

CENTER FOR BIOLOGICAL RESEARCH COLLECTIONS **ANNUAL REPORT April 15, 2022 – March 1, 2023**

Executive Summary

CBRC holds core strengths in the current technological fields of 3D imaging and digital infrastructure development for Indiana University's integrated natural history collections. CBRC procures external funding from NSF and IMLS, and from OVPR and the College to support its growing digital expertise. CBRC invests in training STEM and non-STEM graduate and undergraduate students in 3D technology for enhancement of academic and professional careers. Scientific outreach to national and international academic research communities, and to the residents of the State of Indiana through elementary school corporations and local university-Bloomington engagement, are top priorities.

CBRC is approaching its first decade of operation and has an opportunity to showcase its mission, vision, and products to an external review committee whose members will visit the Center at the same time the transfer of specimens into the remodeled paleontology collections space will be completed, and at the time the new director of WRAZL completes his first year at Indiana University. Graduate students will showcase their digitization knowledge and workshops, and their management expertise from training undergraduate students over the years. STEM and non-STEM undergraduate students will display their knowledge with 3D methods and physical specimen management. CBRC has an opportunity to reveal its strengths and financial plan for continuity and growth within the Indiana University system.

I. Center for Biological Research Collections

Center for Biological Research Collections (CBRC) includes two natural history collections:

- The IU Paleontology Collections (IUPC), housed within the Department of Earth and Atmospheric Sciences, holds > 1.5 million fossil specimens, including more than 1,000 unique type specimens, representing more than 400 million years of Earth's history. The IUPC holdings are global in their geographic scope, but most are representative of the Paleozoic of North America, with many specimens from the State of Indiana.
- The William R. Adams Zooarchaeology Laboratory (WRAZL), located in the Department of Anthropology, houses over 10,000 modern comparative faunal remains inclusive of mammals, reptiles, amphibians and fish. WRAZL holdings include species from across the globe, with the most depth being found in Midwestern fauna. Ongoing zooarchaeological research in WRAZL leverages the collection's breadth and includes projects in the American West, Gulf of Mexico, Chesapeake Bay, and Midwest.

The IU Paleontology Collection and William R. Adams Zooarchaeology Laboratory hold natural history specimens in formal research repositories. The specimens form the basis for research in paleontology, zooarchaeology, functional morphology, ecology and paleoecology, evolutionary biology, and related disciplines. The specimens are the primary sources of data on the structure and composition of organisms of the present and past, and they serve as tangible evidence that those organisms lived in particular places and times. Like archival research libraries, the materials in these collections are used by researchers at IU and around the world. CBRC and the faculty and staff associated with the two collections thus carry out independent research on the collections, but they also maintain the integrity and accessibility of the collections for broader research communities. This arrangement works in kind; faculty and staff at other universities and museums provide IU researchers with equivalent access to collections around the world.

CBRC is a pooled resource to support these collections and the faculty who are responsible for them. CBRC serves as a vehicle for collaborative grants to enhance the collections and to support research; it maintains digital infrastructure such as collection management databases and digitization facilities; it

provides training to faculty, graduate students, and undergraduates in collection-based research methods and in collection care; and it facilitates access and use by researchers by providing support in locating specimens, processing loans, and linking specimens with associated data.

Director, Claudia C. Johnson, Department of Earth and Atmospheric Sciences

Executive Committee Members, P. David Polly, Department of Earth and Atmospheric Sciences

Ryan Kennedy, Department of Anthropology

Collections Manager, Paleontology and Zooarchaeology, Jess Miller-Camp, Department of Earth and Atmospheric Sciences

Laboratory Manager, William R. Adams Zooarchaeology Laboratory, Samantha Couch, Department of Anthropology

Affiliate Member, Gary Motz, Information Technology Manager, University Collections, University Information Technology Services

Governance

CBRC is run by a Director, Executive Committee, and Collections Manager consisting of faculty and research scientists who oversee IU's formal paleontological and zooarchaeological natural history collections.

Operating Budget

CBRC is funded by the College of Arts and Sciences, Office of the Vice Provost for Research, Department of Anthropology, and Department of Geological Sciences.

External sources of funding include National Science Foundation's Advanced Digitization of Biological Collections, and the Institute of Museum and Library Services.

The operating budget for 2022-2023 was allocated for staff, graduate and undergraduate student salaries, travel for research presentations, equipment purchases, equipment repair, contractual services for equipment maintenance, consortium dues, institutional membership dues, and warranties for technical equipment for digitization of specimens.

II. Vision, Mission, Principal Goals, and Primary Role on Campus

Vision

Indiana University's Center for Biological Research Collections supports the College of Arts and Sciences' vision of creating leaders and thinkers by developing digital infrastructure to advance a collaborative biodiversity platform, facilitate research on IU's natural history specimen collections, and promote educational enhancement to create citizen science leaders for the State of Indiana.

Mission

The mission of the Center for Biological Research Collections is to enhance collection-based research and education in biodiversity, zooarchaeology, paleontology, and related disciplines by providing shared infrastructure and data management support of IU's natural history collections. The Center's research focus is on 2- and 3D imaging of specimens, including biological, fossil, and archaeological remains, that have associated taxonomic, geographic, and temporal metadata. CBRC thereby provides stewardship for IU's formal paleontological and zooarchaeological repositories.

Principal Goals

CBRC supports data management platforms and digitization for research grants that use IU's natural history collections, coordinates policy, and develops external funding streams for upkeep and development of collection infrastructure.

CBRC actively promotes training in 3D imaging for STEM and non-STEM undergraduate and graduate students.

Primary Role on Campus

CBRC collaborates with other collections and units to develop shared infrastructure and best practices. Partners include University Collections, Digital Library Project, Institute for Advanced Study, University Information Technology Services, Indiana Geological & Water Survey, IU Museum of Archaeology and Anthropology, Advanced Visualization Laboratory, the Data to Insight Center of the IU Pervasive Technology Institute, and the IU School of Education.

CBRC is not a degree-granting program or department

III. Benefits to the College and Campus

CBRC Educates Students in Underrepresented Groups in STEM, thereby contributing to diversity, equity and inclusion goals of the College of Arts and Sciences and Indiana University.

CBRC enhances the teaching and research mission of Indiana University by training undergraduate students in digitization of zooarchaeology and fossil specimens and their associated metadata, and graduate students in enhanced specimen research and in training undergraduates on specimen-related, technological research, managerial and curatorial procedures.

CBRC Trains Students in 3-D Scanning Techniques, Workflows and Workshops

CBRC prioritizes purchase of 3D scanning equipment and provides training for graduate students to develop workflow documents and videos on procedures for scanning objects of varying sizes and densities. Students develop training documents as test runs prior to presenting formal workshops to the university community of engaged student and faculty researchers.

CBRC Prepares Students for Professional Careers

CBRC funds RA positions for graduate students to learn management and curatorial skills with physical specimens and 3D and digital data methods. Graduate student RAs, in turn, instruct undergraduate hourly workers, who then teach techniques and technologies to their peers. This year more than 50 students expressed interest in the 12 hourly positions available. For many of our undergraduates, this work represents their first exposure to scientific research. Thus, their assignments have been designed to serve a dual purpose: to push the goals of CBRC, WRAZL, and IUPC forward, while simultaneously acting as an introduction to various aspects of the scientific process and the organization of contemporary research collections. In addition, all WRAZL and IUPC undergraduate workers have contributed to, and are responsible for, general collections upkeep, including maintaining equipment, supplies, and work areas within the IUPC.

CBRC Provides Stewardship to the IU Paleontology and the W.R. Adams Zooarchaeology Collections

CBRC faculty, graduate students, and undergraduate hourly workers are trained in specimen management and collection practices, principles, and policy. The IUPC and WRAZL collections' specimens are formally curated in climate-controlled conditions supervised by building management personnel.

CBRC Coordinates Specimen and 3D-imaged Loans to the Academic Research Community

Formalized repository policies allow for exchange of specimens among members of the academic research community. When IU faculty request loans from other institutions for themselves or their students, official institutional loan papers and borrowed specimens are under the supervision of IU's curators and collection manager.

The Institute for Advanced Study provides competitive funding for external researchers to visit the IUPC and examine specimens for their research. In early 2023 two awards were made to non-IU researchers to pursue their paleontologic goals using specimens curated and housed in the IU Paleontology Collections.

CBRC Arranges Specimens and Training for Educational Use Across Disciplines

Specimen loans for classroom use, research projects, tours to public visitors, and outreach and collaboration with educational and research entities occur frequently throughout the academic year.

****Educational Offerings from CBRC Collections*** are listed in Appendix 1.

Of special note is WRAZL's new Director has increased the use of specimens in educational activities. WRAZL's comparative faunal collection provides opportunities for graduate and graduate students to participate in specimen processing and curation.

Major activities in 2022–2023

Highlights of accomplishments of CBRC focusing on creative and research activities are detailed in *Appendix I*, inclusive of educational offerings for IU courses, McCalla and departmental exhibits, grants, publications, conference presentations, and more.

Formal IU repositories such as the W.R. Adams Zooarchaeology Laboratory and the IU Paleontology Collection collectively house millions of individual specimens that must be processed, managed, curated, digitized, and associated with their unique metadata identifiers. Below are activities that each repository has accomplished over the year, in addition to CBRC's activities identified in Appendix I and to this point in this annual review document. Highlighted here are major activities unique to WRAZL and IUPC repositories in 2022-23 that must be undertaken to keep repositories functional, relevant, and in accordance with formal policy.

W.R. Adams Zooarchaeology Laboratory (WRAZL)

Dr. Ryan Kennedy, Assistant Professor in the Department of Anthropology, is now Director of the W. R. Adams Zooarchaeology Laboratory. As part of transferring his research program to WRAZL, Dr. Kennedy loaned ~400 modern skeletal specimens from his personal comparative collection to the lab for use by students and other researchers. Additionally, Kennedy brought ~100 carcasses from Gulf of Mexico fishes to be processed in WRAZL and incorporated into the Laboratory's holdings. Kennedy has established several research projects related to CBRC's mission, including size estimation analysis focused on Gulf of Mexico fishes and a number of ongoing zooarchaeological projects centered on sites in the American West, Gulf of Mexico, and Chesapeake Bay.

Collaborations with outside researchers interested in analyzing the Laboratory's specimens as part of ongoing zooarchaeology by mass spectrometry (ZooMS) and genetic research projects have been initiated. *See Appendix II for details.*

These two initiatives are part of a larger effort to dramatically increase the use of WRAZL specimens as the target of research rather than simply as tools for identifying animal remains from archaeological sites.

Connected to this effort, Kennedy and Miller-Camp were awarded slots in a two-year National Endowment for the Humanities-funded training program, Networking Archaeological Data and Communities, that will provide them with tools needed to link the resulting data from ZooMS, genetic, and other specialized analyses with specimen metadata and make these data discoverable for use by outside researchers.

CBRC-funded personnel increased specimen processing, with focus on a unique collection of sea turtle carcasses from Florida. ~50 animal carcasses were processed into cleaned and inventoried skeletal specimens, valuable for zooarchaeological analysis. Student training including ZoomMS, and ongoing development of a turtle osteology guide/element inventory workflow.

An initial draft of a dual osteo guide/element inventory workflow was completed for turtles in Summer with alpha testing of the turtle guide in Fall 2022. Beta testing is slated for completion in Spring 2023. The process was presented and well-received at the 2022 SVP meeting in Ontario, Canada, and a proposal to conduct a workshop on the process of creating and updating such documents has been accepted for the 2023 AMMP meeting in Seattle, WA.

Efforts were resumed to procure animal carcasses to address gaps and/or add depth to the laboratory's comparative collection. Accessions include the ~100 New Orleans fish specimens, and ~100 bird

carcasses and 15 river otter skulls donated by the Bloomington office of the US Fish and Wildlife Service. WRAZL continues to accept specimens donated by current and past affiliated students and researchers, with recent donations including ~10 small animals like birds and rodents.

CBRC funding supported the purchase of a new hot water bath for processing large animal carcasses quickly and efficiently.

CBRC affiliates and students continue to use WRAZL specimens for digitization and photogrammetry projects.

An inventory of laboratory specimens to identify “problem” specimens that needed to be deaccessioned or returned to other facilities was conducted. Contacts were made with IU School of Medicine, law enforcement agencies, IU NAGPRA, and the IU Museum of Archaeology and Anthropology. Similarly, 100+ bones disassociated from their specimen boxes are being investigated.

The challenge to inventory and reorganize specimens to reflect current taxonomy is continuous. Many of WRAZL’s specimens retain outdated taxonomic identifications that reflect the time when the specimens were first processed (e.g., in the 1980s). Dr. Miller-Camp has taken the lead on this work. Reorganization of mammals was undertaken and completed this year, as was the correction of multiple misidentifications of rabbits and hares in WRAZL’s holdings. It is anticipated that numerous other corrections will arise and will be addressed to update the collections.

Workspaces for CBRC, IUPC, and WRAZL were established in Microsoft Teams, including project and task boards to track activities, and training workers to use these central spaces.

External loans from and visits to CBRC Collections were arranged and more for 2023 summer and fall are being processed.

WRAZL’s annual IU IBC protocol and permit paperwork have been filed.

IU Paleontology Collections

CBRC 3D Imaging Training to Undergraduates. Equipment in the IUPC include a high-resolution FaroArm laser scanner and a photogrammetry imaging system for 3D data collection.

Undergraduate students were trained in photogrammetry methods, including specimen imaging, and were introduced to IU’s large-memory computer cluster, Carbonate, which was used for photogrammetry analysis and 3D mesh construction. Photogrammetry is an iterative, hands-on process, and as part of instruction, students were encouraged to make hypotheses regarding optimal angles for specimen imaging, as well as density of images necessary for high-quality 3D mesh generation. Once meshes were built, students would assess the output, tweak their methods, and then carry out the procedure again. Experienced students were then charged with teaching other, new students in these methods. *Specimens deemed well-representative of the IUPC were prioritized for photogrammetry.* These included, among others: Stotter specimens (e.g., spiny oysters, corals), ammonoids and crinoids.

Mazon Creek and Stanley Cemetery Specimens. The IUPC houses a large collection of specimens from the Mazon Creek fossil beds – a Carboniferous lagerstätte in Illinois – and Stanley Cemetery, a near-coeval locality in Indiana with similar preservation. Undergraduate workers have been involved in a project to identify, catalog, and compare the fauna from these localities. Students are constructing a dichotomous key to aid in future identification of specimens, which includes a

diversity of gymnosperm plants, sea cucumbers, leeches, and several specimens of the enigmatic Tully Monster.

Vertebrate Specimens, Big Horn Basin, WY, Paleogene. Sediment sorting and fossil identification from fossiliferous sediments allowed for training in basic microfossil identification procedures.

Paleobotany donations were sorted but await evaluation for possible accession.

Microfossil slides were catalogued and rehoused for condensed storage with archival-quality materials.

Stotter Collection. The IUPC houses an expansive collection of modern bivalves, gastropods and corals (among others), which were collected and donated by Ross Stotter, an IUB alumnus.

Undergraduates identified many specimens to family, transferred specimens and data cards to archival quality trays, cataloged, and reorganized specimens within the IUPC. Coral taxonomy was provided by a graduate student researcher. Stotter's specimens were donated with a partial catalog that included taxonomic and locality information. Undergraduates contributed to the organization and association of metadata to relevant specimens.

Stotter Exhibit was part of University Collections' inaugural opening and highly regarded by visitors. CBRC and University Collections personnel designed and wrote copy for the exhibit. Undergraduate workers helped catalog, pack, and transport Stotter Collection specimens for exhibition.

Teaching reserves. The IUPC holds a large reserve of specimens for use in Earth and Atmospheric Science courses, including research-quality specimens and casts of vertebrate and invertebrate taxa that represent a broad swathe of phylogenetic and taphonomic diversity. Undergraduate workers spearheaded a reorganization of the teaching reserves by taxonomic designations (Order and Family). All specimens were further rehoused with archival-quality materials to ensure continued preservation.

Loans were organized and inventoried for IUPC's long-term specimen loans to other institutions. Specimens from loan returns were integrated into the IUPC; associated records were updated and stored in IUPC archives.

Reorganization and unpacking. Specimens were rehoused and integrated into appropriate collections cabinets and spaces. Online collections inventory was updated to reflect the new location of items in the collections space.

IUPC Basement Storage reorganization. IUPC retains a large space for specimen storage in the basement of the Department of Earth and Atmospheric Sciences. Collections are largely representative of field collections by current and former IUPC personnel, as well as a large reserve of teaching specimens for geology courses. Field collections were organized by principal investigator, project, and locality of origin. Teaching specimens were organized by relevant course, formation, and rock type.

Signage. Students were involved in designing and construction of new signage throughout the IUPC, including updated geologic time scales, labels for cabinets and drawers, collection-specific storage, and workspace designations for IUPC's various facilities.

Display cases. Hallway display cases have historically housed exhibits related to the collections and ongoing research. Prior to remodeling, these displays were removed and now are re-assembled

with new materials. Undergraduates were active contributors to the new exhibits. They developed themes for each exhibit, were involved in the selection of appropriate specimens, contributed to the development of associated text and descriptions for each exhibit. Undergraduate involvement in this project was particularly emphasized in order to make sure that the exhibits were designed to accurately represent the ongoing work in the collections, while also contributing to IUPC outreach efforts, and attracting students to the historical record of life portrayed in the exhibits.

IV. Plans for the Future

CBRC is initiating new activities

- CBRC is developing National Science Foundation grant proposals for external funding
- Showcasing our Center's mission, vision, and goals to external review committee members in April 2023
- Advancing stronger relationships with University Collections to optimize technological innovations in 3D digitization and imaging techniques
- Integrating more fully into the academic digitization community to learn and share new techniques and their applications
- Cultivating educational opportunities with University Collections for McCalla exhibits for CBRC, IUPC, and WRAZL materials

CBRC is establishing new goals

CBRC has developed very recently *Strategic Planning Documents* that are in circulation among executive committee members, collections manager and affiliate faculty. Priority goals of these strategic plans include:

- digitizing physical specimens in the IUPC and WRAZL with priority rankings
- advertising availability of imaged specimens to research and non-academic communities
- prioritizing equipment for digitization efforts
- utilizing more fully the *Specify* framework for collections metadata
- training the next generation of STEM and graduate and undergraduate students in 3D imaging techniques and in managing associated metadata

CBRC is anticipating changes in operation improvements

Discussions with External Review committee members for targeted improvement of CBRC goals more fully aligned with IU's emerging technology and digital data storage will be initiated and welcomed.

CBRC has special issues and challenges

Preserving individual digitized images and their associated metadata is a technology storage challenge that remains unresolved at IU regarding cost and storage availability. Transfer of digital data from Box to Google to OneDrive and Teams, with no permanent storage solution in sight, risks loss of valuable 3D data and slows progress in developing technological innovations.

- Maintaining stability of digitization expertise in academia as students rotate with semesters
- Communicating effectively the goals and objectives of the Center from a multitude of voices – researchers, graduate students, undergraduates, departmental chairs – in personal interviews and written documents, will be essential in securing the productive future of CBRC.

Summary

CBRC is initiating new activities, establishing new goals, and has special issues and challenges to be addressed with External Review committee members. CBRC has faculty and student researchers with deep knowledge of the unique value of natural history collections. CBRC personnel are dedicated to caring for the natural history specimens in their physical and digital forms with managerial and curatorial skills advocated by policy. With innovations in digital technology CBRC preserves the specimens, protects the history of the Earth embedded in these collections, and uses and shares these resources with researchers within and outside of the State of Indiana to introduce natural history and biological evolution of the Earth to the general public.

Appendix I

Highlights of Accomplishments of CBRC Members, inclusive of IUPC and WRAZL

**Educational Offerings from CBRC Collections*

IU Courses

- Dinosaurs and Their Relatives (EAS G114). Introduction to paleontology and geology from the perspective of the clade Dinosauria. Introduction to the scientific process, morphology, phylogenetics, stratigraphy and geochronology, and Earth history.
- Natural History of Coral Reefs (EAS E341/E700). This course addresses the evolutionary history of reef ecosystems through geologic time, inclusive of reef composition, global distribution, modern reef development, conservation and management practices, and the persistence of the reef ecosystem through climate change scenarios. Topics include biologic, ecologic and geologic principles and processes as they pertain to coral reef ecosystems.
- Invertebrate Paleontology (EAS E411). This course introduces the structure, classification, habitats, geologic history and significance of the invertebrate phyla. Students learn the application of biologic principles and the use of invertebrate fossils in the study of Earth's history, the origin of life and the early fossil record, approaches of taxonomy, chemistry of fossils, ecology of ancient life, and the use of fossils to measure geologic time.
- Vertebrate Paleontology (EAS E412 / E512). This course introduces the biological and geological principles of studying vertebrate evolution in the context of Earth history, including morphology, phylogeny, taxonomy, evolution, biomechanics, biogeography, paleoenvironments, and stratigraphic history.
- Geometric Morphometrics (EAS E562). This course is a practical, applied introduction to geometric morphometrics. Students learn to collect, analyze, and interpret geometric morphometric data. Shape theory and methods are covered, including Procrustes superimposition and its statistical implications, analysis of curves and outlines, and Monte Carlo modeling of shape.
- Problems in Zooarchaeology (ANTH P425). This course combines group discussions of zooarchaeological theory and case studies with practical, hands-on group projects using WRAZL specimens. Students learn basic skeletal anatomy by inventorying curated skeletal specimens, participate in animal carcass processing sessions, and have the option to do a laboratory-based research project in lieu of a final paper (students in Fall 2022 worked on size estimation of Sheepshead fish remains and re-designing WRAZL's public display cases).
- Faunal Analysis (ANTH P426). This course introduces students to zooarchaeological analysis and makes heavy use of WRAZL specimens. Students learn basic skeletal anatomy of a wide range of animal groups (mammals, birds, fish, etc.), take part in an animal carcass processing workshop, and conduct a semester-long research project using archaeological animal remains.
- Prehistoric Diet and Nutrition (ANTH P380). Professor and 20 undergraduate students visited the WRAZL lab to examine specimens.
- Traditional East Asian Civilizations (EALC E251). Instructor and 20 undergraduate students visited the WRAZL lab to examine specimens.
- Capstone in Food Studies (ANTH A650). Graduate students visited WRAZL for specimen examination.

Exhibits

WonderLab Museum Display: WRAZL now has a standing section in WonderLab's upstairs gallery in which 3 specimens are sent every 4 months for display in the *Wonder Under the Waves* coral reef exhibit. The first installation includes Hawksbill Sea Turtle scutes, lionfish spines, and a dolphin skull that support conservation messaging within the exhibit including overfishing, invasive species, and habitat loss. There is potential to expand this relationship for their current other biome representative, *Hidden Life of Deserts* and their future forest exhibit.

University Collections at McCalla: “The Stotter Collection” on exhibit Feb 2022-March 2023.

University Collections at McCalla: “Dentition” installation begins March 2023.

Department of Earth and Atmospheric Sciences: “Extinctions” installation begins March 2023.

External Grants

Completed

- Kravitz, B. (Co-PD/PI), Kieu, C. (Co-PD/PI), Johnson, C. C. (Co-PD/PI), "Marine Sky Brightening: Prospects and Consequences", National Science Foundation, 073543 Award Number, \$299,994.00, July 1, 2019 - June 30, 2022.
- Kort, A. E. Charles A. & June R.P. Ross Research Grant. Geological Society of America. 2022. Enigmatic evolution of lumbar vertebrae and diversification of locomotion in mammals.
- Kort, A. E. Paleontological Society Student Research Grant. 2022. Evolution of lumbar vertebrae in Paleogene mammals.
- LaBarge, T.W. Paleontological Society Student Research Grant. 2022. Application of stable nitrogen isotopes as proxy for trophic relationships of East African Pleistocene megafauna.
- McHenry, L.J. (PI), Njau, J.K. (co-PI), Hynek, B (co-PI). African Rift fluvio-lacustrine analog for Jezero crater, Mars. NASA, Solar System Workings.2022-25. IU subaward (\$71,962).
- Njau, J.K. (PI). Eastern Africa Association of Paleoanthropology & Paleontology (EAAPP). Wenner-Gren Foundation for Anthropological Research. Conference Grant, 2022. (\$20,000).
- Peltier, D. M. The Leakey Foundation Research Grant. 2022. The drivers of faunal community dynamics and its implications on hominin occupation during Bed II times, Olduvai Gorge, Tanzania.
- Stone, A.C. (PI), P.D. Polly (co-PI), S. Winingear, M. Outerbridge. Sequencing the genome of *Poecilozonites bermudensis*, the Bermudian land snail. Dovetail Genomics “Tree of Life” award. 2020-2022. (\$35,000).

In Progress

- Gomez-Robles, A. (PI), P.D. Polly (co-PI). Species or local variant? Using modelling to test hypotheses of speciation in human evolution. Leverhulme Trust.
- Guiry, E.J. (PI), T.C.A Royle (Co-PI), and J.R. Kennedy (Co-PI). Save Our Seas Foundation. “Towards an archaeology of sharks: building millennial-scale records of shark ecology in Monterey Bay.” \$9,987.50.
- Johnson, C. C. (Co-PD/PI), Zimmerman, A. (PD/PI), Ocean Protector: A game-based curriculum to teach the impacts of ocean acidification and positive actions to help. National Oceanic and Atmospheric Administration Award N079081, \$40,000.00.
- Kennedy, J.R. (Team Members: J. Miller-Camp and J. Floyd). National Endowment for the Humanities Institute for Advanced Topics in the Digital Humanities, program run by Alexandria Archive Institute and Open Context. “Networking Archaeological Data and Communities.”

In Review

- Fulghum, H.Z. National Science Foundation – Graduate Research Fellowship Program. Life Sciences. “Living Fast and Dying Young: Is the Bone Structure of Small Mammals Driven by Mechanical Demands?” \$138,000.
- Guiry, E.J. (PI) and J.R. Kennedy (Co-PI). Chelonian Research Foundation. “Building millennial-scale records of turtle ecology in the Chesapeake Bay watershed.” \$4,750.
- LaBarge, T.W. International Association of GeoChemistry PhD Student Research Grants. 2022. Characterizing the Evolution of the Serengeti Ecosystem with Stable Isotopes.
- LaBarge, T.W. Geological Society of America Graduate Student Research Grant. 2023. The Isotopic Ecology of a Serengeti Insectivore and Applications to Hominin Paleoecology.

Internal Grants

Completed

- Fulghum, H.Z. Grant in Aid, Department of Earth and Atmospheric Sciences, Indiana University Bloomington. 2022. \$475.
- Fulghum, H.Z. Fall Travel Award. College of Arts and Sciences, Indiana University Bloomington. 2022. \$200.
- Hawley, K. Tinker Field Research Grant. 2022. Center for Latin American and Caribbean Studies, Indiana University Bloomington.
- Hawley, K. Skomp Feasibility Fellowship. 2022. Department of Anthropology, Indiana University Bloomington.
- Kort, A. E. McCormick Science Grant. 2022. College of Arts and Sciences, Indiana University Bloomington.
- LaBarge, T.W. Galloway/Perry/Horowitz Fellowship Grant-in-Aid. 2022. IU Department of Earth and Atmospheric Sciences.
- Peltier, D. M. William D. Thornbury Research Grant-in-Aid 2022 Dept. of Earth and Atmospheric Sciences, Indiana
- Salcido, C.J. Grant in Aid - Norman R. King Graduate Field Research Fellowship, Department of Earth and Atmospheric Sciences, Indiana University Bloomington. 2022

In Progress

- Kennedy, J.R. (PI), P. Sauer (Co-PI), and E.J. Guiry (Co-PI). IU Social Sciences Research Funding Program. “Developing New Archaeological Approaches to Human-Turtle Relationships.” \$35,000.
- Miller-Camp, J, IU DEAS John Barrett Patton Award, “Comparing Floral Biodiversity Profiles of a new Stanley Cemetery and Mazon Creek Collection in IUPC”, \$1500.

In Review

- Kennedy, J.R. IU IAS Collaborative Research Award. “Advancing collaborative research in IU’s William R. Adams Zooarchaeology Laboratory.” \$12,124.

Peer-Reviewed Publications

Published

- Brassell, S.C., Colcord, D.E., Shilling, A.M., Stanistreet, I.G., Stollhofen, H., Toth, N., Schick, K.D., Njau, J.K., Freeman, K.H. Alkenones in Pleistocene Upper Bed I (1.803-1.900 Ma) sediments from Paleolake Olduvai, Tanzania. 2022. *Organic Geochemistry* 170. [DOI](#).
- Camargo, I., S. T. Álvarez-Castañeda, P. D. Polly, J. D. Stuhler, J. E. Maldonado. 2022. Molecular phylogenetic and taxonomic status of the large-eared desert shrew *Notiosorex evotis* (Eulipotyphla: Soricidae). *Journal of Mammalogy* (10.1093/jmammal/gyac069).
- Farrugia, P. & Njau, J.K. 2022. Paleoeology and Vertebrate Taphonomy of the DK Site, Olduvai Gorge, Tanzania, In S. Reynolds & R. Bobe (eds.). *African Paleoeology and Human Evolution*. Cambridge University Press. Pg. 394-412. [DOI](#).
- Fujioka, F., Benito-Calvo, A., Mora, R., McHenry, L.J., Njau, J.K., Torre, I. 2022. Direct cosmogenic nuclide isochron burial dating of early Acheulian stone tools at the T69 Complex (FLK West, Olduvai Bed II, Tanzania). *Journal of Human Evolution* 165. [DOI](#).
- Hebdon, N., P. D. Polly, D. J. Peterman, K. A. Ritterbush. 2022. Detecting mismatch in functional narratives of animal morphology: a test case with fossils. *Integrative and Comparative Biology* 62: 817-828 (10.1093/icb/icac034).
- Kennedy, J.R. and E.J. Guiry. 2022. Exploring Railroad Impacts on Meat Trade: An Isotopic Investigation of Meat Sourcing and Animal Husbandry at Chinese Diaspora Sites in the American West. *International Journal of Historical Archaeology*. <https://doi.org/10.1007/s10761-022-0663-6>
- Kort, A., H. Ahrens, P. D. Polly, and M. Morlo. 2022. Postcrania and paleobiology of *Patriofelis ulta* (Mammalia, Oxyaenodonta) of the Bridgerian (Early-Middle Eocene) of North America. *Journal of Vertebrate Paleontology*, 41: e2045491, 1-16 (10.1080/02724634.2021.2045491).

- Mo, J. and P. D. Polly. 2022. The role of dispersal, selection intensity, and extirpation risk in resilience to climate change: a trait-based modeling approach. *Global Ecology and Biogeography*, 31: 1184-1193 (10.1111/geb.13495).
- O’Keefe, R., J. Meachen, and P. D. Polly. 2022. On information rank deficiency in phenotypic covariance matrices. *Systematic Biology*, 71: 810-822 (10.1093/sysbio/syab088).
- Pearson, A., P. D. Polly, E. Brunner. 2023. Updated imaging and phylogenetic comparative methods reassess relative temporal lobe size in anthropoids and modern humans. *American Journal of Physical Anthropology*, (doi: 10.1002/ajpa.24712)
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- Zimmerman, A. N., Johnson, C. C., Phillips, G. E., and Ehret, D. J. 2023. Taxonomy and paleobiogeography of rudist bivalves from Upper Cretaceous strata, Gulf Coastal Plain and Puerto Rico, USA. *Journal of Paleontology* (doi: 10.1017/jpa.2022.104)

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Conference Presentations

- Brand, N., Miller-Camp, J. and Uhen, M. 2022, Where in the world does that whale hail from? Paleobiogeography and dispersal history of stem mysticetes. *Journal of Vertebrate Paleontology, Program and Abstracts, 2022*, pg. 86-87. [Poster]
- Fulghum, HZ and Polly, P.D. Evaluating dietary diversity in the tribosphenic dentition: machine learning analysis of simple linear measurements distinguish primary and secondary diet types in extant taxa. *Society of Vertebrate Paleontology 82nd Annual Meeting (Toronto, ON)*. 2022
- Fulghum, HZ., Polly, P.D. Evaluating dietary diversity in modern tribosphenic taxa. *Great Lakes Paleontological Conference (Chicago, IL)*. 2022
- Fulghum, HZ., Polly, P.D. Assessing the diversity of modern tribosphenic dentitions using simple indices of functional morphology. *Crossroads Conference (Bloomington, IN)*. 2022.
- Fulghum, H. Z., Polly, P. D. "Evaluating dietary diversity in the tribosphenic dentition: simple linear measurements distinguish primary and secondary diet types in extant taxa", Conference, Society of Vertebrate Paleontology Annual Meeting, Toronto, Canada, International. (November 5, 2022).
- Guiry, E.J., S. Noël, J. Fowler, J.R. Kennedy, S.D. deFrance, T. Orchard, and S. Needs-Howard. 2022. "Sulfur isotopes as an indicator of wetland use." Paper presented at the International Council for Archaeozoology Fish Remains Working Group Meeting, Vienna, Austria, August 22-27.
- Hawley, K., C. Beeker, C. Johnson, S. Rader. 2023. "Methods to identify post-depositional geochemical alterations to ceramics in Submerged Archaeological Sites: A Case Study using prehistoric ceramics from Eastern Dominican Republic." Presented at the Society for Historic Archaeology Annual Meeting, Lisbon, Portugal, January 3-8.

- Kennedy, J.R., E.J. Guiry, S.D. deFrance. 2022. "The dynamics of fish supply in late-nineteenth-century New Orleans, Louisiana, USA, and some implications for the role of transportation technology in fish trade." Paper presented at the International Council for Archaeozoology Fish Remains Working Group Meeting, Vienna, Austria, August 22-27.
- Kort, A. E. 2022. Bizarre Backbones: A Synapomorphy in the Lumbar Vertebrae for Ferungulata. Society of Vertebrate Paleontology Annual Meeting, 2022.
- Kort, A. E. 2023. Testing the function of interlocking zygapophyses in lumbar vertebrae of early placental mammals. Society of Integrative Biology Annual Meeting, 2023
- LaBarge, T.W. & Njau, J.K. 2022. Taphonomy and Ichnology of Nile Crocodile Feeding Behavior. Society of Vertebrate Paleontology 82nd Annual Meeting, Toronto, ON, Canada [Poster]
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- LaBarge, T.W. & Njau, J.K. 2022. Identifying Diagnostic Crocodile Feeding Traces in Archaeological Sites. Eastern African Association of Palaeoanthropology and Palaeontology, Arusha, Tanzania [Poster]
- Miller-Camp, J. 2022, Dual Osteology Guide/Inventory Workflows as an Answer to Several Museum Collection Problems, Journal of Vertebrate Paleontology, Program and Abstracts, 2022, pg. 243. [Poster]
- Njau, J.K. 2022. Human Origins Research at Olduvai Gorge: Advances in Modern Paleoanthropology. Presented at the joint working meeting between Olduvai and D'manisi hominid projects. Conference organized by the Stone Age Institute and National Museum of Georgia. State University of Tbilisi, Republic of Georgia.
- Njau, J.K., Toth, N., Schick, Stanistreet, I., Stollhofen, H. 2022. New stratigraphy extends Quaternary record at the Olduvai basin, Tanzania. Eastern African Association of Palaeoanthropology and Palaeontology (EAAPP), Arusha, Tanzania.
- Pante, M., de la Torre, I., d'Errico, F., Njau, J.K., Blumenschine, R.J. 2022. Bone tools from Beds II-IV, Olduvai Gorge, Tanzania, and implications for the origins and evolution of bone technology. Paleoanthropology Society, Denver, CO.
- Peltier, D.M., Njau, J.K., 2022. Tectonic influence on Pleistocene vertebrate diversity at Olduvai Gorge, Tanzania. Eastern Africa Association for Palaeoanthropology and Palaeontology Biennial Conference, Arusha, Tanzania.
- Peltier, D.M., Johnson, C., Njau, J. 2022. Biostratigraphic Framework of Bed II, Olduvai Gorge, Tanzania. Geological Society of America 2022 Annual Meeting, Denver, CO
- Pineda Munoz, S., Chandroth, A., Fulghum, H., Hawley, K., LaBarge, T., Lopezalles, S., Nelson, A., Salcido, C. J., Polly, P. D. "The Conservation Archives: Bridging conservation research and practice", Conference, International Biogeography Society Biennial Conference, Vancouver, Canada, Academic, International. (June 2, 2022).
- Polly, P. D. "Functional tradeoffs carry phenotypes across the valley of the shadow of death: why performance trade-offs may not equate to multiple adaptive peaks", Conference, Phylogenetics Symposium 2022, Institute of Evolutionary Biology and Ecology, University of Bonn, Bonn, Germany, Academic, International. (November 19, 2022).
- Polly, P. D. "Spatial processes, statistical models, and vertebrate evolution in a changing environment", Conference, Society of Vertebrate Paleontology Annual Meeting, Toronto, CO, Canada, International. (November 4, 2022).
- Polly, P. D. "Conservation Science of Park Paleontology", Panel, National Parks Conservation Association (NPCA), Zoom, Academic. (November 1, 2022).
- Royle, T.C.A, J.R. Kennedy, E.J. Guiry, L.S. Jackman, Y. Shichiza, and D.Y. Yang. 2022. "Understanding the dynamics of 19th-century Chinese shark fisheries in Northern California through ancient DNA analysis." Paper presented at the International Council for Archaeozoology Fish Remains Working Group Meeting, Vienna, Austria, August 22-27.

Salcido, C. J., Polly, P. D. "Functional drivers of evolutionary rates in mandible shape of carnivorous therian mammals: a study using biomechanical modeling and geometric morphometrics", Conference, Society of Vertebrate Paleontology Annual Meeting, B, Canada, International. (November 5, 2022).

Short, R., Polly, P. D., McGuire, J., Lawing, A.M. "Human impacts disrupt the functional relationship between traits and environment in large mammal communities", Conference, American Society of Mammalogists Annual Meeting, Tucson, AZ, United States, Academic. (June 18, 2022).

Zimmerman, Alex N., Johnson, Claudia, 2022. Predicting suitable habitats and refugia for the deep-sea coral *Lophelia pertusa*, US West Atlantic and Northern Gulf of Mexico. Geological Society of America Abstracts with Programs, Vol. 54, No. 5, Denver, CO. Abstract #379847, <https://doi.org/10.1130/abs/2022AM-379847> Invited presentation.

Department Presentations

Fulghum, HZ. "Evolution of Devonian Reef Systems", Seminar, Department of Earth and Atmospheric Sciences, Indiana University.

Fulghum, HZ. "Pattern and Timing of Cenozoic Mammal Radiation", Seminar, Department of Biology, Loyola University Chicago.

Kennedy, J.R. 2022. "An intro to zooarchaeology and a case study from the Gulf of Mexico." Paper presented for the Indiana State University Department of Earth and Environmental Systems Speaker Series, February 6.

Polly, P. D. "Paleontology and US National Monuments: Implications for Science and Public Lands", Seminar, Royal Tyrrell Museum Speaker Series, online, Drumheller, Canada, International. (February 2022).

Polly, P.D., "Spatial processes and evolutionary models", Seminar, Seminar Series, School of Biological Sciences, University of Nebraska, Lincoln, NE, United States, Academic. (April 6, 2023).

Polly, P.D. "The assembly of New World cat communities: ecometrics and Neogene faunal turnover", Seminar, Seminar Series, School of Biological Sciences, University of Nebraska, Lincoln, NE, United States, Academic. (April 6, 2023).

Creative Works

Miller-Camp, J.A. and M. Bramnik, 2023, "Dinosaurs and Other Prehistoric Beasts of Kortos and Erran" in *Wayfinder #22*, *Paizo Publishing*, LLC, Seattle, WA, pp. TBD. (*accepted, expected May publication*)

Awards

Kort, Anne. Taylor & Francis Award for Best Student Article in the Journal of Vertebrate Paleontology. 2022 (for "Postcrania and paleobiology of *Patriofelis ulta* (Mammalia, Oxyaenodonta) of the Bridgerian (Early-Middle Eocene) of North America.")

Polly, P.D. Fellow, American Association for the Advancement of Science (AAAS) for "for distinguished contributions to the field of vertebrate paleontology, particularly for original studies in morphometrics, for quantitative analyses in paleobiology, and for innovative studies on mammalian evolution" (2022).

Dissertations and Theses

Nelson, Allison, Indiana University, Earth & Atmospheric Sciences, Masters, 2020-2023. Thesis title: "An exploration of the *Canis lupus* and *Canis rufus* species boundary via morphometrics."

Qualifying Exam Presentations

Hawley, Kirsten (PhD Qualifying Exam, Earth & Atmospheric Sciences, Anthropology)

Lopezalles, Sierra (PhD Qualifying Exam, Biological Sciences)

Workshops

- Kort, Anne. CBRC Museum Object Photogrammetry, Center for Biological Research Collections, Indiana University Bloomington, IN. June 2022 and September 2022.
- Kort, Anne. Digital Morphology and Shape Analysis with Slicermorph, Society of Vertebrate Paleontology Annual Meeting, Toronto, ON, Canada. 2022.

Government Reports

- Salcido CJ, Wilson P, Tweet JS, McCann BE, Boyd CA, Santucci VL. 2022. Theodore Roosevelt National Park: Paleontological resource inventory (public version). Natural Resource Report. NPS/THRO/NRR—2022/2385. National Park Service. Fort Collins, Colorado.
<https://doi.org/10.36967/nrr-2293509>
- Salcido, C.J., Wilson, P.J., Tweet, J.S., McCann, B.E., Boyd, CA, and Santucci, V.L. (2022). Theodore Roosevelt National Park: Paleontological resource inventory (sensitive version). Natural Resource Report NPS/THRO/NRR – 2022/2347. National Park Service, Fort Collins, Colorado.

Educational Outreach

- Couch, S. Apr 8, 2022. Specimens lent to WonderLab Museum for use in their virtual educational program "Animal Hour: Loco Locomotion: a discussion on flight."
- Couch, S. June 10, 2022. Brought 22 children ranging from 4-6 grade to WRAZL for WonderLab Museum's summer camp, "Intro Animal MD."
- Couch, S. June 17, 2022. Brought 13 children ranging from 4-6 grade to WRAZL for WonderLab Museum's summer camp, "Animal MD 2.0."
- Kennedy, R. Nov. 11, 2022. Spoke to an audience in WonderLab Museum's virtual educational program, "Animal Hour: AMA Archaeologist."
- Miller-Camp, J. Nov 18, 2022. Spoke to an audience in WonderLab Museum's virtual educational program, "Animal Hour: AMA Paleontologist."
- Miller-Camp, J. June 3, 2022. Spoke to an audience in WonderLab Museum's virtual educational program, "Animal Hour: Who's Who?: A discussion of gender in science."
- Salcido, Charles (Writer). February 2023). When Theropods Went Vegetarian [YouTube series episode]. Nicole Sweeny (Executive Producer). PBS Eons. PBS Digital Studios.

IU Science Fest: WRAZL participated in IU's Science Fest, connecting with 66 visiting community members. Activities included the following: "What is Zooarchaeology?" used 3 known comparatives and an unknown sample for visitors to learn how to identify unknown elements using a comparative collection. "Dimorphism" taught visitors that it is important to understand sex differences in studied species to accurately identify archaeological elements. "3-D Modeling" showed the future of collections management and information dissemination by displaying the process of taking an element, photogrammetrically scanning it and turning it into a virtual 3-D model. We fully intend to participate in next year's fest.

Girls Inc. Science Fest: K. Hawley and A. Chandroth participated in a Science Fest hosted on February 11, 2023 by the Bloomington chapter of Girls, Inc. Teaching materials from the CBRC were used to answer questions about fossils, rocks, and minerals.

WonderLab Museum's *Dino Weekend*: a two-day event in which paleontology was being celebrated with the Bloomington community. The purpose of WRAZL's participation was to show how extant descendants have changed from the ancestral species that were being highlighted by paleontological institutions who were also presenting.

Media Coverage

- Kennedy, J.R. "Inside the diet that fueled Chinese Transcontinental Railroad Workers," Shoshi Parks, 30 Nov 30, 2022. <https://www.atlasobscura.com/articles/diets-transcontinental-railroad>

- Polly, P.D. Indiana Daily Student. "A beaver has found a home on IU's Campus River", Carter Dejong, 15 Nov 2022. Why beavers really aren't so scary. <https://www.idsnews.com/article/2022/11/a-beaver-has-found-a-home-on-ius-campus-river>
- Polly, P.D. CNN. "Jurassic dinosaur fossil will go up for auction in Paris", Kristen Rogers, 12 Sept 2022. <https://www.cnn.com/style/article/dinosaur-skeleton-iguanodon-auction-paris-scn/index.html>
- Polly, P.D. VOI, Voice of Indonesia. Kerangka dinosaurus langka laku dilelang rp90 miliar: Pemenangnya dapat memilih nama, disoroti ilmuwan" by staff, 7 Aug 2022. <https://voi.id/berita/196778/kerangka-dinosaurus-langka-laku-dilelang-rp90-miliar-pemenangnya-dapat-memilih-nama-disoroti-ilmuwan>
- Polly, P.D. BBC. "Gorgosaurus: Ancient dinosaur skeleton sells for \$6m at auction" by Staff, 29 July 2022. <https://www.bbc.com/news/world-us-canada-62339887>
- Polly, P.D. CNN. "Scientists are concerned about the million dollar auction of this dinosaur skeleton" by Kristen Rogers, 28 July 2022. <https://www.cnn.com/style/article/gorgosaurus-dinosaur-skeleton-auction-scn/index.html>
- Polly, P.D. Washington Times. "Gorgosaurus: Ancient dinosaur skeleton sells for \$6m at auction" by Brad Matthews, 29 July 2022. <https://www.washingtontimes.com/news/2022/jul/29/sothebys-sells-gorgosaurus-dinosaur-skeleton-to-pr/>
- Polly, P.D. LiveScience. "Did cats really disappear from North America for 7 million years?", by Joe Phelan, 16 May 2022 <https://www.livescience.com/why-cat-gap-north-america-fossils>

Appendix II

ZooMS is a method for generating taxonomic identifications based on differences in collagen (and other) protein structure that can be measured via analysis of bone collagen using MALDI mass spectrometry. WRAZL has contributed samples from ~200 specimens to Dr. Kristine Richter (Harvard University) to generate baseline ZooMS spectra for a range of species spanning groups including zebras, deer and other medium-sized North American artiodactyls, rabbits and hares, and parrots. Kennedy also sent 60 archaeological Leporidae collagen specimens from archaeological sites in New Orleans, which will be analyzed by Dr. Richter and compared to ZooMS spectra generated from WRAZL's comparative specimens to produce the first ZooMS-based identifications of ancient rabbits to date. ZooMS analysis has revealed that several of WRAZL's rabbit specimens were misidentified when they were originally processed (e.g., a specimen labeled Domestic Rabbit is actually a Snowshoe Hare), and, as noted below, we have updated our specimen records to reflect these identifications. WRAZL also contributed samples from 15 walleye and sauger specimens to a study by Dr. Thomas Royle (Simon Fraser University) to general baseline genetic and ZooMS data for fishes common to the Midwest and Canada, and samples from 30 fish specimens to Dr. Brian Kemp (University of Oklahoma) for generating baseline genetic data and confirming original WRAZL species identifications. We will continue to expand this work to include additional species, with the goal of generating comparative data and correcting misidentified specimens curated in WRAZL.