A coordinated biobank alliance for the zoological and conservation community

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Abstract

With dramatic advancements in biological data generation, genetic rescue and reproductive technologies, and inter-institutional coordination of care across entire animal populations, zoos, aquariums, and their collaborators are uniquely positioned to lead population-wide research benefiting animal wellbeing and species survival. However, procedural and inter-institutional barriers make it exceedingly difficult to access existing zoological biospecimens and data at scale. To address this, the Zoonomics Working Group, representing diverse roles across three zoological associations (AZA, EAZA, WAZA), proposes a biodiversity biobank alliance that develops and delivers shared resources to support the collection, storage, and sharing of biological samples and associated data across the zoological and conservation community. By biobank alliance, we mean a community-guided effort that develops shared resources, standards, ethos, and practices for collecting, storing, and sharing biological samples and associated data voluntarily through transparent processes, consistent with professional accreditation standards and international best practices. While initially focused on addressing the needs and regulatory landscape of U.S. institutions, the alliance is designed to create frameworks that are adaptable and adoptable for international expansion. Such a framework would help the zoological community navigate the ethical, legal, and practical challenges of managing biospecimen collections, making access more efficient, reliable, and robust. Achieving this vision requires collective agreement on ethical principles such as reciprocity, transparency, and data stewardship, ensuring that research is both feasible and proactively supported. Such coordination will drive advances in fundamental biology and accelerate progress in animal health, welfare, management, and biodiversity conservation.

Introduction

A core objective of U.S.-based zoos and aquariums is to advance animal wellbeing, public engagement, and conservation of wildlife (Association of Zoos and Aquariums [AZA] mission; https://www.aza.org). Fulfilling this mission carries an ethical imperative to apply the best information and practices possible, for both the animals and the public who support these institutions. Groundbreaking advancements in information *standardization* and *harmonization* to link *biobanks* at scale have revolutionized our ability to understand and improve human health over the past 20 years (Rush et al. 2024). A parallel transformation is within reach for wildlife, if we adopt consistent processes and standards for high-quality, biobanked specimens and data collected across zoos and aquariums. Zoos and aquariums have a unique opportunity to gather comprehensive life history, genomic, and health information throughout the lifespan of the world's most threatened species, which, if properly communicated and linked with biobanked samples, can complement and inform efforts to save species in nature. Through programmatic and structured collection and sharing of biobanked specimens and associated data, these resources could drive breakthroughs in animal wellbeing, health, biological research, and conservation.

Box 1: Glossary

Biobank: We follow the convention of the human research field in using the term biobank to refer to collections of biological specimens and paired data for research (Annaratone et al. 2021). Critically, a key feature of biobanks is the *coexistence of biological specimens and data* (Annaratone et al. 2021), particularly about the source individual, such as genomic, health, and environmental information. We therefore refer to biospecimens (living or non-living) and associated data together, to reflect their integrated nature within biobanks.

Data standards: Data standards are consensual specifications (e.g., defined vocabularies) for the representation of data from different sources or settings, and are integral for the sharing, portability, and reusability of data (Richesson and Krischer 2007). Existing data standards that are relevant to biospecimen collections in zoos and aquariums include Darwin Core for biodiversity data (Wieczorek et al. 2012), the Global Genome Biodiversity Network (GGBN) Data Standard for physical genomic samples (Droege et al. 2016), and Biospecimen Reporting for Improved Study Quality (BRISQ) for biospecimens used for biomedical research (Moore et al. 2011).

Harmonization: Harmonization refers to the retrospective practice of reconciling and combining conceptually similar datasets to maximize their comparability or compatibility (Cheng et al. 2024). Harmonized data itself may be constructed as a single dataset or remain dispersed across multiple datasets depending on the various ethical, legal, methodological or logistical factors at play (Cheng et al. 2024).

Knowledge-implementation gap: The knowledge-implementation gap refers to the particular gap between scientific research and its applicability to practitioners (Klutsch and Laikre 2022).

Standardization: The practice of unifying data by making all potential dimensions of the data (i.e. structure, syntax, semantics) identical (Cheng et al. 2024).

Zoonomics: An initiative facilitated by the Center for Zoonomics based at Zoo New England, whose mission is to integrate conservation and medical genomics to improve human, animal, and ecosystem health (https://zoonomics.org/).

Currently, most zoo- and aquarium-based biospecimens and linked animal data collected for research are driven through project-specific efforts, often siloed within individual institutions or small networks (Barrett et al. 2025). Even with the limitations of this project-driven approach, the resulting data have enabled advances across an impressive range of disciplines (Hvilsom et al. 2020; Loh et al. 2018; Norman et al. 2019; Welden et al. 2020), including animal welfare (Liptovszky et al. 2024), breeding management strategies (Russello MA and Jensen, 2018), reproductive technologies (Ballou et al .2023; Bolton et al. 2022; Fujihara and Inoue-Murayama 2024), stem cell technologies (Hutchinson et al. 2024), animal and human health research (Baitchman and Deem 2023; Boddy et al. 2020; Murphy et al. 2018; Sulzner et al. 2021), aging research (Tidière et al. 2024), infectious disease research (Fitak et al. 2019), evolutionary biology (Bertorelle et al. 2024), DNA forensics (Pérez-Espona et al. 2018), and conservation (Fa et al. 2011; Mooney et al. 2023). Recognizing the breadth of these applications, members of the zoo community have long proposed shifting from project-driven biospecimen collection to programmatic, cross-institutional biospecimen and data management (Wildt 1991). A strategic shift to scale efforts has been proposed as having the potential to profoundly advance every field it touches (Liptovsky 2024).

To more efficiently investigate and improve animal health and wellbeing, researchers must be able to access biobanked biospecimens and associated data at scale. Several types of data, if collected in a standardized manner across institutions and linked to biospecimens, are particularly well-positioned to deliver high-impact insights in animal care, science, and conservation:

Genomic data. Collaborative generation of population-wide genomic data, through partnerships between population managers and researchers, can serve dual goals. They can provide managers with the information needed to maintain populations that are genetically diverse, and advance discoveries in fields such as health genomics, comparative genomics, and conservation genomics (Norman et al. 2019; Zoonomia Consortium 2020; Hohenlohe et al. 2021).

Health data. Uniformly collected health data across institutions is critical to evaluate progress in health systems (Chan et al. 2010) and can accelerate studies and improvements in veterinary care and animal wellbeing (e.g., Murphy et al. 2018). Importantly, pairing health and genomic data can promote management of healthy, sustainable populations. Moreover, because health data span an animal's entire life, they enable research on fundamental biological processes that are typically not possible to study in wild populations, such as early development (e.g. Wilson et al. 2025), reproductive health (Wildt et al. 2010), aging (Tidière et al. 2024), and cancer (Vincze et al. 2022).

Environmental data. Standardized documentation of environmental factors related to animal management such as diet, housing, group composition, and enrichment can be analyzed with health data. Outcomes may uncover the environmental predictors of health and wellbeing (Wild 2005; Tidiere et al. 2024). These insights could be foundational for improving animal care, welfare, reproductive success, and veterinary care, and could also contribute to research fields such as the developmental origins of health and disease (DOHaD; Suzuki 2018) and the social determinants of health (Snyder-Mackler et al. 2020), especially through collaborative investment in standards and tools that advance both animal care and science.

Biobank challenges ahead

In recent years, zoo- and aquarium-based biobanking in Europe has taken transformative steps toward community coordination. The EAZA Biobank (launched in 2016; Hvilsom et al. 2025, this issue; https://www.eaza.net/biobank/) was developed as a distributed network of four "hub" facilities, each with secure long-term storage capacity and dedicated staff, servicing the EAZA Community, with centralized coordination and oversight. It offers a model for shared policies, standardized metadata practices, and common cyberinfrastructure tools for managing access to biospecimens collected in zoos and aquariums. While still evolving, this network demonstrates that cross-institutional and even cross-country coordination is possible and can significantly increase the visibility, usability, and impact of collections.

In contrast, no equivalent coordination exists across institutions in the U.S. to programmatically collect and share biobanked samples and associated animal-level data (e.g. genomic, health, and environmental data) for research at scale. To close this gap, we formed the *Zoonomics* Working Group to identify and address structural barriers preventing coordinated, large-scale studies in zoos and aquariums across the U.S. Such efforts are urgently needed to provide population-level insights and advance animal health, management, wellbeing, science, and conservation. Historically, several challenges have impeded sample and associated data sharing among institutions.

The *knowledge-implementation gap*. First, a historical lack of synergy between zoo and outside research communities has impeded collaboration and data sharing (Taylor et al. 2017; Klutsch and Laikre 2022). Cultural and institutional differences are reported by these communities, with few opportunities for interaction and a lack of platforms for shared communication (Klutsch and Laikre 2022; Liptovsky 2024). Even when connections are made, differences in professional incentive structures and priorities can hinder the development of truly reciprocal partnerships (Klutsch and Laikre 2022). Many zoos and aquariums also express concerns about trust (Liptovsky 2024), recognition, and control over how biospecimens and associated data are used—particularly regarding commercialization and intellectual property. These concerns parallel long-standing discussions in human biobanks (e.g., Simon 2007; Caulfield et al. 2014) but have been insufficiently addressed for animal collections. While fostering collaboration between zoo and external science communities is important, it is not sufficient—dedicated resources and legal and ethical guidance are critically needed to support controlled data use, track contributions, and address uncertainty that many zoos and aquariums have regarding benefits sharing, commercialization, and intellectual property.

Balancing data access and privacy. As in human healthcare, zoos and aquariums hold private health records. In human health, organizations have invested heavily in frameworks that define shared values and expectations for sharing biospecimens and data, including codes of conduct, legal frameworks, and cyberinfrastructure for responsible data stewardship that maximize data utility while respecting requirements surrounding data confidentiality and privacy (Lane and Schur 2010). Similarly, a central concern for zoos is ensuring that biospecimens and private animal health data are protected from misuse or misinterpretation. Effective frameworks must provide guidance and oversight to balance access and privacy of animal biospecimens and data. For 50 years, Species360 has established governance, data sharing, and data privacy agreements for their members to align and balance data access and privacy. However, community-guided resources to navigate the decision-making process for data sharing are lacking. Developing consensus-based recommendations regarding policies and mechanisms for access and anonymization will be critical to address hesitation and mistrust, enabling zoos and their conservation partners to share biospecimens and data with confidence.

Benefit sharing for all partners and participants. Equitable benefit sharing with all stakeholders, including sovereign states and Indigenous communities for biospecimens of *in situ* populations, zoos and aquariums for biospecimens of animals in human care, and the animal participants themselves, remains a critical area for further understanding and development. Many institutions currently lack the guidance or resources to consistently align with frameworks such as the Nagoya Protocol for biospecimens from *in situ* populations (Comizzoli and Holt 2016; Colella et al. 2023). Coordinated resources are needed to improve equity and trust between partners and support institutional compliance with emerging international norms.

Fragmented access policies. One key obstacle is the absence of consensus-based, predefined criteria that are mutually recognized across institutions for sharing samples and associated animal-level data. Even when samples are physically centralized in large biorepositories, *ownership* of the samples and associated metadata are still typically dispersed across many institutions, and each institution maintains its own review process and access requirements. Thus, to access biospecimens or data of an entire population, users must navigate separate approval processes from each institution that owns biospecimens—sometimes resulting in dozens of institutional reviews—making the work prohibitively time- and labor-intensive. This inefficiency burdens both external partners and internal practitioners, including coordinators whose mandate is to manage genetically diverse populations (e.g., for Species Survival Plans [SSPs]), thus significantly delaying new knowledge that could benefit species conservation. Shared, consensus-based criteria and procedural standards for biospecimen and data sharing, adopted voluntarily across institutions' access committees, can foster trust and mutual recognition, paving the way to greater coordination, collaboration, and delegation between access committees (GA4GH 2021). Institutions that adopt this approach (within the constraints of differing national policies if extending beyond the U.S.) can streamline the administrative effort involved in contributing to research. Successful examples of this concept include the EAZA Biobank and Species360 Conservation Science Alliance (https://species360.org/species360-conservation-science-alliance/).

Lack of discoverability of biobanks, biobank contacts, and biospecimens. Effective utilization of biobanks requires that external users be able to explore information about the existence of biospecimens and associated data. Specifically, users need a central portal to search for biological materials to assess their scope, quality, and usefulness. Although public data portals (e.g., Global Genome Biodiversity Network [GGBN; Droege et al. 2014]) are being used to share sample metadata by zoos and aquariums in Europe, in the U.S., this type of information is inaccessible outside individual institutions. Without the ability to see what biospecimens exist, particularly for studies at the population scale, practitioners and researchers are hesitant to blindly pursue a lengthy and highly redundant approval process. Surfacing such data in a secure platform, trusted and endorsed by the zoological community, will advance science and conservation, opening up new possibilities of study.

Limited adoption of *data standards*. These discoverability issues stem from deeper data limitations. While most institutions maintain internal biospecimen inventories, few have adopted global data standards (e.g. Darwin Core [Wieszorek et al. 2012]) or use data management platforms that enable interoperability or cross-institutional discovery. Data are often stored in inconsistent or incomplete formats, lacking the structure needed to make it usable. Without shared data standards, it becomes difficult or impossible to integrate records across institutions. Even when organizations are eager to collaborate, the work of reconciling disparate systems, data structures, and permission processes can be prohibitively complex.

Addressing these challenges will require long-term investment for financial, operational, and social sustainability (Watson et al. 2014). Achieving such viability will require developing a clear plan that aligns funding, community needs, and goals for user uptake to ensure collections are actively used and deliver sustained impact (Henderson et al. 2017). Institutional collaborations with external partners, built on transparency and trust, may also help address community challenges. For example, formal partnerships with natural history museums, which share similar missions in biodiversity research and education, have the capacity to preserve and manage requests for specimens and biospecimens in perpetuity, potentially providing services that zoos could delegate while maintaining controlled access (Poo et al. 2022).

Call for a biobank alliance across zoos and aquariums

To overcome these challenges, we propose establishing a biobank alliance of zoos and aquariums to develop community-guided resources that support consistent and streamlined practices for collecting, storing, and sharing high-quality biological samples and associated data. While initially focused on addressing the needs and regulatory landscape of U.S. institutions, the proposed alliance is intended to develop frameworks that are adaptable and adoptable across global contexts. By moving from isolated, project-specific sampling and data collection toward more coordinated, programmatic collection and data integration, the zoo and aquarium community could enable discoveries impossible within the current fragmented model. Importantly, this approach would complement the EAZA Biobank, supporting management and research of the populations and species maintained in the U.S., while collaborating with regional networks and other initiatives (e.g. AZA Biobanking Scientific Advisory Group; IUCN SSC Animal Biobanking for Conservation Specialist Group; IUCN SSC Center for Species Survival Biodiversity Banking; IUCN SSC Conservation Genetics Specialist Group; ZooMu Network [Poo et al. 2022]) to build shared resources for worldwide zoos and aquariums to advance global scientific and conservation efforts. We propose establishing a biobank alliance in order to achieve the following aims:

<u>Build trust and ensure equity</u>

- Adopt, for animals, the principle to “protect personal data while sharing vital knowledge that could benefit all” (GA4GH 2025). This concept should guide the alliance’s approach to ethics, transparency, access, and community engagement.
- Delineate benefit sharing, intellectual property, and equitable, transparent engagement with all partners.

<u>Support consistent and efficient access policies</u>

- Establish a shared framework of guiding principles for data collection, access, and use.
- Define clear, pre-approved conditions for sample and data use to speed legitimate access.

<u>Make data discoverable</u>

- Promote data systems that uphold FAIR (Findable, Accessible, Interoperable, and Reusable [Wilkinson et al. 2016]) and CARE (Collective Benefit, Authority to Control, Responsibility, and Ethics [Carroll et al. 2023]) principles.
- Enhance interoperability across collections by developing a common data framework that describes how data are collected, stored, managed, and used, and by whom and for what purposes (Chan et al. 2010).

<u>Promote utilization of shared resources and standards</u>

- Provide communication platforms to connect the zoo and research communities.
- Foster capacity building across the zoo and aquarium workforce in high-quality sample collection, data standards, and optimal data management, consistent with successful global standards to maximize compatibility and impact (e.g. International Society for Biological and Environmental Repositories [ISBER]; Global Alliance for Genomics and Health [GA4GH], a not-for-profit alliance that sets standards and frames policies to expand genomic data use within a human rights framework).

Strategies to get started

Establishing a biobank alliance will depend not only on developing resources but also on deliberate community building and institutional coordination. Early efforts should therefore focus on organizing leadership, defining participation structures, and creating mechanisms for transparent communication and trust. We recommend beginning with these foundational steps, all of which should be developed through community-guided, consensus-based processes:

- Engage partners to explore potential alliance structures, roles, and responsibilities.
- Develop a proposal that establishes structure and leadership, secures formal mandate, and outlines the initial steps and resources needed to launch the alliance.
- Create a codified framework of shared values and expectations for sample and data sharing, such as the framework provided by GA4GH (Knoppers 2014), to build a foundation of trust.
- Develop guidelines and protocols for documenting ownership or stewardship of biospecimens, data, and intellectual property.
- Collaboratively establish the purpose, scope, applications, and conditions under which biospecimens and data are voluntarily shared and used.
- Identify and adapt appropriate formal metadata schemas (e.g., Darwin Core [Wieczorek et al. 2012]) and best-practice guidelines (e.g. Hvilsom et al. 2025; Corrales and Astrin 2023) tailored to zoo and aquarium contexts.
- Perform a collaborative sampling campaign for a single species or SSP across multiple zoos to pilot the aforementioned frameworks, helping refine approaches to ethics,

metadata, and sample management. An endangered, well-coordinated species (e.g. a great ape) could serve as a guiding case study to inform scalable, trust-based systems.

- Develop a coordinated communication and training strategy, building on existing training efforts, to expand the reach of knowledge exchange and capacity building. Models such as GA4GH's open-source resource library and Harvard Catalyst's cross-institutional training platforms could inform scalable approaches.

The importance of ethics

Zoos and aquariums are mission-driven organizations motivated by both a beneficent duty to the animals in their care and to advancing biodiversity conservation. These two goals underlie the aims and core values of research supported by zoos and aquariums. A direct way to fulfill these mandates is the appropriate use of biospecimens and animal data. Organizations arguably have an obligation to the animal donors of these biospecimens to maximize the benefits that can be gained from their use. When done with integrity, fairness, and efficiency, sharing of biospecimens and data amplifies research benefits well beyond what individual institutions could achieve, making optimization of data value both an ethical imperative (Fischer and Zigmond 2010) and a recognized AZA standard (AZA 2025, Standard 5.3).

All biobanks and their associated data use have inherently ethical features, including considerations of data sharing and governance, consent and representation, genetic privacy, ownership and access rights, and genetic diversity management (Cadigan et al. 2025). Biobank alliances have additional ethical dimensions beyond those of individual biobanks in all of these areas. For example, data protection protocols must be standardized across multiple institutions. However, the increased ethical complexity can also ensure more systematically responsible stewardship of biological materials overall.

The list of values crucial to shaping a successful alliance of zoo biobanks includes those required for any responsible conduct of conservation research (Sandler et al. 2021). The FAIR and CARE Principles (Wilkinson et al. 2016; Carroll et al. 2020; Jennings et al. 2023) should be considered as guiding frameworks in the development of shared values and practices, as they may prove integral to ensuring the alliance's integrity. Additionally, the Zoonomics working group has identified three specific principles of ethical research as paramount to the integrity and success of the alliance: 1) responsible stewardship, 2) transparency, and 3) reciprocity. While data stewardship and transparency may be familiar as typical scientific research principles, reciprocity is less commonly included as an explicit responsibility. In this context, reciprocity means that the benefits of the alliance and subsequent data generation flow bidirectionally—to both the researchers and organizations, and to the benefit of the animals in their care and in broader conservation efforts. As such, reciprocity as an expressed value of scientific research has particular resonance to the zoo and aquarium community.

Conclusion

By prioritizing interoperable and programmatic data collection, efficient access, and consistency with global standards and other regional biobank consortia, a wildlife biobank alliance will open entirely new lines of research, and will accelerate progress in animal health, welfare, management, and conservation.

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Conflict of Interest

One coauthor (Rachel Thompson) is an employee of Species360, which is referenced in this Perspective. No financial, commercial, or organizational interests from Species360 influenced the preparation, content, or conclusions of this work.

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