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VALUE AND POTENTIAL OF THE COLLECTION RESOURCE

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Abstract.—The systematic collections of mammals of the world constitute a vital, nonrenewable resource. Historically, the value of these collections has spanned a broad range of disciplines from paleontology and archaeology to ecology and systematics. Libraries whose volumes cannot be replaced, these collections have been extremely important in the development of many areas of science and play an increasingly important role with the passing of time.

The last decade has witnessed major changes in the value and future of systematic collections of mammals. The impact of an increasing human population on the habitats of the world has greatly increased the importance and value of these collections and yet most remain seriously underfunded. In addition, several trends have become evident. For example, the growth rate of collections in North America has slowed considerably in the last decade. At the same time, utility and scope has been increased. The advent of computerization has greatly increased data retrieval. Also, many collections have begun routinely to preserve additional material for each specimen such as postcranial skeletons, chromosomes, material for DNA analyses, and frozen tissues for electrophoretic and other types of studies. These trends are expected to continue in the future.

The collections of mammals throughout the world represent a nonrenewable resource, the full potential value of which is yet to be realized. The nature and value of systematic collections is often poorly understood by the general public and other professionals alike. Although much of the problem lies with a failure of the collections community to properly educate the public, the problem is basically conceptual in nature. Many collections are part of a formal museum structure. Many individuals think of museums as mothball-laden basements where materials are stored until they can be placed on exhibit. Although many museums housing mammal collections do have important exhibit functions in which research collections and the expertise associated with them play important roles, this generally represents only a small fraction of the total value of these collections. A more accurate analogy with research collections would not be museums but libraries, except that most volumes contained in research collections of mammals cannot be replaced.

Specimens contained in these repositories have been and are being generated from a variety of sources, such as taxonomy, basic research, and applied projects. Regardless of the initial reason for the collection, once properly prepared, documented, and deposited in a research collection, the value of these specimens greatly increases. These same specimens are used in other research projects and for educational purposes, and continue to hold the potential to expand our understanding of the world around us.

Currently, collections throughout the world contain in excess of 5,500,000 specimens (Yates *et al.*, 1987; Genoways and Schlitter, 1981). Of these, 3,138,690 are contained in collections in North America (Yates *et al.*, 1987). Many specimens represent historical collections, which can never be replaced. With the heavy impact of an increasing human population on the habitats of the world, the value of these collections is increasing annually. The immediate goal is to call attention to the value of this world resource, to discuss the future of these collections, and to make recommendations for their future preservation, utility, and growth. Although focusing on collections of mammals, many of the points to be discussed will apply also to collections of other Recent organisms as well as to fossils.

Value of Collections

The monetary value of the specimens contained in these collections is difficult to ascertain. As previously noted, most cannot be replaced. One average estimate (Lee *et al.*, 1982) of cost per specimen from field collection to incorporation in a research collection (with some overhead) is 43 U.S. dollars. Using this estimate, the monetary value of the 5.5 million specimens of Recent mammals in the collections of the world is calculated to be $236 million U.S. dollars. This figure does not include the tens of thousands of man hours that have gone into maintenance of collections or the cost of storage cases, fumigants, and other curatorial supplies.

The cost in lost information to the people of the world if these holdings are allowed to deteriorate cannot be measured. What would be the cost to mankind if information contained in our libraries were lost? It is possible, however, to better define what these specimens represent and what their current value is in terms of uses and information content. What their future value will be depends on how well they are maintained.

The majority of specimens contained in the world's repositories are voucher specimens. Lee *et al.* (1982) define a mammalian voucher specimen as "one which serves to physically and permanently document data in an archival report by 1) verifying the identity of the organism(s) used in the study, 2) by so doing, assuring repeatability of the study which otherwise could not be repeated and/or accurately reviewed or reassessed." Thus, voucher specimens are the sole means of verifying the data documented in a report and making historical comparisons (Lee, *et al.*, 1982). Numerous authors (Carriker, 1976; Hedgpeth, 1961; Heppell, 1979; Lee *et al.*, 1978) have noted the importance of accurate identification of organisms under investigation and that such identification is the first step in communicating the results of all reports involving biological entities. Voucher specimens insure that identifications can be verified or changed if necessary and allow historical comparisons to be made by workers in the future. These specimens are critical for a variety of future studies ranging from the environmental impact of human activities to historical biogeography and population genetics. It is essential that the value of systematic collections be

recognized and that ample funding be made available to insure their future maintenance at a level that will maximize their utility for the user community. The cost of maintenance is insignificant compared with the cost of the loss of information that will occur if these holdings are neglected.

Uses for Collections

The future uses of the enormous database contained in the collections of the world are more extensive than even mammalogists may realize. A clearer understanding, however, can be obtained by a closer examination of historical and current uses of these collections.

Historically, many of the specimens in Recent mammal collections have been collected in connection with taxonomic studies. A necessary first step to understanding the biology of any region is a descriptive phase in which organisms are described and classified. In this important function, collections have played and continue to play a primary role. Such research not only documents the existence of new forms of life, but also provides information on where these organisms occur, habitat requirements and other aspects of their biology. Voucher specimens aid other workers in identifying their own research organisms and make studies of faunal change in the same region possible. Once appropriate series of specimens have been collected, classified, and properly accessioned into collections, they form the foundation on which other studies can build. Without this basic information much other research involving the organisms must be viewed with considerable skepticism.

Research collections also play a crucial role in systematics. Often equated with taxonomy in the past, modern usage incorporates a broader spectrum of biological research. Some authors (Mayr, 1969; Nelson, 1970) consider systematics to be synonymous with comparative biology, while Wiley (1981) defines it as "the study of organismic diversity as that diversity is relevant to some specific kind of relationship thought to exist among populations, species, or higher taxa." Systematics thus involves comparative biology and is concerned with both pattern and process.

Taxonomy is thus a subset of systematics, as are studies of speciation, phylogeny, and biogeography, to name a few. The science has experienced considerable growth and theoretical advancement during the past 20 years, aided to a large extent by the research resources available in the world's collections. Most scientific publications involving mammalian distribution, phylogeny, speciation, historical biogeography, taxonomy, and other comparative studies would not have been possible without the availability of collections of mammals. Likewise, without the resulting knowledge of the basic systematics of these mammals, research in other areas of science, such as ethology, genetics, population biology, and ecology, would have been more difficult.

The value of research collections is by no means limited, however, to taxonomy and systematics. During the past few decades, they have become more and more important to a variety of other disciplines spanning many areas of both basic and applied science. Paleontologists and archaeologists, both traditional users of mammal collections, have begun to depend on these collections with increasing frequency over the past 20 years for comparisons with fossil and historic remains. Much of the increase results from requirements for assessments of the environmental impact of land development. These assessments include archaeological and paleontological surveys. One result has been the increase in maintenance of postcranial skeletons by holders of mammal collections to increase the utility of specimens for this clientele. Correct identification, especially of prehistoric mammals, would be difficult without collections of mammals.

Collections have proven to be extremely valuable in basic and applied research in ecology. Series of mammals collected from an area prior to human disturbance have provided some of the best data on the extent of man's impact on the environment. By comparing later samples with these historical series it has often been possible to detect changes in levels of environmental pollutants such as some heavy metals and organopesticides. Systematic collections have also proven useful in various environmental impact studies by aiding in identification, by providing information on species formerly present in a study area, and, in some cases, by providing fairly complete Recent faunal lists.

Collections are also being used in basic ecological research. For example, Findley and Wilson (1982), Gatz (1979), Karr and James (1975), Ricklefs *et al.* (1981), Smartt (1978), and Smartt and Lemen (1980), working in community ecology, have been using morphological data from specimens to investigate whether communities are structured or are random assemblages of species. Morphological data from specimens in systematic collections have been used to test such hypotheses as morphological character displacement. These studies likely would not have been undertaken without the availability of specimens held in collections.

Many reproductive studies on mammals have been conducted using data from specimen labels and from dissection of fluid-preserved specimens. Parasitologists have found it possible to extract parasites from museum specimens. Hundreds of anatomical studies have utilized both the hard and soft anatomy of museum specimens. It now appears that antibodies against certain proteins can be generated from museum study skins (Sarich, personal communication) for use in immunological research.

In addition to the obvious anatomical uses for specimens, medical researchers around the world are finding collections important for identifying wild mammals suspected of being reservoirs of disease. Examples include research on Chagas disease and Leichmaniasis. Correct identification is crucial in these cases and can only be resolved by reference to museum series.

Those wildlife management agencies taking responsibility for nongame, as well as game, species have created an increasing demand for information in museums. Types of studies in which these organizations have an interest include morphological analyses of geographic variation for management purposes, comparisons of variability in different populations prior to transplant operations, and generation of faunal lists prior to land acquisitions.

The value of systematic collections in education is considerable. In addition to their use in courses in mammalogy, systematics, taxonomy, and museum science, they are used for courses in general biology, comparative anatomy, vertebrate zoology, ecology, biometry, paleontology, anthropology, wildlife management, field biology, and numerous medical and dental courses. They also supply materials for exhibits, public demonstrations, and less traditional courses such as photography and art. Many people owe their knowledge of mammals and appreciation of nature to mammal collections. The above discussion is not exhaustive but does call attention to the extreme value of systematic collections of mammals to the people of the world. Not discussed here is the value of many of the newer ancillary collections associated with the more traditional systematic collections. These include frozen tissue collections, collections of karyotypes, and other genetic materials, and will be discussed in the next section.

Future Trends

The last decade has witnessed major changes in the value and future of systematic collections. A major factor in these changes, which will affect collections in the future, is the impact of an increasing human population on the habitats of the world. During this century, many mammalian species have become extinct or endangered, and numerous others are threatened. Specimens of these species currently held in museums may represent all that will be available for study, and thus will be irreplaceable resources. Many of the areas being maximally impacted are those most poorly represented in collections and about whose mammalian faunas we know the least. Of these areas, none are more seriously threatened than the rain forests of the world. Estimates of the rate of destruction vary but most authorities predict that 20 percent or more of what currently remains will be destroyed by the year 2000. Substantial future research efforts need to be concentrated in these areas. Research in these places is already severely hampered by the lack of preserved specimens in collections and the corresponding lack of basic data on the mammalian faunas there. As a result, conservation efforts, comparative biological studies, and even many types of medical research in these places are difficult if not impossible.

A number of current trends promise to have major effects on the future of collections. At least in North America, the rate of collection growth has slowed considerably over the past decade while the amount of data being preserved per specimen has increased (Yates *et al.*, 1987). As the value of

collections has increased, user demands have increased, and demands on curators, especially those in charge of university collections, to spend more time at functions other than curating have intensified. To anticipate future trends it is useful to discuss each of these points, and to consider potential courses of action.

Even though the rate of growth of many collections appears to have slowed, the addition of many new ancillary collections has created additional problems. The trend of more data per specimen is expected to increase in the future. It is common for specimens arriving at many museums to be accompanied by a full skeleton, chromosome slides, a frozen cell suspension, and frozen tissues for electrophoretic and DNA analyses. Such additions substantially increase the curatorial work load but at the same time greatly increase the potential value of each specimen. Like more traditional voucher specimens, the value of these multiple preparations is dependent on accurate and easily retrieved data. They must be properly stored, arranged according to a specific plan, and handled much like other specimens. Suggestions for proper handling, storage and maintenance of frozen tissues are provided by Dessauer and Hafner (1984).

Another trend which will intensify in the future is the use of computers in collection management. Electronic data processing greatly facilitates information retrieval and other curatorial functions, eventually saving time and money. Microcomputers will probably be preferred by most curators over mainframes.

Finally, difficulties in obtaining collecting permits and public opinion against collecting will probably increase in the future. It will be more important than ever to educate the public as well as much of the scientific community in the value of collections. It is important that the need for these collections be clearly understood.

Some may be concerned that the number of specimens in collections is too large. However, "too large" must not be judged against some external standard, it must be judged in context. One relevant context using ecological data was proposed by Yates *et al.* (1987). Using *Peromyscus maniculatus* as the model animal in North American collections, they estimated the environmental impact of collecting from the standpoint of the secondary consumers. Assuming that a large owl or fox eats an average of 10 mice per day, and depreciating their biomass calculations for the 3 million specimens in North American collections over a 25-year period, they found that the annual "catch" of mice represented by these collections had the environmental impact of about 32.9 large owls or foxes. Although from the curatorial point of view the collections of mammals are large enough to provide problems in management and data processing, from an ecological viewpoint they are not very important.

Summary and Recommendations

The full value of systematic collections has yet to be realized. The important taxonomic and systematic research made possible by collections represents only one component of the potential value. Actualization of this potential will depend on high levels of standards and maintenance, and education of the general public and much of the scientific community in the importance and value of these research resources. As collections increase in breadth, size, and accessibility, demands placed on the curatorial staff increase proportionately. Increased value and usage, however, do not necessarily translate into increased funding. The difficulty of attaining high levels of support for collections will be greater than ever. There is a need for well-defined standards and policies, and for free exchange of information.

Much might be gained by developing a means to further international cooperation in solving the common problems facing the research collections of the world. One effort that has proven effective for North American collections has been the establishment by the American Society of Mammalogists of a committee on systematic collections. The committee was charged with helping systematic collections of mammals in any way possible, developing a set of minimal standards and identifying those collections that met them, helping collections that did not meet them, and offering suggestions, through outside reviews, for ways to improve all collections. The committee has been extremely effective and currently accredits collections throughout North America. The minimal standards were published in the *Journal of Mammalogy* (1978, 59:911-914) and are as follows:

(1) Collections should be administered by non-profit public or private institutions unless an individual or profit-making organization is willing to establish a perpetual trust returning a reasonable per-specimen, per-year maintenance cost for the collection.

(2) A collection must have at least one professional mammalogist who is directly responsible for it.

(3) Collections must be housed in buildings that provide adequate protection from fire, water, dust, excessive heat or light, and other physical hazards. We recommend that important permanent records (such as catalogues and field notes) be kept in a fireproof or fire-retardant safe or its equivalent.

(4) Specimens must be stored in insect, dust, and light proof containers.

(5) Specimens must be periodically inspected and fumigated in accordance with federal regulations which stipulate the kinds of fumigants that can be used for this purpose (Williams *et al.*, 1977).

(6) Specimens must be prepared in a manner that insures their utility. It is particularly critical that osteological materials be properly prepared. The use of dermestid beetles and their larvae in cleaning small skulls and other osteological materials is strongly recommended but dermestid colonies should be located so to prevent infestation of the collection proper.

(7) Specimens must be arranged according to a specific plan that is recorded and, preferably, posted.

(8) Field notes and ancillary data must be preserved as a part of the permanent record for each specimen.

(9) Data on specimen labels, in field notes, in the permanent catalogues, and wherever else data are recorded in the collection must be accurate.

(10) A permanent catalogue of all specimens in the collection must be maintained. The catalogue must include at least the minimal data recommended by the American Society of Mammalogists' Committee on Information Retrieval: catalogue number; genus; species; sex; country, continent, or ocean of capture; state or province of capture; method of preparation; date of capture. Implementation of electronic data processing techniques to facilitate management of specimens and data is recommended. Also, it is recommended that collections maintain catalogues of individual accessions, in addition to those of individual specimens, so to facilitate keeping records of collecting permits, field notes, and other information ancillary to the specimens.

(11) The collection must be accessible to all qualified users.

(12) Accessibility to collections by unqualified persons must be restricted. We recommend the formation of separate teaching collections for use in basic courses, and the restriction of catalogued specimens for research purposes.

(13) Loans with other institutions must be handled in a professional manner. Specimens sent on loan should be properly packaged in accordance with federal regulations (Williams *et al.*, 1977).

(14) Type specimens must be identified as such, stored in cases marked accordingly, and made accessible to qualified scientists. They should not be sent on loan. Type specimens should be deposited only in institutions wherein the specimens will receive the perpetual care they require.

(15) Evidence should be furnished that the institution intends to continue support of the collection at least at a level necessary to maintain these standards. Should institutional priorities be changed at some future time, the institution should express a willingness to transfer the collection to another public institution which will insure its perpetual maintenance.

(16) Acquisition and possession of specimens of mammals must accord with federal and state regulations pertaining thereto. Assurance of adherance to such regulations will be sought when a collection is considered for inclusion on the list of collections that meet minimal standards.

(17) The status of a collection may be reviewed at any time at the request of the institution or the discretion of the ASM Committee on Systematic Collections. Curators should strive to cooperate in the review process.

These standards could serve as guidelines for collections worldwide. The need for a similar international organization has never been greater. The newly formed International Commission for Mammalogical Collections (see page 209) may well be able to serve this need and should be encouraged to proceed as soon as possible.

Problems that require immediate attention are numerous. In addition to those mentioned above, issues that need to be addressed are saving curatorless collections, promoting a better international exchange of specimens, strengthening databases in poorly represented areas of the world, promoting a better awareness of the value of these resources worldwide, determining what guidelines should be established for better maintenance and information retrieval for ancillary collections such as frozen tissue, and enhancing our ability to meet the ever-changing needs of the user community.

Few scientific databases have remained as consistantly valuable and yet have been taken as much for granted as research collections. With international cooperation and timely action, we can see that these resources will continue to increase in value and utility for future generations.

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