Biology & Philosophy (2023) 38:22
https://doi.org/10.1007/s10539-023-09911-3

The epistemological and conservation value of biological specimens

Derek Halm[1]

Received: 3 December 2022 / Accepted: 20 May 2023

Abstract
Natural history specimens were collected for diverse reasons, but modern, and likelyfuture, uses often diverge from why they were collected. For example, specimens aresometimes integrated into conservation decision-making, where some practitionersclaim that specimens may be necessary or extremely important for conservation ingeneral. This is an overstatement. To correct this, I engage with the current literatureon specimen collection to show that while specimens have epistemic shortcomings,they can be useful for conservation projects depending on the questions or values ofscientists and conservation decision-makers. This modest approach acknowledgesthat specimens provide a unique information channel while demarcating where andwhen values intercede into conservation planning. In light of the specimen's utility forfuture, sometimes unknown, projects, I also make recommendations for modernspecimen collection.

Keywords Natural history collection · Conservation · Historical baseline · Biological specimens

Introduction

Natural history collections (NHCs) are repositories of diverse information. One information channel utilized by scientists affiliated with NHCs is collected and preserved biological specimens from the recent past, up to several hundred years ago. These specimens may be complete organisms or consist of plant cuttings, pollen, organs, bones, gut contents, parasites, or even less complete biological material.[1]

[1] This also conceptually includes specimens from small or private collections (Casas-Marce et al. 2012). However, I am primarily concerned with public collections at natural history museums or other research institutions.

Derek Halm
derek.halm@utah.edu

[1] Department of Philosophy, The University of Utah, Carolyn Tanner Irish Humanities BLDG 215 S CentralCampus DR., 4th Floor, Salt Lake City, UT 84112, USA

Published online: 05 June 2023

Specimens were frequently, though not exclusively, collected to understand biological organisms, communities, taxonomy, or speciation, but scientists may use them for a range of inquiries.

For example, Arizona mountain kingsnake specimens (*Lampropeltis pyromelana*) can provide several lines of evidence: that the organisms lived in a specific locality, the extent of divergence, selection, introgression, or drift, their gut contents or parasites may point towards broad ecological relationships, and organs may harbor chemicals useful for long-term pollution monitoring. This list, while not exhaustive, is instructive on the diverse uses of specimens. And while this is merely a hypothetical case, real-world examples are voluminous. Specimens can provide information about genetic change in honeybees (*Apis mellifera*) in the face of significant changes in landscape use, parasite presence, and pesticides (Cridland et al. 2018; Parejo et al. 2020). Or specimens may provide lines of evidence to help identify disease vectors, such as deer mice (*Peromyscus maniculatus*) being a wild reservoir of the *Sin Nombre* hantavirus in the United States (Childs et al. 1994; Yates et al. 2002; Thompson et al. 2021). This suggests that museum specimens of diverse taxonomic categories—vertebrates, invertebrates, plants, and fungi—provide information to develop a holistic and historical outlook, which can be useful for many projects, scientific or otherwise.

For this paper, I will focus primarily on the role of specimens in conservation.[2] Specimens may be useful for conservation because specimens provide evidence that practitioners may use to direct conservation goals, such as biodiversity conservation, by using specimens as a baseline for ecological inferences. For example, genetic bottlenecks in honeybees facilitated by changes in landscape or pesticide use might inform what conservation efforts are undertaken.

To explore specimens' role in conservation, I first outline the epistemological value of specimens. Following that, I discuss the link between this information and conservation decision-making. Finally, I suggest ways to reconsider the conservation value of specimens. Conservation practitioners have divergent values about what successful conservation looks like, which can inform what role specimens have in their work. While specimens are not necessary or sufficient for conservation decision-making, they can provide invaluable information depending on the values and scientific questions in mind. Rather than seeing cleavage between conservation practitioners and specimens, I argue that specimens empirically benefit many conservation decisions despite their epistemic difficulties. Therefore, I suggest debate should shift from one between conservation and specimens to one that contextualizes epistemic or ethical worries on a case-by-case basis.

[2] There is controversy on the ethics and utility of collecting specimens, mainly if the aim is for conservation (Havstad 2019). For the moment, I want to set those concerns to the side, but I will return to them later in Sects. "Conservation" and "Disagreement". It is sufficient for now to say that killing and preserving specimens, animals, insects, or otherwise, raises ethical concerns and disagreements.

Specimens

Specimen collection has long been intertwined with biological inquiry, with widespread collecting tracing through Alexander von Humboldt, Charles Darwin, Alfred Wallace, and the present day (Funk 2018). Specimens were collected for a variety of scientific or parochial reasons. A non-exhaustive list includes preservation for subsequent taxonomic study, morphological examination, understanding speciation, limited time in a location, goals that scientists cannot realize in the field, aggregation of information, studying parasites, and the requirement for a type specimen for species designation. Some of these concerns are pragmatic, while others point to specific scientific goals and practices. While historically collected for sometimes narrow scientific reasons, specimens are a source of information for diverse investigations (Parker 1979; Huber 1998; Funk et al. 2005; Lendemer et al. 2020; Miller et al. 2020b).

Consider the rock horned lizard (*Phrynosoma ditmarsi*) and its winding path to rediscovery (Lowe et al. 1971). There were three specimens at NHCs, but specific locality information was unknown: it was unclear where the specimens were from, whether the species still existed, or even if the specimens constituted a new species. Scrutiny of specimen gut contents allowed cross-comparison of insects, seeds, and rocks, suggesting a narrowed location for future investigation. Subsequent surveys of a mountain range in Sonora, Mexico, led to the rediscovery and description of the species. This was possible because of the interdisciplinary science and information that specimens can facilitate. Specimens can provide information that is only sometimes evident from the outset. The value of the specimens was unclear before scientists gleaned detailed and novel information. This assessment is only describable in hindsight, which is an interesting epistemological position that specimens often occupy.

This suggests a cautionary principle in evaluating the epistemological status of specimens: when preserved properly and with ancillary information, scientists and practitioners should use care with specimens. It is unclear what future questions these finite, fragile, and temporally unique resources may provide help with answering (Bradley et al. 2014). For example, herbaria macroalgae have extended the historical understanding of marine upwelling over fifty years (Miller et al. 2020a), which differs from what they were initially collected for. This is why practitioners often say that specimens provide a "snapshot" into past systems that, in many cases, may be unknown, lost, or changed (Monfils et al. 2017; Schmitt et al. 2019). Because specimens are a unique epistemic resource that may be irreplaceable, there are frequent calls for further funding, appreciation of specimen collections, and ongoing, contemporary collection of new specimens (Miller et al. 2020b; National Academies of Sciences 2021).

However, even with these substantial epistemic values, there are problems. For example, some specimens in collections are poorly labeled or preserved, limiting what inferences scientists might draw (Verry et al. 2019). Specimens are often most useful if it is known where the organism originated. A specimen without relevant accompanying information may be of limited value. Likewise, if identifying details are obscured, poorly preserved specimens may have limited epistemological value. Certain organisms, for example, are only identifiable with specific anatomical or morphological information. Poor preservation, as well, may damage genetic information, which circumscribes a specimen's epistemological standing. Therefore, specimen value may vary considerably on a case-by-case basis. That said, as long as acceptable curation practices are followed, specimens are often in sufficient condition for various investigations.

Another serious concern is the ad hoc nature of many collections (Ponder et al. 2001). Certain organisms or localities may be overrepresented due to institutional practices or researchers' interests; alternatively, rare, brightly colored, or unusual organisms may be disproportionately represented (Cooper et al. 2019; Gotelli et al. 2021). Regardless of the cause, this presents an imbalanced "snapshot." Careful modeling may mitigate this concern, but no solution will dissolve the issue (c.f. Pyke & Ehrlich 2010). Many specimens were collected to further particular scientific or parochial goals, so there can be an epistemological mismatch: specimens were, and are, collected for reasons that diverge from how they might be used later, which may hinge on unarticulated questions.

The "snapshot" metaphor requires updating. Rather than a fine-grained photo, the picture is fuzzy; it may still be helpful for specific scientific projects depending on what information is needed. If exactitude is required, specimens may be insufficient. However, specimens may still provide essential information because of other channels' paucity. Importantly, specimens might be the only empirically available source; specimens' inexact nature must be sufficient for some scientific questions, such as those concerning the past.

The (fuzzy) snapshot provides a reference point or baseline to understand past organisms and communities, which suggests that epistemological uncertainty is necessarily part of evaluating specimens (Balaguer et al. 2014; Mihoub et al. 2017). At some point, experts make decisions even in the face of unknowns (McNellie et al. 2020). Collating data from multiple specimens and available modern information can help form a holistic picture. The (fuzzy) snapshot is constituted not only by specimens; data can then be integrated with other scientific knowledge bases—for example, current population sizes, community dynamics, geological or climatic information, and known range maps—to make inferences based on knowledge of extant species (Bonebrake et al. 2010). This is not a sure process, but utilizing multiple information channels helps fill in a picture that will be more or less sufficient depending on the project. If highly granulated information is sought, then specimen data may not suffice. If a coarse-grained analysis is adequate, specimens provide a place to form an incomplete but valuable baseline.

It seems reasonable to conclude the following. First, specimens provide information that can be useful for disparate scientific efforts. Second, specimens offer information for many projects if properly preserved, documented, and contextualized. Finally, even if there are concerns about specimens' ad hoc nature and fuzzy reference points, they provide a unique information channel because they are often the only available information for some scientific questions. Therefore, museum specimens have a role relative to the granularity of the project they are employed in. This characterization acknowledges the information specimens provide without overstating their epistemic value.

Conservation

Conservation planners may use information derived from specimens for varied questions or projects, which forms a diverse literature (Kress et al. 1998; Drew 2011; Nualart et al. 2017; Mihoub et al. 2017; Schmitt et al. 2019; Meineke et al. 2019; Ferguson 2020; Miller et al. 2020b; Nakahama 2021; Gotelli et al. 2021). Scientists may use this information to form a "benchmark" for restoration (Drew 2011), a "baseline" to study biodiversity change (Miller et al. 2020b), or for "understanding biodiversity conservation in the future" (Nakahama 2021). Put another way, specimens can be helpful because they provide a (fuzzy) snapshot of a historical system and its inhabitants if adequately preserved and documented. This information may be used in the conservation of rare or threatened species (O'Donnell et al. 2017; Simanonok et al. 2021) or be collated to form a picture of long-term conservation concerns that incidental or even planned surveys are unsuited to address (Hahn et al. 1993; Schmitt et al. 2019; Nicholson et al. 2020). Specimens can also be used to integrate the past into contemporary population genomics (Bi et al. 2013; Burrell et al. 2015). That said, it is unclear if conservation reference points will be as helpful as climate change continues to alter ecosystems (c.f. Hagerman & Satterfield 2014). This is because historical reference points might significantly diverge from future trajectories, making the past not necessarily a clear guide for conservation. Despite concerns like this, a (fuzzy) snapshot may accommodate many conservation or scientific questions.

A common theme in the conservation and specimen literature is that conserving ecosystems and organisms can use specimens to inform and direct conservation actions because the specimens provide a baseline for conservation decision-making. Some variety of this claim is often present explicitly or implicitly in discussing specimens and conservation (Drew 2011; Schmitt et al. 2019; Meineke et al. 2019; Ferguson 2020; Miller et al. 2020b; Rawlence et al. 2021; Nakahama 2021). The arguments employed are varied, but they express something like this: assessing biodiversity loss or change is a complicated project that includes reviewing published articles, discussions with scientists and experts, on-the-ground surveys, and interdisciplinary integration (Kühl et al. 2020). Unfortunately, many organisms and ecosystems are data deficient, particularly from a historical perspective, which makes empirically informed biodiversity conservation difficult. Specimens provide one way to address the lack of data (Malaney & Cook 2018). Historical baselines informed by specimens are sometimes argued to be necessary or extremely important to make conservation decisions on a local and global scale.

However, these claims overstate the relative importance of museum specimens in conservation decision-making, both practically and conceptually. Remember that specimens face some epistemological hurdles in framing a reference point: they are incomplete, may be poorly labeled, are ad hoc, and cannot indicate an entire ecological assemblage. While information may be drawn from specimens, conservationists should be careful about overselling their value. The (fuzzy) picture can be enhanced for specific conservation projects (Nicholson et al. 2020), but there is no reason to assume it will be sufficient in all or most cases.

Furthermore, this framing presupposes that values close to conservation biology (Soulé 1985; Cardinale et al. 2012) are the correct conservation values. Conservation biology is a normative scientific enterprise with specific goals, values, and concepts, and it is unclear whether conservation biology's priorities should be accepted, either normatively or scientifically (Santana 2014). Conservation biology is one among several conservation paradigms: game or wildlife management (Organ et al. 2012; Mahoney and Geist 2019), conservation science (Doak et al. 2015; Bennett et al. 2017), restoration ecology (Clewell & Aronson 2012), forestry (Hays 2007), and so-called "compassionate conservation" (Wallach et al. 2015) are all unique conservation perspectives with divergent values. For example, wildlife management often focuses on particular stakeholder values and voices, primarily associated with game animals, over other species and conservation concerns. This may be contrasted with restoration ecology, which is more often focused on restoring particular species assemblages or ecological functionality. The former paradigm might manage primarily for deer harvest, while the latter might focus more on plant communities and their ecological properties.[3]

These conservation paradigms have different normative premises that influence what should be prioritized for conservation.[4] Since these paradigms have different premises, practitioners will integrate specimens into conservation decision-making differently depending on which paradigm they most agree with and what is possible given the on-the-ground social and political realities they face: conservation of a game species differs from the conservation of biodiversity. Because there are different conservation paradigms and attitudes, it is not apparent what role specimens should play in all conservation decision-making. Two examples will illustrate this.

Consider the Wasatch front in Utah. Side-blotched lizards (*Uta stansburiana*) were probably once common in the area hundreds of years ago. For the sake of argument, assume specimens were collected that documented these organisms. Due to human development, the valley now, more or less, exists as one extensive novel ecosystem (Hobbs et al. 2009; Santana 2022). With roads and maple trees instead of sagebrush, this altered habitat is a poor fit for these once-common reptiles. It is strange to suggest that lizard specimens existing before widespread habitat modification indicate how conservation should proceed. Epistemologically, specimens provide much information. One salient kind of information is about past ecological communities, which can be integrated into different conservation projects that use

[3] These are abbreviated distinctions. I do not want to give the impression of monolithic attitudes within these fields. However, it is sufficient to say that there are conservation approaches that place different weight on conserving some features, such as a particular species or ecological state, over others.

[4] Overlap of conservation priorities does occur, which I discuss shortly, but it is also important to acknowledge value differences both inter and intra conservation paradigms. Furthermore, there are other conservation paradigms I do not mention, but I aim to motivate the point that there are disagreements, not to index all possible approaches.

the past as a reference point.[5] Normatively, it needs to be clarified how that information can or should be utilized on a case-by-case basis. Specimens provide knowledge of what once was, not what shall, should, or can (Backstrom et al. 2018). The (non) existence of specimens will factor into conservation decision-making differently depending on the values, laws, and obligations different conservation practitioners are subject to.

Here's a more positive example of specimens in conservation. Midget-faded rattlesnakes (*Crotalus concolor*) are cryptic reptiles native primarily to the Colorado Plateau in Utah but also present in Arizona, Wyoming, and western Colorado (Feldner et al. 2016). Because they are challenging to locate, there are questions about the species' abundance and relative distribution. This is a potential conservation concern for the state wildlife agency, the Utah Division of Wildlife Resources (UDWR), because if the species were to warrant listing under the endangered species act, it could disrupt economic and social projects in the state. It is, therefore, a problem for the agency that the species was listed as SNR in the (2015) Utah Wildlife Action Plan (294), which means there was not sufficient information to determine whether the species was at conservation risk or not.[6] If the species warrants listing, this may affect funding, social license, or political influence. Therefore, the UDWR is both prudentially and legally obligated to try and prevent listing, and being caught off guard because of insufficient information is an institutional problem.

Museum specimens can provide one way to shore up data deficiencies for conservation like this (Halm et al. 2022). Recurating and using georeferenced information for all the rattlesnake specimens at the Natural History Museum of Utah, coupled with information from other databases like INaturalist, allowed the UDWR to update *Crotalus concolor* ranking to S3, which means the species is "vulnerable" in Utah.[7] This was possible even with the (fuzzy) snapshot that specimens provide: many locations where specimens had been collected have not been substantively changed since collection, which provides a reasonable inference that the species persists in those localities. Museum specimen information was helpful because the UDWR was primarily interested in abundance and distribution information, which specimens are equipped to provide. A question like "To what extent is this species abundant and distributed across the state?" is partially answerable with specimens. Furthermore, the question aligns with the values of a state agency, such as preventing listing. This is still fuzzy and imperfect information that should be supplemented by surveys, particularly those informed by specimen locality information. However, the specimens can still help inform and direct the allocation of limited conservation funding and attention.

[5] The lizard specimens can still provide indirect information for conservation, which might still be valuable, but it is not necessarily valuable for this particular project or location. I am grateful for an anonymous reviewer for emphasizing this point.

[6] UDWR uses NatureServe (https://www.natureserve.org/), which is a conservation tool to aid communication between conservation practitioners by using the same standards across conservation areas. "SNR" means that a species is not ranked at a specific state level, which is often done when there is insufficient information on the species.

[7] See the updated information for Utah listed here (link from March 2023): https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.101404/Crotalus_oreganus_concolor.

These two examples show how specimens might have an unclear value to some conservation questions but be valuable to others. Background values and the conservation questions in mind will frame specimen importance, which is a corrective from overstating the value of specimens for conservation in general. Pivoting, I turn to how specimens' epistemic value can be recognized and used by heterogeneous practitioners even in the face of value disagreement, which can be substantial concerning specimens and conservation.

Disagreement

Havstad's (2019) work provides a valuable starting point for considering divergences between conservation practices and specimens. Her discussion is wide-ranging, but much focuses on the ethics of collecting voucher animal specimens, which are used, in part, to confirm a species' existence or presence scientifically.[8] This frames different scientists, practitioners, and values at odds with one another, similar to the framing above with the conservation paradigms. There are often substantive disagreements about how or why conservation should proceed and whether scientists should collect or harvest organisms for specimen collections (Miller et al. 2022; Camilo 2022).

In many respects, highlighting disagreement is correct. There are divergent ethical attitudes toward collecting specimens, and when this debate is ratcheted up with species near demographic extinction, it becomes even more heated. However, there are other ways of thinking about this controversy. While there are salient ethical questions about collecting specimens, this should not necessarily orient philosophical or practical discussion as it currently does. Those ethical questions should be considered alongside epistemic dimensions that specimens are uniquely equipped to provide.

Collecting specimens for contemporary projects can be empirically valuable, but it misses one of the reasons specimens are so valuable: they are a resource for understanding the natural world and framing questions through time. There are extensive collections that span decades or longer with large numbers of specimens that may receive little attention by conservation or scientific practitioners from a range of paradigms.[9] This is a mistake. Setting aside whether it was moral to collect the organisms in the first place, existing specimens can provide evidence that is often irreplaceable. Information derived from these specimens may be useful for various projects depending on what goals are in mind. This information may only contribute to some projects or practitioners, as noted above with the lizard example. However, when conservation projects benefit from a historical outlook, broadly construed, specimens provide an often invaluable source of information.

[8] Herbaria and mycology collections do not attract as much discussion in collections-based literature, and my examples do not focus on them much either. However, they can and do have a significant role for many conservation projects, particularly restoration ecology (Paton et al. 2020; Albani Rocchetti et al. 2021). These kinds of collections do not typically have the same ethical questions put to them.

[9] Personal communications.

An example will illustrate this. Bullfrogs (*Lithobates catesbeianus*) often carry and transmit chytrid fungus (genus *Batrachochytrium)*, which is a pathogen that can threaten or imperil populations of other amphibians (Daszak et al. 2004; Fisher & Garner 2020). This fungus is often seen as a pernicious problem because of bullfrog's ability to invade many habitats, particularly those disturbed through human actions, without the fungus necessarily threatening bullfrog populations. Chytrid may be detected in many ways, such as by sampling extant populations or locations that harbor bullfrogs or the fungus. However, museum specimens provide a novel way of detecting when the fungus may have arrived in an area or whether it is a native species to that collection site (Ghirardhi et al. 2011; Rahman 2020). Researchers can detect the fungus on preserved amphibian specimens, bullfrogs or otherwise (e.g., genus *Xenopus*), which provides a view through time on the pathogen's spread and emergence at novel locations (Weldon et al. 2004).

As mentioned before, there are different values toward conservation. That said, there are sub-projects that practitioners converge on for various reasons, such as slowing or eradicating chytrid where possible. As a result, different conservation paradigms might agree on conserving or restoring threatened amphibian populations for unique reasons. And if they do, specimens should be part of that conservation planning.

There are different ways that might happen in practice. One strategy is to try and eradicate a locally "invasive species," such as bullfrogs. Eliminating bullfrog populations due to their contribution to the spread of chytrid raises ethical and ecological questions, but the reasons for engaging in that conservation action stand to benefit from a historical outlook that specimens are uniquely positioned to provide. Have bullfrogs developed chytrid resistance over time? How long have bullfrogs been present at a location? Have species changed their behavior or reproduction in the face of chytrid? How are species affected by the presence or absence of bullfrogs? How long has chytrid been detected in specific locations? Does the appearance of bullfrogs predict chytrid in adjacent populations? What other ecological effects stem from chytrid and bullfrogs? These questions may be investigated and answered in many ways, but an album of (fuzzy) snapshots from specimens provides a unique evidence line for diverse practitioners or projects. This does not overstate the specimen's relative epistemic value, as what should be done with that information might still be unclear: extirpation of non-native bullfrogs might be recommended by some, but so too could alternative strategies that are sensitive to specific values or contexts that practitioners navigate. Other conservation approaches to chytrid, including non-intervention with bullfrogs or the fungus, almost certainly benefit from a historical outlook.

Historically and empirically informed conservation, regardless of background values, will likely benefit from using existing museum specimens. If a pathogen (or species, genetic bottleneck, etc.) is detected, that can often provide useful information for conservation (c.f. Jensen et al. 2022). Consulting an NHC may only benefit some conservation projects, but since conservation often is performed with many unknowns, particularly in terms of historical evidence, it is justifiable to utilize existing collections in robust and creative ways (c.f. Montgomery et al. 2020). Focusing primarily on the ethical dimensions of specimen collection is understandable, but that debate overshadows overlap in conservation goals and useful ways that specimens may be used.

It is also worth noting that collecting some specimens does not obviously cause harm (e.g., collecting dead organisms on roads or preserving plant material). Even if organisms are collected and killed, those effects are often negligible on an ecosystem scale.[10] These points do not defuse all objections; there are welfare concerns in killing many organisms that practitioners should take seriously. The point is that supporters and objectors to collecting often overstate their relative cases, which does not acknowledge the instrumental value of at least some limited collecting, depositing of specimens from other research, and adequately utilizing existing NHCs. No further bullfrogs need to be harmed to learn much about the species' contribution to the spread of chytrid fungus, which might assist global conservation actions.

There may still be concerns about the ethics of continued modern collection. However, it is worth restating that since historical specimens can help with current conservation projects, it is a reasonable inference that collecting more specimens in the present day may be valuable for future, as of yet unknown, projects. When navigating the ethical and epistemic challenges of modern collection, scientists and NHCs would do well to think of future uses and target their collection of new specimens for the future. This recommendation includes best practices for storing and disseminating information (National Academies of Sciences 2021), but it also means attending to epistemic and ethical concerns raised in this paper. Collectors should consider diverse conservation values and perspectives in their work; ideally, this informs what organisms are taken, why they are collected, and what locations are sampled for collection. This is not likely to adjudicate all ethical disagreements, but it will at least make discussions more transparent, particularly as those conversations interweave expansive conservation values.

Conclusion

Specimens have a place in conservation planning, but only if conservation decision-makers view the past as affecting current decision-making. With some plans, such as stocking or propagating game animals or my hypothetical example of repatriating lizards to a metropolitan area, it is sometimes unclear what that value might be. This is not to say there is no conceivable value—basic genetics research may still utilize those specimens—but that there are different contexts and circumstances that suggest there is no direct conservation utility. However, specimens have a more apparent role for many other conservation goals, illustrated with the rattlesnakes or bullfrogs. Rather than seeing specimens and conservation at odds (Miller et al.

[10] Some organisms are taken from the wild, killed, and not preserved as publicly accessible specimens but they still may be used in long-term studies. There are different ethical dimensions to consider for those kinds of cases, and I do not have the space to discuss them at length. However, organisms killed for many scientific projects, such as those in ecology, should be preserved to enable public access to information and for future researchers to utilize them. I am grateful to an anonymous reviewer for this point.

2022; Camilo 2022), specimens should be part of many conservation decisions, particularly when the specimens are epistemically contextualized as (fuzzy) snapshots.

Philosophically, groups simultaneously overstate or understate various propositions about specimens, which is detrimental to empirically informed conservation. I have adopted a modest approach in this paper. Updating attitudes on this issue benefits ecological communities people wish to conserve for pluralistic reasons. Specimens should be utilized and contextualized appropriately by practitioners, curators, conservation decision-makers, and philosophers on a case-by-case basis and with more explicit reasons on why the past, and the organisms from it, matter for the future, particularly in cases of modern collecting.[11]

Declarations

Conflict of interest The author has no relevant financial or non-financialinterests to disclose.

References

Albani Rocchetti G, Armstrong CG, Abeli T, Orsenigo S, Jasper C, Joly S, Bruneau A, Zytaruk M, Vamosi JC (2021) Reversing extinction trends: new uses of (old) herbarium specimens to accelerate conservation action on threatened species. New Phytol 230(2):433–450

Backstrom AC, Garrard GE, Hobbs RJ, Bekessy SA (2018) Grappling with the social dimensions of novel ecosystems. Front Ecol Environ 16(2):109–117

Balaguer L, Escudero A, Martín-Duque JF, Mola I, Aronson J (2014) The historical reference in restoration ecology: re-defining a cornerstone concept. Biol Cons 176:12–20

Bennett NJ, Roth R, Klain SC, Chan K, Christie P, Clark DA, Cullman G et al (2017) Conservation social science: Understanding and integrating human dimensions to improve conservation. Biol Conserv 205:93–108

Bi Ke, Linderoth T, Vanderpool D, Good JM, Nielsen R, Moritz C (2013) Unlocking the vault: next-generation museum population genomics. Mol Ecol 22(24):6018–6032

Bonebrake TC, Christensen J, Boggs CL, Ehrlich PR (2010) Population decline assessment, historical baselines, and conservation. Conserv Lett 3(6):371–378

Bradley RD, Bradley LC, Garner HJ, Baker RJ (2014) Assessing the value of natural history collections and addressing issues regarding long-term growth and care. Bioscience 64(12):1150–1158

Burrell AS, Disotell TR, Bergey CM (2015) The use of museum specimens with high-throughput DNA sequencers. J Hum Evol 79:35–44

Camilo GR (2022) REPLY to Miller et al. Am Entomol 68(3):56–58

Cardinale BJ, Emmett Duffy J, Gonzalez A, Hooper DU, Perrings C, Venail P, Narwani A et al (2012) Biodiversity loss and its impact on humanity. Nature 486(7401):59–67

Casas-Marce M, Revilla E, Fernandes M, Rodriguez A, Delibes M, Godoy JA (2012) The value of hidden scientific resources: preserved animal specimens from private collections and small museums. Bioscience 62(12):1077–1082

[11] This project has been possible due to the support of many people and institutions. First, I thank Matt Haber for spearheading the University of Utah grad term afield program, which provided an opportunity to start this project. Second, I thank Katrina Derieg and Eric Rickart at the Natural History Museum of Utah for their time, support and for allowing me access to the natural history collection. Next, I thank Drew Dittmer for his guidance and good conversation while curating the herpetological collection. I also thank Carlos Santana for guidance on this project. In addition, I am grateful to the audience at the PSA 2022 section on Biology and Values for their helpful questions. I also thank attendees at the 2021 University of Utah Grad work-in-progress series for comments on an earlier draft. Finally, I thank two anonymous reviewers for their suggestions and insights.

Childs JE, Ksiazek TG, Spiropoulou CF, Krebs JW, Morzunov S, Maupin GO, Gage KL et al (1994) Serologic and genetic identification of Peromyscus maniculatus as the primary rodent reservoir for a new hantavirus in the southwestern United States. J Infect Dis 169(6):1271–1280

Clewell AF and Aronson J (2012) Ecological restoration: principles, values, and structure of an emerging profession. Island Press

Cooper N, Bond AL, Davis JL, Miguez RP, Tomsett L, Helgen KM (2019) Sex biases in bird and mammal natural history collections. Proc R Soc B 286(1913):20192025

Cridland JM, Ramirez SR, Dean CA, Sciligo A, Tsutsui ND (2018) Genome sequencing of museum specimens reveals rapid changes in the genetic composition of honey bees in California. Genome Biol Evol 10(2):458–472

Daszak P, Strieby A, Cunningham AA, Longcore JE, Brown CC, Porter D (2004) Experimental evidence that the bullfrog (Rana catesbeiana) is a potential carrier of chytridiomycosis, an emerging fungal disease of amphibians. Herpetol J 14:201–208

Doak DF, Bakker VJ, Goldstein BE and Hale B (2015) What is the future of conservation?. In Protecting the wild, Island Press, Washington, DC pp 27–35

Drew J (2011) The role of natural history institutions and bioinformatics in conservation biology. Conserv Biol 25(6):1250–1252

Feldner MJ, Schuett GW and Slone JM (2016) Species accounts. Crotalus Concolor midget-faded rattlesnake, pp 179–238. In Schuett, Gordon W., Martin J. Feldner, Charles F. Smith, and Randall S. Reiserer, eds. Rattlesnakes of Arizona, vol 1. ECO Publishing

Ferguson AW (2020) On the role of (and threat to) natural history museums in mammal conservation: an African small mammal perspective. J Vertebr Biol 69(2):20028–20031

Fisher MC, Garner TWJ (2020) Chytrid fungi and global amphibian declines. Nat Rev Microbiol 18(6):332–343

Funk VA (2018) Collections-based science in the 21st century. J Syst Evol 56(3):175–193

Funk VA, Hoch PC, Alan Prather L, Wagner WL (2005) The importance of vouchers. Taxon 54(1):127–129

Ghirardi R, López JA, Scarabotti PA, Steciow MM, Perotti MG (2011) First record of the chytrid fungus in Lithobates catesbeianus from Argentina: exotic species and conservation. Revista Mexicana De Biodiversidad 82(4):1337–1339

Gotelli NJ, Booher DB, Urban MC, Ulrich W, Suarez AV, Skelly DK, Russell DJ et al (2021) Estimating species relative abundances from museum records. Methods Ecol Evol 2:431–443

Hagerman SM, Satterfield T (2014) Agreed but not preferred: expert views on taboo options for biodiversity conservation, given climate change. Ecol Appl 24(3):548–559

Hahn E, Hahn K, Stoeppler M (1993) Bird feathers as bioindicators in areas of the German environmental specimen bank-bioaccumulation of mercury in food chains and exogenous deposition of atmospheric pollution with lead and cadmium. Sci Total Environ 139:259–270

Halm D, Dittmer D, Derieg K, Wilkins A, Rickart E (2022) Rediscovery and Redescription of the holotype of *Crotalus Concolor* (Midget-faded rattlesnake). Herpetol Rev 53(2):208–211

Havstad JC (2019) Let me tell you 'bout the birds and the bee-mimicking flies and *Bambiraptor*. Biol Philos 34(2):25

Hays SP (2007) Wars in the woods: the rise of ecological forestry in America. University of Pittsburgh Pre

Hobbs RJ, Higgs E, Harris JA (2009) Novel ecosystems: implications for conservation and restoration. Trends Ecol Evol 24(11):599–605

Huber JT (1998) The importance of voucher specimens, with practical guidelines for preserving specimens of the major invertebrate phyla for identification. J Nat Hist 32(3):367–385

Jensen EL, Díez-del-Molino D, Gilbert MTP, Bertola LD, Borges F, Cubric-Curik V, de Navascués et al. M (2022) Ancient and historical DNA in conservation policy. Trends Ecol Evol

Kress W, John WR, Heyer P, Acevedo J, Coddington DC, Erwin TL, Meggers BJ et al (1998) Amazonian biodiversity: assessing conservation priorities with taxonomic data. Biodivers Conserv 7(12):1577–1587

Kühl HS, Bowler DE, Bösch L, Bruelheide H, Dauber J, Eichenberg D, Eisenhauer N et al (2020) Effective biodiversity monitoring needs a culture of integration. One Earth 3(4):462–474

Lendemer J, Thiers B, Monfils AK, Zaspel J, Ellwood ER, Bentley A, LeVan K et al (2020) The extended specimen network: a strategy to enhance US biodiversity collections, promote research and education. Bioscience 70(1):23–30

Lowe CH, Robinson MD, Roth VD (1971) A population of *Phrynosoma ditmarsi* from Sonora, Mexico. J Ariz Acad Sci 6(4):275–277
Malaney JL, Cook JA (2018) A perfect storm for mammalogy: declining sample availability in a period of rapid environmental degradation. J Mammal 99(4):773–788
Mahoney SP, Geist V eds (2019) The North American model of wildlife conservation. Johns Hopkins University Press
McNellie MJ, Oliver I, Dorrough J, Ferrier S, Newell G, Gibbons P (2020) Reference state and benchmark concepts for better biodiversity conservation in contemporary ecosystems. Glob Change Biol 12:6702–6714
Meineke EK, Davies TJ, Daru BH, Davis CC (2019) Biological collections for understanding biodiversity in the Anthropocene. Philos Trans R Soc B 374(1763):20170386
Mihoub J-B, Henle K, Titeux N, Brotons L, Brummitt NA, Schmeller DS (2017) Setting temporal baselines for biodiversity: the limits of available monitoring data for capturing the full impact of anthropogenic pressures. Sci Rep 7:41591
Miller EA, Lisin SE, Smith CM, Van Houtan KS (2020a) Herbaria macroalgae as a proxy for historical upwelling trends in Central California. Proc R Soc B 287(1929):20200732
Miller SE, Barrow LN, Ehlman SM, Goodheart JA, Greiman SE, Lutz HL, Misiewicz TM et al (2020b) Building natural history collections for the twenty-first century and beyond. Bioscience 70(8):674–687
Miller ZJ, Lynn A, Oster C, Piotter E, Wallace M, Sullivan LL, Galen C (2022) Unintended consequences? Lethal specimen collection accelerates with conservation concern. Am Entomol 68(3):48–55
Monfils AK, Powers KE, Marshall CJ, Martine CT, Smith JF, Alan Prather L (2017) Natural history collections: teaching about biodiversity across time, space, and digital platforms. Southeast Nat 16(sp10):47–57
Montgomery GA, Dunn RR, Fox R, Jongejans E, Leather SR, Saunders ME, Shortall CR, Tingley MW, Wagner DL (2020) Is the insect apocalypse upon us? How to find out. Biol Cons 241:108327
Nakahama N (2021) Museum specimens: an overlooked and valuable material for conservation genetics. Ecol Res 36(1):13–23
National academies of sciences, engineering, and medicine (2021) Biological collections: ensuring critical research and education for the 21st century. National Academies Press
Nicholson EG, Manzo S, Devereux Z, Morgan TP, Fisher RN, Brown C, Dagit R, Scott PA, Bradley Shaffer H (2020) Historical museum collections and contemporary population studies implicate roads and introduced predatory bullfrogs in the decline of western pond turtles. PeerJ 8:e9248
Nualart N, Ibáñez N, Soriano I, López-Pujol J (2017) Assessing the relevance of herbarium collections as tools for conservation biology. Bot Rev 83(3):303–325
O'Donnell KM, Messerman AF, Barichivich WJ, Semlitsch RD, Gorman TA, Mitchell HG, Allan N et al (2017) Structured decision making as a conservation tool for recovery planning of two endangered salamanders. J Nat Conserv 37:66–72
Organ JF, Geist V, Mahoney SP, Williams S, Krausman PR, Batcheller GR, Decker TA et al. (2012) The North American model of wildlife conservation. Wildl Soc Tech Rev 12, 04
Parejo M, Wragg D, Henriques D, Charriere J-D, Estonba A (2020) Digging into the genomic past of Swiss honey bees by whole-genome sequencing museum specimens. Genome Biol Evol 12(12):2535–2551
Parker ED Jr. (1979) Phenotypic consequences of parthenogenesis in Cnemidophorus lizards. I. Variability in parthenogenetic and sexual populations. Evolution. 1150–1166
Paton A, Antonelli A, Carine M, Forzza RC, Davies N, Demissew S, Dröge G et al (2020) Plant and fungal collections: current status, future perspectives. Plants People Planet 2(5):499–514
Ponder WF, Carter GA, Flemons P, Chapman RR (2001) Evaluation of museum collection data for use in biodiversity assessment. Conserv Biol 15(3):648–657
Pyke GH, Ehrlich PR (2010) Biological collections and ecological/environmental research: a review, some observations and a look to the future. Biol Rev 85(2):247–266
Rahman Md (2020) Chytrid infection in Asia: how much do we know and what else do we need to know? Herpetol J 30(2):99–111
Rawlence NJ, Knapp M, Martin MD, Wales N (2021) Applied uses of ancient DNA. Front Ecol Evol 9:217
Santana C (2014) Save the planet: eliminate biodiversity. Biol Philos 29(6):761–780
Santana CG (2022) The value of and in novel ecosystem (s). Biol Philos 37(2):1–18

Schmitt CJ, Cook JA, Zamudio KR, Edwards SV (2019) Museum specimens of terrestrial vertebrates are sensitive indicators of environmental change in the Anthropocene. Philos Trans R Soc B 374(1763):20170387

Simanonok MP, Otto CRV, Scott Cornman R, Iwanowicz DD, Strange JP, Smith TA (2021) A century of pollen foraging by the endangered rusty patched bumble bee (Bombus affinis): inferences from molecular sequencing of museum specimens. Biodiv Conserv 30(1):123–137

Soulé ME (1985) What is conservation biology? Bioscience 35(11):727–734

Thompson CW, Phelps KL, Allard MW, Cook JA, Dunnum JL, Ferguson AW, Gelang M et al (2021) Preserve a voucher specimen! The critical need for integrating natural history collections in infectious disease studies. Mbio 12(1):e02698-e2720

Utah Wildlife Action Plan Joint Team (2015) Utah wildlife action plan: a plan for managing native wildlife species and their habitats to help prevent listing under the Endangered Species Act. Publication number pp 15–14. Utah Division of Wildlife Resources, Salt Lake City, Utah, USA

Verry AJF, Lachie Scarsbrook R, Scofield P, Tennyson AJD, Weston KA, Robertson BC, Rawlence NJ (2019) Who, where, what, wren? Using ancient DNA to examine the veracity of museum specimen data: a case study of the New Zealand Rock Wren (Xenicus gilviventris). Front Ecol Evol 7:496

Wallach AD, Bekoff M, Nelson MP, Ramp D (2015) Promoting predators and compassionate conservation. Conserv Biol 29(5):1481–1484

Weldon C, Du Preez LH, Hyatt AD, Muller R, Speare R (2004) Origin of the amphibian chytrid fungus. Emerg Infect Dis 10(12):2100

Yates TL, Mills JN, Parmenter CA, Ksiazek TG, Parmenter RR, Vande Castle JR, Peters CJ (2002) The ecology and evolutionary history of an emergent disease: hantavirus pulmonary syndrome: evidence from two El Niño episodes in the American southwest suggests that El Niño–driven precipitation, the initial catalyst of a trophic cascade that results in a delayed density-dependent rodent response, is sufficient to predict heightened risk for human contraction of hantavirus pulmonary syndrome. Bioscience 52(11):989–998