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OPINION[1]

Wildlife biologists are on the right track: A mammalogist's view of specimen collection

> *"At this point I wish to emphasize what I believe will ultimately prove to be the greatest value of our museum. This value will not, however, be realized until the lapse of many years, possibly a century, assuming that our material is safely preserved. And this is that the student of the future will have access to the original record of faunal conditions in California and the west, wherever we now work."*
>
> Joseph Grinnell (1910)

> *"Another important issue worldwide is the power and mindset of the animal-rightist movement. These people try to confuse legitimate animal welfare issues with their concepts of animal rights and don't understand that there is no morality in nature; the morality is a human construct."*
>
> Alfred Gardner (2005)

Cataloging life on Earth is the primary task of wildlife biologists and taxonomists (Mayr 1942). Specimens are the most fundamental record of a species' existence and occurrence, and biological collections are the appropriate place to store those vouchers. Collections in their broader definitions are currently held by natural history museums, herbaria, botanical gardens, zoos, and other science centers, with their roots in the 17th century's curiosity cabinets. Since then, scientific and cultural paradigms have evolved together, and the science of natural history is no exception. Systematists, today, work hard to incorporate the cutting edge of science and technology in their disciplines.

Pleas against collecting specimens as vouchers during scientific studies naturally arise during field courses (and they are all welcomed), but I cringe whenever I hear a researcher (often an ecologist or non-systematist) advocating the benefits of alternative methods over the practice of collecting specimens. Minter *et al.* (2014) recently raised some of those arguments, defending the use of alternative methods (e.g., photographs, audio records, and non-lethal tissue sampling for DNA analyses) for species description and documentation. According to them, wildlife biologists, including taxonomists engaged in field research, insist on collecting vouchers mostly for tradition because "a preserved specimen in a natural history collection is the gold standard—or only standard—for publishing a species description or documenting a species' presence." They claim that collecting vouchers from small and isolated populations may increase extinction risks, and they blame naturalists and wildlife biologists for a few episodes of species extinctions in the past 150 years.

Minter *et al.*'s (2014) arguments were promptly rejected by Rocha *et al.* (2014). But I can confidently say that those misconceptions, in the general discussion of collecting specimens, are deeply rooted in the discourse of some Brazilian professionals of different biological science disciplines (including zoologists and ecologists). For almost two decades, during meetings of Brazilian zoological societies and in small group workshops, I have repetitively heard apologists of the alternative methods advocating the usage of those methods over collecting vouchers, based either on the same Minter *et al.*'s rationale or from an "animal rights" perspective. The last time I heard someone arguing against vouchers was during a 2011 small-group workshop to define guidelines for field research with vertebrates. This workshop was organized and sponsored by the Brazilian Federal Council of Biology (Conselho Federal de Biologia), and the presence of those advocates of alternative methods reflects the power of their voices in the community of Brazilian zoologists. Those professionals continue campaigning against the practice of collecting specimens, sometimes labeling wildlife biologists (including taxonomists) as negligent collectors—a label that has been applied to me more than once by "colleagues."

Wildlife biologists do not collect vouchers because of tradition; we do it because we are scientists, and in science the question drives the method. Biological surveys, species descriptions, and rediscoveries are only a few of the investigations that require vouchers as the primary verifiable and testable evidence of such efforts. There are many other scientific questions in the fields of ecology, evolution, animal and human health, physiology, morphology etc. that cannot be correctly assessed unless specimens are collected. Nevertheless, we recognize that some taxa are more sensitive to collecting than others, and we have developed non-lethal methods to study those groups. Also, protocols for most of the field research that has been done in recent decades have been previously approved

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[1] The articles in the section OPINION are of sole responsibility of the authors and do not necessarily reflect the views of the editorial board.

by regulatory agencies and institutional animal care and use committees before the studies were begun. Those regulations have been developed to avoid over-collecting and possible misconduct of scientists, and they have the endorsement of the scientific community engaged in field research.

As an example from my field of expertise (mammalogy), the default permission for mammal surveys include only small rodents, marsupials, and bats, excluding species classified as threatened at any level, primates as a group, and large mammals. Although both small and large mammals still have taxonomic problems, mammalogists agree that most large mammals exist at low densities with slow reproductive rates. Due to the fragmentation and reduction of their natural habitats, those characteristics make them potentially more sensitive to collecting, and alternative non-lethal methods have been developed and applied to survey and improve the resolution of their taxonomy. On the other hand, most small mammals are difficult to identify even using cutting edge techniques in molecular biology (see Bradley & Baker 2001, Baker & Bradley 2006, Dávalos & Russell 2014). In the case of large mammals, the scientific community accepts a lower taxonomic resolution (due to the low representation of specimens in collections) to maintain populations as large as possible. On the other hand, for the smaller mammals—usually much more abundant and with higher reproductive rates than larger mammals—vouchers are "the gold standard" but not because of tradition (as supposed by Minter *et al.* [2014]); they deserve this label because they are the testable evidence of the species existence and occurrence. For these animals, morphological and molecular comparisons are the best approach to achieve accurate identifications and delimit species boundaries.

Vouchers are also essential in the description of new taxa. In these cases, the ICZN (1999) requires the explicit fixation of a holotype or syntypes, and in the cases where these types are extant specimens, the description must be accompanied by a statement of intent that they will be (or are) deposited in a collection (ICZN 1999, Art. 16.4). In small and very well monitored areas, or in a zoological park, we can assume that an individual will be quickly found and prepared in a reasonable time after death, and deposited in a collection; but in all other circumstances (which include the majority) it is impossible to affirm that the individual will be located after death for preparation as a voucher.

Biological collections must be treated as national treasures. They are research resources that document past research and have great potential for future work, a potential that goes beyond the original goals of collectors (Banks 1979, Rocha *et al.* 2014). Through new perspectives and techniques it is possible to recover ecological information from specimens decades or even centuries after they were collected. Their temporal and spatial coverage cannot be achieved from fieldwork, and open windows to the past and future. This information can be used to understand changes in the climate, land-scape etc., and to predict responses of populations in the future. As an example, researchers from the Museum of Vertebrate Zoology (University of California, Berkeley) have used historic (1900–1940) and current (1980–2005) collections from 80 high-elevation sites in California to understand how climate changes over the last 100 years have affected bird and mammal species' distributions and diversity. Their findings have been applied in models to predict effects of global warming on populations (see Moritz *et al.* 2008, Parra & Monahan 2008, Tingley & Beissinger 2009, Tingley *et al.* 2009, Rubidge *et al.* 2011, 2012, Yang *et al.* 2011, Eastman *et al.* 2012). Using museum specimens, Yom-Tov and colleagues have investigated temporal changes in the body weight and body and skull sizes of Japanese rodents (Yom-Tov & Yom-Tov 2004), carnivores (Yom-Tov 2003, Yom-Tov *et al.* 2003), and passerine birds (Yom-Tov 2001, Yom-Tov *et al.* 2006). Their findings have contributed to understand the myriad effects of human-induced climate change and habitat modification on terrestrial vertebrates.

Vouchers in collections are also indispensable in wildlife conservation and management, although often overlooked by researchers in these disciplines. Banks (1979) provided examples of museum studies with practical applications to problems involving endangered and exotic species, faunal surveys, environmental assessments, and regulation and protection of wildlife resources. More recently, Miller & Waits (2003) used microsatellite DNA obtained from 110 museum specimens of grizzly bears—*Ursus arctos* Linnaeus, 1758 (Carnivora: Ursidae)—collected between 1912 and 1981, to compare the genetic variability of the isolated population in the Yellowstone National Park with populations from other localities. They observed a slight decline in the genetic diversity of the Yellowstone population, but less severe than previously hypothesized. They concluded that genetic loss will not compromise Yellowstone grizzly bears in the near future, but call attention to the potential effects of inbreeding and isolation. Also, using ancient DNA extracted from museum koalas—*Phascolarctos cinereus* (Goldfuss, 1817) (Diprotodontia: Phascolarctidae)—collected in the 19th and 20th centuries, Tsangaras *et al.* (2012) investigated the effects of the recent koala population decline on its genetic variability. They found that mtDNA haplotypes in historical and modern koala populations are identical, which suggests that the koala population decline is not the reason for the low mtDNA diversity. Those skins were also the source to investigate the evolution of the koala retrovirus among koala populations (Ávila-Arcos *et al.* 2012). Results indicate that koalas have experienced increased susceptibility to diseases. Their findings have potential implications in the species survival. Finally, studying East African herbivore and plant tissues collected between 1905 and 2008, Uno *et al.* (2013) have developed a forensic technique to combat the illegal trade of animal parts.

Collections also have been used in investigations of infectious diseases that compromise human and animal health. Pinto *et al.* (2010) used DNA extracted from tissue samples of the woodrat *Neotoma micropus* Bair, 1855 (Rodentia: Cricetidae), collected some years before in southern Texas, to investigate the presence and prevalence of the etiological agent of Chagas disease, *Trypanosoma cruzi* Chagas, 1909 (Trypanosomatidae). Their findings show *N. micropus* as a potentially important reservoir of this disease, revealing prevalence higher than the observed in studies using other diagnostic methods. In another example, when an unknown pulmonary syndrome killed 10 people in less than two months (70% mortality) in Southwestern United States, researchers from different disciplines combined efforts to identify the agent, causes and dynamics of the outbreak. In a few weeks, the Centers for Disease Control and Prevention (CDC) identified the agent as a previously unknown *Hantavirus* (Bunyaviridae), named Sin Nombre virus ([SNV] Nichol *et al.* 1993). With rodents known as reservoirs of hantiviruses, scientists focused their efforts on intensively sampling local terrestrial small mammals. The deer mouse, *Peromyscus maniculatus* (Wagner, 1845) (Rodentia: Cricetidae), was promptly identified as the reservoir; and bioterrorism and accidental release of a military biowarfare agent were among the speculative outbreak causes (see Horgan 1993, Yates *et al.* 2002). To understand the phenomenon and whether the virus was historically present in the deer mouse local population before 1993, scientists analyzed blood samples from 740 cryogenically preserved *P. maniculatus* from different localities in North America. Antibody detection (13%) dated back to 1979, and genomic RNA extracted from frozen hearts and lung tissues confirmed the presence of the strain in deer mouse populations before 1993. Retrospective analyses using blood from cryogenically preserved heart muscles revealed a 100,000-hectare expansion in the SNV from 1989 to 1991. This data crossed with archived human medical records dating back to 1970, and preserved tissues from patients with similar symptoms of hantavirus pulmonary syndrome (HPS) confirmed its sporadic occurrence before 1993. But if the virus was previously present in North America, why did the 1993 outbreak occur? Field investigations compared the rodent composition and abundances in HPS case localities and nearby control localities. Results revealed an average of 30% of SNV infected rodents in all localities, but with significant higher abundances detected in HPS case localities. Scientists concluded that the greater the number of infected rodents the higher the risk of human hantavirus detection. Ecological analyses revealed the increased precipitation caused by the El Niño of 1992 as the catalyst trophic cascade that resulted in the rodent population increase that resulted in the SNV outbreak (Yates *et al.* 2002). This is one elegant example of how field and museum research can be integrated to solve a problem. Which new directions can we explore integrating fieldwork and museum collections? With new approaches and techniques being quickly developed, I am confident that in the near future collections will be a strong tool to understand the dynamics of some infectious diseases.

These are only some of the reasons we should collect specimens at the same well known localities over a long time; if possible, for more than a century! Based on estimates of population density and demography for one of the most frequent bat species in the Neotropics (*Artibeus jamaicensis* Leach, 1821 [Chiroptera: Phyllostomidae]; see Leigh & Handley 1991, Gardner *et al.* 1991), I can confidently assume that 20–30 individuals collected per year at the same locality do not affect the maintenance of populations of the most common Neotropical bats. This number will be probably reached only for three or four species depending on the locality—e.g., *Artibeus lituratus* (Olfers, 1818) (Phyllostomidae), *A. planirostris* (Spix, 1823) (Phyllostomidae), *Carollia perspicillata* (Linnaeus, 1758) (Phyllostomidae), *Desmodus rotundus* (É. Geoffroy, 1810) (Phyllostomidae), *Platyrrhinus lineatus* (É. Geoffroy, 1810) (Phyllostomidae), *Sturnira lilium* (É. Geoffroy, 1810) (Phyllostomidae), *Myotis nigricans* (Schinz, 1821) (Vespertilionidae), *Molossus molossus* (Pallas, 1766) (Molossidae); and a couple of owls, hawks, or falcons are indisputably more effective than biologists in removing bats from their populations. The same happens with non-volant small mammals pushed to the brink of extinction by domestic or feral cats on islands or along the borders of natural areas (Medina *et al.* 2011, Loss *et al.* 2013). Free-ranging cats have been responsible for 14% of bird, mammal and reptile extinctions on islands (Medina *et al.* 2011). They also kill 1.4–3.7 billion birds and 6.9–20.7 billion mammals annually in the United States alone (Loss *et al.* 2013).

Misconceptions about the behavior of wildlife biologists and taxonomists (and the role of natural history museums) constitute an important step back in decades of hard work to raise awareness about what scientists have contributed to understanding and sustaining life on Earth. This can lead misinformed citizens in general and decision makers in particular to remove vital support that keeps biological collections and field and museum-based research running. Those negative impacts can be magnified in developing countries where the investment in basic research is much more limited.

Minter *et al.*'s (2014) comments stress the risk of extinction by collecting samples from small populations. Of course the risk exists, but in these cases, if collecting a voucher would push the taxon to extinction, then the species or population is already lost. There are several forces that can promote extinction, but only biological collections (in the near future and apart from the ethical discussion) might be capable of promoting de-extinction, bringing extinct species back to life. Biologists must struggle to preserve populations, not individuals, and considering the pros and cons in the game of understanding and sustaining life on Earth, I am certain that wildlife biologists are on the right track in continuing to collect vouchers.

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