (Mayr 1982).

Current permit structures and procedures actively prohibit and discourage the practices (use of the comparative method) that have built our understanding of avian diversity and distribution. This constitutes government-sponsored curtailment and denial of scientific progress in the absence of proof that this line of inquiry causes any harm and in the face of evidence that this science produces substantial amounts of knowledge benefiting both the natural world and society. Current policies severely infringe on the rights of the researchers, educators, and students who use specimens in their work. It is sadly ironic that wildlife management institutions are actively thwarting the accumulation of knowledge that will enable comprehensive wildlife management and conservation schemes. These agencies need to understand the contributions of specimen-based science, the value of the comparative method, and that "Observation in biology has probably produced more insights than all experiments combined" (Mayr 1982:32).

Many people opposed to collecting fall into the trap of typological thinking, an anathema to modern biological science (Mayr 1969, 1982). Agencies issuing permits that allow "2 birds per species up to 50 birds," or scientists taking only blood or tissue samples to compare subspecies (or species) seem to be blissfully ignorant of the variation that collections seek to document. Two birds per species are useless for most studies, and subspecies (and species) descriptions were often based on a few widely scattered specimens. Studies of more specimens from other areas frequently change the validity of taxa and also may change our concepts of species and subspecies relationships. Together with typological thinking often comes the unspoken idea that avian diversity and distribution are static biological phenomena—that range shifts, clines, hybrid zones, and so forth either do not occur or are well known. This could not be farther from the truth (Phillips 1986, 1991; Zink & Remsen 1986; Grant & Grant 1992). Verification of nomenclatural status, understanding the variability within a taxon, and documentation of hybrid zones and range shifts require the preservation of a number of traditional specimens. Field researchers should be encouraged to sample broadly, because few areas are adequately sampled and temporally adequate samples essentially do not exist.

Opposition to collecting on moral grounds should be treated as a religious view: a view to be respected but not to be imposed upon others. Taking up the moral banner against scientific collecting of birds, which makes such an insignificant contribution to avian mortality (King & Bock 1978; Banks 1979), seems hypocritical

in a society (the U.S.) where 7 billion animals are slaughtered for human consumption each year (Washington Post, 13 Aug 1994:A9), and where the number of birds of all species added to North American collections during the past *century* is far less than the number of mallards (*Anas platyrhynchos*) or mourning doves (*Zenaida macroura*) shot in a single hunting season (King & Bock 1978; Banks 1979). The burden is on anticollecting zealots to propose functional alternatives. So far we know of none (Stiles 1983; Diamond 1987; Winker et al. 1991; Remsen 1995).

Those advocating nondestructive sampling and the preservation of blood or tissue samples instead of traditional voucher specimens are misled. A voucher is a specimen that can be compared by present and future researchers with other such specimens to determine identity, similarities, and dissimilarities. Because ornithology has a skin-based taxonomy, the preservation of skins as vouchers is mandatory—and is simply good field science. Responsible collectors will also preserve skeleton, stomach contents, and tissue samples. These materials are needed by other researchers and maximize the usefulness of each collected individual.

Although molecular studies offer powerful tools for helping us understand avian diversity and evolution, they are at their strongest (in this context) when used together with phenotypic evidence (Zink 1986; Mayr 1989; Rising & Avise 1993; Parsons et al. 1993). Molecules give added scope, but will never serve as a replacement for a taxonomy based on two centuries of careful examination of phenotypes. It is far better to use both phenotype and genotype to resolve questions of diversity. Advocating or practicing an approach that neglects proper voucher specimens is sloppy science, and misguided practitioners have been roundly and deservedly criticized (LeCroy & Vuilleumier 1992; Peterson & Lanyon 1992; Banks et al. 1993). It is not acceptable to preserve blood and tissues in place of a complete specimen unless the latter is either impossible or unwise for biological reasons. For example, endangered and threatened taxa should be collected only when justifiable and when collection is unlikely to have lasting effects on already low population sizes. Because all individuals eventually die, every effort should be made to salvage dead birds from these populations and deposit them in systematics collections.

The problem exemplified in Fig. 1 has been growing steadily, and the solution(s) will not be simple. Permit bureaucracy has taken on a life of its own, largely free of an understanding of either biology or scientific inquiry. This must be rectified; current permit restrictions are so biologically and scientifically absurd as to be indefensible. Our science has also changed. Necessary specialization in avian research means that fewer researchers can afford the time to make broad collections but must instead focus on one or a few taxa. Curators are like other investigators, but with the added task of maintaining the usefulness of a collection. In the struggle to be competitive in grant proposals and research, maintaining collection growth (thus keeping it at its most useful) takes a lower priority. It is unrealistic to expect otherwise, and we cannot continue to allow a relative few to bear the responsibility of maintaining the usefulness of something of such value.

Recognizing that the touchstone of avian diversity is both incomplete and crumbling is a first step. The next step is to renew collecting activities to prevent this touchstone from reaching doddering old age and becoming totally disconnected from the present. This is a large task, one requiring broad support. Field researchers, granting institutions, and permit-granting agencies should recognize the importance of collecting representative examples of the world's avifauna and should contribute to the effort by collecting specimens, granting funds, and lending governmental support, respectively. The benefits derived from avian collections are extensive, and it is not too much to expect that return contributions should reflect this breadth. Currently, they do not.

Acknowledgments

For collection data, I thank the curators and staff of the U.S. National Museum of Natural History, the Field Museum of Natural History, and the Academy of Natural Sciences of Philadelphia. R. C. Banks, F. B. Gill, G. R. Graves, S. M. Lanyon, E. Mayr, K. C. Parkes, J. V. Remsen, Jr., S. A. Rohwer, and an anonymous reviewer gave helpful comments.

Literature Cited

American Ornithologists' Union. 1957. Check-list of North American birds. 5th edition. Lord Baltimore Press, Baltimore, Maryland.

American Ornithologists' Union. 1983. Check-list of North American birds, 6th edition. Allen Press, Lawrence, Kansas.

Banks, R. C. 1979. Human related mortality of birds in the United States. Special scientific report—wildlife no. 215. U.S. Fish and Wildlife Service, Washington, D.C.

Banks, R. C., S. M. Goodman, S. M. Lanyon, and T. S. Schulenberg. 1993. Type specimens and basic principles of avian taxonomy. Auk **110**:413–414.

Brooks, D. R., R. L. Mayden, and D. A. McLennan. 1992. Phylogeny and biodiversity: conserving our evolutionary legacy. Trends in Ecology and Evolution **7**:55–59.

Cory, C. B., C. E. Hellmayr, and H. B. Conover. 1918–1949. Catalogue of birds of the Americas. Chicago Field Museum Zoological Series 13, parts I-XI.

Darwin, C. 1871. The descent of man and selection in relation to sex. Murray, London.

Diamond, J. M. 1987. Justifiable killing of birds? Nature **330**:423.

Dumbacher, J. P., B. M. Beehler, T. F. Spande, H. M. Garraffo, and J. W. Daly. 1992. Homobatrachotoxin in the genus *Pitohui*: chemical defense in birds? Science **258**:799–801.

Friedmann, H., L. Griscom, and R. T. Moore. 1950. Distributional check-list of the birds of Mexico. Part I. Pacific Coast Avifauna **29**:1–202.

Goodman, S. M., and S. M. Lanyon. 1994. Scientific collecting. Conservation Biology **8:**314–315.

Grant, P. R., and B. R. Grant. 1992. Hybridization of bird species. Science **256:**193–197.

Graves, G. R. 1991. Bergmann's rule near the equator: latitudinal clines in body size of an Andean passerine bird. Proceedings of the National Academy of Sciences **88:**2322–2325.

Hann, H. W. 1948. Longevity of the Ovenbird. Bird-Banding **19:**5–12.

International Council for Bird Preservation. 1992. Putting biodiversity on the map. Cambridge, United Kingdom.

Karr, J. R., J. D. Nichols, M. K. Klimkiewicz, and J. D. Brawn. 1990. Survival rates of birds of tropical and temperate forests: will the dogma survive? American Naturalist **136:**277–291.

King, J. R., and W. J. Bock. 1978. Workshop on a plan for ornithology. Final report. National Science Foundation and American Ornithologists' Union, Washington, D.C.

LeCroy, M., and F. Vuilleumier. 1992. Guidelines for the description of new species in ornithology. Bulletin of the British Ornithological Club Centenary (Suppl.) **112A:**191–198.

Mayfield, H. 1960. The Kirtland's Warbler. Cranbrook Institute of Science, Cranbrook, Michigan.

Mayr, E. 1942. Systematics and the origin of species. Columbia University Press, New York.

Mayr, E. 1969. Introduction: the role of systematics in biology. Pages 4–15 in Systematic biology. Publication no. 1692. National Academy of Sciences-National Research Council, Washington, D.C.

Mayr, E. 1982. The growth of biological thought. Harvard University Press, Cambridge, Massachusetts.

Mayr, E. 1988. The contributions of birds to evolutionary theory. Acta Congressus Internationalis Ornithologici **19:**2718–2723.

Mayr, E. 1989. A new classification of the living birds of the world. Auk **106:**508–512.

Miller, A. H., H. Friedmann, L. Griscom, and R. T. Moore. 1957. Distributional check-list of the birds of Mexico. Part II. Pacific Coast Avifauna **33:**1–436.

Nolan, V., Jr. 1978. The ecology and behavior of the Prairie Warbler *Dendroica discolor*. Ornithological Monographs **26:**1–595.

Parkes, K. C. 1963. The contribution of museum collections to knowledge of the living bird. Living Bird **2:**121–130.

Parsons, T. J., S. L. Olson, and M. J. Braun. 1993. Unidirectional spread of secondary sexual plumage traits across an avian hybrid zone. Science **260:**1643–1646.

Peters, J. L., et al. 1931–1986. Check-list of birds of the world, vols. I-XVI. Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts.

Peterson, A. T., and S. M. Lanyon. 1992. New bird species, DNA studies and type specimens. Trends in Ecology and Evolution **7:**167–168.

Phillips, A. R. 1986. Known birds of North and Middle America, part I. Published by the author, Denver, Colorado.

Phillips, A. R. 1991. Known birds of North and Middle America, part II. Published by the author, Denver, Colorado.

Remsen, J. V., Jr. 1984. High incidence of "leapfrog" pattern of geographic variation in Andean birds: implications for the speciation process. Science **224:**171–173.

Remsen, J. V., Jr. 1995. The importance of continued collecting of bird specimens to ornithology and bird conservation. Bird Conservation International **5:**177–212.

Ridgway, R., and H. Friedmann, 1901–1950. The birds of North and Middle America. U.S. National Museum. Bulletin 50, parts 1–11.

Rising, J. D., and J. C. Avise. 1993. Application of genealogical-concordance principles to the taxonomy and evolutionary history of the Sharp-tailed Sparrow (*Ammodramus caudacutus*). Auk **110:**844–856.

Roberts, J. O. L. 1971. Survival among some North American wood warblers. Bird-Banding **42:**165–184.

Sibley, C. G., and B. L. Monroe, Jr. 1990. Distribution and taxonomy of birds of the world. Yale University Press, New Haven, Connecticut.

Stiles, F. G. 1983. On sightings and specimens. Auk **100:**225–226.

Systematics Agenda 2000. 1994. Charting the biosphere: technical report. Systematics Agenda 2000, New York.

Winker, K., B. A. Fall, J. T. Klicka, D. F. Parmelee, and H. B. Tordoff. 1991. The importance of avian collections and the need for continued collecting. Loon **64:**238–246.

Zink, R. M. 1986. Patterns and evolutionary significance of geographic variation in the Schistacea group of the Fox Sparrow (*Passerella iliaca*). Ornithological Monographs **40:**1–119.

Zink, R. M., and J. V. Remsen, Jr. 1986. Evolutionary processes and patterns of geographic variation in birds. Current Ornithology **4:**1–69.