

VIRGINIA MUSEUM OF NATURAL HISTORY
Board of Trustees Research and Collections Committee

Saturday, Nov. 18, 2023

9 a.m.

A G E N D A

- Call to order
- Roll Call: Dr. Art Evans, Dr. Tom Benzing, Dr. Carole Nash, Melany Stowe, Mark Buss.
- August 2023 Research and Collections Committee meeting minutes (action item)
- July-Sept. 2023 acquisitions (action item)
- Review of attached document “The Silent Extinction of Species and Taxonomists”
- Other business
- Adjourn

The mission of the Virginia Museum of Natural History:

To interpret Virginia’s natural heritage within a global context in ways that are relevant to all citizens of the Commonwealth.

VIRGINIA MUSEUM OF NATURAL HISTORY BOARD OF TRUSTEES
MINUTES OF THE RESEARCH AND COLLECTIONS COMMITTEE
August 11, 2023

Present at the virtual meeting were Dr. Art Evans, Dr. Tom Benzing, Dr. Carole Nash, Mark Buss, Melany Stowe, Dr. Nancy Moncrief, Dr. Hayden Bassett, Dr. Adam Pritchard, Dr. Arianna Kuhn, Lucy Treado, Marshall Boyd, Dr. Joe Keiper, Ryan Barber, Jonathan Martin, Mary Zell Galen, Roberto Quinones, DB Poli, Cindy Marquez, Bill Kirby, and Ben Williams

Committee Chairman Dr. Art Evans called the meeting to order. The minutes of the May 20, 2023 meeting were unanimously approved. The committee will circulate the recent acquisitions sign-off sheet and return it to Ben Williams.

Dr. Art Evans asked if anyone would speak to the proposed Research Associate appointment of Dr. Isaac Overcast. Dr. Hayden Bassett said that he could not be more impressed with the quality of Dr. Overcast's work and the specialty he brings. With his experience in AI machine learning, Bassett said that Dr. Overcast is on the cutting edge of the natural history world and staff are looking forward to using his knowledge across multiple disciplines. Dr. Joe Keiper said that having a Research Associate with a background in AI will be excellent for collections. Mark Buss moved to approve Dr. Overcast as a Research Associate, which was seconded by Dr. Tom Benzing. Dr. Overcast was unanimously approved.

Dr. Art Evans asked the committee to consider accepting the current version of the museum's collections policy and live animals policy to forward to the full board for consideration. The collections policy was last reviewed in 2013 and is being reconsidered as VMNH moves towards reaccreditation. Dr. Evans said that the first round of additions and corrections began earlier this year and a second round was completed in July. He thanked Dr. Nancy Moncrief and Jill Harris for their hard work as well as Dr. Hayden Bassett, Madeleine Bassett, and Ryan Barber for their contributions. Dr. Mark Buss moved to recommend the documents to the full board for approval, and Dr. Carole Nash seconded the motion. The recommendation was approved unanimously.

Dr. Art Evans asked for input regarding the concept of creating "Centers of Excellence" at VMNH, which would be a new way of packaging the different research labs at the museum to better communicate the museum's work to legislators and other entities.

Mark Buss said that the centers could be an excellent way to publicize the work being done at VMNH across multiple disciplines, but the concept of a Center of Excellence would need to be clearly defined. Dr. Carole Nash said that it's a fabulous idea, but the idea of a "center" has multiple different meanings. Buss clarified that we have to make sure that we are able to support the centers with the current amount of staff.

Dr. Arianna Kuhn said that Centers of Excellence would be an opportunity to show the overlap between the museum's existing labs, although these labs do already collaborate frequently. She added that one concern is the sustainability of these centers and the amount of time that would need to be invested into maintaining these centers versus the existing labs. For example, she said, would the centers need their own social media or marketing? What are their practical applications? There is also the concern, she said, the centers might be misleading to outside entities. It's good to think big, she said, but Centers of Excellence might be an idea for further down the road as the museum continues to grow.

Dr. Hayden Bassett said that at the recent board retreat in Harrisonburg, Virginia, the question arose of the difference between a center, an institute, and a lab. For the Cultural Heritage Monitoring Lab (CHML), the term "lab" was specifically chosen because it required far fewer infrastructures and capacities than a center or institute, which generally have full-time dedicated staff. A lab is generally housed within an existing entity and is flexible in terms of staff, and is also more achievable and realistic in practice.

Dr. Adam Pritchard said that at larger museums than VMNH, labs are generally the preferred designation for a project like the one described, as institutes or centers generally have separate education and administration departments. Pritchard said he supported the lab designation.

Dr. Nancy Moncrief said that labs are generally more associated with scientific research than centers or institutes, and science is at the core of what these entities would be focusing on rather than exhibits, education, and outreach.

Dr. Art Evans said that it sounded like curators preferred individual labs over centers as they are more nimble, streamlined, and flexible. He said that in his conversations with Dr. Kal Ivanov, Ivanov agreed that the lab model was preferable. As the museum evolves it may be worth revisiting the topic, but in the short term, it sounded like curators were satisfied working in individual labs under the VMNH banner.

Dr. Joe Keiper said that the Centers for Excellence were an idea that the board had incorporated into the museum's strategic plan, so for the sake of formality, it would be necessary to address this change of course at the full board of trustees meeting.

DB Poli said that while she is not a curator nor a board member, centers offer the opportunity to highlight VMNH's goal of diversity in the sciences and could offer a lecture series that highlights where people are coming from.

Dr. Art Evans said that there is already a museum-wide effort to promote diversity in the sciences, but that this was an interesting idea. Cindy Marquez, in her role as attorney, advised that diversity includes not only races but many other designations.

Dr. Hayden Bassett said that it would be advantageous to add new labs to the museum's offerings. Dr. Art Evans added that he would be in favor of adding additional disciplines to the museum in the form of labs, which would prevent having to add an additional administrative layer.

Roberto Quinones said where all of these points overlap is in terms of funding and swaying politicians, and we need to expand our net of stakeholders. When it comes time to offer funding, politicians give money to the "squeakiest wheel," so it's important that the man on the street advocates for VMNH and writes to key people to tell them to support our initiatives.

Changing topics, Dr. Art Evans asked for board and curator input regarding the proposal to potentially expand the museum's footprint to make more space for collections.

Dr. Carole Nash said that in the field of archaeology, there is a massive abundance of collections requiring safe storage that simply doesn't exist anywhere in the Commonwealth. Expansion of VMNH collections makes sense, she said.

Mark Buss said that getting the funding for an expansion will prove challenging and should be approached realistically, but is an important goal.

Dr. Art Evans said that in talking to Dr. Kal Ivanov, the museum's dry invertebrate collection has room for 100 additional drawers and will then be out of space. There is the opportunity to use the museum's Douglas Avenue facility for storage as well once various environmental issues are dealt with. Dr. Joe Keiper added that the roof and drainage projects have been completed, and next fiscal year, maintenance reserve funds will be used to fix portions of the HVAC system. Collections storage will be a priority, Dr. Keiper said, but the one disadvantage of the Douglas Avenue facility is that it's a mile away, which may be a challenge for some portions of the collections.

Dr. Hayden Bassett said that archaeology is at roughly 98 percent capacity currently. When Douglas Avenue is available, it will allow archaeology to once again accept orphaned collections. Bassett added that archaeology's per box fee is the same one that the Department of Historic Resources maintains. When asked for clarification by Dr. Art Evans, Bassett said that when archaeology is asked to properly curate archaeological materials, they charge a one-time flat fee of \$375 per box. Dr. Carole Nash added that this is a fairly low rate, while other states are up to \$500 per box. It is part of doing business, she added.

Roberto Quinones compared this fee to Iron Mountain Records Management Service and asked if this storage could be monetized. Dr. Joe Keiper said that the fee is to offset the staff time to process the specimens, and while it could be a moneymaker, it also requires the investment of curatorial time.

Dr. Art Evans said that these fees are not standard for biological specimens and are new to him. Dr. Adam Pritchard said that because there is not as much legal structure

around fossils as there is around archaeological materials, these fees are not often seen in paleontology either.

Lucy Treado recommended that Douglas Avenue be turned into not just a place for collections storage, but also a lab space for working or retired Research Associates. DB Poli seconded that this was a good idea.

Dr. Arianna Kuhn said that space is at a premium for vertebrate zoology specimens, especially when it comes to large specimens that must be preserved in fluid.

Dr. Tom Benzing asked if the museum should prioritize specimens from Virginia over specimens from other parts of the country and world, given that it's the Virginia Museum of Natural History. Just as VMNH repatriated artifacts to Guatemala, he asked if we should repatriate fossils collected in Wyoming.

Dr. Adam Pritchard said that the Wyoming material is from land owned by the Bureau of Land Management, as is other paleontology material. Many of these specimens, he said, fill in gaps in earth history that are not reflected in Virginia's fossil record. Pritchard added that reorganization has freed up some space in paleo collections, but he still must be choosy when it comes to accepting donated material.

Dr. Carole Nash asked if the museum has a curation agreement with the Bureau of Land Management and if their specimens are merely on loan. Dr. Pritchard said that the agreement, which has existed for several decades, allows VMNH to house and maintain BLM specimens, but the specimens are owned by the federal government.

Dr. Nancy Moncrief said that mammal specimens are probably the most sensitive to humidity and temperature fluctuations.

Dr. Art Evans asked about tissue samples in collections. Dr. Arianna Kuhn said that tissue samples are the backbone of her research program. These specimens generally stored in -80 degree Celsius freezers to preserve the delicate genetic material.

Dr. Nancy Moncrief said that mammalogy is currently collaborating with a student at West Virginia University who is studying otter population dynamics using 15-year-old otter tissue samples donated to VMNH by the Department of Wildlife Resources. This collaboration highlights the difficulty of predicting what specimens should be added to VMNH collections; sometimes, she said, curators are torn when they cannot see an immediate question that a specimen could answer, but years later, that specimen may prove invaluable.

Dr. Art Evans thanked the curators for their time and suggested the moving forward, curators jot down ideas regarding the best ways to use the Douglas Avenue facility.

Dr. Art Evans adjourned the meeting.

JULY-SEPTEMBER 2023 VMNH ACQUISITIONS FOR APPROVAL BY BOARD OF TRUSTEES RESEARCH AND COLLECTIONS COMMITTEE

RIM* #	Collector/Donor	Date at VMNH	VMNH Dept.	QTY	Description	Method	To Be Accessioned (Y/N)
RIM 36-2023	Jill K. Harris	7/18/2023	ORNITHOLOGY	1	Eastern Towhee, male (<i>Pipilo erythrophthalmus</i>)	Salvaged	Y
RIM 37-2023	Kathryn Frisco Helms	7/28/2023	ICHTHYOLOGY	1	Gar, taxidermy mount on natural wood table- top display stand	Gift	Y
RIM 38-2023	Marshall Boyd	8/2/2023	MAMMALOLOGY	1	Opossum (<i>Didelphis virginiana</i>)	Salvaged	Y
RIM 39-2023	Joel Clifton	8/3/2023	ORNITHOLOGY	1	Wood Thrush (<i>Hylocichla mustelina</i>) juv.?	Salvaged	Y
RIM 40-2023	Nancy D. Moncrief	8/4/2023	HERPETOLOGY	1	Black Snake (<i>Coluber constrictor</i>)	Salvaged	Y
RIM 41-2023	Hayden Bassett	8/2/2023	HERPETOLOGY	2	<i>Storeria dekayi</i> and <i>Agkistrodon contortrix</i>	Salvaged	Y
RIM 42-2023	David H. Womack (Family of Charles A. Womack)	6/6/2023	HERPETOLOGY	26	24 taxidermy/freeze-dried mounts and 2 articulated skeletons	Gift	N
RIM 43-2023	Eric Prokopi	1/24/2023	PALEONTOLOGY	38 boxes	Misc. fish fossils	Gift	Y
RIM 44-2023	Bureau of Land Management (BLM) - Wyoming	7/20/2023	PALEONTOLOGY	41	13 limestone rocks w/ small invertebrate specimens; 28 bags and foil-wrapped dinosaur bones and skin impressions	Field Collection	N – BLM Property
RIM 45-2023	Dr. Kal Ivanov	8/4/2023	HERPETOLOGY	1	Rough Green Snake (<i>Opheodrys aestivus</i>)	Salvaged	Y
RIM 46-2023	Tom Benzing	8/11/2023	HERPETOLOGY	1	Hellbender (<i>Cryptobranchus alleganiensis</i>) skeleton	Gift	Y
RIM 47-2023	Laurel Ridge Community College	7/28/2023	MAMMALOLOGY	TBD	QTY to be determined; mammal specimens (mostly skins and some skeletal material)	Gift	Some may be accessioned, some may not be.
RIM 48-2023	Laurel Ridge Community College	7/28/2023	ORNITHOLOGY	TBD	QTY to be determined; bird specimens (mostly skins and some taxidermy)	Gift	Some may be accessioned, some may not be.
RIM 49-2023	Laurel Ridge Community College	7/28/2023	ICHTHYOLOGY	TBD	QTY to be determined; fish specimens (taxidermy)	Gift	N
RIM 50-2023	Laurel Ridge Community College	7/28/2023	HERPETOLOGY	TBD	QTY to be determined; herpetology specimens (wet and dry)	Gift	Some may be accessioned, some may not be.
RIM 51-2023	Jason Gibson	9/8/2023	HERPETOLOGY	7	6 (six) amphibian and 1 (one) reptile specimen	Gift	Y

* RIM is an acronym for the Record of Incoming Material form

JULY-SEPTEMBER 2023 VMNH ACQUISITIONS FOR APPROVAL BY BOARD OF TRUSTEES RESEARCH AND COLLECTIONS COMMITTEE

RIM* #	Collector/Donor	Date at VMNH	VMNH Dept.	QTY	Description	Method	To Be Accessioned (Y/N)
RIM 52-2023	Ralph P. Eckerlin	9/24/2023	RECENT INVERTEBRATES	408	407 slides w/ Acari, Cimicidae, Pseudoscorpiones, Diptera, Hymenoptera, Coleoptera, Leiodidae, Ixodida) and 1 vial of alcohol preserved unidentified Ixodida	Gift	Y
RIM 53-2023	Arianna Kuhn	9/26/2023	HERPETOLOGY	1	Rough Green Snake (<i>Opheodrys aestivus</i>)	Salvaged	Y
RIM 54-2023	Marshall Boyd	10/1/2023	MAMMALOLOGY	2	Gray Fox (<i>Urocyon cinereoargenteus</i>) and Raccoon (<i>Procyon lotor</i>)	Salvaged	Y
RIM 55-2023	Adam Pritchard	9/8/2023	PALEONTOLOGY	18	fish and plant specimens, and coprolites	Field Collection	Y
RIM 56-2023	Adam Pritchard	9/8/2023	PALEONTOLOGY	27	3 sandstone samples w/small fossil reptiles (teeth, bone frags) and 24 shale samples w/small skeletal elements (fish)	Field Collection	Y
RIM 57-2023	Adam Pritchard	5/8/2023	PALEONTOLOGY	10	plant fossils in shales or mudstone	Field Collection	Y
RIM 58-2023	Ben Kligman	9/29/2023	PALEONTOLOGY	52	30 slabs shale w/fish skeletons; 2 small teeth, reptile; 3 shale slabs w/small inverts; 17 shale slabs w/plant fossils	Gift	Y

* RIM is an acronym for the Record of Incoming Material form

JULY-SEPTEMBER 2023 VMNH ACQUISITIONS FOR APPROVAL BY BOARD OF TRUSTEES RESEARCH AND COLLECTIONS COMMITTEE

VMNH Collections Committee and Executive Director have Approved Recent Acquisitions: RIM 36-2023 through RIM 58-2023

VMNH Board of Trustees Research & Collections Committee Review of Acquisitions: RIM 36-2023 through RIM 58-2023

Arthur V. Evans, Chair

(signature) Arthur V. Evans, Chair

Date

Thomas R. Benzing

(signature) Thomas R. Benzing

Date

Mark J. Buss

(signature) Mark J. Buss

Date

Carole L. Nash

(signature) Carole L. Nash

Date

Melany Stowe

(signature) Melany Stowe

Date

(signature)

Date

Calendar Year 2023 Acquisition Plans

Research and Collections

Archaeology Dr. Hayden Bassett

The main impediment to collections care and accessibility in 2022-2023 is storage space. Several large collections were accepted between 2017-2019, putting the Archaeological collections room at capacity (98% filled). This makes accessibility of the collection difficult, as we will increasingly have to rely on opportunistic or off-site storage. In 2022, the archaeology curator and staff archaeologist continued to reorganize collections to maximize limited space. All available general-use storage space outside of designated archaeological storage has now been filled by other curatorial departments. Because of this, acquisition of new archaeological collections is currently on hold. The remaining space will be reserved for VMNH-generated archaeological collections from the Smith River Survey and Leatherwood projects.

- Priority 1.** Collections from local/regional archaeological sites, generated by VMNH Archaeological fieldwork. The VMNH Archaeology department has received two major grants for fieldwork in Henry County, to be conducted between 2022-2024: 1.) the Smith River Survey, and 2.) the Patrick Henry Leatherwood project. Fieldwork has begun, involving targeted phase I and phase II excavations, which are now generating new collections. Because the Archaeological storage room is at capacity, these new collections will be stored in Room 130 for in-processing, accessioning, active study, reporting, new exhibit creation, and specialized analyses.

- Priority 2.** Collections related to published research, with high research potential, currently housed elsewhere. A special emphasis will be placed on acquisition of local/regional collections.

- Priority 3.** Collections currently held by other state agencies, colleges or universities, or companies/organizations participating in cultural resource management projects.

- Priority 4.** Salvage and opportunistic. Archaeological specimens recovered through opportunistic site visits or through donations. This includes unsolicited donations that may contain research quality or exhibit/educational quality specimens.

- Priority 5.** Collections from non-academic or research-based sources, *i.e.*, private collections.
These collections tend to be large and have little to no research value. Few of these collections are accepted and then only if they have exceptional exhibit or education value or include a rare artifact type with some provenience information.

Earth Sciences

There is currently no Earth Sciences curator and no plan to acquire new materials; however, there may be some opportunistic acquisitions. These will be handled on a case by case basis and existing storage space should be sufficient to store them. It is possible that education and/or exhibits material may be added to the collections. If this includes mineral specimens, these may be accessioned.

Paleontology **Dr. Adam C. Pritchard**

The following materials are expected to be acquired within the next year and can be accommodated in existing paleontology storage areas. This does not preclude the possibility of acquisition of additional material that becomes available because of orphaned collections or new discoveries.

- Priority 1. Triassic fossils of Virginia.** Multiple one day to one week excavations in Ashland, VA and the circum-Richmond area. Acquisitions will include multiple types of rock containing plants, invertebrates (clam shrimp, insects), and vertebrates. Likely to total two to three double-wide cabinet drawers full of specimens.
- Priority 2. Wyoming dinosaur project, Two Sisters Quarry.** One three-week excavation planned for Summer of 2023, headed by Brooke Haiar (U Lynchburg), Lucy Treado, and myself. Work will recover 10+ plaster jackets and isolated bones of dinosaurs. Likely to total two to three double-wide cabinet drawers full of specimens. Specimens owned by BLM, but managed by VMNH Paleontology.
- Priority 3. Cultivated Relationships with Private Collectors.** After cultivating relationships w/ private collectors, specimens will be through donations. This will concentrate on northern VA fossils. Recent donations have included Atlantic Coastal Plain reptiles and invertebrates, and Triassic vertebrates and invertebrates.
- Priority 4. Atlantic Coastal Plain Vertebrates/Carmel Church Quarry.** One to two two-week excavations in Spring 2023, targeted at excavation of

baleen whale from the St. Marys Formation. Opportunistic discoveries will almost certainly occur as well. Likely to bring in one large plaster jacket and one double-wide cabinet drawer's worth of material.

Invertebrate Zoology

Dr. Kaloyan Ivanov

The following materials are expected to be acquired within the next year. Wet and dry storage space is adequate to accommodate any new specimens acquired.

Terrestrial Invertebrates

- Priority 1.** Specimens generated by ongoing research activities, with primary focus on material from Virginia and the southeastern USA. Specimens from other areas in the USA and/or other countries may also be included.
- a. Hymenoptera (ants, bees, and wasps) as pinned/pointed and alcohol-preserved specimens.
 - b. Millipedes, especially in the orders Polydesmida and Chordeumatida as alcohol-preserved specimens.
 - c. Terrestrial isopods (Isopoda: Oniscidea) as alcohol-preserved specimens.
 - d. Cicadas (Hemiptera: Cicadidae) as pinned specimens.
 - e. Dragonflies and damselflies, true bugs, earwigs, walkingsticks, mantids, cockroaches, and beetles as pinned specimens.
 - f. Leaf-litter and soil invertebrates as alcohol-preserved (annelids, pseudoscorpions, spiders, myriapods, and non-insect hexapods) and pinned (true bugs and beetles) specimens.
- Priority 2.** Opportunistic acquisitions of specimens obtained through site visits, salvage, or through donations (prepared to handle if such material becomes available).
- a. Alcohol-preserved Embioptera (webspinners) (M. Bertone, NCSU).
 - b. Pinned Formicidae (ants) and alcohol-preserved Zoraptera (angel insects) (S. Dash, Hampton University).
 - c. Various pinned and alcohol-preserved arthropods from Virginia and adjacent areas (A. Evans, S. Roble, C. Harden, D. Hennen, others).
- Priority 3.** Specimens to support exhibits and/or education programs (as needed or become available).

Aquatic Invertebrates

There is currently no plan to acquire new materials. If such materials become available (opportunistic acquisitions), they will be handled on a case-by-case basis.

Forensic Work

There is currently no plan to acquire new materials. If such materials become available (casework and teaching efforts), they will be handled on a case-by-case basis.

Vertebrate Biology (except Reptiles and Amphibians) **Dr. Nancy D. Moncrief**

No large quantities of specimens are anticipated in the next year, and existing storage space is sufficient to house any new specimens acquired. Priorities for individual vertebrate biology departments are listed below.

Ichthyology

- Priority 1.** Research-quality specimens of taxa present in Virginia. These will be obtained through salvage and collaborations with colleagues.
- Priority 2.** Specimens to support exhibits and education programs. These will be obtained through salvage, purchase, and/or collaborations with colleagues.

Mammalogy

- Priority 1.** Specimens to support my research projects or generated by my research activities. These would include 1) mammals from eastern North America, especially those from Virginia, and 2) comparative material related to those projects and activities.
- Priority 2.** Research-quality specimens of taxa present in Virginia. These will be obtained through salvage, opportunistic collecting and collaborations with colleagues most of whom are in Virginia (e.g., VDWR, DCR-VNHP).
- Priority 3.** Specimens to support exhibits and education programs. These will be obtained through salvage, opportunistic collecting, purchase, and/or collaborations with colleagues.

Ornithology

- Priority 1.** Research-quality specimens of taxa present in Virginia. These will be obtained through salvage and collaborations with colleagues.
- Priority 2.** Specimens to support exhibits and education programs. These will be obtained through salvage, purchase, and/or collaborations with colleagues.

Ancillary Collections (Especially Frozen Tissues)

- Priority 1.** Specimens to support my research projects or generated by my research activities. These would include 1) mammals from eastern North America,

especially those from Virginia, and 2) comparative material related to those projects and activities.

- Priority 2.** Research-quality specimens of vertebrate taxa present in Virginia. These will be obtained through salvage, opportunistic collecting, and collaborations with colleagues most of whom are in Virginia (e.g., VDWR, DCR-VNHP).

Vertebrate Biology (Reptiles and Amphibians)

Arianna Kuhn

- Priority 1. Opportunistic Acquisitions.** Reptile and amphibian specimens and tissues will be obtained through salvage events and donations when appropriate to augment the herpetology collection. At present, no large donations are anticipated for 2022–2023.
- Priority 2. Research-targeted Acquisitions.** Through focused, research-driven efforts, reptile and amphibian specimens and tissues will be added to the collections as current permitting allows to (1) fill gaps in regional species representation and (2) facilitate regional and international research and collaborations (e.g., Spring 2023 collaboration with University of Florida).
- Priority 3. Educational and Outreach Acquisitions.** Reptile and amphibian specimens (wet, osteological, taxidermy), particularly those with no associated data/captive bred, will be added to the collection to elevate outreach and education events as well as in-house exhibits.

Education and Public Programs

Christy Deatherage

There is currently no plan to acquire new materials in the DEPP. However, we will report materials that would enhance current exhibits or programs if offered to the Department.

**VIRGINIA MUSEUM OF NATURAL HISTORY
RESEARCH AND COLLECTIONS ACTIVITIES**

**Report to the Board of Trustees
July-Sept. 2023**

**Kaloyan Ivanov, Ph.D.
Associate Curator of Invertebrate Zoology**

- Dr. Ivanov and colleagues published papers in *European Journal of Taxonomy*, *Ecosphere*, and *Revista Chilena de Entomologia*.
- Drs. Ivanov and Means, and colleagues have a manuscript in press at *Biota Neotropica*.
- Dr. Ivanov and colleagues presented research findings at the 19th International Congress of Myriapodology and the 3rd annual meeting of the Virginia Natural History Society.
- Drs. Ivanov and Adams presented programs to students from the 2023 Summer Residential Governor's School for Mathematics, Science, and Technology.
- Dr. Ivanov participated in VMNH's Dino Fest and interacted with 2,000+ visitors.

Research & Collections

Drs. Means and Ivanov, R. Bouzan, Drs. L. F. M. Iniesta and A. D. Brescovit (Instituto Butantan, Brazil), D. Martinez-Torres (Universidad Nacional de Colombia, Colombia), and L. F. Vasquez-Valverde (Virginia Tech, Virginia) published a paper in *European Journal of Taxonomy*. The work reviews the previously monotypic South American millipede genus *Dibolostethus* (Polydesmida: Chelodesmidae) and includes the description of two new species (one of which from VMNH's invertebrate collection), and a summary of the Chelodesmidae taxa known from the Tropical Andes Biodiversity Hotspot.

[Means, J. C., R. S. Bouzan, L. F. M. Iniesta, D. Martínez-Torres, L. F. Vasquez-Valverde, A. D. Brescovit, and K. Ivanov. 2023. A review of the monotypic tribe Dibolostethini (Chelodesmidae: Chelodesminae) with a description of two new species and a summary of the Chelodesmidae of the Tropical Andes Biodiversity Hotspot. *European Journal of Taxonomy* 885: 65-85. <https://doi.org/10.5852/ejt.2023.885.2189>]

Dr. Ivanov and Virginia Tech colleagues (former graduate student M. Malone, Drs. R. Schürch and S. Taylor) published a paper in *Ecosphere*. The work focuses on the range expansion of the invasive Red Imported Fire Ant, *Solenopsis invicta* Buren, in Virginia. The manuscript also explores the potential spread of this notorious invasive species across the United States using predictive distribution modelling.

[Malone, M., K. Ivanov, S. V. Taylor, and R. Schürch. 2023. Fast range expansion of the red imported fire ant in Virginia and prediction of future spread in the United States. *Ecosphere* 14(8): e4652. <https://doi.org/10.1002/ecs2.4652>]

Drs. Ivanov and Means, A. Parra-Gómez (Universidad Austral de Chile, Chile), and Dr. J. Pérez-Schultheiss (Museo Nacional de Historia Natural, Chile) published a paper in *Revista Chilena de Entomologia*. The paper includes the description of two new

endemic *Anaulacodesmus* species (Polydesmida: Dalodesmidae) from Valdivian temperate forests in southern Chile.

[Parra-Gómez, A., J. Pérez-Schultheiss, J. C. Means, and K. Ivanov. 2023. Two new species of *Anaulacodesmus* Attems, 1898 (Polydesmida: Dalodesmidae) from temperate forest fragments in southern Chile. *Revista Chilena de Entomología* 49(3): 557-569.]

Drs. Ivanov and Means, R. Bouzan, Drs. L. F. M. Iniesta, and A. D. Brescovit, and G. B. Pupin (Instituto Butantan, Brazil) have a manuscript in press at *Biota Neotropica*. The paper reports the first case of mass occurrence in the millipede family Chelodesmidae and includes the description of the heretofore unknown female of *Sandalodesmus araujo* (Schubart, 1946), previously known only from the male holotype collected in the state of São Paulo, Brazil in 1943. In addition, the paper discusses the utility of female genitalic characters for species delineation in *Sandalodesmus*.

Following recent work at the Florida State Collection of Arthropods, Dr. Ivanov was invited to join a team of myrmecologists working on an updated list of non-native ants in Florida for a special issue of *Florida Entomologist*. When completed, the paper will offer a comprehensive account of all non-native ant taxa recorded from Florida, a global hotspot of introduced and invasive ants.

Drs. Ivanov and Means, and colleagues presented research findings at the 19th International Congress of Myriapodology regarding their recent work on the millipede tribe Dibolostethini (Polydesmida: Chelodesmidae). (August 7-12)

Drs. Ivanov and Means, L. Hightower, C. Harden (Clemson U), and N. Jones (AIMG) presented research findings at the annual meeting of the Virginia Natural History Society regarding their work on the isopod fauna of Virginia, and the soil and litter biodiversity of Stuart, VA. (September 23).

Drs. Ivanov and Means, and L. Hightower completed the last round of sampling (August 2023) for a project focused on the leaf-litter and soil arthropod fauna of a private property located at the foothills of the Blue Ridge Mountains in Stuart, VA. The work, which is partly funded by the property's owner and longtime museum supporter L. Reagan, has resulted in the collection of an unusual species of terrestrial isopod (possibly undescribed *Ligidium*), new species of millipedes (*Nannaria*; *Pseudotremia*), four undescribed beetle species (*Anilinus*, *Arianops*, *Dasycerus*, *Lathrobium*), and a rare ant species (*Proceratium creek* De Andrade).

Drs. Ivanov and Means, and L. Hightower processed 57 nests as part of recently launched project focused on the arthropod diversity associated with the nests of cavity-nesting birds utilizing Eastern bluebird boxes. The work is conducted in conjunction with a Citizen Science bluebird monitoring project conducted by the Southwestern Piedmont Chapter of the Virginia Master Naturalist.

Dr. Ivanov conducted fieldwork at various sites in Bulgaria and Greece in support of ongoing research projects.

Dr. Ivanov identified 650+ recently collected specimens as part of an ongoing work on the non-native ants of Florida.

As part of a long-term inventory, updating, reorganization, and databasing of VMNH's invertebrate holdings, L. Hightower, with help from Dr. Ivanov, inventoried 2,100+ beetle specimens. As of the end of September, 39,323 specimens representing 1,238 species in 36 beetle families have been curated and inventoried.

VMNH Collections Manager H. Cartmell, with help from Dr. Ivanov, completed the curation and inventory of VMNH's Bivalvia (clams, mussels, et alia) holdings which also included the incorporation of 2,000+ unionid specimens transferred from the museum's storage facility at Douglas Ave. The digitization of the materials, which is largely completed, was put on hold in early September 2023 due to a medical emergency.

Dr. Ivanov oversaw the acquisition of 407 slides of mounted arthropod specimens (Acari, Cimicidae, Pseudoscorpiones, Diptera, Hymenoptera, and Coleoptera: Leiodidae) and 1 lot of alcohol preserved Ixodida donated to VMNH by Dr. R. Eckerlin (RIM2023-52); and an unknown number (yet to be processed) of insects (chiefly Lepidoptera) from Laurel Ridge Community College, Middletown, VA.

Dr. Ivanov satisfied a loan request regarding VMNH's invertebrate holdings: 64 lots of unidentified Lithobiomorpha and 15 lots of *Arenobius manegitus* (Chamberlin 1911) (stone centipedes) (Dr. D. Hennen; VMNH Research Associate).

Education & Outreach

Drs. Ivanov and Adams led 3 sessions of a hands-on science programming to 96 high school students from the 2023 Summer Residential Governor's School for Mathematics, Science, and Technology. (July 18)

Dr. Ivanov and museum staff participated in VMNH's Dino Fest, which offered a variety of dinosaur casts and fossils, dino-themed activities and crafts, and opportunities to interact with expert paleontologists. The two-day event attracted 4,211 children and adults from Virginia, 5 additional US states (California, Colorado, Georgia, North Carolina, and Tennessee), Germany, and Mexico. (July 21-22)

Student mentorship (with Dr. Means): P. Garrard (U Lynchburg; since September 2023; Salticidae of Virginia); H. Adams (Franklin County High School; since September 2023; arthropod diversity of Franklin Co., VA).

Dr. Ivanov gave tours of VMNH's labs, collections, and exhibits to participants in VMNH's "Science Exploration" Summer Camp, and visitors from Richmond, VA (July 12, 18)

Professional Service

Dr. Ivanov copy edited three articles for the Virginia Natural History Society's periodical *Banisteria* (Volume 57, 2023). (completed July 17, September 22)

Drs. Ivanov and Means completed work on Virginia Natural History Society's new website which was launched in late July, and together with Dr. N. Moncrief and Dr. K.

Powers (U Radford) helped organize the Society's annual meeting held at Radford University in late September.

Dr. Ivanov reviewed manuscripts for *Insects* and *Ecology and Evolution*. (completed July 25 and September 28).

Drs. Ivanov and Means are serving as co-editors of VMNH's *Memoirs* series for a manuscript titled "The groundwater isopods of Virginia (Isopoda: Asellidae and Cirolanidae)" by Dr. J. J. Lewis and colleagues. The manuscript is currently in press.

Nancy D. Moncrief, Ph.D.
Curator of Mammalogy

- Dr. Moncrief presented a poster on her research at the annual meeting of the Virginia Natural History Society
- Dr. Moncrief participated in science programming for high school students from the Summer Residential Governor's School for Science, Mathematics and Technology, which is based at Lynchburg University.
- Dr. Moncrief and Mr. Boyd participated in several meetings to discuss the "Masters of the Night" exhibit about bats, which will open at VMNH in February 2024.

Research and Collections

Throughout the quarter, Dr. Moncrief met numerous times with collaborators and VMNH Research Associates Drs. John Porter and Ray Dueser. They discussed plans for testing digital camera traps for small mammals. This methodology will allow them to perform surveys of shrews and rodents without live-trapping, which can be very labor-intensive and time-consuming. Also throughout the quarter, Dr. Moncrief and Biology Research Technician Mr. Marshall Boyd maintained and monitored several traps at a site in Franklin County, Virginia as a trial for developing and refining efficient techniques for deploying this kind of trap.

Also, throughout the quarter, Dr. Moncrief continued working with Mr. Boyd and Mss. Hightower, Cartmell, and Harris to prepare, install, document, and organize traditional specimens and frozen tissues of mammals and birds and their accompanying museum documents (electronic and hardcopies). In late June, Laurel Ridge Community College in Middletown Virginia transferred several hundred bird and mammal specimens to VMNH. Many are research-quality. During August and September, Dr. Moncrief worked with Mr. Boyd to organize and identify the mammal and bird specimens. They also developed plans for reorganizing most of the dry mammal research collection to allow expansion of the dry herpetology collection.

In September, Dr. Moncrief presented her poster "*Using museum specimens to study geographic expansion of Lyme disease in the southeastern United States*" at the annual meeting of the Virginia Natural History Society, which was held at Radford University.

Professional Service and Other Duties

Dr. Moncrief continued serving on the Council of the Virginia Natural History Society (VNHS). She also continued serving (with Dr. Ivanov) as Co-Treasurer of VNHS. She also worked with Dr. Ivanov and VMNH Myriapodologist Dr. Jackson Means to organize the 2023 VNHS annual meeting.

In July, Dr. Moncrief participated in VMNH's Dino Fest. She worked both days at the admissions table for VMNH and ASTC members with Ms. Charlotte Harter. They interacted with a total of 438 visitors (215 adults and 233 children).

Scientific Programs, Exhibits, and Other Activities

In July, Dr. Moncrief and Ms. Hightower presented a specimen-based program to 60 high school students from the Summer Residential Governor's School for Science, Mathematics and Technology, which is based at Lynchburg University.

During July and August, Dr. Moncrief continued working with Education Manager Ms. Christy Deatherage to develop a new hands-on specimen-based education program. Students will use microscopes in the IMLS-funded microscope lab to examine a variety of skulls from shrews and rodents. These animals can be identified based on difference in the size, shape, and number of their tiny teeth, but these differences can only be seen using microscopes such as the ones now available at VMNH. Dr. Moncrief plans to offer a trial version of this program to a group of Virginia Master Naturalists this Fall.

In August, Dr. Moncrief taught a basic training class to the Southwest Piedmont Chapter of Virginia's Master Naturalists. She discussed methods for studying wild mammals and reviewed details of species that are native to Virginia.

Dr. Moncrief and Mr. Boyd met numerous times with other VMNH staff in education and exhibits to discuss the "Masters of the Night" exhibit and plan activities for the opening day celebration. Dr. Moncrief contacted two colleagues who study bats. Each of them agreed to present powerpoint lectures about their research and demonstrations of the techniques they use to capture and study bats. This exhibit is scheduled to open at VMNH in February 2024.

Hayden Bassett, Ph.D.
Assistant Curator of Archaeology

Dr. Hayden Bassett is on military leave and is scheduled to return in February.

Adam Pritchard, Ph.D.
Assistant Curator of Paleontology

- Dr. Pritchard consulted on a project at the Virginia Living Museum focused on a newly acquired mastodon skeleton. He provided the VLM staff with anatomical description, preparation proposals, and advice on laboratory development.
- Dr. Pritchard developed 3D scan data and displays for a collaboration with Dr. DB Poli. The collaboration will produce a small exhibit at the WonderUniverse science center in Christiansburg, VA, and it has provided additional funds for the VMNH Paleontology Lab.
- Dr. Pritchard collaborated with teams from Virginia Tech, Stony brook University, the University of Utah, and the Natural History Museum of Utah on a manuscript describing an bipedal toothless reptile from over 200-million-year-old rocks from New Mexico.
- Dr. Pritchard completed the 2023 Wyoming Dinosaur Project field trip to Wyoming. This year was the first of the project funded by the National Science Foundation, which funded all Virginia Museum of Natural History expenses. The team included six students from Virginia institutions.

Research & Collections

Dr. Pritchard worked with VMNH Paleontology technician Lucy Treado and University of Lynchburg professor Dr. Brooke Haiar on completing the 2023 Wyoming Dinosaur Project field season. The work recovered portions of the vertebral column and forelimb of a small, long-necked dinosaur that likely represents a new species.

Dr. Pritchard led a field team to the Ashland Triassic Site, a 230-million-year-old locality that has produced large numbers of small fossils from fishes, reptiles, and plants. The trip recovered multiple fish skeletons, reptile teeth, and sandstone boulders that seem to contain high-quality reptile bones.

Dr. Pritchard worked with Dr. Ben Kligman (Smithsonian National Museum of Natural History) on taking some of the first Virginia Jurassic specimens into the VMNH collections. Dr. Kligman's fieldwork in northern Virginia has produced fish skeletons, plant fossils, and reptile teeth from a newly discovered site.

Dr. Pritchard wrote a manuscript on a toothless relative of early crocodiles in collaboration with a team of researchers from other American institutions. The manuscript is intended for submission to the *Journal of Vertebrate Paleontology* in Q4 2023.

Dr. Pritchard worked with officials and volunteers in Henrico County, Virginia to survey a newly discovered marine fossil site on conservation land that seems to preserve a record spanning 50 million years of coastal ecosystems.

Dr. Pritchard began work with a research intern from the University of Lynchburg on descriptions and comparisons of dinosaur skin samples from the Wyoming Dinosaur Project. These samples are among the most numerous from any long-necked dinosaur-bearing fossil site.

Dr. Pritchard recruited a collections volunteer with whom he collaborates on curating the many newly arrived specimens.

Dr. Pritchard collaborated with paleontology technician Lucy Treado and prep lab volunteers on continued preparation of Petra the Cave Cat. The work has uncovered fine details of the fingers, wrists, and toes of Petra, which are all highly fragile bones.

Dr. Pritchard and BYU professor Dr. Brooks Britt began a new manuscript describing a series of complete Triassic reptile skeletons from southern Utah.

Dr. Pritchard fielded 3 information requests about VMNH collections from researchers at the National Museum of Natural History, the College of William & Mary, and the University of Delaware.

Education & Outreach

Dr. Pritchard consulted for the Virginia Living Museum on the anatomy, curation, preparation, and display of a mastodon skeleton newly acquired by the VLM. The trip involved photo documentation of the entire specimen, planning for the repairs of key damaged specimens (most notably the tusks), and initial planning for a small preparation facility. He will present his main findings to the VLM in November 2023.

Dr. Pritchard and paleontology technician Lucy Treado developed eight table fossil-based displays for the 2023 Dinosaur Festivals. These were managed with three paleontology volunteers during the festival.

Dr. Pritchard and Dr. Kal Ivanov presented an educational program on fossil shark teeth for the Virginia Governor's School program.

Dr. Pritchard loaned VMNH insect fossils to Virginia Tech technician Aryanna James for a display at a Delaware-based entomology conference.

Dr. Pritchard presented on the essentials of paleontology to the local Master Naturalist chapter.

Dr. Pritchard provided a digital presentation from the VMNH paleontology collections for a group at the San Diego County Public Library in California.

Dr. Pritchard provided photos and video for VMNH social media from the Wyoming Dinosaur Project in July.

Dr. Pritchard identified fossil specimens for two groups of Virginia residents.

Grants & Funding

Dr. Pritchard continued development of grant budgets and documents with Howard University professor Ray Bernor and his HU team on a revised submission of their National Science Foundation grant submission about horse evolution, intending for an October 17 2023 submission. The grant would fund a VMNH special exhibit on the

evolution of horses. Dr. Pritchard provided resources and content regarding the integration of molecular data into the phylogeny.

Dr. Pritchard received an honorarium for his work at the Virginia Living Museum, which will go to laboratory supplies and development of the VMNH fossil lab.

Dr. Pritchard received funding for his work with the Virginia Governor's School in July 2023.

Professional Service

Dr. Pritchard reviewed a manuscript on early crocodile evolution for the journal *Palaeontologia Electronica*.

Dr.

Arianna Kuhn, Ph.D.
Assistant Curator of Herpetology

- Dr. Kuhn and collaborators had a paper accepted to *Molecular Ecology Resources* (Impact Factor: 8.678).
- Dr. Kuhn gave a talk at the SouthEastern Population Ecology and Evolutionary Genetics Conference at Mountain Lake Biological Station, VA.
- Dr. Kuhn and collaborators were awarded \$20,000 in seed funds from the University of Radford to collect preliminary salamander genomic data for their NSF proposal.
- Dr. Kuhn submitted a grant to North Carolina Herpetological Society Fund.
- Dr. Kuhn taught a workshop at the Field Museum of Natural History entitled “*RADcamp: Assembly, filtering and analysis of RADseq data*”.
- Dr. Kuhn gave a seminar at the University of Richmond entitled “*Global change insights from reptile and amphibian genomes*”.
- Dr Kuhn gave a talk at the Wayne Theatre in Waynesboro, VA, entitled “*The Hidden Jewels of Appalachia*”
- Dr. Kuhn designed and taught a hands-on lecture to the Piedmont Chapter of Virginia Master Naturalists on identifying snakes in Virginia.
- Dr. Kuhn was interviewed for a children’s Scholastic book entitled “*Reptiles are Awesome!*”

Research & Collections

Peer reviewed publications

Drs Kuhn (VMNH)*, Schiebelhut LM*, Guillaume AS*, Schweizer RM, Armstrong EE, Beaumont MA, Byrne M, Cosart T, Hand BK, Howard L, Mussmann SM, Narum S, Rasteiro R, Rivera-Colón AG, Saarman N, Sethuraman A, Taylor HR, Thomas GWC, Wellenreuther M, and Luikart G. have a paper in publication at *Molecular Ecology Resources* (Impact Factor 8.678) entitled “*Practical guidance in conservation genomics: from study design to application*” that reviews best practices for conservation biologists using genomic data in their research. (*=*equal first author contribution*)

Ongoing research

Drs Kuhn and B. Stuart (North Carolina State Museum of Natural Sciences, NCMS) are continuing their collaboration with S. Kuchta at the University of Ohio to investigate the systematics of Wehrlei’s plethodontid salamanders in southwest Virginia using genomics data and morphology. This project will also incorporate a Master’s student genomics lead at the University of Ohio, and Dr. Kuhn will serve on the students’ dissertation committee.

Drs Kuhn (VMNH), Burbrink FT (AMNH), Ruane S (FMNH), Raxworthy C (AMNH), Rabibisoa NHC (UAntananarivo, Madagascar), Achille R (UAntananarivo, Madagascar) and Overcast I (California Academy of Sciences) are working on a manuscript that uses genomic data to examine the co-demographic history of snake assemblages on Madagascar using newly developed phylogeographic methods. The target journal for

this manuscript submission is *Molecular Ecology*. Significant progress has been made this quarter and submission is expected by February 2024.

Drs Kuhn (VMNH), Burbrink FT (AMNH), S. Harrington (UWyoming), Ruane S (FMNH), Raxworthy C (AMNH), Rabibisoa NHC (UAntananarivo, Madagascar), Achille R (UAntananarivo, Madagascar) and Overcast I (California Academy of Sciences) are working on a manuscript that uses Machine Learning approaches and genomic data to examine evolutionary processes driving speciation for snakes on Madagascar. The target journal for this manuscript submission is *Molecular Biology and Evolution*. The expected submission date is Spring 2024.

Drs Kuhn (VMNH), Lee-Yaw J (UOttawa) and Weisrock D (UKentucky) are analyzing data and preparing a manuscript and provincial report resulting from Dr Kuhn's postdoctoral research that uses genomic data to provide critical insights in the guidance of successful amphibian reintroductions. This work integrates spatial, ecological, and genomic data with careful study design to provide the best opportunity for successful protected species' reintroductions. The target journal for this manuscript is *Biological Conservation*.

Drs Kuhn (VMNH), Lee-Yaw J (UOttawa), and Weisrock D (UKentucky) along with Master's student Hunter D (ULethbridge) are working data analysis and manuscript are analyzing data and preparing a manuscript and provincial report resulting from Dr Kuhn and D Hunter's field and laboratory work at the University of Lethbridge and Waterton Lakes National Park in southwest Alberta, Canada. This research uses genomic data and occupancy modeling to investigate the impact of an extreme fire in a national park on genetic diversity over space and time for small terrestrial vertebrates. A new student has been recruited in Dr. Leeway's lab to lead finalization of the project. The target journal for this manuscript is *Conservation Biology*.

Drs Kuhn (VMNH) and Lee-Yaw J (UOttawa) are analyzing data and preparing a manuscript resulting from Dr Kuhn's postdoctoral research that uses genomic data to understand the role of refugial dynamics in driving intraspecific amphibian divergence in the Pacific northwest. The results of this study will underscore the importance of wide-ranging taxa to understanding the role of LGM dynamics in promoting amphibian diversity in this region which has been understudied from a phylogeographic perspective. The target journal for this manuscript is *Journal of Biogeography*.

Drs Kuhn (VMNH), Bauer AM (VillanovaU), Jackman T (VillanovaU), and Brennan I (Natural History Museum in London) are finalizing a manuscript entitled "*Rhoptropus* day geckos support the antiquity of the Namib". This study identified several new species from Angola and Namibia, and estimates the diversification history and speciation of endemic terrestrial Namib day geckos from the pro-Namib region. The diversification of this group provides insight into the role of historical climate change in shaping regional biodiversity in the Namib Desert. The target journal for this manuscript is the *Biological Journal of the Linnean Society*. Significant progress has been made this quarter and submission is expected by December 2023.

Drs Kuhn (VMNH), Parilla, D., Cerico, L, Bauer AM (VillanovaU), Jackman T (VillanovaU), and Brennan I (Natural History Museum in London) are finalizing a manuscript entitled "Two new species of *Rhoptropus* day geckos from the proNamib

regions of southwest Angola and Northwest Namibia”. The target journal for this manuscript is the *Zootaxa*. Expected submission timeline is December 2023.

Field work

Drs Kuhn (VMNH) and B. Stuart (NCMNS) and M. Boyd (VMNH) have begun fall collections work at Smith Mountain Lake and southwestern VA to get morphological and molecular vouchers of putatively new species of Plethodontid salamanders in the *P. wehrlei* complex. These collections will serve as vouchers for molecular and morphological analyses to determine the evolutionary uniqueness of these populations in an ongoing study.

Dr. Kuhn received training for SPARCnet for future integration at sites near Martinsville to be used in educational programming and research from Dr. K. Grayson (URichmond). Data collected from these sites will contribute to teaching modules and hands-on survey work for local highschool students and VA Master Naturalists to foster appreciation of terrestrial salamanders, their biology, and their role in forest ecosystems, learn how to analyze salamander census data and understand value observational and experimental studies in coordinated research networks. Sites are anticipated to be setup by Winter 2024.

Dr. Kuhn is establishing a research program at Mountain Lake Biological Station for the NSF program “Research Experiences for Undergraduates” (REU). Pending IACUC approval, this project will support 1–2 undergraduate researchers to conduct a summer-long project on topics pertaining to (1) Biological collection digitization and documentation, (2) Thermal preference and predicted responses of amphibians to climate change and/or (3) Comparison of eDNA and bioacoustic techniques for detection and monitoring of anuran populations.

Dr. Kuhn and I. Mali (North Carolina State University) have started a collaboration to begin a project in Spring 2024 comparing eDNA and auditory frog surveys to predict presence/absence of rare frog species in the southwest United States. This project will support one doctoral student and external funding will be sought out to supplement molecular aspects of this project for species of special concern in Virginia.

Professional Presentations/Conferences

Dr. Kuhn gave a talk at the SouthEastern Population Ecology and Evolutionary Genetics Conference (SEPEEG) that will take place September 22–24 at Mountain Lake Biological Station. At this conference, she engaged in networking with many professors and students from the region, shared details of her research program at the VMNH, and attended many conference talks on relevant research in evolutionary genomics, ecological adaptation and population genetics from experts in her field.

Dr. Kuhn will be giving a talk at the Virginia Herpetological Society Meeting (July 12–16). Her talk, entitled “*Establishing best practices for species translocations using genomic data and ecological niche models*” will discuss her work involving the genomics of Long Toed Salamanders (*Ambystoma macrodactylum*) as well as her new programs at the VMNH.

M. Boyd will be giving a talk at the Virginia Herpetological Society Meeting at the VMNH entitled “*Welcome to VMNH Herpetology*”. The talk will cover information about the VMNH Herpetology collections, opportunities for collaboration with VHS members, and future growth plans of the Herpetology lab.

Dr. Kuhn gave a seminar at the University of Richmond on October 2, 2023. The title of her talk was “*Global change insights from reptile and amphibian genomes*”. This seminar covered discussion about Dr. Kuhn’s role at the Virginia Museum of Natural History and curatorial career paths alongside her updated research program. During this visit, she met with the R. De Sa and K. Grayson labs to discuss student research and career trajectories.

M. Boyd attended the Virginia Natural History Society meetings at Radford University this fall. At this meeting, he and other curators from the VMNH biology department had the opportunity to network with other professionals and students with interest specifically in the natural history of Virginia and its long term preservation.

Professional Development

Dr. Kuhn will be attending Island Systems Integration Consortium Working Group Meeting on Nov 14–17 at the California Academy of Sciences, San Francisco to work with collaborators in person on their upcoming NSf grant and network with other researchers using genomic and ecological approaches to understand biodiversity.

M. Boyd was accepted to and currently attending a museum collections digitization class offered by the iDigBio initiative through Florida State University. The training covers specimen photogrammetry, digital databases, all aimed at increasing collections visibility, management, and preservation. He will disseminate relevant information from the course to the biology labs at the VMNH and integrate these workflows into his management of the VMNH vertebrate biology collections.

Dr Kuhn joined the Amphibian Genomics Consortium (AGC), which holds monthly meetings to discuss advances and techniques associated with salamander genomics. Involvement with this consortium will be valuable to her current research program in Virginia which aims to understand salamander diversities and distributions using genomic data.

Collections Growth and Management

The Herpetology Department received 13 new amphibian and reptiles specimens this month from salvage permit holders at Patrick and Henry Community College (N=8), Liberty University (N=1), James Madison University (N=1) and VMNH museum staff (N=3). Currently, all records have been accessioned, and voucher tissue samples will be taken in November 2023.

The Herpetology department is in the process of accessioning recently acquired 25 new taxidermy and dry mount specimens from a donation by the Danville Science Center. Several have already been used in education and outreach programming for training courses, relevant festivals and collections tours.

M. Boyd is in the process of accessioning/cataloging 120 research specimen donation lots from Laurel Ridge College including fluid preserved salamanders and dry rattlesnake skins. Several have already been used in education and outreach programming for training courses, relevant festivals and collections tours.

Research technician M. Boyd cataloged 16 new records to the Herpetology database, and several additional specimens will continue to be added to this growing catalog.

M. Boyd is documenting, organizing, and integrating 110 previously acquired research specimen lots from throughout Virginia. These, with help of VMNH Registrar, will be cataloged and incorporated into the VMNH Herpetology Collection.

M. Boyd and Herpetology intern J. Kuhn finished identifying, sorting, rehousing and cataloging 195 new fish records into the VMNH's ichthyological collections.

Grants

Dr. Kuhn is currently working on a proposal to NSF Division of Biological Research call "*Organismal Responses to Climate Change (ORCC)*". She will be a Co-PI of the project along with L. Lawson (University of Cincinnati), R. Lamb (University of Florida) entitled "*Estimating terrestrial and marine responses to sea level fluctuations in the Galapagos*" which will be submitted on December 13, 2023.

Drs. Kuhn and S. Ruane have used funds awarded by the Feay Field Research Fund at the Field Museum of Natural History to sponsor their joint work entitled "*Documenting the Diversity of Reptiles and Amphibians in Madagascar*". They will fly to Madagascar December 1st with a team of Malagasy biologists to survey the humid forests and karst formations of the Andrafiarana-Andavakoera Protected Areas in northern Madagascar. This trip will primarily involve collection-based work on reptiles and amphibians and will serve to build collaborative networks with the Malagasy non-profit Association Vahatra. In the spring, they will return to train students and conduct workshops.

Dr. Kuhn is putting together a workshop with collaborators S. Ruane, F. Rakotoarimalala and S. Goodman entitled "*Emergent Conservation Methodologies for a Global Biodiversity Hotspot*". The workshop will provide training in emerging conservation methods to Malagasy graduate students and researchers with a focus on developing skills in emerging technologies and bioinformatics, giving priority to women and other disadvantaged groups underrepresented in STEM fields in Madagascar. The workshop will be held in Spring 2024.

Dr. Kuhn submitted a grant on May 31, 2023 to The North Carolina Herpetological Society for funds to support regional work on the systematics of salamanders. The proposal, entitled "*Integrating molecular and morphological data to investigate the enigmatic "southern lineage" of Wehrlei's salamander from the North Carolina-Virginia border*" requested \$1,000 for support of molecular data collection.

Drs. Kuhn, T. Pettelier (Radford University), and M. DeBiasse (Radford University) have been awarded 20,000 in seed funds for their project "*Disentangling speciation processes through an integration of gene expression and holobiome approaches*". This project will investigate species boundaries and reproductive isolation in Virginia salamanders using an integrative approach with genomic data, expression of courtship

pheromones and skin microbiome profiles. They are currently finalizing the IACUC and permit application for this project, and will begin fieldwork as soon as both are approved. Their pre-proposal was submitted to a program officer in September and received positive feedback for submission to the DEB “*Evolutionary Processes*” call.

Dr. Kuhn is working on a proposal for the American Philosophical Society Franklin Grant which will be submitted December 1. Funds will be requested for travel to 3 natural history collections to gather morphological and archival data to support regional work on the systematics of salamanders. The proposal, entitled “*Integrating molecular and morphological data to investigate the enigmatic “southern lineage” of Wehrlei’s salamander from the North Carolina-Virginia border*” will request \$6,000 to complete the project.

Education & Outreach

VMNH-based Activities

Dr. Kuhn and M. Boyd and Vertebrate Biology intern J. Benzing designed and hosted two new Herpetology tables at VMNH’s 2023 Bones & Boos Festival and Member’s night. Dr. Kuhn and M. Boyd designed education materials for two herpetology-focused booths, which highlighted morphological adaptations of skeletal and dentary elements in salamanders, frogs, snakes and lizards. The event, which brought a diverse audience to the museum, attracted over 2,500 visitors.

Dr Kuhn gave a public interest lecture about salamander biology and research at the Wayne Theatre in Waynesboro, VA, entitled “*The Hidden Jewels of Appalachia*”. This talk was attended by 50 visitors in person, with additional audience members joining virtually via the live stream.

Dr. Kuhn gave a tour of the herpetology department and research collections to Dr. T. Petellier and 12 students from the undergraduate course “Evolution and Extinction of the Dinosaurs” at Radford University.

M. Boyd and Dr. Kuhn are collaborating with the other biology labs at the VMNH to curate informational exhibit items for the new VMNH Pavillion highlighting local fauna in Martinsville and Henry county. M. Boyd attended a meeting to plan these exhibits with other VMNH staff.

Dr. Kuhn and M. Boyd attended the Waynesboro biology planning meeting to contribute to the dialogue on vertebrate content with the Waynesboro exhibit planning and design team.

non-VMNH based Activities

Dr. Kuhn served as a student conference mentor at the SEPEEG 2023 meeting. Duties associated with this role were to work with an assigned group of undergraduate and graduate students before, during and after the conference to aid them in networking, professional development, career preparation, and overall navigation of the conference

environment.

Dr. Kuhn served as a student poster judge at the SEPEEG 2023 meeting at Mountain Lake Biological Station. For this role, Dr. Kuhn attended the student poster session, spoke with students about their research and provided feedback to final judges.

Dr. Kuhn served as a judge for the Rosemary Graduate Student Awards for the Society of Systematics and Evolution (SEE). For this role, Dr. Kuhn reviewed and provided feedback for 5 grant applicants.

Media

Dr. Kuhn was interviewed for a children's Scholastic book entitled "*Reptiles are Awesome!*" which highlight her experiences with reptiles in the field and in collections at the Virginia Museum of Natural History. Final proofs have been approved, and the book will move to production with an anticipated publication date of Spring 2024.

Dr. Kuhn and M. Boyd were interviewed by the Martinsville Bulletin for an article that will be published on Nov 3rd about the Annual Virginia Herpetological Society Meeting being hosted at the Virginia Museum of Natural History. The article discusses the importance of this meeting being held at the VMNH in Martinsville for the first time in the 50+ year history of the society.

Professional Service

Dr. Kuhn served as a reviewer for *Scientific Reports* (Impact Factor 4.6) for the manuscript "*The South East Africa Montane Archipelago (SEAMA) – a biogeographical appraisal of a threatened ecoregion*".

Dr. Kuhn is serving as Associate Editor at *Herpetologica* in the topic area of Systematics, and handled two publications this quarter.

Dr. Kuhn is serving as an Associate Editor for the *Herpetological Journal* (the journal of the British Herpetological Society), and has handled three publications this quarter.

Dr. Kuhn is serving on the organization committee for the upcoming meeting "*Centennial Celebration of The Systematics of the Lizards*" to be held at the American Museum of Natural History November 2023. All speakers have been invited, abstracts have been selected, and final edits are being made to the schedule for facilitating speaker attendance.

Dr. Kuhn is serving on the organization committee and serving as co-host with M. Boyd for the Annual Virginia Herpetological Society Meeting. For the first time, the meetings will be hosted at the VMNH. Currently, 41 attendees are registered, and 8 scientific talks will be presented. Live auctions and raffles will generate funds to support the society and student grants, and a social event will take place in the Hall of Ancient Life after presentations.

Dr. Kuhn is serving as counselor for the Virginia Natural History Society. She and other members of the executive committee met on Oct. 28th for an executive committee business meeting with plans to hold the next meeting of the society at Radford

University next fall.

Dr. Kuhn is serving on the meeting sponsorship committee for the Herpetologist's League for the 2024 Meetings in Pittsburgh, PA.

Teaching

Dr. Kuhn designed and taught a workshop for the Piedmont Chapter of the Virginia Master Naturalist Program at the VMNH. The focus of this workshop was identification and natural history of Virginia snakes, and the exercise used real snake specimens from the Herpetology Collections for testing identification skills learned in the lecture. This hands-on activity was taught using museum specimens to 61 students on 19th, 2023.

Dr. Kuhn co-taught a workshop with VMNH Research Associate I. Overcast at the Field Museum of Natural History entitled "*RADcamp: Assembly, filtering and analysis of RADseq data*" which will be disseminated. The 3-day workshop was attended by 30 (2 virtual, 28 in person) students, postdoctoral fellows, and professionals on August 20–23 by postdoctoral fellows, and professionals and covered methods associated with analyzing and processing genomic data using python and r programming languages. The workshop was sponsored by the Granger Bioinformatics Center and included two socials for networking and collaboration.

Dr. Kuhn and collaborator S. Ruane taught a workshop entitled "Extracting DNA from archival museum specimens: study design to data analysis" at the Granger Bioinformatics Center at the Field Museum of Natural History. This hands-on workshop was attended by two professors and one doctoral student from Madagascar and covered contemporary techniques for obtaining next generation sequence data from ~70 year old museum specimens from the FMNH Herpetology Collections.

Dr. Kuhn and M. Boyd completed the summer mentorship program in the Herpetology department which involved sorting, identifying, and digitizing unidentified herpetological specimens from former pitfall trap studies to expand the Herpetology Database and Record Files. Data for >300 specimens to the Herpetology collections was added by interns, and results will be presented by intern M. Burnette (Roanoke College) at the Fall VHS meetings held at the VMNH. Future work digitizing these data will be carried out in part by VMNH Vertebrate Biology volunteer J. Benzing.

Research and Collections

Jill K. Harris, Registrar

Twenty-three (23) collections acquisitions were recorded for over 600 specimens and 38 boxes. These specimens were added to the invertebrate zoology, paleontology, herpetology, and vertebrate zoology collections.

Two (2) outgoing loans were recorded this quarter from paleontology and invertebrate zoology collections. Loans were made to the University of Lynchburg and a VMNH research associate.

Ms. Harris (database administrator) and Joel Clifton (IT tech/ISO) installed the latest patch to the VMNH electronic collections management database (Proficio). Staff modified/updated 8,768 existing records and added 303 records to Proficio, for all collection disciplines. In addition, paleontology staff updated 5 existing records (no new records were added) in the electronic database (EGEMs), for paleontology only.

# of Activities	TYPE OF ACTIVITY	PROFESSIONALS AND 13+ STUDENTS	K-12 STUDENTS	K-12 TEACHERS	PUBLIC			TOTAL #	
9	Conference presentations (A)	585	0	0	0			585	
3	Meetings chaired (B)	15	0	0	0			15	
9	Review documents/manuscripts (B)	9	0	0	0			9	
0	Requests for information about collections (C)	0	0	0	0			0	
2	Visiting researcher (C)	2	0	0	0			2	
4	Collections tours (D)	22	17	0	21			60	
3	Lab Tours (D)	22	0	0	0			22	
1	Receptions	0	0	0	50			50	
4	Responses to requests for information about specimens at VMNH (D)	1	0	0	3			4	
7	Lectures and presentations at VMNH (D)	3	211	4	174			392	
1	Technical consultations (B, D, & E)	3	0	0	0			3	
8	Display table with specimens	0	0	0	2106			2106	
2	Off-site education programs	20	15	0	0			35	
2	Lectures Not at VMNH (E)	30	0	0	0			30	
1	Off-site presentations (E)	0	0	0	6			6	
2	Field trips/Field Work	4	0	0	8			12	
0	TOTALS							3331	

TOTAL # INDIVIDUALS SERVED

3331

The attached article "*The Silent Extinction of Species and Taxonomists—An Appeal to Science Policy Makers and Legislators*" recognizes that, despite its fundamental importance to organismal science, taxonomy has been undervalued and underfunded for decades. The authors do an excellent job at stating the problem, identifying some of the reasons for this decline in support, and offering specific suggestions to help turn taxonomy into a thriving science once again, including the need for natural history museums to focus on collections-based research. With adequate staffing and digitized collections, small and mid-size institutions like the VMNH can play a major role in global biodiversity research, especially in understudied regions such as Virginia. The authors offer multiple suggestions to increase and sustain support for taxonomic research, including several that directly involve natural history museums.

Many of the elements presented in this article will not only be useful in our efforts in the Research and Collections Committee to support the VMNH's primary mission, but they will also inform ongoing discussions in the Strategic Planning Committee that will help determine the direction of the Museum in the future.

Dr. Art Evans

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The Silent Extinction of Species and Taxonomists—An Appeal to Science Policymakers and Legislators

Article in *Diversity* · September 2023

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The Silent Extinction of Species and Taxonomists—An Appeal to Science Policymakers and Legislators

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Abstract: The science of taxonomy, albeit being fundamental for all organismic research, has been underfunded and undervalued for about two generations. We analyze how this could happen, particularly in times of a biodiversity crisis, when we have increased awareness amongst the population and decision makers that knowledge about species we share the planet with is indispensable for finding solutions. We identify five major issues: the habit of holding taxonomy in low esteem; the focus on inappropriate publication metrics in evaluating scientific output; the excessive focus on innovative technology in evaluating scientific relevance; shifting priorities in natural history museums away from their traditional strengths; and changing attitudes towards specimen collecting and increasing legislation regulating collecting and international exchange of specimens. To transform taxonomy into a thriving science again, we urgently suggest significantly increasing baseline funding for permanent positions in taxonomy, particularly in natural history museums; reviving taxonomic research and teaching in universities at the tenured professor level; strongly increasing soft money for integrative taxonomy projects; refraining using journal-based metrics for evaluating individual researchers and scientific output and instead focusing on quality; installing governmental support for open access publishing; focusing digitizing efforts to the most useful parts of collections, freeing resources for improving data quality by improving identifications; requiring natural history museums to focus on collection-based research; and ending the trend of prohibitive legislation towards scientific collecting and international exchange of taxonomic specimens, and instead building legal frameworks supportive of biodiversity research.

Keywords: taxonomy; science policy; biodiversity research; natural history museums; universities; red tape



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1. Introduction

“Although often ignored or belittled, the role of taxonomy in biological research and in other fields like ecology and biodiversity management is central. To paraphrase a famous sentence, nothing makes sense in biology if the organisms studied are not identified and named, as their taxonomic placement in special units, the taxa, provides irreplaceable information on their characters, relationships, and evolution. Misidentification or misnaming of organisms may have unfortunate consequences not only on the accuracy of biological works and on their repeatability, but also in domains like medicine, pharmacology, breeding, agriculture, conservation biology, ecosystem management and climatology.” (Dubois et al. 2013 [1])

It has long been recognized that the threat to populations and species and their extinction rates have reached an alarming level [2,3]. The general concern in an increasing part of society is boosted by the latest figures of the International Union for the Conservation of Nature (IUCN), documenting that 28% of all assessed species are threatened with extinction [4]. This is a disturbingly high figure, but what does it mean? A total of 150,388 species have been assessed, of which 20,835 species are data deficient. In Insecta, the coverage is, as expected, even smaller: only 12,441 insect species have been assessed, of which 3217 are data deficient. Less than 130,000 assessed species, including less than 10,000 insect species, is a dismally small portion of the whole biodiversity of this planet.

The authors of this paper, who have been involved for a combined 220 years in the painstaking recording and documentation of biodiversity, wonder what portion of the whole species diversity might be threatened by extinction and what the absolute number of threatened species would be. In fact, nobody knows the number, or even the magnitude, of species currently still living on Earth. Estimates are based on extrapolations from local assessments, have high uncertainty, and vary enormously [5–8]. Estimates for the Australian beetle fauna, for instance, vary between 80,000 and 100,000 species, which is four to five times the known species number [9]. Based on expert opinion, we might expect 704,000 to 972,000 marine eukaryote species, with only one fourth to one third described so far [10]. For the whole animal kingdom, estimates fluctuate between two and eighty million, with a wide consensus of a minimum of five to eight million currently living species [11,12]. Our ignorance of the diversity of species we share the planet with is astonishing and gets almost surreal when we look at microorganisms with estimates between six million and one trillion species (or basic evolutionary units) [13]. While we have good figures for the known marine eucaryote diversity [10], we do not know the overall number of described species on the planet. While the Catalogue of Life lists over 2 million species of all organism groups [14], this number is skewed by unknown quantities of unresolved synonymies and yet unconsidered described species.

Anyway, after almost three centuries of taxonomic research, we are still far from the conclusion of our endeavor. At the same time, the interaction of global factors like climate change and environmental pollution with direct local destruction by, e.g., the development of housing, mineral resources, or agriculture, leads to an ever-accelerating loss of natural habitats worldwide and, in turn, to a reduction in species diversity and abundance of non-human organisms. Considering the overwhelmingly high number of yet-to-be-discovered species that appear to be destined for silent extinction, recording and studying the still-existing diversity of life on our planet should be one of the priorities of modern biology [15–18].

It would make sense that this task received support commensurate with its importance, but in reality, we find the opposite. It is taxonomists who discover, diagnose, and classify the basic entities of biodiversity, creating the frame of reference for most organismic biologists, such as evolutionary biologists, parasitologists, and ecologists, but also for practitioners, such as foresters, farmers, and conservationists. Without taxonomists, threatened species could not be identified, and species lists were not provided, leading to hampered conservation efforts [19,20]. Without taxonomists, time and money might be wasted in misled control efforts targeting the wrong species [21] or just by publishing worthless studies [22]. Without taxonomists, medically important model species could be misidentified or misinterpreted, as in the case of the medicinal leech [23]. Without taxonomists, datasets used by other scientists lead to erroneous or imprecise results [24]. Yet taxonomy, natural history museums, and herbaria have long been undersupported and underfunded both in the northern [25–30] and in the southern hemisphere [31,32]. Underfunding taxonomy inevitably leads to persisting knowledge gaps [33] or, if sustained, even loss of knowledge.

Until about two generations ago, the work of taxonomists was highly regarded; taxonomy was taught at many universities, and natural history museums boasted a wealth of comprehensive taxonomic expertise [34–36]. It was recognized that without robust

taxonomy, fields like ecology, biogeography, or phylogenetics lack their foundation. Many productive taxonomists achieved leading positions in academic institutions and were supported by technical staff. Natural history museums, with their large collections, were held in high esteem. It was recognized that they not only preserve the archives of life in a sustained way but also document the distribution of species in space and time and the variability of populations. Museum specimens are not only indispensable for comparative studies but also form the foundation for a universal nomenclature that allows unequivocal communication about life on Earth [37], bridging cultural, linguistic, and national differences. Every described species and every higher taxon have been diagnosed or defined according to the knowledge, techniques, and capabilities of the time. With growing knowledge, newly recognized species and characters, and progressing analytical technology, these old hypotheses need to be revisited and reevaluated, which is impossible without preserved voucher specimens.

Nonetheless, taxonomy is currently sidelined and undervalued [3,38]. Emphasizing the large descriptive component, taxonomy frequently is not considered proper science and can supposedly be performed by amateurs [27,39,40], similar to the intertwined but broader field of natural history [40,41]. While “descriptive” in science is often considered a pejorative, being the argument for paper rejections by high-impact journals and disdained by parts of academia, it is still the indispensable foundation for most sciences, including biodiversity research [42,43]. Evidence still needs to be described. Nevertheless, many, if not most, universities’ curricula neglect taxonomy. The number of professors of taxonomy is paltry compared to other fields of biology that rely on robust taxonomy. Taxonomy is rarely taught these days and is generally not accepted as a topic of doctoral dissertations [44,45]. In England and the United States, financial support for taxonomic projects decreased at least from the 1990s [46,47], with short-lived exceptions, such as the Planetary Biodiversity Inventory (PBI) [48] or the Partnerships for Enhancing Expertise in Taxonomy (PEET) programs [49] of the National Science Foundation. An erosion of taxonomic knowledge and taxonomic education has been happening for a long time at universities in Germany [50], Switzerland [51], Austria [52], and likely most countries that were traditional taxonomic strongholds. The expression “taxonomic impediment” has become omnipresent globally [53]. We note a profound paradox: the public and politics are touched by the declining diversity of life, whereas the discoverer of this diversity and the institutions documenting it often receive insufficient support or even experience obstructions [54]. This paradox is not new. Thirty years ago, Claridge [55] noted, “The astonishing paradox then is that at a time when it is widely agreed that much more taxonomic research is urgently needed, research and training are at a low level and funding is completely inadequate.” Little has changed.

Large-scale initiatives, such as the Catalogue of Life, Global Biodiversity Information Facility, and the Consortium of European Taxonomic Facilities, or national programs, such as “Biodiversität: Forschung für die Artenvielfalt” of the German Federal Ministry of Education and Research give the impression that taxonomy receives efficient support. In reality, these initiatives are rather distant from the painstaking descriptive day-to-day taxonomic work. They do facilitate information retrieval, flow, and dissemination but are often still of limited use [56–58], and the taxonomic baseline work remains largely unsupported. Some programs, such as the ongoing Synthesis of the European Union [59], facilitate access to collections and are undoubtedly useful. The Biodiversity Heritage Library [60] and similar projects, such as the German AnimalBase [61], provide easy access to an increasing portion of the historical literature, saving taxonomists uncountable (albeit enjoyable) library hours. The NSF program PEET [48] did train young taxonomists, but all these initiatives did and do not touch the fundamental problem of taxonomy: the low and decreasing number of permanent positions for taxonomists that would allow multi-year revisions and comprehensive work [49,62,63].

Citizen science (lately, sometimes re-christened community science) initiatives are often propagated as solutions, providing taxonomy and species-focused research with

relevant data. While we value such projects, they can only provide a small fraction of the data needed for taxonomic research, mainly distributional and phenological data for easily recognizable species in accessible places [64]. One of us had great success with mapping the easily recognizable Japanese Beetle in Colorado with the help of a couple hundred citizen scientists [65]. For the identification of most insects, however, the involvement of expert taxonomists is necessary, including the large and important group of private scholars, amateurs who educated themselves for many years to become respected specialists for particular taxa. Without their competence and their scientific publications over more than 150 years, our taxonomic knowledge would be much more fragmentary. Giving them access to ample support and funding should be a top priority [45,66,67], but it is not.

The following examples are symptomatic of the current state of taxonomy:

- From Hungary, a well-researched European country with a long taxonomic tradition, 35,650 animal species (excl. “Protozoa”) are recorded. For 15,250 of these (42.7%), there is no taxonomic expert in the country; for another 33.7% (12,010 species), there are only one or two, often retired experts. Currently, Hungarian taxonomists can reliably identify only 23.6% (8410 species) of the Hungarian fauna (B. Páll-Gergely, pers. comm.).
- In Great Britain, the number of authors of taxonomic publications and the number of publications has decreased constantly and significantly since the mid 20th century [68].
- Many biodiversity publications do without species identifications, relying on identification to higher taxa, which admittedly can be justified in cases [69], or naively relying on “morphospecies” sorting [70], containing serious misidentifications (references withheld, but see [71,72]), or, more often, the reliability of taxonomic identifications cannot be validated because of insufficient documentation of methods and sources [73,74].
- Authors of database or citizen science-based analyses sometimes do not even mention the potential of misidentification [75,76], hence overlooking or neglecting the elephant in the analysis.
- Countless species collected by expeditions in poorly known and highly diverse regions of the planet remain unstudied while accessible in museums. For instance, after 38 years, only about a quarter of the insects of the British research endeavor in 1985 in Dumoga-Bone National Park, Sulawesi, have been identified (M.V.L. Barclay, pers. comm.).

How could it happen that taxonomy is no longer respected as a solid fundamental science [63,77–79]; that we ended up with a severe global deficit of taxonomists in times of a biodiversity crisis [47,78–81]; and that fieldwork is hampered by increasing red tape [22,26,82–84]? It is high time to reflect on these developments and their causes. We have identified the following issues that we will discuss in detail:

- Low appreciation of taxonomy;
- Publication metrics as a crooked yardstick of scientific performance;
- Focusing on technology;
- Priorities in natural history museums;
- Ideology and legislation.

2. Low Appreciation of Taxonomy

At its beginnings three centuries ago, taxonomy was an exclusively descriptive activity. Since then, it has developed into a highly integrative field of biological sciences [63]. While “dry” descriptions of specimens remain an integral and essential part of taxonomic studies, taxonomy has become so much more. Taxonomists are often involved in determining the ecological role of species in ecosystems, their evolution, biology, and habits. It is incomprehensible that taxonomy is still reproached for morphological descriptions [40,85] when descriptive approaches in other fields, such as medical research (e.g., pathological descriptions) or astronomy, are apparently acceptable.

Another misunderstanding seems to be grounded in the wide use of identification keys. If they are well composed, users see simple theses and antitheses (e.g., one or two denticles on the tibia), which leads easily to results and might create the impression of effortless, unscientific work. Users overlook that creating user-friendly identification keys involves the selection of the few least intraspecifically variable characters that can easily be seen and correctly interpreted out of an immense number of characters of a biological species. It is often true that the easier the key is to use, the more effort its construction requires. Frequently, taxonomy is simply equated with identification, which is comparable to confounding a medical diagnosis with medical research. When mingling in ecological circles, the exclamation, “But this is only identification!” (implying not real science), was heard all too often (FTK., pers. obs.). The “unsatisfactory level of recognition [taxonomy] has in academia” is widely experienced in the taxonomic community [86].

Another common misunderstanding relates to the purpose of taxonomic discovery. For some, the taxonomic goal is naming species [87,88], but names are only labels that enable the exchange of information [89,90]. The eminent mycologist Keith A. Seifert questions: “Does the act of naming a sequence provide new information that is not already inherent in the sequence itself? I would say not.” [91]. The naming process, nomenclature, is a technical complex of rules and not science. Having a lot of names for questionable or largely undescribed taxa just for the sake of having names is not necessarily advantageous. The proponents of metabarcoding (see Section 4) do not even bother with names and consider it sufficient to know the number of species in a sample. To cite Keith A. Seifert again, “In modern ecology, when you have a substrate in your hand that contains DNA sequences of a thousand species, half of them unknown, have you discovered 500 new species or have you picked up a handful of dirt?” [91]. To present results with the highest predictive power and to provide the most exact and reproducible descriptions of biota, communities, and assemblages, taxonomy needs to be involved. It is taxonomy that discovers and describes the millions of leaves (species) on the tree of life, which should get named when they are sufficiently diagnosed.

3. Publication Metrics as Crooked Yardstick of Scientific Performance

The Institute of Scientific Information (ISI) was founded in 1958 by Eugene Garfield. Garfield and Irving H. Sher created the Journal Impact Factor in the 1960s “to help select journals for the Science Citation Index” [92], the main product of ISI, which meanwhile has evolved into the “Journal Citation Review” of Clarivate Analytics. The Journal Impact Factor is defined as the number of citations within a given year of items published by a journal in the preceding two years divided by the number of citable items published by the journal in those two years. It is the average number of citations a paper of a journal attracts in the two years following its publication. It ranks the journals of the selected pool according to the attention they attract in the two years after publication and was used increasingly by libraries to decide which journals to keep and which subscriptions to cancel. However, the pool of journals selected to be assigned an Impact Factor is rather small. The journals containing the papers indexed by “Zoological Record” since 1864, which represent the major part of all taxonomic and faunistic publications, are largely not considered [77]. Later, papers published in a journal with a higher Impact Factor were often considered to be of a higher quality. The short-term attention a journal attracts was seen as equivalent to the quality of every single paper published by this journal and, in turn, to the scientific ability and skills of the authors. This assumption turned out to be erroneous [93], but still, the Journal Impact Factor has been used in many countries for evaluating the performance of scientists [94–96]. Researchers publishing in journals with higher Impact Factors are considered better scientists. This continues to happen despite the early warning of the Impact Factor’s creator [97] and his persistent follow-ups, e.g., [94], clearly stating that neither single papers nor authors should be evaluated by cumulative journal citation counts.

Besides the general inapplicability of Journal Impact Factors for the evaluation of authors, taxonomy-specific citation patterns worsen the situation even more. In a spot check of a few larger monographs, Krell [98] found the mean age of taxonomic references to be 61 years. Köhler [99] found a similar high age, 47.7 years, for cited references in coleopterology. Given that the Impact Factor considers citations only from the two years following publication, taxonomy has a huge disadvantage when this metric is used for evaluation. Additional metrics are currently in use, e.g., the H-index, that are researcher-related, not journal-based. Such indices appear to be more appropriate for evaluating individuals but have their own issues and are based on the belief that quantity equals quality. While they may influence career success and budgets, they do not consider that taxonomic results generally have a low citation rate in the first years but continue to be used and referred to for decades, or even centuries, to come.

The internet facilitated another problem for journals that traditionally published taxonomic content. Journals of learned societies, local natural history associations, natural history institutions, or privately funded specialist journals experience competition from a wave of new, electronically or mainly electronically published journals. Electronically published journals are cheaper to produce and can easily offer open-access models that provide higher visibility, which, in turn, as many authors believe, leads to more citations. Evidence for such correlation is ambiguous [100–102], but it is still a selling point.

A huge and growing number of online journals of low to no quality, the so-called predatory journals, emerged in the last two decades as money-making enterprises [103]. Taxonomy has largely been spared by this wave, but the number of papers suffering from immediately obvious misidentification, even at the family level, impossible results, or erroneous claims is increasing. An early report on this phenomenon relates to Indian ichthyology [104]. We can at least breathe a little sigh of relief that papers in predatory journals attract very few citations [105]. While largely neglected, they are still a nuisance and, for the uninitiated, outright harmful.

The financial implications of modern, metrics-driven publishing also put taxonomy at a disadvantage. Open-access publishing, where authors pay fees to make their works available for free to everybody, leading to the desired exposure, comes at a high price. Publishing processing fees in a reputable journal with a decent Impact Factor can be substantial. PLoS Biology requests USD 3000–5300, and PLoS ONE charges USD 800–1850, the latter attracting 20,000 new authors every year [106]. A large proportion of taxonomic research is performed by private scholars or retirees without funding, by professional researchers on institutional shoestring budgets, or on the side of ecological or phylogenetic projects. Paying high processing fees for publication is not an option. The fees for predatory journals are lower, often attracting authors in good standing from poorer countries or countries that are less highly regarded in traditional peer review, depriving them of the experience of a publication process that improves their papers and leaving them with the stain of having published in a predatory journal.

Focusing on publication metrics has resulted in the paradigm of science shifting from “discovering new things and making them known” to “publishing as much as possible in the journals with the highest Impact Factors.” It has also led to a struggle for the existence of traditional scholarly journals of societies or institutions that some already lost. At the same time, the “publish or perish” mantra leads to an inflation of publications. Salami-slicing strategies, i.e., publishing multiple papers of least publishable units from one study, are facilitated by the rising number of journals competing for publications and satisfy research assessments focusing on quantity. The gold standard in taxonomy is revisionary work. Extensive revisions take a long time and result in only one publication after several years. Would it not be better for one’s academic CV to publish several dozen single species descriptions as separate papers in the same time period? Long, comprehensive revisionary studies have become a disadvantage for a scientific career because the number of resulting papers is low, the time invested is high, and the number of expected citations in the immediate, career-relevant period post-publication is most likely

very low. Considering the last point, working on neglected groups with few taxonomists involved turns out to be a disadvantage. It is a great advantage to choose a popular group with numerous colleagues who can potentially cite your work. Hence, it is no wonder that we maintain large knowledge gaps in neglected groups, particularly in parts of the world with an overwhelmingly large biodiversity and underwhelming financial resources. Under such circumstances, the focus on better-known groups such as Lepidoptera [107] is understandable.

As long as we focus on quantity and metrics, taxonomy will continue to lose out. Which early-career biologist would invest years in studying old literature in many languages and specimens from institutions all over the world, only to have a few publications in their CV and then struggle to find permanent employment? Revisionary taxonomic work on species-rich groups is unattractive and unfeasible to execute when in term-limited employment. Rushing revisions at the end of a contract does not help the quality of such fundamental works, and publishing incomplete revisions is unwise and potentially harmful.

The problems are systemic and extend across many scientific disciplines well beyond taxonomy, from mathematics to geology, and have been called out innumerable times [108–113]. Fortunately, stronger voices have emerged in favor of an improved research evaluation. Criticism of too much focus on publication metrics finds its way into well-supported international declarations, such as DORA, the San Francisco Declaration on Research Assessment [114], or national policy statements implementing DORA, such as

- The Dutch universities' "Room for everyone's talent, toward a new balance in the recognition and rewards of academics" [115];
- The new research assessment reform in China moving away from "Science Citation Index worship" [116];
- Or the new CV format of the Swiss National Science Foundation that devalues publication metrics [117].

Also, an increasing number of UK universities and funders implement DORA principles into their policies [118]. These are all good developments that can only help the recognition taxonomists receive in the future.

4. Focusing on Technology

Science has always adopted new technologies. Taxonomy is no exception. X-ray microscopy [119], phase-contrast synchrotron X-ray microtomography [120], micro-CT scans [121], or genomic and other molecular technologies [122,123], often combined with morphological studies [124], provide great examples of technologically advanced taxonomic approaches. Bioacoustical characters also provided an important data source for entomo-taxonomy, e.g., the drumming signals of stone flies, the mating calls of cicadas, or the sounds of grasshoppers. In ornithology, songs have been important characters for taxonomic decisions for a long time [125]. Good taxonomists have always integrated different approaches, character systems, and technologies that were at their disposal [38].

Technology, however, should be a means to gain knowledge, not the goal itself. Advanced technology is not necessarily an indicator of the quality of taxonomic analyses. Over seventy years ago, Hennig [126] had already noted that the way of data analysis is much more important than by which technology these data were gathered. Popper [127] stressed that hypotheses must be intersubjectively testable and falsifiable. This is the main criterion of a scientific hypothesis, not by which means or methods it was conceived. While these propositions are widely accepted, they often seem to be forgotten when taxonomic work is assessed. At the end of the 20th century, a good taxonomic study was expected to contain a cladistic analysis. Currently, molecular methods have taken over the place of comparative morphology. Molecular methods are a treasure trove for studies of phylogenetic relationships, phylogeography, polymorphic species, diagnosing cryptic species, or for the taxonomic assignment of preimaginal stages, but are most efficient and revealing in an integrative approach.

DNA taxonomy, as proposed by Tautz and colleagues [128], found many followers because of its simple approach but also attracted criticism right from the beginning [129,130]. DNA taxonomy, particularly when relying on a short “barcode” sequence, is still widely considered a questionable approach and inferior to an integrative taxonomy that combines several techniques and approaches [131–134]. The core of the problem is the enticement to replace the use of complex morphological characters with a simple technology [135]. This limited approach has even been presented as revolutionary progress for tackling the planet’s undescribed biodiversity and saving time and money and has led to the description of hundreds of new species based on 2% differences in a single gene, largely without considering even obvious phenotypical differences [88,136]; see also [63,137,138]. Using short DNA barcodes as the sole identification tool without solving issues of calibration might easily lead to incorrect identifications and artificial classifications. Proponents of metabarcoding often go a step further and do without species identification altogether and count “operational taxonomic units” instead [139,140]. As a result, we obtain the number of units but do not know which species there are and what portion of those units represent species at all. Moreover, the numbers metabarcoding reveals can be significantly lower than the actual number of species in a sample [141]. After all, the DNA barcodes of only a small fraction of all species are known. For example, of the 400,000 described beetle species, only 4% of the species have associated DNA barcodes [9]. From a limited sample of beetles Stork and Hine examined, 53% were known only from one locality, and 13% were just from one single specimen [142]. Even in the unlikely case that these numbers turn out to overstate the rarity or collectability of species, this example shows that achieving a very high barcoding rate in invertebrates is challenging and probably, with current collecting restrictions, not achievable.

We do not dismiss technological progress and new methods at all. Novel methods and techniques attract funding and new blood, provide novel sets of data, and are generally a positive development [143]. As always, the problem is not the methods or techniques themselves. There is nothing wrong with new techniques or molecular approaches per se. The big mistake is overemphasizing newer techniques to the detriment of long-established, tested, and proven methods. However, we also notice positive developments: the integrative approach in taxonomy is on the rise [144], which gives us hope that taxonomy will have a future as a scientific endeavor.

5. Priorities in Natural History Museums

Natural history museums are the places that hold collections that document the biological diversity of our planet, past and present. These specimen collections are fundamental to our understanding of life forms and biotic processes [145]. They show the changes and influences of ecological conditions on flora and fauna over time and enable reconstruction and modeling evolution. While the number of specimens in these collections is constantly increasing, the number of curators and technical staff is still generally decreasing [146], often dramatically [36,81]. This tendency is caused by the underrating of natural history collections by decision makers and by part of the scientific community, combined with the lack of understanding of the epistemological function of voucher specimens, which provide the only basis for reproducibility in organismic research [40,147,148].

The current priority for natural history collections is not, as one would expect, the discovery of novelties in nature but the digitization of already existing specimens, with the justification of providing access to the whole scientific community and even to the public [149]. Scientists can find interesting material in databases, helping particularly smaller and mid-sized collections that would not regularly be approached with loan requests. The general public, however, is unlikely to profit much from lists of millions of little flies or dung beetles. They would rather have a selection of remarkable specimens, as exhibited in traditional museum exhibits in the past. While scientists can find specimens they want to study, they might still have to consult the specimen on loan, as even with high-quality photography, not all the relevant characters will be available online. Moreover,

the identification of many museum specimens is doubtful, wrong, or outdated [150,151] because we do not have enough taxonomists to provide up-to-date identifications for even the existing museum specimens. Transcribing wrong identifications into online databases can lead to the dissemination of wrong information but can also initiate feedback by users, helping to correct such mistakes. The uncritical use of collection databases for scientific studies is dangerous and discouraged, but it happens. “Indeed, not all scientific users understand that globally aggregated data always need filtering and post processing, as well as dealing with data gaps” [152]. Targeted digitization and high-quality photographic documentation of, e.g., type material, historical material, or reliably identified specimens can be extremely useful for the scientific community, having easy access, and for the preservation of the specimens, avoiding shipment. This is obvious to people working with collections but not necessarily to decision makers who expect universal digitization efforts and promote this as great progress to mitigate the taxonomic impediment without supporting data quality, i.e., taxonomy, at the same time. A huge investment of funds and time is targeted to an effort that is certainly useful but might not serve the most urgent needs of collections and taxonomy.

Distortion in valuating traditional scientific research activities forces museums to find new ways and priorities that can better secure support from administrations and the public. The result has been, for decades, a shift from collection-focused biodiversity research (taxonomy) to more fashionable topics. This happens despite the immeasurable potential of natural history to produce stories that the general public understands and appreciates. We see a declining number of natural history museums that still focus long-term on biodiversity studies in understudied areas and publish their fieldwork results, e.g., the Naturkundemuseum Erfurt in Germany (directed by one of the coauthors, M.H.). This is a largely missed opportunity that will never come again.

6. Ideology and Legislature

The preservation of the still extant life in nature is one of the most important tasks of humankind, particularly in times of a biodiversity crisis, changing climate, and accelerating destruction of habitats worldwide. Legislatures in all parts of the world support this task and introduced numerous regulations with the best intentions, nationally and internationally. These regulations help the preservation of nature in many ways but have also resulted in prejudices against any collecting of animals and plants. They often hamper scientific collecting by increasing bureaucratic hurdles, which may put off researchers [153] if not prevent research at all [79,154]. The fundamental difference between tiny, fast-reproducing invertebrates and large, slowly reproducing vertebrates is often bluntly ignored [67]. As a result, it became difficult, or even impossible, to collect in some countries, and comprehensive projects considering the fauna or flora of multiple countries become increasingly unworkable, although collecting is the foundation for all taxonomic research [79,155,156].

The absurdity of many bureaucratic regulations can be easily demonstrated by many examples. The size and health of populations are influenced by many factors, one of them being predation. A single colony of the Greater mouse-eared bat (*Myotis myotis*) in Switzerland consumes over two million arthropods per year [157]. They predate the arthropods in their territory year after year without any damaging influence. Songbirds are another group of efficient predators. A pair feeds their chicks 450 insects per day, which equals a full insect drawer in a collection, which adds up to seven breeding pairs of songbirds killing as many insects in one season as one insect collector in a lifetime [158]. Nyffeler and Birkhofer [159] estimate that spiders globally kill about 400 to 800 million metric tons of insects per year. They consume approximately 10^{15} arthropods in one year, whereas the number of specimens collected by humans during the last 200 years and preserved in museums is closer to 10^9 . And then, we must consider the inadvertent consequences of human activities that do not even deliberately target insects. According to Gepp [160], road traffic in Austria kills 14×10^{15} animals annually, which is millions of times more specimens than in all scientific collections worldwide combined. This happens

not only in Austria. Road traffic kills an estimated 20 million butterflies and moths per week in the State of Illinois [161]. Baxter-Tilbert and colleagues [162] extrapolate that up to 187 billion pollinators are killed on North American roads per year. These astronomical numbers are likely to be dwarfed by the losses caused by the destruction of habitats and the application of insecticides in agriculture and urban areas. Restricting scientific collecting of invertebrates for the purpose of species conservation appears dishonest. It results in the obstruction of research while having no noticeable impact on conservation efforts apart from preventing the creation of crucial knowledge.

An example of this bold statement might be the European Apollo, a butterfly that has been strictly protected by law for almost a century and has been and still is in dramatic decline all the same [163,164]. The bureaucracy that allowed “Flurbereinigung” (land consolidation), destruction of river meadows and flood plains, or the generous application of fertilizers and pesticides in agriculture obstructs the collecting of specimens by entomologists. Making collecting difficult or illegal alienates the upcoming generation from the study of natural history, which is counterproductive to efficient nature conservation [45]. Moreover, even most Red List species cannot be reliably identified without studying specimens. Photography, often suggested as a replacement for collecting, has limited use [165]. To assess the species diversity of an area, to assess the conservation value, or to suggest a particular management scheme, we must collect, prepare, and identify first.

The “red tape” for collecting affects even more severely tropical and subtropical countries, where biodiversity is very rich but poorly known [84,154]. Habitats are getting destroyed on an industrial scale. Scientists can point out this development but can rarely influence it and never stop it. Scientific priority should be to collect as many samples of moribund fauna and flora as possible and preserve them in well-curated collections—as an invaluable source of information for current and future research when a large proportion of taxa will no longer be present in nature. Ironically, an international framework aiming at just and equitable access to genetic resources and the sharing of benefits gained from genetical resources seems to develop into a severe hindrance to taxonomic research and international collaboration. The Nagoya protocol [166], signed by 136 states and the European Union and ratified by most, does not distinguish between commercial and non-commercial use. It does, however, distinguish between monetary and non-monetary benefits, such as local capacity building or contributions to the local economy. Most of those non-monetary benefits still require funding, and most taxonomy is performed unfunded. As countries may equate benefits with monetary resources, and every organism contains genetic information, benefit sharing might be difficult for unfunded taxonomy, and collecting without the required—but difficult to obtain—paperwork is an offense and can result in jail time. Consequently, researchers shift their interests to areas where they can work without too much red tape and without the risk of prosecution ([153]; I.L., pers. experience), resulting in the neglect of threatened and biodiversity-rich biota. The authors of the Nagoya protocol, but more so national implementations, seem to have disregarded that even underfunded taxonomy results in publications that are accessible, useful sources of information for biodiversity-rich countries. Moreover, the myth of ubiquitous commercially exploitable compounds from animals and plants [167] has raised unrealistic expectations about the profitability of biodiversity research even if the industry itself focuses increasingly on efficient laboratory research instead of tediously bioprospecting, as Ehrenfeld had already noted in 1988 [168]. Sensible national implementation of international frameworks, such as the Nagoya or Rio Protocols, is urgently needed to avoid the further decline of taxonomy and related fields.

7. Suggestions

Our own experiences convince us that recording and understanding the species with which we share the planet touch a broad audience. Natural history is a welcome topic for public presentations, telling stories that people understand and appreciate. Countless volunteers, citizen scientists, or amateur researchers try to fill gaps in our knowledge [169–171] despite often frustrating and unsupportive circumstances. From 2000 to 2014, European

taxonomists described 3968 rove beetle (Staphylinidae) species. Twenty-four professional, paid taxonomists described 519 species; the remaining, almost 3500, were published by 44 unpaid retired and unpaid amateur taxonomists [172]. We still have a workforce contributing significantly to the grand challenge of discovering, describing, and understanding Earth's biodiversity, albeit collecting by amateurs is declining [173]. We must make sure that this workforce is nourished, supported, and replenished, not obstructed or even criminalized. This is in line with a recent community exercise of the Royal Entomological Society of London that determined the priorities for action in entomology in the coming decades, which included taxonomic training, funding, early career development, and integration, amongst others [174]. Additionally, we see the necessity to change legal and societal attitudes to create welcoming conditions for basic biodiversity research if we want to discover and understand the undescribed species of the planet before they become extinct.

Our suggestions are as follows:

- To significantly increase financial support and the number of paid non-term-limited positions in taxonomy in general and particularly in natural history museums, which house in their collections reference material of already described, but also of still undiscovered species—"Biodiversity research requires more boots on the ground", as E.O. Wilson [175] aptly stated;
- To immediately revive taxonomic research and teaching at universities at the tenured professor level to secure the education of the next generation of taxonomists;
- To strongly increase funding for integrative taxonomic research to build the foundation for the usefulness and general applicability of genetic barcoding;
- To refrain from using metric evaluation at the journal level (Journal Impact Factors) for evaluating the quality of researchers and their work;
- To provide governmental support for scholarly journals that provide open access without charging authors large article processing fees;
- To focus digitization efforts on parts of collections that experts consider useful instead of binding scarce resources in all-embracing digitization endeavors of large collections as a whole;
- To require natural history museums to focus on collection-based research;
- To end the trend of prohibitive legislation towards scientific collecting and international exchange of taxonomic specimens; a supportive legal framework is paramount for achieving a realistic idea of the global species diversity, a solid foundation for efficient nature observation, deciding upon sustainable management strategies in ecosystems, and securing a new generation of motivated scientists targeting all aspects of biodiversity research.

These are straightforward strategies to provide a sustained workforce documenting and analyzing the biodiversity of our planet in times of peril. We are perfectly able to study and potentially rescue major parts of our organismic diversity on Earth if we want.

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