

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

Saturday, Feb. 19, 2022

9:00-9:45 a.m.

A G E N D A

- Call to order: **Dr. Art Evans**
- Roll Call: Dr. Art Evans, Dr. Tom Benzing, Dr. Carole Nash, Lisa Carter, Melany Stowe, Mark Buss.
- November 2021 Research and Collections Committee meeting minutes (action item)
- October-December 2021 acquisitions (action item)
- Consideration of Dr. Derek Hennen as a Research Associate (action item)
- Consideration of Dr. Julian J. Lewis as a Research Associate (action item)
- Consideration of term renewals for the following Research Associates: Dr. Robert Bodnar, Dr. Art Evans, William Henika, Dr. Cynthia Liutkus-Pierce, Dr. Sterling Nesbitt, Dr. John Pagels, Dr. DB Poli, and Dr. William Schmachtenberg.
- Update on the herpetology curator search: **Dr. Adam Pritchard**
- Other business: **Dr. Art Evans**
- Adjourn: **Dr. Art Evans**

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 MEETING
Nov. 20, 2021

Present at the meeting were Dr. Art Evans, Dr. Carole Nash, Mark Buss, Dr. Nancy Moncrief, Dr. Kal Ivanov, Dr. Adam Pritchard, Mary Zell Galen, and Ben Williams. Committee members Lisa Carter and Melany Stowe participated via teleconferencing.

Committee Chairman Dr. Art Evans called the meeting to order.

The minutes were unanimously approved with no additions or corrections, although with only three members present a quorum was not reached.

Dr. Art Evans, Dr. Carole Nash, Mark Buss, and later Lisa Carter signed off on the museum's recent acquisitions.

Dr. Art Evans told Dr. Adam Pritchard that he had noticed the museum had accepted some material owned by the Bureau of Land Management (BLM) and asked if BLM provided any funding for the curation of this material given that it remains under BLM ownership. Dr. Pritchard said that while BLM does not provide funding, having BLM material in VMNH collections is functionally the same as having accessioned material since BLM does not limit what research the museum conducts on the specimens, up to and including destructive sampling. Dr. Carole Nash added that in her experience, BLM has run out of room to store its own material and is having discussions about partnering with facilities to store these collections.

The committee considered Bill Welsh as an affiliated researcher. Welsh was recommended by Dr. Hayden Bassett who wishes to use Welsh's expertise in the museum's Cultural Heritage Monitoring Lab (CHML). Dr. Carole Nash said that she was familiar with Welsh and he would be an excellent addition to the team. The committee later recommended Welsh to the Board of Trustees and the board approved him as an affiliated researcher.

Dr. Adam Pritchard offered an update on the museum's search for an assistant curator of herpetology. According to Dr. Pritchard, 23 out of the 24 candidates who submitted applications had relevant experience, and on Monday, Nov. 22, the hiring committee was going to meet to narrow the list down to a handful of candidates who would be interviewed over Skype and/or Zoom. Ideally, he said, the top 3-4 candidates will visit the museum in person in January 2022, and the target start date is June 2022.

Dr. Art Evans asked the curators about the current state of the museum's herpetology collections. Dr. Nancy Moncrief said that the collection contains about 6,000 specimens. Dr. Kal Ivanov added that the specimens are in generally good shape, adding that the collection favors salamanders and frogs and contains comparatively few reptiles.

Dr. Kal Ivanov said that the museum's Molecular Lab is fully functional; the first extractions were performed in August and the first amplifications were performed more recently. The lab is available to all Research and Collections departments, along with visiting and affiliated researchers.

Dr. Art Evans moved to adjourn the meeting.

OCTOBER-DECEMBER 2021 VMNH ACQUISITIONS FOR APPROVAL BY BOARD OF TRUSTEES RESEARCH AND COLLECTIONS COMMITTEE

RIM #	Collector/Donor	Date at VMNH	VMNH Dept.	Quantity	Description	Method	To Be Accessioned (Y/N)
RIM 28-2021	Liberty Hightower	9/20/2021	ORNITHOLOGY	1	Common Yellowthroat (<i>Geothlypis trichas</i>)	Salvaged	Yes
RIM 29-2021	Joe B. Keiper	10/31/2021	ORNITHOLOGY	6	Worm-eating Warbler (<i>Helmitheros vermivorum</i>), Gray Catbird (<i>Dumetella carolinensis</i>), Pileated Woodpecker (<i>Drycopus pileatus</i>), Black and White Warbler (<i>Mniotilta varia</i>), Eastern Bluebird (<i>Sialia sialis</i>), Golden-crowned Kinglet (<i>Regulus satrapa</i>)	Salvaged	Yes
RIM 30-2021	Nancy D. Moncrief	10/31/2021	MAMMALOLOGY	4	White-tailed Deer, juv (<i>Odocoileus virginianus</i>), Virginia Opossum (<i>Didelphis virginiana</i>), Short-tailed Shrew (<i>Blarina brevicauda</i>), Eastern Gray Squirrel (<i>Sciurus carolinensis</i>)	Salvaged	Yes
RIM 31-2021	VA DWR (Kenneth CJ Adkins)	10/1/2021	MAMMALOLOGY	1	Least Weasel (<i>Mustela nivalis</i>)	Gift	Yes
RIM 32-2021	VA DWR (Rick Reynolds)	11/3/2021	MAMMALOLOGY	1	Little Brown Bat (<i>Myotis lucifugus</i>)	Transfer	Yes
RIM 33-2021	Nancy D. Moncrief	11/5/2021	MAMMALOLOGY	1	White-tailed Deer, juv (<i>Odocoileus virginianus</i>)	Salvaged	Yes
RIM 34-2021	Adam Pritchard		PALEONTOLOGY	5	1 brachiopod in matrix; 3 siltstone rocks with shells (brachiopod, bivalve); 1 siltstone rock with shells (brachiopods)	Field Collection	Yes
RIM 35-2021	Adam Pritchard	9/27/2021	PALEONTOLOGY	20	14 sandstone rocks w/reptile teeth, 4 siltstone slabs w/plants, 2 shale pieces w/fish bones	Field Collection	Yes
RIM 36-2021	Roy Plotnick	8/1/2021	PALEONTOLOGY	4	slabs with exoskeleton Eurypterida	Gift	Yes
RIM 37-2021	Carol Scheina	11/12/2021	PALEONTOLOGY	3	skull elements, Ocean Sunfish? (Molidae)	Gift	Yes

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

OCTOBER-DECEMBER 2021 VMNH ACQUISITIONS FOR APPROVAL BY BOARD OF TRUSTEES RESEARCH AND COLLECTIONS COMMITTEE

RIM #	Collector/Donor	Date at VMNH	VMNH Dept.	Quantity	Description	Method	To Be Accessioned (Y/N)
RIM 38-2021	Trevor Clarke		PALEONTOLOGY	9 lots	whale lumbar and thoracic odontocete vertebrae; seal verts/atlas vert; Triassic fish and plants on slabs; microvertebrate fossils and Nanjemoy micro burrows; disarticulated Odontocete skull; <i>Scapanorhynchus texanus</i> shark teeth; coprolites; ray and shark teeth; Perciform skeleton and micro fossils	Gift	Yes
RIM 39-2021	Arthur V. Evans	11/20/2021	RECENT INVERTEBRATES	913	(845 identified to genus and/or species; 68 unidentified) dry pinned specimens: Coleoptera, Hymenoptera, Diptera, Hemiptera, Dermaptera, Siphonaptera, Megaloptera, Neuroptera, and Lepidoptera	Gift	Yes
RIM 40-2021	Liberty Hightower	11/15/2021	MAMMALOGY	1	Eastern Gray Squirrel (<i>Sciurus carolinensis</i>)	Salvaged	Yes
RIM 41-2021	Jeffery Carpenter	7/28/2021	PALEONTOLOGY	17	16 bird bones and 1 lizard vertebra	Gift	Yes
RIM 42-2021	Alexander K. Hastings	10/4/2021	PALEONTOLOGY	1	Felidae (cat) skeleton - fossil	Field Collection	Not to be accessioned: U.S. Forest Service Property
RIM 43-2021	William F. Schmachtenberg	10/12/2021	PALEONTOLOGY	12	worm tubes, brachiopoda, bivalvia, ceohalopod	Gift	Yes
RIM 44-2021	William F. Schmachtenberg	10/12/2021	PALEONTOLOGY	5	worm burrows?	Gift	Yes
RIM 45-2021	William F. Schmachtenberg	12/7/2021	PALEONTOLOGY	4	worm tubes	Gift	Yes
RIM 46-2021	William F. Schmachtenberg	12/21/2021	PALEONTOLOGY	5	<i>Orthorhynchula</i> and <i>Glyptoglossella</i> "Lingula"	Gift	Yes
RIM 47-2021	Michael Folmer	11/22/2021	PALEONTOLOGY	~300	fossils: crocodylian, turtle, lizard, reptile, snake, shark, fish, ray, bivalve, snail	Gift	Yes
RIM 01-2022	Derek Hennen	1/7/2022	RECENT INVERTEBRATES	42 vials	arthropods	Gift	Yes

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

OCTOBER-DECEMBER 2021 VMNH ACQUISITIONS FOR APPROVAL BY BOARD OF TRUSTEES RESEARCH AND COLLECTIONS COMMITTEE

VMNH Collections Committee and Executive Director have Approved Recent Acquisitions: RIM 28-2021 through RIM 01-2022

VMNH Board of Trustees Research & Collections Committee Review of Acquisitions: RIM 28-2021 through RIM 01-2022

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

Lisa Carter

(signature) Lisa Carter

Date

Carole L. Nash

(signature) Carole L. Nash

Date

Melany Stowe

(signature) Melany Stowe

Date

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

**Report to the Board of Trustees
October-December 2021**

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

- Dr. Ivanov and colleagues have a manuscript in press at the American Society of Mammalogists periodical Journal of Mammalogy.
- Drs. Ivanov and Means and L. Hightower presented research findings at the annual meeting of the Entomological Society of America.
- Dr. Ivanov and colleagues submitted abstracts for the upcoming meeting of the Entomological Society of America – Eastern Branch regarding their work on the terrestrial isopod fauna of Virginia and range predictions and novel means for detection of the invasive red imported fire ant, *Solenopsis invicta*.
- Drs. Ivanov and Means and L. Hightower initiated work on a catalogue of VMNH's invertebrate type holdings.
- Dr. Ivanov and colleagues submitted a grant proposal to the IMLS Inspire! Program.
- Dr. Ivanov participated in VMNH's Dragon Festival and interacted with 1,000+ visitors.

Research & Collections

VMNH Curator of Mammals Dr. N. Moncrief, VMNH Biology Technician L. Hightower, Georgia College & State University faculty Dr. A. Mead, and Dr. Ivanov have a paper in press at the American Society of Mammalogists periodical Journal of Mammalogy.

[Moncrief, N. D., L. Hightower, A. J. Mead, and K. Ivanov. Prevalence and location of survivable skeletal injuries in two species of North American *Sciurus*. Journal of Mammalogy. (in press).]

Drs. Ivanov and Means and L. Hightower presented research findings at the annual meeting of the Entomological Society of America regarding their ongoing work on the terrestrial isopod fauna of Virginia. The presentation included the first comprehensive list of the terrestrial isopods of Virginia based on published records, museum collections, review of online databases, and original collecting. Currently, 26 species and subspecies of terrestrial isopods are reliably reported from the Commonwealth including 10 taxa not previously known to occur in the state (October 31 – November 3)

Dr. Ivanov and colleagues prepared and submitted abstracts for the upcoming meeting of the Entomological Society of America – Eastern Branch regarding their work on: 1) the terrestrial isopod fauna of Virginia (with J. Means and L. Hightower, VMNH), and 2) range predictions and novel means for detection of the invasive red imported fire ant, *Solenopsis invicta* (with R. Schürch, M. Malone, S. Pinar, J. Hurley, G. I. Van Wertz, S. Yang, and S. Taylor, Virginia Tech).

Drs. Ivanov and Means conducted field work in Caldwell Co., NC and Patrick Co., VA in support of their ongoing “*Nannaria incertae sedis*” project. The research focuses on the diversity of the *minor* clade of the xystodesmid genus *Nannaria* and, to date, has resulted in the recognition of 12 undescribed species.

Drs. Ivanov and Means and L. Hightower initiated work on a catalogue representing the first synopsis of the 400+ invertebrate types in the collection of the Virginia Museum of Natural History.

Drs. Ivanov, Means, and Evans submitted progress report to the Virginia Department of Conservation and Recreation (incl. Division of Natural Heritage) regarding research activities during the 2021 field season.

VMNH Collections Manager Haley Cartmell and Biology Technician Liberty Hightower, with help from Dr. Ivanov, continued work on a dataset of the museum’s invertebrate holdings to be posted to VMNH’s website.

Visiting researcher W. Orndorff (Virginia DCR, Natural Heritage Program; November 19) used VMNH’s invertebrate holdings to capture data on asellid isopod taxa from Virginia.

Dr. Ivanov satisfied loan requests concerning VMNH’s invertebrate holdings: 237 asellid isopods (Isopoda: Asellota) to Dr. J. J. Lewis (Lewis & Associates, LLC); 7 Byturidae, 9 Biphyliidae, and 351 Scirtidae (Insecta: Coleoptera) to Dr. D. Waller (ODU); 8 *Sandalus* spp. (Coleoptera: Rhipiceridae), 5 *Trichodesma* sp. (Coleoptera: Ptinidae), and 9 *Agraphus bellicus* (Coleoptera: Curculionidae) to K. Schnepp (FSCA); and 41 *Fallicambarus* (Crustacea: Malacostraca: Decapoda) to Dr. Z. Loughman (WLU).

Dr. Ivanov oversaw the acquisition of 913 (mostly determined) dry-preserved pinned/pointed insects in the orders Coleoptera, Hymenoptera, Diptera, Hemiptera, Dermaptera, Siphonaptera, Megaloptera, Neuroptera, and Lepidoptera from AZ, CA, GA, NC, OH, OK, and VA donated to VMNH by Dr. A. Evans (VMNH Research Associate; RIM2021-39); 20 lots of ethanol-preserved arthropods (Arachnida, Chilopoda, Diplopoda, and Insecta) and 22 bulk litter samples from OH, VA, and WV donated to VMNH by Dr. D. Hennen (VDACS; RIM2022-01).

Education & Outreach

Dr. Ivanov and museum staff participated in VMNH’s 2021 Dragon Festival, which successfully joined science and myth and brought a generally new audience to the museum. The two-day event attracted over 1,200 children and adults from Virginia, North Carolina, and 5 additional states (California, Colorado, Ohio, South Carolina, and Wisconsin). (October 15-16)

Dr. Ivanov, VMNH Curator of Mammals Dr. N. Moncrief, Deputy Director R. Barber, and Education Manager C. Deatherage submitted a grant proposal to the IMLS Inspire! Program to fund the conversion of an existing, underutilized VMNH laboratory space into a modern multidisciplinary research and education facility.

Dr. Ivanov responded to arthropod and bird identification and information requests to individuals from Ohio (Columbus), Virginia (Callands, Richmond, and Stuart), and

elsewhere (not specified). Many of the requests were submitted to VMNH's FB page by museum patrons.

Exhibits

Dr. Ivanov and museum staff completed text and specimen preparation for the museum's upcoming "The Science of Flight" exhibit. This original exhibit, scheduled to open to the public on 22 January 2022, will be VMNH's first exhibit to be offered in both English and Spanish.

Professional Service

Dr. Ivanov and museum staff reviewed applications and completed online interviews of applicants for the position of Assistant Curator of Herpetology at VMNH. (December 8, 10)

Dr. Ivanov participated in Virginia Tech's graduate student M. Malone (virtual) Advisory Committee meeting on October 18 and in Morgan's successful thesis defense held in the Department of Entomology at Virginia Tech on December 9. (October 18 and December 9)

Drs. Ivanov (President and co-Treasurer), Moncrief (co-Treasurer and past President), and Means (Secretary) participated in the [virtual] Virginia Natural History Society Executive Committee meeting on 11 December 2021. Among the discussed topics were the election of new officers, construction of new Society website, membership incentives, and time and location of the next general meeting of the Society. (December 11)

Dr. Ivanov served as a peer reviewer for a manuscript submitted to *Diversity* (completed December 1).

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

- Two of Dr. Moncrief's manuscripts were published this quarter. One of them was featured on the cover of the December issue of *G3: Genes, Genomes, Genetics*.
- Dr. Moncrief was interviewed by several media outlets about her recent armadillo article.
- Dr. Moncrief worked with other VMNH staff to prepare and submit a grant proposal (for about \$35,000) to the Institute for Museum and Library Services.
- Dr. Moncrief participated in the VMNH Dragon Festival on both days.

Research and Collections

Earlier this year, VMNH Curator of Mammals Dr. Nancy Moncrief published a paper about armadillo expansion into Virginia. She was recently interviewed by several media outlets including Cardinal News (<https://cardinalnews.org/2021/10/04/armadillos-are-moving-into-southwest-virginia>) and The Guardian (<https://www.theguardian.com/environment/2021/nov/15/its-like-hunting-aliens-inside-the-town-besieged-by-armadillos>).

Dr. Moncrief's manuscript about mammals of the Virginia barrier islands was published by *Northeastern Naturalist* in December. Her co-authors are VMNH Research Associates Dr. Raymond Dueser and Dr. John Porter, both whom are at the University of Virginia. The citation is: Moncrief, N.D., Porter, J.H. and Dueser, R.D., 2021. Annotated Checklist of Terrestrial Mammals of the Virginia Barrier Islands and the Adjacent Delmarva Peninsula Mainland. *Northeastern Naturalist*, 28:462-483.

In addition, Dr. Moncrief's published an article that reports the first whole genome of the eastern fox squirrel. It was featured on the cover of the December issue of *G3: Genes, Genomes, Genetics*. Her coauthors are Drs. Lin Kang, Pawel Michalak, and Eric Hallerman. Drs. Kang and Michalak are on the faculty of the University of Louisiana at Monroe, and Dr. Hallerman is a faculty member of the Department of Fish and Wildlife Conservation at Virginia Tech. It is available online at: <https://doi.org/10.1093/g3journal/jkab315> The citation is: Kang, L., Michalak, P., Hallerman, E. and Moncrief, N.D., 2021. A draft genome assembly for the eastern fox squirrel, *Sciurus niger*. *G3*, 11(12), p.jkab315.

Another manuscript, which provides details about healed skeletal fractures in eastern fox squirrels and eastern gray squirrels, has been accepted by *Journal of Mammalogy*. Many of the specimens for this study are housed at VMNH. Her co-authors are VMNH Associate Curator of Recent Invertebrates Dr. Kal Ivanov, VMNH Biology Research Technician Ms. Liberty Hightower and Dr. Alfred Mead, who is on the faculty of Georgia College and State University. Dr. Moncrief corrected page proofs of this article in December.

Dr. Moncrief continued her collaboration with Dr. R. Jory Brinkerhoff (University of Richmond) and Lisa Gatens (North Carolina Museum of Natural Sciences). They are using skin clips of white-footed deermice (*Peromyscus leucopus*) to detect DNA from

the Lyme disease pathogen (*Borelia burgdoferi*) in specimens of deermice collected in Virginia and North Carolina before 1990, when Lyme disease was first reported in Virginia.

Dr. Moncrief is collaborating with VMNH Research Associates Drs. Raymond Dueser and John Porter (University of Virginia), along with Drs. Don Young and Julie Zinnert (Virginia Commonwealth University) on a manuscript that details rapid changes in geomorphology, vegetation, and small mammal populations on one of the Virginia barrier islands (Myrtle).

Dr. Moncrief continued working with VMNH Research Associate Dr. Raymond Bernor, Assistant Curator of Paleontology Dr. Adam Pritchard, Education Manager Christy Deatherage, and Deputy Director Ryan Barber to prepare a grant proposal that will be submitted to the National Science Foundation for collections-related research and education programs. VMNH is participating in this project as a collaborating institution with the University of Oregon, the University of Florida, and several other universities.

Dr. Moncrief continued working with Mss. Hightower, Cartmell, and Harris to prepare, install, document, and organize (electronically and in archival hardcopies) traditional specimens and frozen tissues of mammals and birds.

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) a four-year term (ends December 2022) as Co-Treasurer.

Dr. Moncrief continued serving as manuscript editor for a manuscript about northern bobwhites, which has been submitted for publication in VMNH's series of occasional papers, *Jeffersoniana*. She corresponded with the author about changes that are necessary for the manuscript to be accepted for publication.

Dr. Moncrief reviewed a manuscript about rodents in Virginia for *Northeastern Naturalist*. The analyses included specimens from the VMNH Mammal Collection.

Scientific Programs, Exhibits, and Other Activities

Dr. Moncrief worked with numerous other staff members to deinstall the cat exhibit and return the taxidermy mounts and other specimens to collections storage.

Dr. Moncrief continued work on a special exhibit about flight. She sourced photos, audio files, and videos of birds and mammals. She also wrote, edited, and proofread text. She met numerous times with VMNH Exhibits Manager Ms. Jessica Davenport and VMNH Education Manager Ms. Christy Deatherage to discuss interactive components, specimens, and options for displaying them. In addition, she worked with Ms. Davenport and Museum Technician Mr. Donnie Jones to assemble, paint, and wallpaper major exhibit components and began installing specimens.

In mid-October, Dr. Moncrief participated in VMNH's Dragon Festival. She worked at the admissions table for VMNH members with Ms. Charlotte Harter.

Dr. Moncrief met several times with Ms. Harris and Deputy Director Ryan Barber to discuss logistics and supplies needed for packing and moving the contents of the VMNH library from the Starling Avenue building to Douglas Avenue.

Dr. Nancy Moncrief worked with Associate Curator of Recent Invertebrates Dr. Kal Ivanov, Education Manager Christy Deatherage, and Deputy Director Ryan Barber to prepare and submit a grant proposal (for about \$35,000) to the Institute for Museum and Library Services. They are seeking funds for a microscope lab that will serve as a resource for VMNH science education programs, outreach activities, and visiting researchers.

Adam Pritchard, Ph.D.
Assistant Curator of Paleontology

- In concert with an international team of paleontologists, Dr. Pritchard published a paper on the Triassic reptile *Malerisaurus* in the journal *Papers in Palaeontology*. The paper, led by Dr. Sterling Nesbitt of Virginia Tech, detailed the discovery of widespread fossils in India and the southwestern United States.
- Dr. Pritchard managed the intake, initial preparation, and science outreach focused on 'Petra,' a complete skeleton of an Ice Age cat excavated by former VMNH paleontology curator Dr. Alex Hastings. The specimen is being prepared at the VMNH, where visitors can see the progress as it happens.
- Dr. Pritchard led a field trip and collecting effort at the Malvern Hill site in Henrico County with Powhatan-based amateur paleontologist Trevor Clarke. During the site visit, he coordinated with Henrico county officials to open the site for further paleontological excavations.
- Dr. Pritchard presented collections tours to numerous audiences. These included a class of 10 undergraduates from the University of Lynchburg, a class of 25 undergraduates from Virginia Tech, and two family tours.

Research & Collections

Dr. Pritchard collaborated with co-authors Sterling Nesbitt, Michelle Stocker, Martin Ezcurra, Nicholas Fraser, Adam Marsh, William Parker, Saradee Sengupta, Saswati Bandyopadhyay, and Andrew Heckert on an article on a widespread group of Triassic reptiles called *Malerisaurus* for the journal *Papers in Palaeontology*. The final article was published in December 2021.

Dr. Pritchard oversaw the intake and initial preparation of the 'Petra' cave cat specimen in October 2021. The preparation of the specimen is ongoing, and the partially prepped specimens are on display in the fossil preparation laboratory. He presented the initial results of the project to VMNH members at a reception in October of 2021.

In December of 2021, Dr. Pritchard was joined by amateur paleontologist Trevor Clarke for a visit to the Malvern Hill fossil locality in Henrico, VA. They were joined by county officials to determine whether or not the site could be made accessible for future fossil collections. The permitting process is still ongoing.

Dr. Pritchard managed the intake of 100s of new fossil specimens from the Nanejmoy Formation (~50 million years old) into the VMNH collections. This formation was previously very poorly documented in VMNH holdings.

Education & Outreach

Dr. Pritchard presented on the Ashland, VA Triassic fieldwork to a group from the King's Grant retirement community. He also presented comments on the discovery of the 'Petra' cave cat specimen for a VMNH Members reception.

Dr. Pritchard hosted four collections tours: one for a University of Lynchburg undergraduate course, one for a Virginia Tech undergraduate course, and two for Roanoke-area families.

Dr. Pritchard produced three 'Tales of Ancient Life' videos for VMNH social media. Dr. Pritchard completed two manuscript reviews for the journals *Royal Society Open Science* and *Jeffersoniana*.

Exhibits

Dr. Pritchard selected paleontology specimens for the Science of Flight exhibit. He also coordinated the posture of a pterosaur wing specimen with Jessica Davenport.

Dr. Pritchard and Research Associate Dr. Bill Schmactenberg developed a column case display on the earliest fossils ever found in Virginia.

Media

Dr. Pritchard's work on the extinct gliding reptile *Weigeltisaurus* was featured in an article in *Smithsonian Magazine* authored by Tess Joose (<https://www.smithsonianmag.com/blogs/national-museum-of-natural-history/2021/10/13/the-oldest-airborne-animal-was-a-reptile-with-weird-wings/>).

Hayden Bassett, Ph.D.
Assistant Curator of Archaeology

For much of this quarter, VMNH Assistant Curator of Archaeology Dr. Hayden Bassett was on paternity leave from his day-to-day responsibilities at the museum. For the two weeks before and after his period of leave, he focused his efforts on preparing an archive of digitized VMNH data and reports to make available to researchers online, growing the VMNH's Cultural Heritage Monitoring Lab (CHML) with new staff and funding, and developing a state-wide vulnerability model for all archaeological sites in the Commonwealth of Virginia.

Research and Collections

In November, Dr. Bassett continued his study of the terminal Late Woodland period (AD 1200-1450) in SW and southside Virginia, as a part of the VMNH's Smith River Survey (a 2-year VMNH archaeological survey of the Smith River in Henry County, VA). As a major component of this, Dr. Bassett leveraged VMNH's access to NASA and commercial satellites, and the museum's advanced modeling capabilities, to develop a prototype for assessing impacts to archaeological resources from recent and future riverine flooding. VMNH Staff Archaeologist Madeleine Gunter Bassett and Dr. Hayden Bassett used GIS to measure the geographic scope of annual flooding activity for 5, 10, 20, 50, 100, and 500 year flooding events. The results of this study will be used to identify field sites to evaluate for integrity (if they are still intact), monitoring during future flooding events, and prioritize for future excavation.

In February, the VMNH Archaeology Department expanded this predictive impact modeling to all archaeological sites in the Commonwealth of Virginia. By March 2022, the model – both an early warning system and monitoring tool - will be deployed by the VMNH to identify Virginia's most vulnerable archaeological sites and tribal resources, to assist professionals, tribal governments, and policy makers in prioritization of attention, funding, and protective measures. This work adds to the VMNH's expanding portfolio of efforts to apply cutting-edge science and economical solutions to conservation challenges faced by the Commonwealth of Virginia today and in years to come. In collaboration with the Smithsonian Institution, the VMNH's Cultural Heritage Monitoring Lab (CHML), under the direction of Dr. Bassett, made significant progress this quarter on projects in Virginia, California, Haiti, Honduras, Ukraine, and Afghanistan. Through the CHML at VMNH, Dr. Bassett continues to lead a team of 7 cultural heritage professionals and 8 virtual interns in data production and satellite imagery analysis. As the producer and curatorial repository of these new digital collections, the VMNH Archaeology Department has expanded its digital collections holdings by nearly 2,000 "objects" since November 2021, and anticipates further growth in digital collections with each new quarter. Over 3,000 digital objects in the VMNH's CHML collections were requested/accessed by outside researchers between November 2021 and February 2022. Additionally, as Dr. Bassett initiates a long-term project to monitor the cultural heritage of Virginia from impacts related to climate change, he anticipates a significant number of requests from Virginia state agencies for these data and digital collections in 2022 and beyond.

Between late November and early February, Dr. Bassett gave 6 presentations on the findings of the VMNH's Cultural Heritage Monitoring Lab (CHML). These presentations were given virtually to the Smithsonian Institution, the US Department of State, the US Department of Defense, University of Pennsylvania, the MITRE Corporation, and the Government of Honduras. Additionally, Dr. Bassett and his team delivered 4 reports of findings to key stakeholders for implementation or ground responses. Noteworthy among these was the VMNH's satellite study of cultural heritage impacts in Mali, and their ongoing monitoring of cultural heritage impacts in Ukraine. The study of impacts in Mali was delivered by the VMNH to the US Department of State, and informed a major bilateral agreement renewed between the US Government and the Republic of Mali. The CHML's ongoing work in Ukraine is likewise informing State Department decision making and diplomatic activity with respect to the current situation in the region. Last, Dr. Bassett's manuscript on the VMNH's CHML as a case study for modern Applied Research Labs received a medal as a top-three paper in the *2021-22 CA Issue Papers* journal. This publication will be released in March 2022.

As a programmatic objective of 2022, the VMNH Archaeology Lab have begun the process of digitizing VMNH Archaeology data and reports to make available to researchers online. To accommodate the increasing requests for data, the Archaeology Lab will be making these resources available on The Digital Archaeological Record (tDAR), the go-to online digital repository for open-science in Archaeology. Digital Virginia and CHML collections will be made available for access/download, by a simple request/approval process controlled by VMNH Archaeology staff. The team believes this will expand the use of VMNH collections and data significantly in 2022 and beyond. The VMNH Archaeology Department was successful in receiving funding for two of its initiatives this quarter. The first included the successful award of funding from MITRE Corporation for operation of the CHML, which has allowed the VMNH Archaeology Department to add a dedicated staff member for the CHML. The second award was from the Sons of the American Revolution (SAR), to begin the Patrick Henry Leatherwood project. Dr. Bassett completed refinements in the Smith River Survey scope of work, and this funding from the NPS/VDHR is also expected to arrive late this quarter.

Education and Outreach

Dr. Bassett is nearing completion of the direct commissioning processes to enter to the US Army Reserves as one of approximately 8 new "Monuments Men" Army reserve Captains, Majors, and Lt. Colonels. As a major outreach effort for the museum, he continues to position the VMNH's Cultural Heritage Monitoring Lab as the primary research lab for the Army's Monuments Men program.

The VMNH Archaeology department worked with several colleges and universities this quarter. Dr. Bassett and VMNH Staff Archaeologist Madeleine Gunter Bassett continued to work 8 virtual interns at the undergraduate and graduate level. The U.S. Department of State provided the VMNH Archaeology Department with these 8 virtual intern positions through the Virtual Student Federal Service (VSFS) program. Between November 2021 and February 2022, the interns and associated virtual volunteers contributed a combined 1200 hours to the CHML at VMNH. Last, Dr. Bassett and his team continue to work with administration of the University of Virginia. The VMNH's CHML is now in the planning stages of a UVA partnership to begin in 2022.

Dr. Bassett responded to two public requests for identification of artifacts, both of them from Virginia. Artifact identifications were made in-person (in the museum lobby, masked, and distanced).

Professional Service

Dr. Bassett continued his duties as Vice President of the Board of Trustees for Falmouth Heritage Renewal, an international historic preservation non-profit. He also continued his appointment as a Research Associate at the Smithsonian Institution to support international efforts and contributions made through VMNH's new Cultural Heritage Monitoring Lab. This included delivering a national cultural heritage training workshop for FEMA in mid-December. He also continued his duties to the Legislative Affairs Committee of the Council for Virginia Archaeologists (CoVA). In January, Dr. Bassett renewed his appointment as Adjunct Faculty at the College of William & Mary. From November to February, Dr. Bassett co-organized two meetings of the Culture Conflict Resource Network (CCRN), an NSF-funded group of collaborative researchers working on research surrounding the impacts of armed conflict on cultural heritage. The VMNH, through the Cultural Heritage Monitoring Lab (CHML), is a collaborative partner of the CCRN, along with the University of Pennsylvania, the Smithsonian, and several other institutions. Dr. Bassett presented the findings of his lab at both meetings.

This quarter, Dr. Bassett and VMNH staff archaeologist Madeleine Gunter Bassett continued to fulfill their duties in the Archaeological Society of Virginia (ASV). In these roles, VMNH Archaeology staff provide direction, technical review, grant approvals, among other tasks for state-wide archaeological research for the foreseeable future. From November to February, Dr. Bassett was consulted on 5 occasions by VA state and US federal agencies to implement his technical methods for using satellite imaging and remote sensing to document ground disturbance, and/or destruction of cultural heritage in conflict zones and after natural disasters. The consultations included contributions of expertise and virtual delivery of training.

Research and Collections

Jill K. Harris, Registrar

Twenty (20) collections acquisitions were recorded for ~1,303 specimens and 9 lots of specimens. These specimens were added to the invertebrate zoology, vertebrate zoology, and paleontology collections.

Five (5) outgoing loans were recorded this quarter from the paleontology and invertebrate zoology collections. Loans were made to: the College of William & Mary, Virginia Tech, Florida State Collection of Arthropods, Old Dominion University, and Lewis & Associates.

Haley Cartmell, Collections Manager

Curators and staff modified/updated 3,640 existing records and added 263 new records to the VMNH collections databases Proficio (all museum collections) and EGEMS (paleontological collections only).

Two loads of collections materials were processed through the CO2 bubble this quarter. This included recent additions to the Entomology collection and taxidermy mounts from the closing cats exhibit.

PEOPLE SERVED DATABASE printed 2/7/2022
Summary

# of Activities	TYPE OF ACTIVITY	PROFESSIONALS AND 13+ STUDENTS	K-12 STUDENTS	K-12 TEACHERS	PUBLIC			TOTAL #	
7	Conference presentations (A)	163	0	0	0			163	
1	Meetings chaired (B)	7	0	0	0			7	
4	Review documents/manuscripts (B)	6	0	0	0			6	
0	Requests for information about collections (C)	0	0	0	0			0	
2	Visiting researcher (C)	3	0	0	0			3	
6	Collections tours (D)	4	10	1	14			29	
0	Lab Tours (D)	0	0	0	0			0	
1	Receptions	0	0	0	20			20	
10	Responses to requests for information about specimens at VMNH (D)	6	1	0	3			10	
0	Lectures and presentations at VMNH (D)	0	0	0	0			0	
1	Technical consultations (B, D, & E)	0	0	0	8			8	
2	Display table with specimens	0	56	0	853			909	
0	Off-site education programs	0	0	0	0			0	
1	Lectures Not at VMNH (E)	0	0	0	12			12	
0	Off-site presentations (E)	0	0	0	0			0	
1	Field trips/Field Work	2	0	0	4			6	
3	Publications	0	0	0	0			0	
39	TOTALS							1173	

TOTAL # INDIVIDUALS SERVED

1173

**Research & Collections Facebook & Instagram Statistics
(October 1 - December 31, 2021)**

Total Research & Collections Post Reach

126,281

Total Research & Collections Post Reactions

3,182

Total Research & Collections Post Comments

275

Total Research & Collections Post Shares

453

Total Research & Collections Link Clicks (user clicks on picture/video, link within post, "see more", etc.)

2,981

Top 5 Performing Research & Collections Posts by Total Engagement (Reactions, Comments, Shares, Link Clicks)

1. Announcement of Petra (October 5) - 1,393
2. Armadillo in Wise County (November 6) - 625
3. Armadillos, Porcupines and Fishers in Virginia (October 20) - 614
4. Update on Petra (December 2) - 225
5. Dr. Pritchard presents at King's Grant Retirement Community (November 8)
- 177

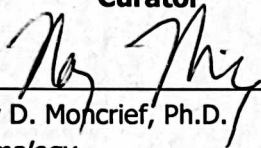
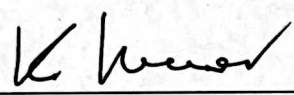


Total VMNH Facebook Audience Growth from April 1 to June 30, 2021

- The total number of followers increased by 242 (from 13,811 to 14,053).
- The total number of likes increased by 207 (from 13,493 to 13,700).

**NEW APPLICATION
AS RESEARCH ASSOCIATE**

Derek Hennen, Ph.D.

I have reviewed the information submitted for Derek Hennen (Kal Ivanov, Sponsor) and have indicated his/her recommendation as a Research Associate for the Virginia Museum of Natural History.

Curator	Date	Recommend	Do Not Recommend
 Nancy D. Moncrief, Ph.D. <i>Mammalogy</i>	2 Feb 2022	<input checked="" type="checkbox"/>	<input type="checkbox"/>
 Kal Ivanov, Ph.D. <i>Recent Invertebrates</i>	2 FEB. 2022	<input checked="" type="checkbox"/>	<input type="checkbox"/>
 Adam Pritchard, Ph.D. <i>Paleontology</i>	2 Feb '22	<input checked="" type="checkbox"/>	<input type="checkbox"/>
 Hayden Bassett, Ph.D. <i>Archaeology</i>	2 Feb 2022	<input checked="" type="checkbox"/>	<input type="checkbox"/>



Kaloyan Ivanov, Ph.D.
Virginia Museum of Natural History
21 Starling Ave.
Martinsville, VA 24112
kal.ivanov@vmnh.virginia.gov

19 January 2022

Virginia Museum of Natural History
21 Starling Ave.
Martinsville, VA 24112

To Whom It May Concern,

I write to nominate Dr. Derek A. Hennen as a Research Associate of the Virginia Museum of Natural History (VMNH). Dr. Hennen recently completed teaching an entomology course at the Virginia Polytechnic Institute and State University and has now joined the Virginia Department of Agriculture and Consumer Services as a coordinator for the “Slow the Spread” program to control the invasive forest pest moth *Lymantria dispar*.

Dr. Hennen holds a Ph.D. in Entomology from the Virginia Polytechnic Institute and State University and a Master’s degree in Entomology from the University of Arkansas. His expertise includes biogeography, systematics, and natural history of myriapods (millipedes and centipedes) with a strong focus on Appalachian taxa. His work also includes a science communication component, and he runs a Twitter account (@DearMillipede) to spread knowledge and appreciation for myriapods. As his enclosed documents demonstrate, Dr. Hennen is uniquely qualified to contribute to the mission and research objectives of this institution.

I have known Derek for over five years and I have come to admire his intimate knowledge of myriapods and wide-ranging familiarity with insects and other arthropods. During the course of his Ph.D. work he has deposited numerous invertebrate specimens at the Virginia Museum of Natural History and he will undoubtedly continue to do so during the course of his professional career. His dissertation work on the millipede genera *Pseudopolydesmus* (Polydesmida: Polydesmidae) and *Nannaria* (Polydesmida: Xystodesmidae) of the southern Appalachian Mountains has included examination, identification, curation, and digitization of numerous specimens from VMNH’s millipede

collection. Dr. Hennen has published results of his research in many peer-reviewed journals. His recently published field guide to the millipedes of Ohio represents the first field guide to millipedes anywhere in the United States. Dr. Hennen is currently continuing his work on Appalachian millipedes and the poorly studied North American stone centipedes in the family Lithobiidae.

Derek has expressed interest in continuing to use VMNH's facilities and invertebrate collections for his specimen-based research. Dr. Hennen, Dr. Means, and I have discussed several potential joint research projects that would use material from VMNH's collections as well as new material obtained through fieldwork.

This mutually beneficial appointment will not only provide Dr. Hennen with an institutional outlet for his ongoing research and facilitate the generation of publications vital to our understanding of myriapod systematics and natural history but will allow VMNH to benefit from his expertise, curatorial efforts, and fieldwork which contribute directly to the museum's mission. I invite you to refer to Dr. Hennen's enclosed CV and a letter expressing his interest and commitment.

Sincerely,



Kaloyan Ivanov, Ph.D.
Associate Curator of Recent Invertebrates
Virginia Museum of Natural History

Dr. Derek Hennen
1800 Foxhunt Ln Apt A
Blacksburg, VA 24060

6 January 2022

Board of Trustees
c/o Dr. Kaloyan Ivanov
Scientific Collections, Recent Invertebrates
Virginia Museum of Natural History
21 Starling Avenue
Martinsville, VA 24112

Dear Trustees,

I am writing to request a Research Associate position with the Recent Invertebrates Collection at the Virginia Museum of Natural History. My prior experience and research with millipedes and centipedes nicely complements the work being done by collection staff, and formalizing my collaboration with the Recent Invertebrates staff will benefit both the VMNH and my own research.

I received my Ph.D. in Entomology from Virginia Tech in 2020, where I studied the systematics and natural history of Appalachian millipedes. During my Ph.D., I conducted extensive field work, which included travel to three countries and 21 states in the US to collect millipedes. The main thrust of my work was combining phylogenetics and morphological investigations for taxonomic revisions of the millipede genera *Pseudopolydesmus* (Polydesmida: Polydesmidae) and *Nannaria* (Polydesmida: Xystodesmidae). Both are widespread throughout eastern North America, and *Nannaria* has a distinct lineage found only in the Appalachian Mountains. I discovered 17 undescribed species within *Nannaria*, and my publication describing these species has been accepted in the journal *ZooKeys* and will be published soon.

My research on both these taxa included many specimens loaned from the VMNH, which I digitized and re-curated. These specimens were integral to my research, and I added more specimens to the VMNH collections through the designation and deposition of type material. My current research continues my focus on Appalachian Myriapoda (millipedes and centipedes), and I have ongoing projects on the millipede families Parajulidae and Xystodesmidae and the poorly studied American Lithobiidae centipedes, which have not been systematically studied since the 1950s. Through my local field work, I have uncovered additional localities for the rarely-collected centipede *Garibius psychrophilus*, a species previously known from only two locations, and I have also collected many ant specimens to contribute to Dr. Ivanov's research. I met Dr. Jackson Means during graduate school, before his employment at the VMNH, and our research collaborations continue with field work searching for the millipede genera *Nannaria* and *Pseudotremia*, both of which have astounding species diversity of over 70 species each. We recently traveled to West Virginia to search for myriapods, and discovered at least five state records for centipedes, which we are in the beginning stages of writing up for publication.

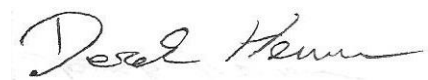
I have paired my scientific research with a science communication component, and have sought out training whenever possible during my scientific career to improve my communication skills. By making a strong case for the importance of myriapods and other “leaf litter critters,” I believe support for conservation and a realization of the importance of our local arthropod species will follow. To accomplish these goals, I have taught workshops focused on science communication and millipede biology and identification in both Mexico and the United States, tailored for biology students as well as the general public. I’ve given invited talks about my research and science communication at The Ohio State University Museum of Biological Diversity and the Smithsonian National Museum of Natural History, as well as at general public events at public libraries and local science organizations.

The accomplishment I’m proudest of is the recent publication of my Field Guide to the Millipedes of Ohio, a collaboration with the Ohio Division of Wildlife. This is the only field guide for millipedes in the United States, and emphasizes photographs and field characters. Importantly, the publication is free since it was funded by the state of Ohio, which eliminates a significant barrier for anyone wanting to learn more about these interesting animals. Previously, there was no entry-level text to learn about millipedes, but this field guide fills that niche. It will hopefully encourage more people, both scientists and general public alike, to take another look at millipedes.

During this past fall, I was the Instructor for the Virginia Tech Entomology Department’s Insect Biology course, in which I taught a class of ca. 70 graduate and undergraduate students. The course included a laboratory component, in which students were expected to assemble a large insect collection. For this component, I taught the students how to identify ca. 100 families of insects they’re likely to encounter in Virginia, how to properly pin and label insect specimens, and insect field collection techniques. Recently, I have been hired as the Slow the Spread Survey Coordinator for the Virginia Department of Agriculture and Consumer Services. In this capacity, I will be working as part of an inter-institutional program to control the invasive moth *Lymantria dispar*. I will be carrying on my research projects still, and would also like to aid the VMNH in arthropod identification and curation, as time allows. I envision that my main focus will concern the Myriapoda, particularly the centipedes, but am more than willing to help out with related projects and collaborations with museum staff. I also plan to deposit specimens and type material in the VMNH collections, adding to the already impressive Myriapoda holdings.

Receiving a Research Associate appointment with the VMNH will allow me continue my research on Appalachian myriapods and further communicate the importance of our local natural history. I am sure it will be a mutually beneficial relationship, and I am happy to answer any questions about my research goals. I look forward to future collaborations with the museum, and links to my published research and science communication work are available in my attached curriculum vitae.

Sincerely,



Derek Hennen, Ph. D.

Derek A. Hennen, Ph.D.
1800 Foxhunt Ln Apt A, Blacksburg, VA 24060
derhennen@gmail.com

Education

- 2015 – 2020 **Ph.D. in Entomology**
Virginia Polytechnic Institute and State University, Blacksburg, Virginia
Major Professor: Paul Marek
Dissertation: Natural history, taxonomy, and phylogenetics of Appalachian flat-backed millipedes (Diplopoda: Polydesmida)
- 2013 – 2015 **M.S. in Entomology**
University of Arkansas, Fayetteville, Arkansas
Major Professor: Ashley Dowling
Thesis: An inventory of endemic leaf litter arthropods of Arkansas with emphasis on certain insect groups and Diplopoda
- 2008 – 2012 **B.S. in Biology & B.A. in Spanish**, *Cum Laude* with Curriculum Honors,
Marietta College, Marietta, Ohio

Employment

1. **Slow-the-Spread Survey Coordinator**, Virginia Department of Agriculture and Consumer Services, Christiansburg, VA
January 2022 – present
 - Planned, coordinated, and implemented survey and field operations for the slow the spread program to control the invasive forest pest moth *Lymantria dispar*. Trained trappers and quality control personnel on field techniques, trap deployment, taxonomic identification, and data collection procedures.
2. **Entomology Instructor**, Department of Entomology, Virginia Polytechnic Institute and State University, Blacksburg, VA
July 2021 – December 2021
 - Taught Insect Biology lecture and laboratory for undergraduate and graduate students, developed course material, instructed and supervised teaching assistants.
3. **Laboratory Assistant**, Marek Lab, Department of Entomology, Virginia Polytechnic Institute and State University, Blacksburg, VA
May 2020 – July 2021
 - Conducted research on the Myriapoda of North America, with an emphasis on the Appalachian fauna. Research duties included writing and preparation of scientific manuscripts and illustrations (taxonomic figures, phylogenies, distribution maps) for peer-reviewed publication, preservation and curation of myriapod specimens, identification of specimens from all myriapod classes, phylogenetic investigation

and bioinformatics of myriapods with phylogenetic software (Mesquite, MrBayes, IQtree, BEAST, etc.), submission of gene sequences to Genbank, photographing and digitizing insect specimens from the Virginia Tech Insect Collection and uploading specimen information to online database.

4. Ph.D. Candidate, Marek Lab, Department of Entomology, Virginia Polytechnic Institute and State University, Blacksburg, VA

August 2015 – May 2020

- Conducted independent taxonomic research on the Diplopoda of North America, with an emphasis on the Appalachian fauna. Research duties included synthesis of pertinent literature, planning and execution of fieldwork throughout North America, morphological investigation of collected specimens via microscopy (dissection, compound, and SEM), molecular investigation of species limits via Sanger sequencing, primer design, and phylogenetic software (Mesquite, MrBayes, IQtree, BEAST, etc.), description of new species with integrative taxonomic methods, preparation of manuscripts and illustrations for peer-reviewed publication. Teaching responsibilities included laboratory preparation, grading, and teaching students in the 3000 level Insect Biology course. Curatorial responsibilities in the Virginia Tech Insect Collection included species identification, creating a list of species in the collection, curation of specimens, and specimen accession.

5. Graduate Assistant, Dowling Lab, Department of Entomology, University of Arkansas, Fayetteville, AR

July 2013 – August 2015

- Conducted independent research focused on the endemic arthropods of Arkansas via trapping methods including Malaise trapping, leaf litter concentration, and Berlese-Tullgren funnel extraction. Sorted and identified collected arthropods (including myriapods, arachnids, and insects) and preserved them by pinning or storage in alcohol with proper labels. Worked as a teaching assistant for the introductory Insects, Science and Society course: prepared labs, graded assignments, and lectured.

6. Americorps OSM/VISTA: Friends of Lower Muskingum River, Marietta, OH

May 2012 – May 2013

- Increased capacity building within the organization. Worked on grant writing, event planning, education and outreach, coordinating volunteers, and collecting water quality data.

Teaching Assistant Experience

Fall 2016 & 2019 Insect Biology, Entomology Department, Virginia Tech

Spring 2014 & 2015 Insects and Society, Entomology Department, University of Arkansas

Publications

1. **Hennen, D.A.**, Means, J.C., and Marek, P.E. 2022. A revision of the *wilsoni* species group in the millipede genus *Nannaria* Chamberlin, 1918 (Diplopoda, Polydesmida, Xystodesmidae). *ZooKeys*. *Accepted manuscript*.
2. Means, J.C., **Hennen, D.A.**, and Marek, P.E. 2021. A revision of the *minor* species group in the millipede genus *Nannaria* Chamberlin, 1918 (Polydesmida: Xystodesmidae). *ZooKeys* 1030: 1-180. <https://doi.org/10.3897/zookeys.1030.62544>
3. Means, J.C., **Hennen, D.A.**, Tanabe, T., and Marek, P.E. 2021. Phylogenetic systematics of the millipede family Xystodesmidae. *Insect Systematics and Diversity* 5(2): 1-26. <https://doi.org/10.1093/isd/ixab003>
4. Jiang, X., **Hennen, D.A.**, Chen, H., and Xie Z. 2020. First description of the male of *Glyphiulus formosus* (Pocock, 1895) (Diplopoda: Spirostreptida: Cambalopsidae) from China. *Zootaxa* 4861(2): 281-289. <https://doi.org/10.11646/zootaxa.4861.2.8>
5. Wong, V.L., **Hennen, D.A.**, Macias, A.M., Brewer, M.S., Kasson, M.T., and Marek, P.E. 2020. Natural history of the social millipede *Brachycybe lecontii* Wood, 1864. *Biodiversity Data Journal* 8: e50770. <https://doi.org/10.3897/BDJ.8.e50770>
6. Sierwald, P., **Hennen, D.A.**, Zahnle, X.J., Ware, S., and Marek, P.E. 2019. Taxonomic synthesis of the eastern North American millipede genus *Pseudopolydesmus* Attems, 1898 (Diplopoda: Polydesmida: Polydesmidae), utilizing high-detail ultraviolet fluorescence imaging. *Zoological Journal of the Linnean Society* 187(1): 117-142. <https://doi.org/10.1093/zoolinnean/zlz020>
7. Jiang, X., Shear, W.A., **Hennen, D.A.**, Chen, H., and Xie, Z. 2019. One hundred million years of stasis: *Siphonophora hui* sp. nov., the first Mesozoic sucking millipede (Diplopoda: Siphonophorida) from mid-Cretaceous Burmese amber. *Cretaceous Research* 97: 34-39. <https://doi.org/10.1016/j.cretres.2019.01.011>
8. Shorter P.L., **Hennen D.A.**, and Marek P.E. 2018. Cryptic diversity in *Andrognathus corticarius* Cope, 1869 and description of a new *Andrognathus* species from New Mexico (Diplopoda, Platydesmida, Andrognathidae). *ZooKeys* 786: 19-41. <https://doi.org/10.3897/zookeys.786.27631>
9. Marek, P.E., Means, J.C., and **Hennen, D.A.** 2018. *Apheloria polychroma*, a new species of millipede from the Cumberland Mountains (Polydesmida: Xystodesmidae). *Zootaxa* 4375 (3): 409-425. <http://dx.doi.org/10.11646/zootaxa.4375.3.7>

10. **Hennen, D.A.** and Shelley, R.M. 2015. A contribution on the milliped tribe Nannariini (Polydesmida: Xystodesmidae): Revalidation of *Mimuloria* Chamberlin, 1928; identities of *Fontaria oblonga* C. L. Koch, 1847, and *Nannaria minor* Chamberlin, 1918; elucidation of the tribal range; and commentaries on *Nannaria* Chamberlin, 1918, and *Oenomaea* Hoffman, 1964. *Insecta Mundi*. 0418: 1–21.
<https://digitalcommons.unl.edu/insectamundi/924/>

Published Abstracts

1. Means, J.C., **Hennen, D.A.**, and Marek, P.E. 2017. Discovery of Two Monophyletic Clades Within the Appalachian Millipede Genus *Nannaria* Chamberlin, 1918 (Diplopoda: Polydesmida: Xystodesmidae). *Tropical Natural History*, Supplement 5: 29.
2. **Hennen, D.A.** and Marek, P.E. 2017. Taxonomic Synthesis of the North American Millipede Genus *Pseudopolydesmus* Attems, 1898 (Diplopoda: Polydesmida: Polydesmidae). *Tropical Natural History*, Supplement 5: 8.

Non-refereed Publications

1. **Hennen, D.A.** and Brown, J. 2021. Millipedes of Ohio field guide. Publication 5527. Ohio Department of Natural Resources, Division of Wildlife, Columbus, OH. 75 pp.
<https://ohiodnr.gov/static/documents/wildlife/backyard-wildlife/Millipedes+of+Ohio+Pub+5527.pdf>

Invited Presentations

1. **Hennen, D.A.** and Brown, J. 2021. Every leg counts: the millipedes of Ohio. Ohio Wildlife Diversity Conference. Columbus, OH [virtual].
<https://www.youtube.com/watch?v=4-2UcCGZdnI>
2. **Hennen, D.A.** 2018. Designing an entomological social media campaign. Entomological Society of America, Eastern Branch. Annapolis, MD.
3. **Hennen, D.A.** 2017. Untapped resources: The overlooked biodiversity of urban forests. Entomological Society of America. Denver, CO.
4. **Hennen, D.A.** 2016. Surprising smells and sculptures of glass: Discovering the diversity of Appalachian millipedes. National Museum of Natural History. Washington, D. C.
5. **Hennen, D.A.** 2015. The future of science outreach: How millennials are changing science communication. Entomological Society of America. Minneapolis, MN.
6. **Hennen, D.A.** 2015. More than just cat photos: Using social media professionally. Ohio State University Museum of Biological Diversity. Columbus, OH.

7. **Hennen, D.A.** 2014. The benefits of the selfie: Grad students and the imagined distraction of social media. Entomological Society of America. Portland, OR.

Presentations

1. **Hennen, D.A.**, Means, J.C., and Marek, P.E. 2019. Phylogenetics of the Appalachian twisted claw millipedes (Polydesmida: Xystodesmidae: *Nannaria*). Virginia Natural History Society, Martinsville, VA.
2. **Hennen, D.A.** and Marek, P.E. 2019. First molecular phylogeny of the swift pink millipedes *Pseudopolydesmus* Attems, 1898 (Diplopoda: Polydesmida: Polydesmidae). Entomological Society of America, Eastern Branch. Blacksburg, VA.
3. Sierwald, P., **Hennen, D.A.**, Zahnle, X., Nguyen, A.D., and Bueno-Villegas, J. 2019. Siphoniulida: 125 years after discovery found alive. 18th International Congress of Myriapodology. Budapest, Hungary.
4. **Hennen, D.A.** 2019. The Unknown Diversity. Entomological Digest Talk, Entomological Society of America, Eastern Branch. Blacksburg, VA.
5. Means, J.C., **Hennen, D.A.**, and Marek, P.E. 2018. Molecular phylogenetics of the twisted claw millipedes (Polydesmida: Xystodesmidae). Virginia Natural History Society. Martinsville, VA.
6. Means, J.C., **Hennen, D.A.**, and Marek, P.E. 2018. A taxonomic revision of the Appalachian millipede genus *Nannaria* Chamberlin, 1918. Society for Systematic Biologists. Columbus, OH.
7. **Hennen, D.A.** and Marek, P.E. 2018. A First Phylogeny of the North American millipede genus *Pseudopolydesmus* Attems, 1898 (Diplopoda: Polydesmida: Polydesmidae). Society for Systematic Biologists. Columbus, OH.
8. **Hennen, D.A.** and Marek, P.E. 2017. Taxonomic synthesis of the North American millipede genus *Pseudopolydesmus* Attems, 1898 (Diplopoda: Polydesmida: Polydesmidae). 17th International Congress of Myriapodology. Krabi, Thailand.
9. Means, J.C., **Hennen, D.A.**, and Marek, P.E. 2017. Discovery of two monophyletic clades within the Appalachian millipede genus *Nannaria* Chamberlin, 1918 (Diplopoda: Polydesmida: Xystodesmidae). 17th International Congress of Myriapodology. Krabi, Thailand.
10. **Hennen, D.A.** and Marek, P.E. 2017. How to deal with a mixed up group: unraveling the species of the millipede genus *Pseudopolydesmus* (Polydesmida: Polydesmidae). Interfaces of Global Change Graduate Student Research Symposium. Blacksburg, VA.

11. **Hennen, D.A.** 2016. Many legs, much heart: An Appalachian millipede adventure. Virginia Tech Entomology Department Lightning Talks. Blacksburg, VA.
12. **Hennen, D.A.** and Dowling, A.G. 2015. An updated synopsis of the millipedes of Ohio and Arkansas. Joint meeting, Arkansas & Kansas Entomological Societies. Fayetteville, AR.
13. **Hennen, D.A.** 2015. Legs, leaves, and logs: a 21st century Ohio millipede adventure. Ohio Natural History Conference. Columbus, OH.
14. **Hennen, D.A.** and Dowling, A.G. 2014. Obeying the zeitgebers: Circadian rhythms of forest leaf litter arthropod communities. Entomological Society of America. Portland, OR.
15. **Hennen, D.A.** and Dowling, A.G. 2014. 80 years later: Revisiting the millipedes of Ohio. Kansas Entomological Society. Emporia, KS.
16. **Hennen, D.A.** and Dowling, A.G. 2013. Arkansas's enigmatic (but not unknown) millipedes. Arkansas Entomological Society. Magnolia, AR.

Poster Presentations

1. Britt, K., Catron, K., Brichter, K., Brown, J., Chalise, P., Hadden, W., **Hennen, D.A.**, Quinn, N., Ragozzino, M., and Roth, M. 2018. Parasitoid Power: putting pests in their place by invading their space. Entomological Society of America. Vancouver, BC.
2. **Hennen, D.A.** and Marek, P. E. 2018. Chemical defense gland evolution in a millipede Müllerian mimicry ring. Interfaces of Global Change Graduate Research Symposium. Blacksburg, VA.
3. Shorter P.L., **Hennen, D.A.**, and Marek, P.E. 2016. Cryptic diversity in *Andrognathus corticarius* Cope, 1869 (Diplopoda, Polydesmida, Andrognathidae). Virginia Tech Graduate Student Association Research Symposium. Blacksburg, VA.
4. **Hennen, D.A.** and Marek, P.E. 2016. Millipedes under our feet: Taxonomic revisions of the common North American millipede genera *Pseudopolydesmus* (Polydesmida: Polydesmidae) and *Nannaria* (Polydesmida: Xystodesmidae). Interfaces of Global Change Graduate Research Symposium. Blacksburg, VA.
5. McShaffrey, D., **Hennen, D.A.**, Mays, M., Spring, M., Turner, N., Reed, B., Eckels, L., Lustofin, K., and Monroe, C. 2016. An Updated ATBI (All-Taxa Biotic Index) for the Barbara A. Beiser Field Station, Washington County, Ohio. Ohio Natural History Conference. Columbus, OH.

6. McShaffrey, D.G., **Hennen, D.A.**, Lustofin, K., Spring, M., and D. Remeneric. 2014. Baseline ATBI for the Barbara A. Beiser Field Station Washington County, Ohio. Ohio Natural History Conference. Columbus, OH.
7. **Hennen, D.A.** and McShaffrey, D.G. 2012. A biological survey of the assassin bugs (Hemiptera: Reduviidae) at the Barbara A. Beiser Field Station. Ohio Natural History Conference. Columbus, OH.
8. Lustofin K., **Hennen, D.A.**, and McShaffrey, D.G. 2012. UV fluorescing millipedes from southeastern Ohio. Ohio Natural History Conference. Columbus, OH.

Mentorship

- 3 undergraduates (Loren Jones, Maddie Hellier, Patricia Wooden), Virginia Tech, 2017-2020

Relevant Skills (selected)

Phylogenetics: Mesquite, BEAST, Geneious, IQ-TREE, Opal, MrBayes, RAxML, PartitionFinder2. **Bench Skills:** DNA extraction, PCR, specimen imaging, insect curation. **Fieldwork:** Macrophotography, leaf litter extraction, malaise trap, pitfall trap, sweep netting.

Manuscripts Reviewed

Zootaxa (12); Annals of the Brazilian Academy of Sciences (1); Banisteria (1); Journal of Paleontology (1); Southwestern Naturalist (1); The Canadian Entomologist (1); Zookeys (1); Zoological Studies (1)

Extended Field Expeditions

2019: Coastal North Carolina, 3 days; Great Smoky Mountains National Park, 5 days;
2018: Illinois, Iowa, 1 week; eastern Tennessee, 1 week; Mexico, Los Tuxtlas Biosphere Preserve, 2 weeks; North Carolina, Tennessee, Georgia, 1 week; northern Alabama, 5 days;
2017: Tennessee, Arkansas, Missouri, Indiana, Kentucky, 10 days; northern Vietnam, 10 days; Pennsylvania, New York, 5 days; West Virginia, Kentucky, 5 days; North Carolina, South Carolina, 5 days; North Carolina, Georgia, Alabama, 5 days;
2016: Oregon, Washington, 1 week; coastal Virginia, 4 days; Tennessee, Georgia, Alabama, 1 week; North Carolina, 4 days; Indiana, Ohio, West Virginia, 5 days; Virginia, Maryland, Pennsylvania, 5 days; southern Ohio, 4 days; east Tennessee, 3 days
2015: Southwestern North Carolina, 2 weeks
2014: Southern Ohio, 2 weeks; western Arkansas, 2 weeks

Professional Workshops Taught

- 2019 ComSciCon-Virginia Tech 2019
Tweeting Science Workshop
Virginia Tech, Blacksburg, Virginia
March 8, 2019
- 2018 Myriapoda and Arachnida International Workshop
Los Tuxtlas Tropical Biology Station, Veracruz, Mexico
September 23-October 5, 2018
- 2018 Millipedes of Ohio
Advanced Naturalist Workshops Series 14
Cincinnati Museum Center's Edge of Appalachia Preserve
West Union, Ohio, May 18-20, 2018

Professional Workshops Attended

- 2017 Susan Hassol Science Communication Workshop
Interfaces of Global Change Program, Virginia Tech
Blacksburg, Virginia
- 2015 Alan Alda Center Science Communication Workshop
Interfaces of Global Change Program, Virginia Tech
Blacksburg, Virginia
- 2015 Biology & Diversity of Myriapoda Workshop
Highlands Biological Station
Highlands, North Carolina
- 2012 Opiliones Advanced Naturalist Workshop
Cincinnati Museum Center's Edge of Appalachia Preserve
West Union, Ohio
- 2011 Myriapoda and Pillbugs Advanced Naturalist Workshop
Cincinnati Museum Center's Edge of Appalachia Preserve
West Union, Ohio

Awards and Honors

Virginia Polytechnic Institute and State University:

- 2019 First place, J. M. Grayson Scholarship Award for outstanding Ph.D. Student
- 2019 First place, Entomological Digest talks, Entomological Soc. of America Eastern Branch
- 2019 Second place, PhD student competition, Entomological Soc. of America Eastern Branch
- 2017 Alwood Extension Award
- 2017 Kosztarab Scholarship for Distinguished Achievement in Systematics

- 2017 Third place, J. M. Grayson Scholarship Award for outstanding Ph.D. Student
- 2015 Loke and Vicki Kok Graduate Fellowship
- 2015 Interfaces of Global Change Fellowship

University of Arkansas:

- 2014 Third place, student paper competition, Kansas Entomological Society annual meeting
- 2013 Charles G. Lincoln Fellowship
- 2013 Third place, student paper competition, Arkansas Entomological Society annual meeting

Marietta College:

- 2012 Eggleston-Ruby Prize
- 2012 Delta Upsilon Good Citizenship Award
- 2011 David F. Young Alumni Scholarship
- 2011 Benjamin A. Gilman International Scholarship
- 2011 Howard Writing Prize

Grant Applications (funded)

- 2018. American Museum of Natural History. Theodore Roosevelt Memorial Grant. **\$1,800**
- 2018. Virginia Tech Graduate School. Graduate Research Development Program. **\$992**
- 2017. Virginia Tech Department of Entomology. Dodson Travel Grant. **\$998**
- 2017. Virginia Tech Department of Entomology. Hill Travel Scholarship. **\$250**
- 2014. University of Arkansas travel grant. **\$250**
- 2014. Ohio Biological Survey. Survey of the millipedes of Ohio. **\$500**
- 2011. Marietta College Investigative Studies Program. A biological survey of the assassin bugs (Hemiptera: Reduviidae) at the Barbara A. Beiser Field Station. **\$500**

Professional Membership

- 2012-present Entomological Society of America
- 2014-present Ohio Biological Survey
- 2014-present Entomological Collections Network
- 2018-present Virginia Natural History Society

Professional Volunteerism and Service

- 2019 Field Trip Leader, Spring Wildflower Pilgrimage, Great Smoky Mountains National Park, Gatlinburg, TN
- 2013-2019 Field Trip Leader, Mothapalooza. Portsmouth, OH
- 2014-2018 Social media coordinator, Entomological Collections Network

- 2017 Organizer, Member Symposium, Entomological Collections Network Meeting
- 2015 Writing Committee Member, ESA Position Statement on the Importance of Entomological Collections. <https://www.entsoc.org/sci-pol/collections>
- 2015 Organizer, Professional Development Workshop, University of Arkansas
- 2014 Organizer, Program Symposium, Entomological Society of America Meeting
- 2013-2014 Student volunteer, Entomological Society of America Annual Meeting
- 2011-2012 Field Trip Leader, Midwest Native Plants Conference. Dayton, OH

University and Department Service

Virginia Polytechnic Institute & State University:

- 2020 Student Handbook Committee
- 2019 Linnaean Games Team, Eastern Branch Entomological Society of America
- 2018 Captain, Linnaean Games Team, Eastern Branch Entomological Society of America
- 2018 W. B. Alwood Society President
- 2017 Search Committee Member, Arbovirology Assistant Professor
- 2017 Seminar Committee
- 2016 Hokie Bugfest Chair

University of Arkansas:

- 2014 Linnaean Games Team, Southeastern Branch Entomological Society of America
- 2014-2015 Isely-Baerg Entomology Club - Outreach Coordinator

Media Appearances

- 2021 Just the Zoo of Us podcast 115: [Myriapods \(Millipedes, Centipedes & Pauropods\) w/ Dr. Derek Hennen!](#)
- 2021 North Carolina Museum of Natural Sciences: Science Tonight - [Millipedes with Dr. Derek Hennen](#)
- 2021 Conservation Cast Episode 53 - [Dr. Derek Hennen](#)
- 2021 Lil Dudes Insect Academy podcast – Episode 51: [The Mysterious life of Millipedes \(Feat. Derek Hennen\)](#)
- 2020 Funky, new parasitic species named after Twitter, where it was discovered, CNET - [Link](#)
- 2020 Surface Learning podcast – Episode 3: [Millipedes with Derek Hennen](#)
- 2019 Circles of Life ebook by Franz Anthony - [Link](#)
- 2019 How many legs does a millipede really have?, HowStuffWorks - [Link](#)
- 2018 Centipedes and Millipedes: Lots of Legs, What's the Difference?, LiveScience - [Link](#)
- 2018 Lemurs May Be Making Medicine Out of Millipedes, National Geographic - [Link](#)
- 2018 Up Close With the First and Only Millipede Lab in the United States, Atlas Obscura - [Link](#)
- 2018 Bugs Blood & Bones podcast – Episode 4: [Millipede Mania with Derek Hennen](#)
- 2017 400,000 and counting: Out of mothballs, Virginia Tech insect collection thriving, The Roanoke Times - [Link](#)

2016	College Campuses Are Being Overrun by Pokémon Go, The Chronicle of Higher Education - Link
2016	Virginia Tech bug man is 'always looking at the ground', The Roanoke Times - Link
2015	6 Extra Pairs of Genitals Is Just Too Much of a Good Thing, Wired - Link
2015	Reaching Beyond Our Horizons: Combining Insects With Enthusiasm on Social Media, Entomology Today - Link
2014	Charles Darwin's Rove Beetle Imaged On-site in Portland, OR, Entomology Today - Link

Internet Outreach

- **DearMillipede** – A dedicated Twitter account focused on informing the public about the science and beauty of millipedes and centipedes, ongoing since 2018. Current follower count: **2,416**. <https://twitter.com/dearmillipede>
- **iNaturalist** – I have identified over **28,000** user-submitted images of millipedes and centipedes on iNaturalist since joining the website in 2016. This website allows anyone to upload their photographs of plants, animals, etc. and learn more about the nature around them. I help users on the website identify their myriapods, since there are few accessible identification resources for these taxa. In particular, I have focused identifying observations from North America, and have identified all millipedes uploaded for the state of Ohio (currently over 3,000). <https://www.inaturalist.org>

Writing Outreach

2018	Diplopoda: The Not-So Creepy Crawlies, Virginia Master Gardeners
2015	The Benefits of Supplementing Science with Social Media, Entomology Today
2010-2015	Personal research blog, Normal Biology
2014	The Conversation, Scientists at Work series
2013	How is Twitter Useful for Entomologists?, Entomology Today
2012	Marietta Natural History Society Newsletter, Featured article
2012	Insects Galore, Explore the Outdoors Ohio, Guest Blog Post
2012	Tool Tales: Project Noah – A Community for Nature Lovers, Soapbox Science for Nature.com Blogs

Community Activities and Outreach

Presentations:

Aug. 2020	Myriapod Madness, Biology Class Interview, Western Sydney University (online)
Aug. 2020	Chem Tales – Millipedes, SciBugs Gamified Entomology Workshop, Online
June 2019	Millipedes of Virginia, Science on Tap (New River Valley), Blacksburg, VA
Nov. 2018	Bugs!, ThinkerCon 2018, Huntsville, AL
Jan. 2018	Ohio's Many Millipedes, Marietta Natural History Society, Marietta, OH
Aug. 2017	Samuel P. Hildreth: Pioneering Science in the Mid-Ohio Valley, Castle Museum

June 2017 An Introduction to Appalachian Millipedes, Virginia Master Gardeners College
 June 2014 Investigating Ohio's Millipedes, Buzzard's Roost Nature Preserve
 May 2013 Insects of Washington County, Marietta Natural History Society
 Feb. 2012 Entomology: A Window to a New World, Jackson Middle School
 Mar. 2012 Inventing the Wheel(bug), Marietta Natural History Society
 Apr. 2012 Ecology of Assassin Bugs, Marietta College All Scholars Day
 June 2012 Dream Big with Insects, Monroe County Public Library

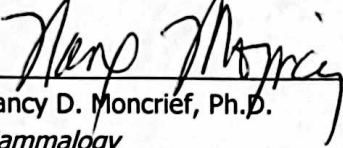
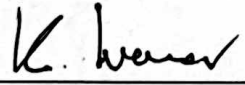
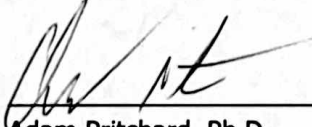

Outreach Events:

Sep. 2021 Judging student insect collections for Hokie Bugfest, Blacksburg, VA
 Mar. 2019 Girl Scout STEM Career Fair, Blacksburg, VA
 Jan. 2019 Skype call with elementary school student, West Lebanon, NH
 Oct. 2018 Hokie Bugfest, Blacksburg, VA
 July 2018 Hokie BugCamp, Virginia Tech, Blacksburg, VA
 Feb. 2018 Become a Naturalist, Boy Scout Troop 44, Blacksburg, VA
 Oct. 2017 Hokie Bugfest, Blacksburg, VA
 Oct. 2016 Hokie Bugfest, Blacksburg, VA
 Aug. 2016 Montgomery County Heritage Festival, Christiansburg, VA
 July 2016 Hokie BugCamp, Virginia Tech, Blacksburg, VA
 Mar. 2016 Hahn Horticulture Garden, Virginia Tech, Blacksburg, VA
 Feb. 2016 Skype call with high school class, Aurora, NE
 Sep. 2015 Rocky Knob Bioblitz, Blue Ridge Parkway, Floyd, VA
 Apr. 2015 Asbell Elementary School Green Team, Fayetteville, AR
 Dec. 2014 Sonora Elementary School, Springdale, AR
 Nov. 2014 Harp Elementary Science Club, Springdale, AR
 Oct. 2014 Arkansas Insect Festival, Fayetteville, AR
 July 2014 Walker Elementary School, Springdale, AR
 May 2014 Fayetteville Farmers' Market, Fayetteville, AR
 May 2014 Asbell Elementary School Food Camp, Fayetteville, AR
 May 2014 Jones Elementary School, Springdale, AR
 Oct. 2013 George Washington Carver National Monument BioBlitz, Diamond, MO
 Sep. 2013 Northwest Arkansas Preparedness Fair, Bentonville, AR
 July 2013 Fayetteville Farmers' Market, Fayetteville, AR

**NEW APPLICATION
AS RESEARCH ASSOCIATE**

Julian J. Lewis, Ph.D.

I have reviewed the information submitted for Julian J. Lewis (Kal Ivanov, Sponsor) and have indicated his/her recommendation as a Research Associate for the Virginia Museum of Natural History.

Curator	Date	Recommend	Do Not Recommend
 Nancy D. Moncrief, Ph.D. <i>Mammalogy</i>	2 Feb 2022	<input checked="" type="checkbox"/>	<input type="checkbox"/>
 Kal Ivanov, Ph.D. <i>Recent Invertebrates</i>	2 FEB. 2022	<input checked="" type="checkbox"/>	<input type="checkbox"/>
 Adam Pritchard, Ph.D. <i>Paleontology</i>	2 Feb '22	<input checked="" type="checkbox"/>	<input type="checkbox"/>
 Hayden Bassett, Ph.D. <i>Archaeology</i>	2 Feb 2022	<input checked="" type="checkbox"/>	<input type="checkbox"/>



Kaloyan Ivanov, Ph.D.
Virginia Museum of Natural History
21 Starling Ave.
Martinsville, VA 24112
kal.ivanov@vmnh.virginia.gov

15 December 2021

Virginia Museum of Natural History
21 Starling Ave.
Martinsville, VA 24112

To Whom It May Concern,

I write to nominate Dr. Julian J. Lewis as a Research Associate of the Virginia Museum of Natural History (VMNH). Dr. Lewis is a professional cave biologist, myriapodologist and carcinologist based in Kentucky. He is currently the President of Lewis and Associates, a Cave, Karst and Groundwater Biological Consulting Company, an Adjunct Professor at the University of Louisville, and a Research Associate at the National Museum of Natural History. Dr. Lewis holds a Ph.D. in Aquatic Biology from the University of Louisville and a Master's degree in Biology from the same institution. His expertise includes isopod and millipede taxonomy, systematics, and natural history with a strong focus on troglobitic (cave adapted) taxa. As his enclosed documents demonstrate, Dr. Lewis is uniquely qualified to contribute to the mission and research objectives of this institution.

Although I have only known Julian for less than a year, I have come to admire his intimate knowledge of freshwater isopods and his wide-ranging familiarity with many cave taxa including millipedes, arachnids, and insects. Dr. Lewis is intimately familiar with VMNH's invertebrate holdings as a result of his work in the collection since the early 1990s and he has expressed interest in continuing to use VMNH's invertebrate collection for his specimen-based research. His work on the freshwater isopods of Virginia and the adjacent areas has included examination, identification, and curation of numerous specimens from VMNH's crustacean collection and the majority of the nearly 800 asellid isopods in the collection have been expertly identified by Dr. Lewis.

During his career, Dr. Lewis has authored numerous publications including the description of many new asellid and millipede taxa. In the past five years he has had multiple projects focused on the rare and endangered isopod crustacean fauna of Virginia. He is currently completing work on a monograph on the groundwater isopod crustaceans of Virginia and the adjacent Appalachians which is to be published in



VMNH's Memoirs series. As a result of this work, many taxa, including newly described species, will be added to the museum's invertebrate holdings.

I have no doubt that VMNH would benefit from Julian's expertise, curatorial efforts, and fieldwork all of which contribute directly to the museum's mission.

Sincerely,

Kaloyan Ivanov, Ph.D.
Associate Curator of Recent Invertebrates
Virginia Museum of Natural History

Lewis & Associates, LLC
17903 State Road 60
Borden, IN 47106
10 December 2021

Board of Trustees
Virginia Museum of Natural History
21 Starling Avenue
Martinsville, VA 24112

To whom it may concern,

I am writing to apply for the position of Research Associate at the Virginia Museum of Natural History (VMNH). My interest stems from the museum's collections and publication series in conjunction with my research interest in Virginia invertebrates (particularly isopod crustaceans and millipedes). I started working with the collections of the VMNH with Richard Hoffman in the 1990s and subsequently attended the 80th birthday symposium in his honor, speaking and contributing two papers to the proceedings volume. I am currently finishing a book-length manuscript on the groundwater isopod crustaceans of Virginia and the adjacent Appalachians that I hope to publish as a VMNH contribution.

From an educational standpoint, my training includes an M.S. and Ph.D. in aquatic biology from the University of Louisville. I also have a B.A. in French from Indiana University and a B.S. in photography from Southern Illinois University.

I am the president of Lewis & Associates, LLC, a biological consulting company specializing in cave, karst and groundwater projects. Our company primarily provides services to conservation-oriented organizations for whom we perform bioinventory surveys and endangered species projects. We also perform cave and karst faunal evaluations for large scale engineering projects, typically things like pre-construction surveys of interstate highway routes. In the past five years we have had multiple projects working on rare and endangered isopod crustacean fauna of Virginia, with funding from the U.S. Fish & Wildlife Service, Virginia Natural Heritage Program, National Park Service, Cave Conservancy of the Virginias, and the Smithsonian Institution.

Besides my previous work at the VMNH, I have experience with a variety of other museums and am reasonably versed in institutional procedures. I am a research associate at the National Museum of Natural History, where I have collaborated since 1976. Elsewhere, I've worked with the collections at museums from the Bishop Museum in Honolulu to the Museum of Natural History, London, and many others in between.

Sincerely,

A handwritten signature in black ink, appearing to read 'Julian J. Lewis', written in a cursive style.

Julian J. Lewis, Ph.D.

Julian J. Lewis, Ph.D.
17903 State Road 60
Borden, IN 47106 USA
(812) 967-7592 (office)
(812) 786-1744 (cell)
lewisbioconsult@gmail.com

Affiliation: President
Lewis and Associates
Cave, Karst and Groundwater
Biological Consulting, LLC

Adjunct Professor
University of Louisville

Education: Ph.D., Aquatic Biology 1988
with Highest Honors
University of Louisville
Louisville, Kentucky

M.S., Biology 1985
with Highest Honors
University of Louisville
Louisville, Kentucky

B.A., French 2014
with Highest Honors
Indiana University
Bloomington, Indiana

B.S., Cinema & Photography 1976
with Honors
President's Scholar
Southern Illinois University
Carbondale, Illinois

Memberships: Beckham Bird Club, Kentucky Ornithological Society
Biological Society of Washington
Cave Research Foundation
Indiana Academy of Sciences
Indiana Karst Conservancy
 President (2007-2021)
 Board of Directors (2001-2007)
National Speleological Society
 Fellow of the Society
 Associate Editor for Biological Sciences and Conservation,
 Journal of Cave and Karst Studies
 NSS Science Award for Lifetime Contributions
 Stone Research Award
Phi Kappa Phi
Société Internationale de Biospéologie (SIBIOS)
The Nature Conservancy

Publications

Lewis, S.L., Lewis, J.J. and W. Orndorff. 2021. *Caecidotea burkensis*, new species, a unique subterranean isopod from Burke's Garden, with a synthesis of the biogeography and evolution of southwestern Virginia asellids. *Journal of Cave and Karst Studies*, 83 (2): 78-87.

Lewis, J. J., Lewis, S. L., Orndorff, W., Malard, F., Douady, C., and L. Konecny. 2020. Endangered species management in an era of ever-increasing biodiversity: A case study of the molecular phylogenetics of *Lirceus hargerii*. *Proceedings of the 2019 National Cave and Karst Management Symposium, Bristol, Virginia.*

Lewis, J. J., Milne, M., Stephen, C., and D. Dourson. 2020. Sinkholes as foci of terrestrial biodiversity in the Hoosier National Forest. *Journal of Cave and Karst Studies*, volume 82.

Lewis, J. J., Milne, M., Lewis, S. L., Stephen, C., Dunlap, K., and Daniel Dourson. 2020. Sinkholes – biodiversity hotspots in epigean terrestrialecosystems on the Hoosier National Forest. *Proceedings of the 2019 National Cave and Karst Management Symposium, Bristol, Virginia.*

Lewis, S. L. and J. J. Lewis. 2020. Cavers conserving karst: The Indiana Karst Conservancy. *Proceedings of the 2019 National Cave and Karst Management Symposium, Bristol, Virginia.*

Peck, S.B., Lewis, J.J. and J.O. Whitaker. 2020. Cave faunas of the Upper Mississippi Valley - Region. *in* *Natural History of the Upper Mississippi Valley Region.*

Milne, M. A., J. Louderman, B. Foster, I. Grijalva, J. J. Lewis, L. Bishop, B. L. Deno, J. Acosta,

- L. Frandsen, and E. Stern. 2019. More spiders in Indiana: 100 new and updated distribution records. *Proceedings of the Indiana Academy of Science* 128 (1): 87-105.
- Lewis, Julian J., Lewis, Salisa L. and William D. Orndorff. 2018. The Lee County cave isopod (*Lirceus usdagalun*) debacle: an endangered species discovered not to be a species. *Proceedings of the National Cave and Karst Management Symposium*, Eureka Springs, Arkansas.
- Milne, M. A., B. Foster, J. J. Lewis, L. Bishop, A. Hoffman, T. Ploss, and B. Deno. 2017. Spiders in Indiana: Seventy-one new and updated distribution records. *Proceedings of the Indiana Academy of Science* 125 (1): 75-85.
- Lewis, Julian J. and Thomas R. Sawicki. 2016. *Mexistenasellus floridensis*, sp. n., the first stenasellid isopod discovered from the Floridan aquifer (Crustacea: Isopoda: Asellota). *Subterranean Biology*, 17: 121-132.
- Lewis, Julian J. and D.C. Rogers. 2016. Isopods of the United States. Chapter 16, Thorpe and Covich, *Freshwater Biology*, 593-605.
- Lewis, Julian J. and Salisa L. Lewis. 2015. The Extirpation of a population of the endangered Illinois Cave Amphipod (*Gammarus acherondytes*) by an exotic species: The Wednesday Cave debacle. *Proceedings of the 2015 National Cave and Karst Management Symposium*, Cave City, Kentucky.
- Lewis, Julian J. and Salisa L. Lewis. 2015. Karst wreckage: Subterranean fauna as collateral damage. *Proceedings of the 2015 National Cave and Karst Management Symposium*, Cave City, Kentucky.
- Lewis, Julian J. 2015. The subterranean asellids of Indiana (Isopoda), with the description of *Caecidotea dunlaporum*, new species. *Journal of Cave and Karst Studies*, v. 77, no. 2, p. 99-107.
- Lewis, Julian J. and Michael Slay. 2013. *Chaetaspis attenuatus*, a new species of cavernicolous milliped from Arkansas (Diplopoda: Polydesmida: Macrosternodesmidae). *Journal of Cave and Karst Studies*, 75 (1): 60-63.
- Lewis, Julian J. 2013. *Caecidotea insula*, a new species of subterranean asellid from Lake Erie's South Bass Island (Crustacea: Isopoda: Asellidae). *Journal of Cave & Karst Science*, 75: 64-67.
- Lewis, Julian J. 2012. Subterranean Ecosystems. Chapter 8 *in* *Habitats and Ecological Communities of Indiana: Pre-settlement to Present*. Whitaker, John O. and Charles J. Amlaner, editors. Indiana University Press, Bloomington, 491 pages.

- Lewis, Julian J. and Salisa L. Lewis. 2012. The cave fauna of Indiana. *In* Frushour, S.S., A guide to the caves and karst of Indiana. Indiana University Press, Bloomington, 142 pages.
- Lewis, Julian J., Thomas E. Bowman and Daniel Feller. 2011. A synopsis of the subterranean asellids of Maryland, U.S.A., with description of Caecidotea alleghenyensis, new species (Crustacea: Isopoda: Asellota). *Zootaxa* 2769: 54-64.
- Loria, Stephanie, Zigler, Kirk and Julian J. Lewis. 2011. Molecular phylogeography of the troglobiotic millipede Tetracion Hoffman, 1956 (Diplopoda, Callipodida, Abacionidae). *International Journal of Myriapodology*, 5 (2011): 35-48.
- Lewis, Julian J. and Thomas E. Bowman. 2010. The subterranean asellids of Maryland: Description of Caecidotea nordeni, new species, and new records of C. holsingeri and C. franzi (Crustacea: Malacostraca: Isopoda). *Journal of Cave & Karst Studies*, 72 (2): 100-104.
- Lewis, Julian J. and John Whitaker. 2010. Bioinventory of caves inhabited by Gray bats in the Central Basin and Highland Rim area of Tennessee. Tennessee Academy of Sciences.
- Lewis, Julian J. and Salisa L. Lewis. 2009. On the distribution and range of the subterranean ostracod Pseudocandona jeanneli. *Biospeleology Notes*: 1: 14-16.
- Lewis Julian J. 2009. Isopoda (Aquatic Sowbugs). In: Gene E. Likens, (Editor), *Encyclopedia of Inland Waters*. volume 2, pp. 346-355 Oxford: Elsevier.
- Lewis, Julian J. 2009. On the identity of Caecidotea nickajackensis (Crustacea: Isopoda: Asellidae). *Proceedings of the Biological Society of Washington*. 122 (2): 215-224.
- Lewis, Julian J. 2009. Three new species of subterranean asellid from Virginia (Crustacea: Isopoda: Asellidae). Pages 245-259, In Roble, S. M. and J. C. Mitchell, editors, *A lifetime of contributions to Myriapodology and the natural history of Virginia: A festschrift in honor of Richard L. Hoffman's 80th birthday*. Virginia Museum of Natural History Special Publication 16.
- Lewis, Julian J. 2009. Eight new species of the millipede Pseudotremia (Diplopoda: Chordeumatida). Pages 251-265, In Roble, S. M. and J. C. Mitchell, editors, *A lifetime of contributions to Myriapodology and the natural history of Virginia: A festschrift in honor of Richard L. Hoffman's 80th birthday*. Virginia Museum of Natural History Special Publication 16.

- Lewis Julian J. 2009. Isopoda (Aquatic Sowbugs). In: Gene E. Likens, (Editor), Encyclopedia of Inland Waters. volume 2, pp. 346-355 Oxford: Elsevier.
- Paquin, P, N. Dupere, D. Buckle and J. Lewis. 2009. Oreonetides beattyi, a new troglobitic spider (Araneae: Linyphiidae) from eastern North America, and redescription of Oreonetides flavus. Journal of Cave and Karst Studies.
- Lewis, Julian J. 2008. Oregonasellus and Bowmanasellus, two new subterranean isopod genera from the western United States (Crustacea: Isopoda: Asellidae). Subterranean Biology 6: 23-80.
- Lewis, Julian J. and Salisa L. Lewis. 2008. Some "Commandments" for Conservation in Karst Faunal Sections of Environmental Impact Statements. Proceedings of the National Cave & Karst Management Symposium, St. Louis, Missouri, 43-45.
- Chandler, Donald S. and Julian J. Lewis. 2008. Notes on the cave-associated pselaphinae (Staphylinidae) of Indiana. The Coleopterist's Bulletin, 62 (1): 114-119.
- Lewis, Julian J. and Salisa L. Lewis. 2007. The cave fauna of Indiana. Convention 2007 Guidebook, National Speleological Society, Marengo, Indiana.
- Shear, William A., Julian J. Lewis and Monica Farfan. 2007. Diplopoda, Chordeumatida, Cleidogonidae, Pseudotremia salisae Lewis: Distribution, extension north of the Ohio River in Ohio and Illinois, U.S.A. Check List 2007: 1-3.
- Lewis, Julian J. and Salisa L. Lewis. 2007. Sampling for biota in IKC preserves. IKC Update, 84: 10-11, 22.
- Lewis, Julian J. and Janet W. Reid. 2007. Patterns and processes of groundwater invasion by Copepods in the Interior Low Plateaus of the United States. Acta Carsologica 36 (2): 279-289.
- Lewis, Julian J., G.O. Graening, D.B. Fenolio and E.A. Bergey. 2006. Caecidotea mackini, new species, with a synopsis of the subterranean asellids of Oklahoma. Proceedings of the Biological Society of Washington 119 (4): 563-575.
- Lewis, Julian J. and Salisa L. Lewis. 2006. Fauna in the Interstate 66 Somerset to London Corridor. Proceedings of the National Cave & Karst Management Symposium, Albany, New York.
- Culver, D.C., L. Deharveng, A. Bedos, J. J. Lewis, M. Madden, J. R. Reddell, B. Sket, P. Trontelj, and D. White. 2006. The mid-latitude biodiversity ridge in terrestrial cave fauna. Ecography, 29 (1): 120-128.

- Lewis, Julian J. 2005. Six new species of Pseudotremia from caves of the Cumberland Escarpment, Tennessee. *Zootaxa* 1080: 17-31.
- Lewis, Julian J. 2004. Brackenridgia ashleyi, a new species of terrestrial isopod from Tumbling Creek Cave, Missouri (Crustacea, Isopoda: Trichoniscidae). *Proceedings of the Biological Society of Washington* 117 (2): 176-185.
- Lewis, Julian J., Joel W. Martin and Regina Wetzer. 2003. Columbasellus acheron, a new genus and species of subterranean isopod from Washington (Crustacea: Isopoda: Asellidae). *Proceedings of the Biological Society of Washington* 116 (1): 190-197.
- Lewis, Julian J. 2003. Pseudotremia reynoldsae, a new species of troglobitic milliped, with a synopsis of the cavernicolous millipeds of the Hoosier National Forest. *Proceedings of the Indiana Academy of Science* 112 (1): 36-42.
- Lewis, Julian J. and Kelle Reynolds. 2003. Proactive cave management on the Hoosier National Forest. *Proceedings of the 16th National Cave and Karst Management Symposium*, Gainesville, Florida, 33-35.
- Lewis, Julian J. and S. T. Rafail. 2003. Development of an index of biological integrity for Endangered species monitoring in southern Illinois. *Proceedings of the 16th National Cave and Karst Management Symposium*, Gainesville, Florida, 65-69.
- Lewis, Julian J., Philip Moss, Diane Tecic and Matt Nelson. 2003. A Conservation focused inventory of the subterranean invertebrates of the southwestern Illinois karst. *Journal of Cave and Karst Studies*, 65 (1): 9-21.
- Lewis, Julian J. 2002. Chaetaspis aleyorum, a new species of milliped from Tumbling Creek Cave, Missouri, with a synopsis of the cavernicolous species of Chaetaspis (Diplopoda: Polydesmida). *Myriapodologica* 7 (11): 101-111.
- Lewis, Julian J. 2001. Three new species of subterranean asellids from western North America, with a synopsis of the species of the region (Crustacea: Isopoda: Asellidae). *Speleology Monograph Series*, Texas Memorial Museum, 5: 1-15.
- Lewis, Julian J. 2000. Five new species of Pseudotremia from caves in the Blue River area of southern Indiana (Diplopoda: Chordeumatida: Cleidogonidae). *Myriapodologica*, 6 (6): 55-68.
- Lewis, Julian J. 2000. Caecidotea cumberlandensis, a new species of troglobitic isopod from Virginia, with new records of other subterranean Caecidotea (Crustacea: Isopoda: Asellidae). *Proceedings of the Biological Society of Washington*, 113 (3): 458-464.
- Lewis, Julian J. 2000. Scoterpes sollmani, a new species of subterranean milliped from the Blue River basin of southern Indiana (Diplopoda: Chordeumatida: Trichopetalidae). *Myriapodologica*, 6 (13): 115-120.
- Lewis, Julian J. 2000. The biological inventory of Indiana caves. *Cave Research*

Foundation Annual Report, 1994-1997, 54-56.

- Lewis, Julian J. 1999. Caecidotea simulator, a new subterranean isopod from the Ozark Springfield Plain (Crustacea: Isopoda: Asellidae). Proceedings of the Biological Society of Washington, 112 (1): 175-180.
- Reid, J.W., D.L. Strayer, J.V. McArthur, S.E. Stibbe and J.J. Lewis. 1999. Rheocyclops, a new genus of copepods from the southeastern and central U.S.A. (Copepoda: Cyclopoida: Cyclopidae). Journal of Crustacean Biology, 19 (2): 384-396.
- Lewis, Julian J. 1997. Bioinventory underway in Blue River caves. IKC Update, 46: 20-21.
- Lewis, Julian J. 1997. Caves of the Blue River. Natural Area News, 1 (2): 8-9.
- Lewis, Julian J., F. Allen Pursell and Henry Huffman. 1997. The biological inventory of caves of the Blue River Bioserve. Karst Waters Institute, Special Publication No. 3, Conservation and Protection of the Biota of Karst, 37-41.
- Hoffman, Richard L. and Julian J. Lewis. 1997. Pseudotremia conservata, a new cleidogonid milliped (Diplopoda: Chordeumatida), with a synopsis of the cavernicolous millipeds of Indiana. Myriapodologica, 4(13): 107-119.
- Lewis, Julian J. 1997. Bioinventory underway in Blue River caves. The Nature Conservancy Newsletter, Summer 1997: 4.
- Lewis, Julian J. and Thomas E. Bowman. 1996. The subterranean asellids of Texas (Crustacea: Isopoda: Asellidae). Proceedings of the Biological Society of Washington, 109(3): 482-500.
- Lewis, Julian J. 1996. The devastation and recovery of caves affected by industrialization. Proceedings of the 1995 National Cave Management Symposium, October 25-28, 1995, Spring Mill State Park, Indiana: 214-227. [Keynote address]
- Lewis, Julian J. 1996. Cave bioinventory as a management tool. Proceedings of the 1995 National Cave Management Symposium, October 25-28, 1995, Spring Mill State Park, Indiana: 228-236.
- Lewis, Julian J. 1996. The Nitric Acid Caves of the Indiana Army Ammunition Plant. American Caves, 9 (1): 6-10
- Lewis, Julian J. and John R. Holsinger. 1996. Thomas E. Bowman (Obituary). N.S.S. News, July (1996), 195-196.
- Lewis, Julian J. 1994. Observations on the distribution and ecology of the aquatic troglobitic snail Antroselates spiralis. Proceedings of the Mammoth Cave National Park Third Annual Science Conference.

- Lewis, Julian J. and Ann Marie Lewis. 1994. Distribution of Antrosetates spiralis in Indiana. Cave Research Foundation 1993 Annual Report: 40-42.
- Lewis, Julian J. 1993. The effects of cave restoration on some aquatic cave communities in the central Kentucky karst. in Proceedings of the National Cave Management Symposium, D. L. Foster, editor. American Cave Conservation Association, Inc., 346-350.
- Lewis, Julian J. 1993. Arthropod communities associated with Indiana woodrat caves. Cave Research Foundation 1992 Annual Report: 37-38.
- Lewis, Julian J. and A. Lewis. 1993. Observations on the distribution and ecology of Antrosetates spiralis in southern Indiana. Cave Research Foundation 1992 Annual Report: 43-45.
- Lewis, Julian J. 1993. Cavefish return to the former "dead zone" of Hidden River Cave. American Caves.
- Lewis, Julian J. 1993. Life returns to Hidden River Cave: The rebirth of a destroyed cave system. National Speleological Society News, (June) 208-213.
- Lewis, Julian J. 1993. The rebirth of Hidden River. American Caves, 15.
- Lewis, Julian J. 1992. The blind snail of Mammoth Cave and Indiana. Cave Research Foundation Newsletter, 20(4): 13.
- Lewis, Julian J. 1991. Water quality, habitat degradation and community composition in cave streams of the Mammoth Cave karst. Proceedings of the Mammoth Cave National Park First Annual Science Conference, 41-49.
- Lewis, Julian J. 1990. The Outlook for Reclamation of Hidden River Cave, Hart County, Kentucky. Cave Research Foundation 1989 Annual Report:59-61.
- Lewis, Julian J. 1989. Aquatic communities in Mammoth Cave. Cave Research Foundation 1988 Annual Report, 40-42.
- Bowman, Thomas E. and Julian J. Lewis. 1989. Occurrence of the calanoid copepod Eurytemora affinis (Poppe) in the Ohio River at Louisville, Kentucky. Journal of Crustacean Biology, 9(1): 83-84.
- Lewis, Julian J. 1988. The systematics, zoogeography and life history of the troglobitic isopods of the Interior Plateaus of the eastern United States. Ph.D. dissertation, University of Louisville, Louisville, Kentucky, 281 pages.
- Lewis, Julian J. 1988. Aquatic communities in the Cathedral Domes section of Mammoth Cave.

Cave Research Foundation 1987 Annual Report, 35-38.

- Henry, Jean Paul, Julian J. Lewis and Guy Magniez. 1986. Isopoda: Asellota: Aselloida, Gnathostenetroidoidea, Stenetrioidea). in *Stygofauna Mundi: a faunistic, distributional and ecological synthesis of the world fauna inhabiting subterranean waters (including the marine interstitial)*, L. Botosaneanu, editor. E. J. Brill, Leiden, Netherlands, 434-464.
- Lewis, Julian J. 1985. The subterranean Caecidotea of Texas (Crustacea: Isopoda: Asellidae). M.S. thesis, University of Louisville, Louisville, Kentucky, 82 pages.
- Lewis, Julian J. and John R. Holsinger. 1985. Caecidotea phreatica, a new phreatobitic isopod crustacean (Asellidae) from southeastern Virginia. *Proceedings of the Biological Society of Washington*, 98(4):1004-1011.
- Bowman, Thomas E. and Julian J. Lewis. 1984. Caecidotea rotunda, a new species of troglobitic asellid from Indiana and Ohio (Crustacea: Isopoda: Asellidae). *Proceedings of the Biological Society of Washington*, 94(2):425-431.
- Lewis, Julian J. 1983. The obligatory subterranean invertebrates of glaciated southeastern Indiana. *National Speleological Society Bulletin*, 45:34-40.
- Lewis, Julian J. 1983. Redescription and assignment to the genus Lirceolus of the Texas troglobitic water slater Caecidotea pilus (Crustacea: Isopoda: Asellidae). *Proceedings of the Biological Society of Washington*, 96(1):145-148.
- Lewis, Julian J. 1983. Caecidotea fonticulus, the first troglobitic water slater from the Ouachita Mountains (Crustacea: Isopoda: Asellidae). *Proceedings of the Biological Society of Washington*, 96(1):149-153.
- Lewis, Julian J. and Teresa M. Lewis. 1983. The life history and distribution of two troglobitic Caecidotea in Mammoth Cave National Park. *Cave Research Foundation 1982 Annual Report*, 10-11.
- Lewis, Julian J. 1982. Aquatic ecosystems and management problems in the Mammoth Cave area. **in** *National Cave Management Symposia Proceedings*, R. C. Wilson and J. J. Lewis, editors. Pygmy Dwarf Press, Oregon City, Oregon, 73-76.
- Lewis, Julian J. 1982. A diagnosis of the Hobbsi Group, with descriptions of Caecidotea teresae, n. sp., and C. macropropoda Chase and Blair (Crustacea: Isopoda: Asellidae). *Proceedings of the Biological Society of Washington*, 95(2):338-346.
- Lewis, Julian J. 1982. Systematics of the troglobitic Caecidotea (Crustacea: Isopoda: Asellidae) of the southern Interior Low Plateaus. *Brimleyana*, 8:65-74.
- Wilson, Ronald C. and Julian J. Lewis, editors. 1982. *The 1980 National Cave Management Symposium Proceedings*. Pygmy Dwarf Press, Oregon City, Oregon, 234 pages.

- Lewis, Julian J. 1981. Distribution of aquatic isopods in Mammoth Cave. Cave Research Foundation 1979 Annual Report, 21.
- Lewis, Julian J. 1981. Caecidotea salemensis and C. fustis, new subterranean asellids from the Salem Plateau (Crustacea:Isopoda:Asellidae). Proceedings of the Biological Society of Washington, 94(2):579-590.
- Lewis, Julian J. 1981. The subterranean Caecidotea of the Interior Low Plateaus. Proceedings of the Eighth International Congress of Speleology, 1:234-236.
- Lewis, Julian J. and Thomas E. Bowman. 1981. The subterranean asellids (Caecidotea) of Illinois (Crustacea: Isopoda: Asellidae). Smithsonian Contributions to Zoology, 335:1-66.
- Lewis, Julian J. and Teresa M. Lewis. 1981. The distribution and ecology of two species of subterranean Caecidotea in Mammoth Cave National Park. Cave Research Foundation 1980 Annual Report, 23-27.
- Lewis, Julian J. 1980. A comparison of Pseudobaicalasellus and Caecidotea, with a description of Caecidotea bowmani, new species (Crustacea: Isopoda: Asellidae). Proceedings of the Biological Society of Washington, 93(2):314-326.
- Peck, Stewart B. and Julian J. Lewis. 1978. Zoogeography and evolution of the subterranean invertebrate fauna of Illinois and southeastern Missouri. National Speleological Society Bulletin, 40(2):39-63.
- Lewis, Julian J. and Thomas C. Bowman. 1977. Caecidotea carolinensis, n. sp., the first subterranean water slater from North Carolina (Crustacea: Isopoda: Asellidae). Proceedings of the Biological Society of Washington, 90(4):968-974.
- Lewis, Julian J. 1974. The invertebrate fauna of Mystery Cave, Perry County, Missouri. Missouri Speleology, 14(4):1-19.

Lewis & Associates, Biological Consulting Projects

Evaluation of cave and karst fauna at the Indiana Highway 60 sinkhole collapse. Lochmueller Group, Evansville, Indiana for Indiana Department of Transportation. 2020.

Evaluation of cave and karst fauna, Interstate 69 section 4. Lochmueller Group, Evansville, Indiana for Indiana Department of Transportation. 2019-2020.

Description of a new species of subterranean isopod from Tazewell County, Virginia. Cave Conservancy of the Virginias and Virginia Department of Conservation & Recreation. 2019-2020.

Description of three new karst species of Appalachian isopods of the genus Lirceus. U.S. Fish and Wildlife Service, Abingdon, Virginia. 2019-2020.

Two new cavernicolous isopods of the genus Lirceus from southwestern Virginia. Cave Conservancy of the Virginias and Virginia Department of Conservation & Recreation. 2018-2019.

World asellid isopod molecular phylogenetics project. Laboratoire d'Ecologie des Hydrosystèmes Naturels et Anthropisés, Université Lyon-1, Lyon, France 2017-present.

Evaluation of new potentially rare and endangered species of Lirceus related to the endangered Lee County Cave Isopod. U.S. Fish and Wildlife Service, 2018- present.

The subterranean fauna of Indiana and adjoining regions. The Nature Conservancy of Indiana, 2018-present

Evaluation and description of new species of Ozark asellid isopods of the genus Lirceus. Ozark Highlands Program, The Nature Conservancy. 2018.

Evaluation of the endangered Lee County Cave Isopod (*Lirceus usdagalun*): taxonomy and comparative morphology of *Lirceus usdagalun* versus *Lirceus hargeri*. Virginia Natural Heritage Program and U.S. Fish & Wildlife Service. 2016-present

Bioinventory of caves and springs of the Bernheim Arboretum and Research Forest, Clermont, Kentucky. Isaac Bernheim Foundation. 2016-2017.

Revision of the asellid isopod genus Lirceus. Smithsonian Institution fellowship, 2016.

Evaluation of sinkholes on the Hoosier National Forest: Community composition, habitats and nutrient flow. U.S. Forest Service, Department of Agriculture. 2015-2017.

Cave ecology workshop for Cincinnati Museum Center, at Edge of Appalachia Preserve, West Union, Ohio. 2016

Western Kentucky University, Karst Field Studies at Mammoth Cave National Park: Cave

ecology class. 2016

Final evaluation of four cave beetle species (*Pseudanophthalmus*) for listing as federal endangered species. U.S. Fish & Wildlife Service, Kentucky Field Office. 2015- 2016.

Identification of subterranean isopods of Virginia. Virginia Natural Heritage Program, 2016

Revision of the isopod genus *Lirceus*. U.S. National Museum of Natural History, Smithsonian Institution. 2016

Bioinventory of the Shawnee Cave System, Lawrence County, Indiana. Indiana Natural Heritage Program, Indiana Department of Natural Resources. 2015-2016.

Cave stream population censusing at Big Oaks National Wildlife Refuge. U.S. Fish & Wildlife Service, Big Oaks National Wildlife Refuge. 2015.

Biological evaluation of Boone Cave System, Green's Bluff Nature Preserve, Owen County, Indiana. The Nature Conservancy, and Indiana Natural Heritage Program. 2014-present.

Site evaluations for karst fauna, Interstate 69, Section 4. Bernardin, Lochmueller & Associates, Inc. 2012-present.

Molecular and morphological analysis of subterranean asellid isopods of Indiana. The Nature Conservancy and Indiana Academy of Science, 2013-2015.

Evaluation of the subterranean fauna of the Hidden River groundwater basin of central Kentucky. Kentucky Conservation Land Foundation, and American Cave Conservation Association, 2013-2015

Censusing of the federal endangered species, the Illinois cave amphipod Gammarus acherondytes. Illinois Department of Natural Resources, Endangered Wildlife Program, and U.S. Department of the Interior, Fish & Wildlife Service, 2013-2014.

Expert witness, Dickson Landfill, Tennessee. Natural Resources Defense Council, 2010-2012.

Subterranean fauna of the Hoosier National Forest: Patoka Lake and Lost River tracts. Hoosier National Forest, U.S. D. A. Forest Service, 2011-2012.

Censusing of the federal endangered species, the Illinois cave amphipod Gammarus acherondytes. Illinois Department of Natural Resources, Endangered Wildlife Program, and U.S. Department of the Interior, Fish & Wildlife Service, 2010-2011.

Conservation assessment of subterranean communities of the Hoosier National Forest. U.S. D. A. Forest Service, 2010-2011.

Subterranean asellids of Maryland. Department of Invertebrate Zoology, Smithsonian Institution, and Maryland Department of Natural Resources, 2010-2011.

Karst faunal evaluation of proposed Water Treatment Plant 4, Austin, Texas. SOS Alliance, Austin, Texas 2010.

Evaluation and description of the cave asellids of Maryland. Maryland Department of Natural Resources, and Department of Invertebrate Zoology, Smithsonian Institution, 2009-2010.

Subterranean fauna of the Hoosier National Forest, Huron and Hillham Quadrangles. U.S. D. A. Forest Service, 2009-2010

Evaluation of cave and karst resources of the Crump Cave Reserve. Western Kentucky University, 2009.

Subterranean fauna of the Hoosier National Forest, Deam Wilderness, Springs Valley and Oriole tracts. U.S. D. A. Forest Service, 2008.

Groundwater fauna of glaciated Indiana. Indiana Department of Natural Resources, Division of Nature Preserves, 2008.

Bioinventory of the Wayne Cave Nature Preserve, Monroe County, Indiana. Indiana Department of Natural Resources, Division of Nature Preserves, 2008.

Bioinventory of the Sullivan Cave Preserve, Lawrence County, Indiana. Indiana Department of Natural Resources, Division of Nature Preserves, 2007-2008.

Non-lethal censusing of the endangered Illinois cave amphipod for 2007. U.S. Fish & Wildlife Service, and Endangered Species Program, Illinois Department of Natural Resources 2007.

Karst site evaluation, Holloway karst impoundment area. Hoosier National Forest, Bedford, Indiana, 2007.

Biological reconnaissance of fens associated with Pigeon River State Fish & Wildlife Area. Indiana Department of Natural Resources, Division of Nature Preserves, 2007.

Karst fauna evaluation for Interstate 69 Corridor Section 4, Indianapolis-Evansville, Indiana. Environmental Solutions and Innovations, 2006-2007.

Classification and recommendations for the Indiana DNR list of Threatened and Endangered Species. Division of Nature Preserves, Indiana Department of Natural Resources, 2006.

Bioinventory of the Gray bat hibernacula sites. The Nature Conservancy of Tennessee 2006-2007.

Composition of the chapter Isopoda for Encyclopedia of Inland Waters, Elsevier, London, UK (2006-2007)

Composition of the chapter Caves and Cave Fauna, in Natural Communities of Indiana, for Indiana Department of Natural Resources (2006-2007)

Bioinventory of the Robinson Ladder Cave Preserve, Crawford County, Indiana. Indiana Department of Natural Resources, Division of Nature Preserves, 2006.

Identification of fauna and description of new species, The Nature Conservancy and Oklahoma Biological Survey, 2005-2006.

Bioinventory of the Buddha Karst Preserve, Lawrence County, Indiana. Indiana Department of Natural Resources, Division of Nature Preserves, 2005-2006.

Karst fauna evaluation for Interstate 69 Corridor Section 5, Indianapolis-Evansville, Indiana. Baker & Associates and Ozark Underground Laboratory, 2005.

Warren County I-65/US 31W Access project for Bowling Green-Warren County Trimodal Transpark. Presnell Associates (QK4), Louisville, Kentucky, 2004-2005.

Karst faunal evaluation for Interstate 66 Corridor, Somerset-London, Kentucky. Gannett-Fleming Engineering, Inc., Columbus, Ohio, 2003-2005.

Bioinventory of the caves of the South Cumberlands Project Area, The Nature Conservancy of Tennessee (2004-2005).

Environmental Site Evaluation and Conservation Assessment of Cave Habitat, Ullrich Water Treatment Plant 160 MGD Expansion Project, Austin, Texas, 2003.

Bioinventory of the caves of the Hoosier National Forest, U.S. Department of Agriculture Forest Service, 2000-2004.

Status and Distribution Surveys for Rare Cave-Dependent Organisms Recently Identified from the Rumbling Falls Cave System, Van Buren County, Tennessee. U.S. Department of the Interior, Fish & Wildlife Service, 2002-2003.

Censusing of the federal endangered species, the Illinois cave amphipod Gammarus acherondytes. Illinois Department of Natural Resources, Endangered Wildlife Program, and U.S. Department of the Interior, Fish & Wildlife Service, 2002-2003.

Evaluation and description of new species of cavernicolous invertebrates associated with the federal endangered species Antrobia culveri, from Tumbling Creek Cave, Missouri. U.S. Department of the Interior, Fish & Wildlife Service, Ozark Underground Laboratory, and The Nature Conservancy, 2002.

Evaluation and description of new species of cavernicolous millipeds from southern Indiana. Indiana Department of Natural Resources, Natural Heritage Program, 2001-2002.

Evaluation and identification of aquatic crustaceans from the karst of Arkansas and Oklahoma. The Nature Conservancy, 2002-2003.

Bioinventory of the caves of the Big Oaks National Wildlife Refuge, formerly U.S. Army Jefferson Proving Ground. U.S. Department of the Interior, Fish & Wildlife Service, 2000-2001

Evaluation and bioinventory of the Rumbling Falls Cave System, Van Buren County, Tennessee. Tennessee Environmental Council, National Speleological Society, The Nature Conservancy, World Wildlife Fund, 2001.

Censusing of the federal endangered species, the Illinois cave amphipod Gammarus acherondytes. Illinois Department of Natural Resources, Endangered Wildlife Program, and U.S. Department of the Interior, Fish & Wildlife Service, 2001.

Evaluation and description of new cavernicolous species from Indiana
Indiana Department of Natural Resources, Natural Heritage Program, 1999-2000.

Evaluation of the status of the subterranean isopod Caecidotea spatulata. Columbia Quarry Company, Falling Spring Quarry Company, Illinois Department of Natural Resources, Endangered Wildlife Program, 2000.

Development of a non-lethal census method for the Illinois cave amphipod. U.S. Department of the Interior, Fish & Wildlife Service, Illinois Department of Natural Resources, Illinois Endangered Wildlife Program, 2000.

Description of a new species of bathynellid from Blue River, Indiana. U.S. National Museum of Natural History, Smithsonian Institution, 2000.

Ecoregional plan for subterranean invertebrates of the Interior Low Plateaus. The Nature Conservancy, 1999.

Environmental evaluation and bioinventory of aquatic cave systems in proposed suburban areas of Harrison County, Indiana. U.S. Department of the Interior, Fish & Wildlife Service, Ohio River Valley Ecosystem. 1997-1998.

Bioinventory of caves and springs of the Illinois sinkhole plain karst. The Nature Conservancy, U.S. Department of the Interior, Fish & Wildlife Service, 1998-1999

Inventory of the subterranean biota threatened by the urbanization of Clark and Floyd counties, Indiana, Non-game and Endangered Wildlife Program, Indiana Department of Natural Resources, 1996.

Bioinventory of caves, springs and groundwaters of the Blue River Bioreserve of southern

Indiana. The Nature Conservancy, Indiana Department of Natural Resources, Natural Heritage Program and Endangered Wildlife Program, and U.S. Department of the Interior, Geological Survey Species at Risk Program, 1995-1999.

Inventory of the troglobitic fauna of the Crosley State Fish and Wildlife Area, Jennings County, Indiana. Non-game and Endangered Wildlife Program, Indiana Department of Natural Resources, 1994-1995.

Inventory of the potentially endangered or threatened subterranean aquatic Invertebrates of Indiana. Final Report, Non-game and Endangered Wildlife Program, Indiana Department of Natural Resources, 1993.

Lost River cave and karst biological survey. Final Report, U.S. Army Corps of Engineers, Louisville District, Contract No. DACW27-94-M-0110, 1993-1994.

Reports

Lewis, Julian J. and Salisa L. Lewis. 2019. Interstate 69 Evansville to Indianapolis Section 4 Karst Fauna: Post-construction Evaluation. Indiana Department of Transportation in association with Lochmueller Associates, 71 pages.

Lewis, Julian . 2018. Evaluation and description of four new species of cavernicolous isopods of the genus Lirceus. Virginia Department of Recreation and Conservation and U. S. Fish and Wildlife Service, 42 pages.

Lewis, Julian J. 2017. Evaluation of the taxonomic status of the Lee County Cave Isopod, Lirceus usdagalun. Virginia Department of Recreation and Conservation and U. S. Fish and Wildlife Service, 40 pages.

Lewis, Julian J. 2017. Evaluation of sinkhole communities and their environments on the Hoosier National Forest. Hoosier National Forest, U. S. D. A. Forest Service, 132 pages.

Subterranean fauna inhabiting selected caves and springs of the Bernheim Arboretum and Research Forest. Bernheim Arboretum and Research Forest, 47 pages.

Lewis, Julian J. and Salisa L. Lewis. 2016. Pre-listing evaluation of populations and habitats of four species of Kentucky cave beetles (*Pseudanophthalmus*): Results of 2016 field work U.S. Fish and Wildlife Service and Kentucky Natural Land Trust, 39 pages.

Lewis, Julian J. and Salisa L. Lewis. 2015. Pre-listing evaluation of populations and habitats of four species of Kentucky cave beetles (*Pseudanophthalmus*). U.S. Fish and Wildlife Service and Kentucky Natural Land Trust, 38 pages.

Lewis, Julian J., Salisa L. Lewis and Peggy Nims. 2015. Observations on the ecology of Hidden River Cave: Bioinventory, community census and water quality analysis. Kentucky

- Heritage Land Conservation Fund and American Cave Conservation Association, 59 pages.
- Lewis, Julian J. and Salisa L. Lewis. 2015. The fauna of Boone Cave, Owen County, Indiana. The Nature Conservancy and Indiana Natural Heritage Program, 34 pages.
- Lewis, Julian J. and Salisa L. Lewis. 2015. Comparative community censuses of cave streams of Big Oaks National Wildlife Refuge. Final Report, U.S. Fish & Wildlife Service and Indiana Natural Heritage Program, 43 pages.
- Lewis, Julian J. and Salisa L. Lewis. 2014. The 2014 census of Gammarus acherondytes Communities in southwestern Illinois. Final Report, Endangered Species Program, U.S. Fish & Wildlife Service, and Endangered Species Program, Illinois Department of Natural Resources, 40 pages + appendices.
- Lewis, Julian J. and Salisa L. Lewis. 2012. Subterranean fauna of the Hoosier National Forest: Patoka Lake and Lost River tracts. Hoosier National Forest, U.S. D. A. Forest Service, 136 pages.
- Lewis, Julian J. and Salisa L. Lewis. 2011. The 2011 census of Gammarus acherondytes Communities in southwestern Illinois. Final Report, Endangered Species Program, U.S. Fish & Wildlife Service, and Endangered Species Program, Illinois Department of Natural Resources, 29 pages + appendices.
- Lewis, Julian J. 2011. Conservation assessment of subterranean communities of the Hoosier National Forest. Hoosier National Forest, U.S. D. A. Forest Service, 60 pages.
- Lewis, Julian J. 2010. Deposition, Dickson Landfill. Natural Resources Defense Council, 265 pages.
- Lewis, Julian J. 2010. Expert Witness Report, Dickson Landfill. Natural Resources Defense Council.
- Lewis, Julian J. and Salisa L. Lewis. 2010. Biological inventory of the Crumps Cave preserve, Warren County, Kentucky. Final Report to Western Kentucky University.
- Lewis, Julian J. and Salisa L. Lewis. 2009. The subterranean fauna of the Hoosier National Forest. Final Report, U.S. Department of Agriculture, Forest Service, 127 pages.
- Lewis, Julian J. and Salisa L. Lewis. 2008. The subterranean fauna of the Hoosier National Forest. Final Report, U.S. Department of Agriculture, Forest Service, 186 pages.
- Lewis, Julian J. and Salisa L. Lewis. 2008. The fauna of Sullivan Cave, Lawrence County, Indiana. Final Report, Indiana Department of Natural Resources, Division of Nature Preserves, 22 pages.

- Lewis, Julian J. and Salisa L. Lewis. 2007. The 2007 census of Gammarus acherondytes Communities in southwestern Illinois. Final report, U.S. Fish and Wildlife Service and Endangered Species Program, Illinois Department of Natural Resources.
- Lewis, Julian J. and Salisa L. Lewis. 2007. Subterranean fauna of selected caves of central Tennessee. The Nature Conservancy, 2006-2007.
- Lewis, Julian J. 2007. Biological reconnaissance of fens associated with Pigeon River State Fish & Wildlife Area. Indiana Department of Natural Resources, Division of Nature Preserves,
- Lewis, Julian J. 2006. Classification and recommendations for the Indiana DNR list of Threatened and Endangered Species. Final Report, Division of Nature Preserves, Indiana Department of Natural Resources, 18 pages.
- Lewis, Julian J. and Salisa L. Lewis. 2006. Cave fauna of the I69 Corridor in Monroe County, Indiana, Section 4. Environmental Impact Statement, Ecological Solutions and Innovations.
- Lewis, Julian J. and Salisa L. Lewis. 2006. Subterranean fauna of the Robinson Ladder Cave Preserve, Crawford County, Indiana. Indiana Department of Natural Resources, Division of Nature Preserves.
- Lewis, Julian J. and Salisa L. Lewis. 2006. Subterranean fauna of the Buddha Karst Preserve, Lawrence County, Indiana. Indiana Department of Natural Resources, Division of Nature Preserves, 19 pages.
- Lewis, Julian J. 2005. Bioinventory of the caves of the South Cumberlands Project Area. Final Report to The Nature Conservancy of Tennessee, 154 pages.
- Lewis, Julian J. 2005. Cave fauna of the I69 Corridor in Monroe County, Indiana, Section 5. Environmental Impact Statement, Baker Engineering, Inc. and Ozark Underground Laboratory.
- Lewis, Julian J. and Salisa L. Lewis. 2005. Survey for the Kentucky Cave Shrimp in the Graham Springs Groundwater Basin in the vicinity of the proposed I-65 to US 31W connector KYTC Item No.: 3-16.00 in Warren Co., Kentucky, 27 pages.
- Lewis, Julian J. and Salisa L. Lewis. 2005. Bioinventory of the subterranean fauna of Tims Ford State Park, Franklin County, Tennessee. Tennessee Natural Heritage Program, 28 pages.
- Lewis, Julian J., Ronald Burns and Salisa Lewis. 2004. The subterranean fauna of the Hoosier National Forest. U.S. Department of Agriculture, Forest Service, 190 pages.
- Lewis, Julian J. 2003. The 2003 non-lethal censusing of Gammarus acherondytes communities in southwestern Illinois. Final report, U.S. Fish and Wildlife

- Service and Endangered Species Program, Illinois Department of Natural Resources, 62 pages.
- Lewis, Julian J. and Salisa T. Rafail. 2003. The subterranean fauna of Leonard Springs Nature Park (Monroe County, Indiana). Final report, City of Bloomington, Department of Parks and Recreation, 37 pages.
- Lewis, Julian J. and Salisa T. Rafail. 2002. The subterranean fauna of the Big Oaks National Wildlife Refuge. U. S. Department of the Interior, Fish & Wildlife Service, Indiana Department of Natural Resources, Natural Heritage Program, 77 pages.
- Lewis, Julian J., Ronald Burns and Salisa Rafail. 2002. The subterranean fauna of the Hoosier National Forest. U.S. Department of Agriculture, Forest Service, 115 pages.
- Lewis, Julian J. 2002. Status and Distribution Surveys for Rare Cave-Dependent Organisms Recently Identified from the Rumbling Falls Cave System, Van Buren County, Tennessee. U. S. Department of the Interior, Fish & Wildlife Service, 46 pages.
- Lewis, Julian J. 2001. A Biological Reconnaissance of the Rumbling Falls Cave System, Van Buren County, Tennessee. Tennessee Environmental Council, World Wildlife Fund, National Speleological Society, The Nature Conservancy.
- Lewis, Julian J. 2001. Establishing population sizes for the Illinois cave amphipod, Gammarus acherondytes, in cave stream communities in the sinkhole plain karst of southwestern Illinois. Final report, U.S. Fish and Wildlife Service and Endangered Species Program, Illinois Department of Natural Resources, 18 pages + appendix.
- Lewis, Julian J. 2000. Establishing a methodology for non-lethal censusing of Gammarus acherondytes populations in cave stream communities of southwestern Illinois. Final report, U.S. Fish and Wildlife Service and Endangered Species Program, Illinois Department of Natural Resources, 35 pages + appendix.
- Lewis, Julian J. 2000. An evaluation of the status of the aquatic isopod Caecidotea spatulata in the vicinity of the Columbia Quarry Company Dupo Plant 9, St. Clair County, Illinois. Final Report, Illinois Department of Natural Resources, Columbia Quarry Company, Casper Stolle Quarry, 22 pages.
- Lewis, Julian J. 1999. The subterranean fauna of the Interior Low Plateaus. Final report, Interior Low Plateaus Ecoregional Plan, The Nature Conservancy, 40 pages.
- Lewis, Julian J. 1998. The subterranean fauna of the Blue River Area. Final Report, The Nature Conservancy, Indiana Natural Heritage Program, & U.S.G.S Species at Risk Program, Volume I, 267 pages; Volume II (map portfolio) 60 pages.
- Lewis, Julian J. and Thomas P. Sollman. 1998. Groundwater monitoring in significant aquatic caves that lie beneath impending residential developments in the Blue River Basin of southern Indiana. Final report, Ohio River Valley Ecosystem, U.S. Fish & Wildlife Service and Indiana

Karst Conservancy, 89 pages.

Lewis, Julian J. 1996. Inventory of the subterranean biota threatened by urbanization of Clark and Floyd Counties, Indiana. Final report, Non-game and Endangered Wildlife Program, Division of Fish and Wildlife, Indiana Department of Natural Resources, 71 pages.

Lewis, Julian J. 1995. Inventory of the troglobitic fauna of the Crosley State Fish and Wildlife Area, Jennings County, Indiana. Special Project of the Non-game and Endangered Wildlife Program, Indiana Department of Natural Resources, 71 pages.

Lewis, Julian J. 1994. Lost River cave and karst biological survey. Louisville District, U.S. Army Corps of Engineers, Environmental Analysis Branch, Contract DACW27-94-M-0110, 63 pages.

Lewis, Julian J. 1993. Inventory of the potentially endangered or threatened subterranean aquatic invertebrates of Indiana, with censusing of Antroselates spiralis in the Sharpe Creek Valley. Special Project of the Non-game and Endangered Wildlife Program, Indiana Department of Natural Resources, Division of Fish and Wildlife, 132 pages.

G3

Genes | Genomes | Genetics

A draft genome assembly for the eastern fox squirrel, *Sciurus niger*

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Abstract

The eastern fox squirrel, *Sciurus niger*, exhibits marked geographic variation in size and coat color, is a model organism for studies of behavior and ecology, and a potential model for investigating physiological solutions to human porphyrias. We assembled a genome using Illumina HiSeq, PacBio SMRT, and Oxford Nanopore MinION sequencing platforms. Together, the sequencing data resulted in a draft genome of 2.99 Gb, containing 32,830 scaffolds with an average size of 90.9 Kb and N₅₀ of 183.8 Kb. Genome completeness was estimated to be 93.78%. A total of 24,443 protein-encoding genes were predicted from the assembly and 23,079 (94.42%) were annotated. Repeat elements comprised an estimated 38.49% of the genome, with the majority being LINEs (13.92%), SINEs (6.04%), and LTR elements. The topology of the species tree reconstructed using maximum-likelihood phylogenetic analysis was congruent with those of previous studies. This genome assembly can prove useful for comparative studies of genome structure and function in this rapidly diversifying lineage of mammals, for studies of population genomics and adaptation, and for biomedical research. Predicted amino acid sequence alignments for genes affecting heme biosynthesis, color vision, and hibernation showed point mutations and indels that may affect protein function and ecological adaptation.

Keywords: whole-genome sequencing; *de novo* assembly; tree squirrels; candidate genes; heme biosynthesis; color vision; hibernation; eastern fox squirrel; *Sciurus niger*; Sciuridae

Introduction

Squirrels are among the most familiar wild mammals in the world (Thorington *et al.* 2012), and tree squirrels (Sciuridae; Sciurini) comprise one of the most rapidly diversifying lineages of mammals (de Abreu *et al.* 2020). The eastern fox squirrel (*Sciurus niger*; hereafter fox squirrel) is widespread over most of North America east of the Rocky Mountains (Koprowski 1994). This species exhibits marked geographic variation in size (from 500 to 1500 g) and striking patterns of geographically structured variation in coat color (Weigl *et al.* 1998). In addition, fox squirrels exhibit melanism as the result of mutations at two independent loci (McRobie *et al.* 2019).

Fox squirrels are also potential models for investigating physiological solutions to human porphyrias, diseases caused by defects in the enzymes of the heme biosynthetic pathway, because fox squirrels seem to be adapted to accumulate porphyrins without injurious consequences (Levin and Flyger 1973). Fox squirrels sequester excess uroporphyrin I in their bones, which then fluoresce pink under ultraviolet light (Turner 1937; Flyger and Levin 1977). Even bones preserved in archaeological and fossil deposits fluoresce, indicating that this condition has persisted in fox squirrels for at least several thousand years (Dooley and

Moncrief 2012; Moncrief and Dooley 2013). Elucidating the underlying genetic network that allows fox squirrels to avoid porphyrin pathogenicity may complement the use of laboratory models and provide new insights into the treatment of these disorders in humans (de Oliveira Neves and Galván 2020), which may drive a broad spectrum of neurological symptoms (O'Malley *et al.* 2018).

Squirrels are highly visual rodents that may be excellent model systems for understanding mechanisms of function and disease in the human visual system (Van Hooser and Nelson 2006). They use vision for navigating in their environment, predator avoidance, and foraging for food. Unlike the more traditional mouse and rat model systems, most squirrel species are diurnal with cone-dominated retinas, similar to those of primates, and have excellent dichromatic color vision that is mediated by green and blue cones. Many basic anatomical and physiological properties in the visual system of squirrels have now been described, permitting investigations of cellular mechanisms. While the genes responsible for color vision deficiencies in humans are reasonably well known (El Moussawi *et al.* 2021), their variation within and among squirrel species remain uncharacterized.

Hibernation in squirrels is a dynamic phenotype, with timing set by an annual clock. Noting that captive 13-lined ground

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Table 1 Publicly available genomes used for phylogenetic analysis of *Sciurus niger* (eastern fox squirrel)

Species	Common name	NCBI accession	Reference
<i>Ictidomys tridecemlineatus</i>	Thirteen-lined ground squirrel	GCF_000236235.1	Lindblad-Toh et al. (2011) and Broad Institute (2021a)
<i>Urocyon parryi</i>	Arctic ground squirrel	GCF_003426925.1	Goropashnaya et al. (2020)
<i>Spermophilus dauricus</i>	Daurian ground squirrel	GCA_002406435.1	Koepfli et al. (2015) and Genome 10K Community of Scientists (2021)
<i>Marmota monax</i>	Woodchuck or groundhog	GCA_901343595.1	Alioto et al. (2019)
<i>Xerus inauris</i>	South African ground squirrel	GCA_004024805.1	Broad Institute (2021b)
<i>Sciurus carolinensis</i>	Eastern gray squirrel	GCA_902686445.2	Mead et al. (2020b)
<i>Sciurus vulgaris</i>	Eurasian red squirrel	GCA_902686455.2	Mead et al. (2020a)
<i>Aplodontia rufa</i>	Mountain beaver	GCA_004027875.1	Broad Institute (2021b)

squirrels (*Ictidomys tridecemlineatus*) exhibited variation in the seasonal onset of hibernation, Grabek et al. (2019) hypothesized that genetic factors drive variation in hibernation timing. They applied genotyping-by-sequencing to characterize genetic variation in 153 individuals and estimated high heritability (>61%) for hibernation onset. Applying a genome-wide scan with 46,996 SNP variants, they identified two loci significantly and 12 loci suggestively associated with hibernation onset. At the most significant locus, whole-genome resequencing revealed a putative causal variant in the promoter of *FAM204A*. Expression quantitative trait loci analyses revealed gene associations for 8 of the 14 loci.

To date, genomes have been published for five ground squirrels (Sciuridae; Xerini, Marmotini), and two tree squirrels in the genus *Sciurus*: the Eurasian red squirrel (*Sciurus vulgaris*) and the eastern gray squirrel (*Sciurus carolinensis*, Table 1). The fox squirrel genome assembly that we report will serve as a reference genome for this species, and it will allow further genomic, proteomic, and phylogenetic comparisons among tree squirrels and other sciurids, as well as other rodents and mammals.

Materials and methods

Sample and DNA extraction

A male fox squirrel was obtained from the wild in Allegan County, Michigan (coordinates 42.641749°N, 85.886986°W) on December 21, 2018 and archived as a voucher specimen at the Virginia Museum of Natural History (NDM4471 and VMNH3098). The tissue sample from skeletal muscle was stored in RNAlater solution (ThermoFisher Scientific) and frozen at -80°C until DNA extraction. The genomic DNA was isolated using Puregene Cell & Tissue Kit (Qiagen) following the manufacturer's protocol for purification of total DNA from animal tissues.

Genome assembly and sequencing

DNA sequence reads were generated using three sequencing platforms. A TruSeq DNA library was prepared and sequenced on the HiSeq platform following Illumina's protocols, and two lanes of 2 × 150-bp paired-end reads were generated (242.8 Gb). A PacBio SMRT (single molecule real time) library with Sequel chemistry was prepared and sequenced on three SMRT cells (19.0 Gb). Finally, genomic DNA was sequenced using the Oxford Nanopore MinION system. Libraries were made using the VolTRAX Sequencing Kit (VSK-VSK002) and were sequenced on two FLO-MIN 107 R9 flow cells (18.3 Gb). The raw sequence reads from Illumina, PacBio, and Oxford Nanopore were used as the input to generate a *de novo* assembly using the MaSuRCA assembler v3.3.2 (Zimin et al. 2013).

Gene prediction and annotation

Repeat families were identified by using the *de novo* modeling package RepeatModeler v1.0.8 (<http://www.repeatmasker.org/RepeatModeler>). Then, the *de novo* identified repeat sequences were combined with manually selected mammalian repeats from RepBase v22.12 (<https://www.girinst.org/repbase>) and a customized repeat library was formed. Before the gene prediction, the draft assembly was first masked using RepeatMasker v4.0.3 (<http://www.repeatmasker.org/>) with parameters set to “-s -a -nolow” and using the customized repeat library. Protein-encoding genes were predicted using MAKER2 (Holt and Yandell 2011), which integrates prediction methods including BLASTX, SNAP (Korf 2004), and Augustus (Stanke and Waack 2003). The Augustus model file was generated by training the core genes of Mammalia from the genome completeness assessment tool BUSCO (Benchmark Universal Single-Copy Orthologs; Simão et al. 2015). Predicted genes were subsequently used as query sequences in a BLASTX database search of the NR database (the non-redundant database, <http://www.ncbi.nlm.nih.gov>) with *e*-value cutoff of $1e^{-20}$ and percent identity cutoff of 50. The top hit of BLASTX alignments with the lowest *e*-value was used to annotate the query genes.

Genome completeness

For genome completeness estimation, BUSCO (Simão et al. 2015) was used to assess 4,104 universal single-copy orthologs of Mammalia in the assembly.

Phylogenetic analyses

Protein sequences of 4,104 Mammalia core genes were extracted from BUSCO (Simão et al. 2015) for analysis of *S. niger* and eight other publicly available genomes (Table 1). Sequences of these core genes were concatenated and then aligned using MAFFT v. 7.475 (Rozevicki et al. 2019). The phylogenetic tree was reconstructed using Bayesian inference in BEAST 2.51 (Bouckaert et al. 2014). In the BEAST analysis, a strict clock was selected, and the Yule process of speciation was selected as tree prior. The BEAST Markov chain Monte Carlo run was conducted for 5 million generations, and the first half-million generations were set as burn-in. The consensus tree was inferred by TreeAnnotator 2.51 (Bouckaert et al. 2014). The divergence time of 52.30 MYA (CI 48.94–55.67 MYA, Menéndez et al. 2021) between *Aplodontia rufa* and Sciuridae was used for the calibration.

Sequence alignments

Alignments of candidate genes for heme biosynthesis, color vision, and control of hibernation were inspected for variation among *Sciurus* sp. and other sciurids. Details of gene function were obtained from GeneCards (2021), a database of information on all annotated and predicted human genes.

Table 2 Summary of the composite genome assembly of *Sciurus niger* (eastern fox squirrel)

Assembly attributes	
Total size	2,985,236,946 bp
No. of scaffolds	32,830
No. of scaffolds > 10 Kb	30,561
Scaffold N ₅₀	183,784 bp
Longest scaffold	1,891,617 bp
GC content	44.00%
Gene annotation	
No. of predicted genes	24,443
No. (percentage) of annotated genes	23,079 (94.42%)
Completeness (BUSCO)	
Complete	83.74%
Fragmented	10.04%
Missed	6.22%

Table 3 Summary statistics for 24,443 predicted protein-coding genes in *Sciurus niger* (eastern fox squirrel)

Statistic	Number
Average gene length (bp)	17,072
Average CDS length (bp)	1,336
Average exons per gene	6.9
Average exon length (bp)	195
Average intron length (bp)	2,677

Results and discussion

Assembly and annotation of the fox squirrel genome

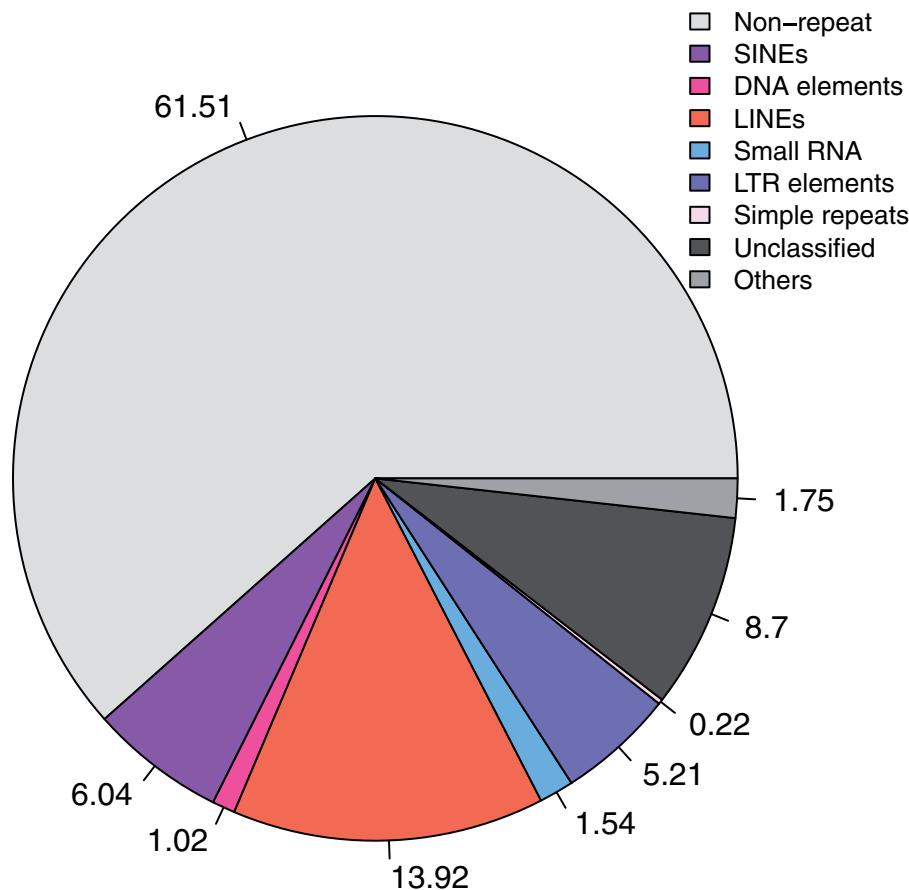
A total of 242.8 Gb Illumina, 18.0 Gb PacBio, and 18.3 Gb Oxford Nanopore sequencing data were generated. Together, the sequencing data resulted in a draft genome of 2.99 Gb, which contains 32,830 scaffolds with an average size of 90.9 Kb and N₅₀ of 183.8 Kb (Table 2). The genome completeness estimated by BUSCO (Simão et al. 2015) was 83.74% (C) + 10.04% (F) [Complete = 83.74% (Single = 81.94%, Duplicated = 1.80%), Fragmented = 10.04%, Missed = 6.22%, Gene = 4,104; Table 2]. A total of 24,443 protein-encoding genes were predicted from the assembly (Table 3), and 23,079 (94.42%) were annotated (Table 2).

Repeated genomic elements

The estimated percentage of repeat elements in the genome is 38.49% (Figure 1 and Supplementary File S1) with the majority being LINEs (13.92%), SINEs (6.04%), and LTR elements (5.21%).

Phylogenomic relationships

Maximum-likelihood phylogenetic analysis of relationships of *S. niger* and seven other sciurids, using mountain beaver (*A. rufa*) as an outgroup, generated a species tree (Figure 2). *Sciurus niger* clustered most closely with *S. carolinensis* and *S. vulgaris*, with an estimated divergence time of 19.27 MYA. The congeneric tree

**Figure 1** Repeat content of the *Sciurus niger* (eastern fox squirrel) genome.

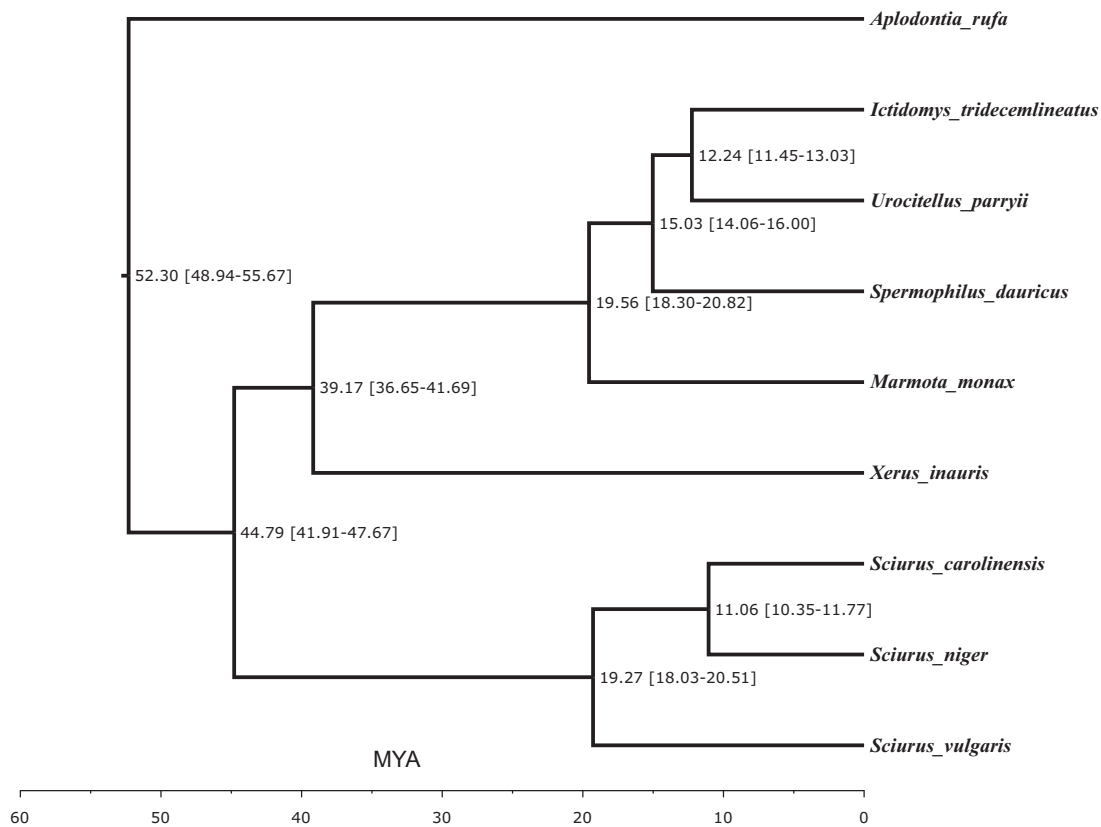


Figure 2 Molecular phylogeny of eight squirrel species, including *Sciurus niger* (eastern fox squirrel), rooted using *Aplodontia rufa*, mountain beaver. Branch lengths in millions of years ago (\pm 95% CI) were estimated on the basis of numbers of amino acid substitutions per site.

squirrels clustered separately from the ground squirrels, with an estimated divergence time of 44.79 MYA. The topology of this species tree is congruent with those of previous studies (Zelditch *et al.* 2015; Menéndez *et al.* 2021).

Sequence alignments for selected genes

Predicted amino acid sequence alignments for 17 genes (9 involved with heme biosynthesis, 5 with color vision, and 3 with regulation of hibernation) are presented in [Supplementary Files S2–S4](#), respectively. Point differences among sequences were observed in all sequence alignments among *Sciurus* species, as well as among *Sciurus* sp. and the other rodents. Amino acid sequences were highly conserved among members of the genus *Sciurus* at ALAS1, ALAS2, FECH, UROS, and among all species studied at CPOX, GNAT2, EXOC4, and large segments of CNGA3 and OPN1MW. We observed insertions or deletions of multiple contiguous amino acids among *Sciurus* sp. at ALAD, HMBS, PPOX, UROD, UROS, ATF6, PDE6C, CHCHD3, and FAM204A. We observed insertions or deletions of multiple contiguous amino acids among *Sciurus* sp. and the other rodents at ALAD, ALAS2, FECH, HMBS, PPOX, UROD, ATF6, CNGA3, PDE6C, CHCHD3, and FAM204A. Future work might address the functional significance of these differences in terms of protein function and ecological adaptation.

Data availability

This genome assembly has been deposited at DDBJ/ENA/GenBank under the accession JAHUXG000000000. The version described in this paper is version JAHUXG010000000. All sequencing

data were deposited at NCBI SRA (accession number: PRJNA744496).

[Supplementary material](#) is available at G3 online.

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Conflicts of interest

The authors declare that there is no conflict of interest.

Literature cited

- Alioto TS, Cruz F, Gomez-Garrido J, Triyatni M, Gut M, *et al.* 2019. The genome sequence of the eastern woodchuck (*Marmota monax*): a preclinical animal model for chronic hepatitis B. *G3* (Bethesda). 9: 3943–3952.
- Bouckaert R, Heled J, Kuhnert D, Vaughan T, Wu CH, *et al.* 2014. BEAST 2: a software platform for Bayesian evolutionary analysis. *PLoS Comput Biol.* 10:e1003537.
- Broad Institute. 2021a. 29 Mammals Project. (Accessed: 2021 April 26). <https://www.broadinstitute.org/mammals-models/29-mammals-project>.

- Broad Institute. 2021b. The 200 Mammals Variant Data. (Accessed: 2021 April 26). <https://www.broadinstitute.org/200-mammals-variant-data>.
- de Abreu EF, Jr, Pavan SE, Tsuchiya MTN, Wilson DE, Percequillo AR, et al. 2020. Museomics of tree squirrels: a dense taxon sampling of mitogenomes reveals hidden diversity, phenotypic convergence, and the need of a taxonomic overhaul. *BMC Evol Biol.* 20:77. doi:10.1186/s12862-020-01639-y.
- de Oliveira Neves AC, Galván I. 2020. Models for human porphyrias: have animals in the wild been overlooked? Some birds and mammals accumulate significant amounts of porphyrins in the body without showing the injurious symptoms observed in human porphyrias. *Bioessays.* 42:e2000155. doi:10.1002/bies.202000155.
- Dooley AC, Jr, Moncrief ND. 2012. Fluorescence provides evidence of congenital erythropoietic porphyria in 7000-year-old specimens of the eastern fox squirrel (*Sciurus niger*) from the Devil's Den. *J Vert Paleo.* 32:495–497.
- El Moussawi Z, Boueiri M, Al-Haddad C. 2021. Gene therapy in color vision deficiency: a review. *Int Ophthalmol.* 41:1917–1927.
- Flyger V, Levin EY. 1977. Animal model: normal porphyria of fox squirrels (*Sciurus niger*). *Am J Pathol.* 87:269–272.
- GeneCards. 2021. GeneCards: The Human Gene Database. (Accessed: 2021 June 7). <https://www.genecards.org/>.
- Genome 10K Community of Scientists. 2021. Genome 10K Project. (Accessed: 2021 April 26). <https://genome10k.soe.ucsc.edu/>.
- Goropashnaya AV, Barnes BM, Fedorov VB. 2020. Transcriptional changes in muscle of hibernating arctic ground squirrels (*Urocitellus parryii*): implications for attenuation of disuse muscle atrophy. *Sci Rep.* 10:9010.
- Grabek KR, Cooke TF, Epperson LE, Spees KK, Cabral GF, et al. 2019. Genetic variation drives seasonal onset of hibernation in the 13-lined ground squirrel. *Commun Biol.* 2:1–13.
- Holt C, Yandell M. 2011. MAKER2: an annotation pipeline and genome-database management tool for second-generation genome projects. *BMC Bioinformatics.* 12:491.
- Koepfli KP, Paten B, O'Brien SJ; Genome 10K Community of Scientists 2015. The Genome 10K Project: a way forward. *Annu Rev Anim Biosci.* 3:57–111.
- Koprowski JL. 1994. *Sciurus niger*. *Mammal Spec.* 479:1–9.
- Korf I. 2004. Gene finding in novel genomes. *BMC Bioinformatics.* 5:59.
- Levin EY, Flyger V. 1973. Erythropoietic porphyria of the fox squirrel *Sciurus niger*. *J Clin Invest.* 52:96–105.
- Lindblad-Toh K, Garber M, Zuk O, Lin MF, Parker BJ, et al.; Genome Institute at Washington University. 2011. A high-resolution map of human evolutionary constraint using 29 mammals. *Nature.* 478:476–482.
- McRobie HR, Moncrief ND, Mundy NI. 2019. Multiple origins of melanism in two species of North American tree squirrel (*Sciurus*). *BMC Evol Biol.* 19:140. doi:10.1186/s12862-019-1471-7.
- Mead D, Fingland K, Cripps R, Miguez RP, Smith M, et al. 2020a. The genome sequence of the Eurasian red squirrel, *Sciurus vulgaris* Linnaeus 1758. *Wellcome Open Res.* 5:18. doi:10.12688/wellcomeopenres.15679.1.
- Mead D, Fingland K, Cripps R, Miguez RP, Smith M, et al. 2020b. The genome sequence of the eastern grey squirrel. *Wellcome Open Res.* 5:27. doi:10.12688/wellcomeopenres.15721.1.
- Menéndez I, Gómez Cano AR, Cantalapedra JL, Peláez-Campomanes P, Álvarez-Sierra MÁ, et al. 2021. A multi-layered approach to the diversification of squirrels. *Mammal Rev.* 51:66–81.
- Moncrief ND, Dooley AC, Jr. 2013. Using fluorescence of bones and teeth to detect remains of the eastern fox squirrel (*Sciurus niger*) in archaeological deposits. *Southeast Archaeo.* 32:46–53.
- O'Malley R, Rao G, Stein P, Bandmann O. 2018. Porphyria: often discussed but too often missed. *Pract Neurol.* 18:352–358.
- Rozewicki J, Li S, Amada KM, Standley DM, Katoh K. 2019. MAFFT-DASH: integrated protein sequence and structural alignment. *Nucleic Acids Res.* 47:W5–W10.
- Simão FA, Waterhouse RM, Ioannidis P, Kriventseva EV, Zdobnov EM. 2015. BUSCO: assessing genome assembly and annotation completeness with single-copy orthologs. *Bioinformatics.* 31:3210–3212.
- Stanke M, Waack S. 2003. Gene prediction with a hidden Markov model and a new intron submodel. *Bioinformatics.* 19(Suppl. 2):ii215–ii225.
- Thorington RW, Jr, Koprowski JL, Steele MA, Whatton JF. 2012. *Squirrels of the World*. Baltimore, MD: Johns Hopkins University Press. p. 459.
- Turner WJ. 1937. Studies on porphyria. 1. Observations on the fox-squirrel, *Sciurus niger*. *J Biol Chem.* 118:519–530.
- Van Hooser SD, Nelson SB. 2006. The squirrel as a rodent model of the human visual system. *Vis Neurosci.* 23:765–778.
- Weigl PD, Sherman LJ, Williams AI, Steele MA, Weaver DS. 1998. Geographic variation in the fox squirrel (*Sciurus niger*): a consideration of size clines, habitat vegetation, food habits and historical biogeography. In: MA Steele, JF Merritt, DA Zegers, editors. *Ecology and Evolutionary Biology of Tree Squirrels*. Martinsville, VA: Virginia Museum of Natural History Special Publication 6. p. 171–184.
- Zelditch ML, Li J, Tran LAP, Swiderski DL. 2015. Relationships of diversity, disparity, and their evolutionary rates in squirrels (*Sciuridae*). *Evolution.* 69:1284–1300.
- Zimin AV, Marçais G, Puiu D, Roberts M, Salzberg SL, et al. 2013. The MaSuRCA genome assembler. *Bioinformatics.* 29:2669–2677.

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Annotated Checklist of Terrestrial Mammals of the Virginia Barrier Islands and the Adjacent Delmarva Peninsula Mainland

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Abstract - The Virginia barrier islands lie along the seaward margin of the southern Delmarva Peninsula in the mid-Atlantic region of the United States, and collectively they comprise an internationally recognized biosphere reserve. Despite this recognition, no comprehensive checklist of mammals exists for the islands or the adjacent Delmarva Peninsula mainland. Herein we report on the species composition of terrestrial mammals of this region based on (1) a search of museum collections, (2) a compilation of literature sources and personal communications, and (3) our own extensive fieldwork (1975–2020). We documented 6 orders, 12 families, and 25 species of native terrestrial mammals. The islands are depauperate in comparison with the mainland, with several native species missing from the islands. We also documented 3 orders, 3 families, and 4 species of non-native mammals that are currently established on the islands. In addition, we herein present a historical overview of livestock species that were introduced to the islands, but (with 1 exception) no longer occur there. European settlement of the mainland and the islands began in the early 1600s; however, permanent human structures have been absent from most of the islands for the past 60+ years, leaving them undeveloped and in a natural state. These islands are undergoing rapid geological and ecological change under the pressure of accelerated sea-level rise associated with climate change. This checklist provides a foundation for future biogeographic studies of mammals in this region and serves as a baseline against which to measure future ecological and distributional changes.

Introduction

The entire coastline of the mid-Atlantic region of the United States is undergoing rapid geological and ecological change under the pressure of accelerated sea-level rise (Boon and Mitchell 2015). Many of the Virginia barrier and marsh islands lying along the seaward margin of the southern Delmarva Peninsula are experiencing unprecedented rates of erosion and migration over sub-decadal time scales (Deaton et al. 2017). Consequent changes in the landscapes of these undeveloped, essentially wild, islands are readily apparent (Wolner et al. 2013, Zinnert et al. 2019).

The first complete checklist of mammals on any of the islands was compiled for Assateague Island by Paradiso and Handley (1965). Dueser et al. (1979)

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subsequently conducted systematic surveys and reported comprehensive lists for 11 of the islands south of Assateague. Since then, numerous studies have contributed to our knowledge of the ecology and genetics of the land mammals that inhabit these islands (Adkins 1980, Cranford and Maly 1990, Dueser and Brown 1980, Dueser and Porter 1986, Dueser and Terwilliger 1987, Dueser et al. 2013, Forsys and Dueser 1993, Forsys and Moncrief 1994, Kirkland and Fleming 1990, Krim et al. 1990, Loxterman et al. 1998, Moncrief and Dueser 2001, Moncrief et al. 2017, Porter and Dueser 1982, Porter et al. 2015, Scott and Dueser 1992). However, with the exception of Paradiso and Handley (1965) and Dueser et al. (1979), there have been no attempts to summarize the entire mammalian species composition for this group of islands.

Annotated checklists provide fundamental information for conservation and management efforts as well as for other analyses, such as those that consider questions related to patterns and drivers of species occurrence (e.g., Svenning et al. 2011, Turvey and Fritz 2011). For this study, we sought to provide (1) a comprehensive list of species of terrestrial mammals for the Virginia barrier islands and the adjacent Delmarva Peninsula mainland; (2) a comprehensive list of islands on which each species is a resident; and (3) details of the multiple lines of evidence we used to compile these lists. Based on 45 years of fieldwork on the islands (1975–2020), this checklist provides a baseline against which to assess the response of the terrestrial mammal fauna to the panoply of ecological changes occurring on the islands.

Study Area

The Delmarva Peninsula includes the state of Delaware, the Eastern Shore of Maryland (Caroline, Cecil, Dorchester, Kent, Queen Annes, Somerset, Talbot, Wicomico, and Worcester counties), and the Eastern Shore of Virginia (Accomack and Northampton counties). This peninsula has clear-cut geographical boundaries, a rich archeological history, a long written record of naturalist observations, and extensive remaining potential habitat for mammalian species (Hogue and Hayes 2015).

The Virginia barrier islands extend ~150 km along the seaward margin of the Peninsula, centered at approximately 37°30'N and 75°40'W in Accomack and Northampton counties, VA (Fig. 1). This land was inhabited by the Accomac and Occohannock people at the time of European settlement (Rountree and Davidson 1997). This 1000-km² landscape is a dynamic, highly fragmented mosaic of open bays, salt marshes, marsh islands, back barriers, and barrier islands that formed during a period of Holocene era sea-level rise ~5000 years ago (Hayden et al. 1991, Newman and Munsart 1968). We have identified 25 barrier and marsh islands for sampling during the time we have been working on the islands (Fig. 1). The islands lie 0.4–12.1 km offshore and vary from 1 to 10 m in elevation and from 14 to 9344 ha in area. Vegetation composition includes emergent sandbars, low-lying marsh, grassland with extensive overwash zones, shrub thickets, and mature forests on elevated islands (McCaffrey and Dueser 1990). The soils are typically poorly drained, loamy soils in the marshes and deep sands on the uplands (Cobb and Smith 1989, Peacock and Edmonds 1994).

The islands are separated by estuarine marshes and bays that connect to the Atlantic Ocean through deep inlets, which are drowned drainage basins (Krantz et al. 2016, Oertel et al. 1989). Moncrief et al. (2017) provided a brief overview of the recent Holocene geologic history of this watery landscape.

As measured from the National Oceanic and Atmospheric Administration (NOAA) Coastal-Change Analysis Program (C-CAP) land-cover data layers for the lower Delmarva Peninsula (Virginia and Maryland) for the year 2001 (<https://coast.noaa.gov/digitalcoast/data/ccapregional.html>), the average distance between nearest-neighbor islands was 808 m (SE = 162.7) and between adjacent islands that are separated by deep, swift-running inlets was 518 m (SE = 83.5). The average distance from the mainland was 5835 m (SE = 745.5; min-max: 351–12,868 m). Given the rates of erosion and accretion in this dynamic environment, the distances

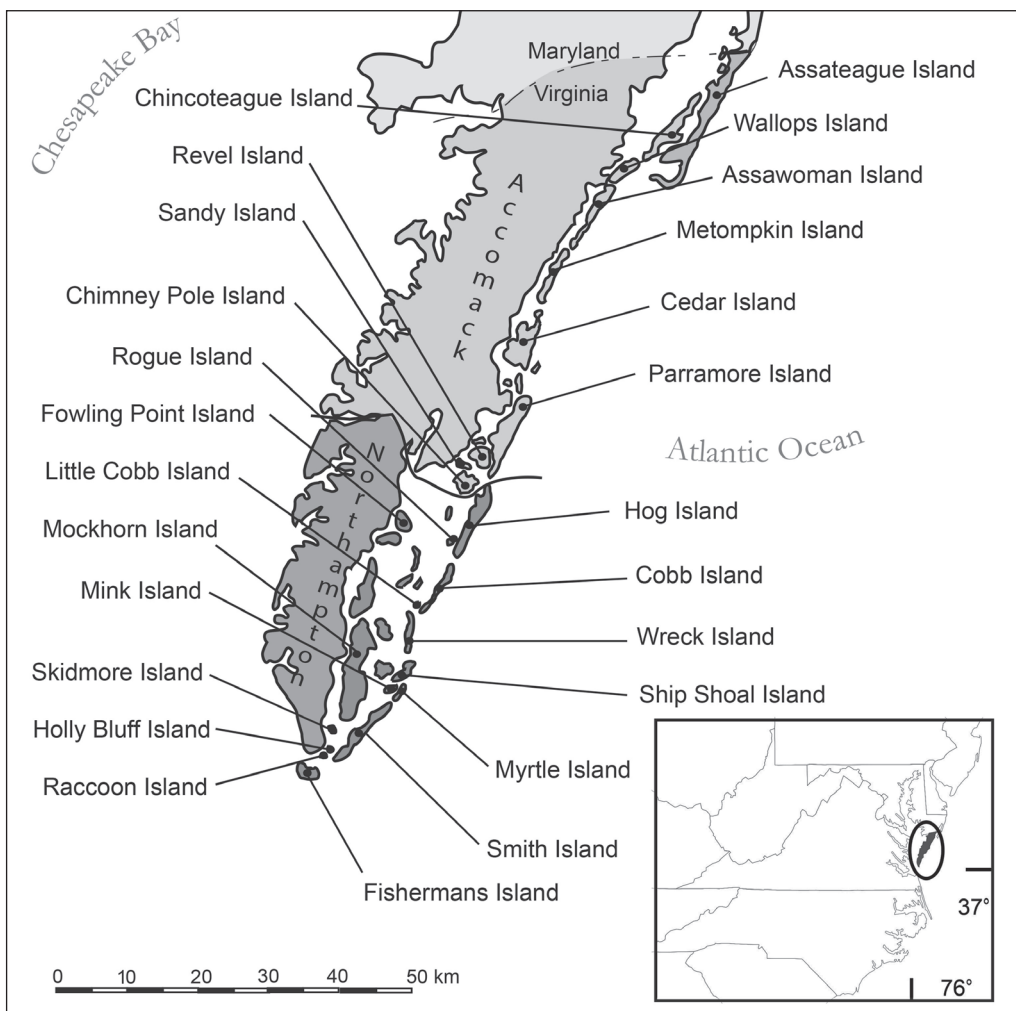


Figure 1. Location of the barrier and marsh islands of the Virginia barrier island complex. Assateague, Chincoteague, and Wallops islands support permanent human residences and facilities, but the other islands lack human structures and exist in an essentially wild state.

between nearest-neighbor islands might be subject to changes on the order of 10s to 100s of meters in any given year.

The 3 northernmost islands (Assateague, Chincoteague and Wallops) have permanent human residences and facilities. Some of the other islands have been occupied sporadically since at least the 1600s, but have been without permanent structures since a series of severe coastal storms in the early 1930s (Badger and Kellam 1989, Barnes and Truitt 1997, Graham 1976a). From the mid-17th into the mid-20th centuries, many of the islands were used to pasture horses, cattle, sheep, and swine (Barnes and Truitt 1997, Graham 1976b). The islands now exist in a natural state, with the evidence of human presence largely absent. Except for a few small, scattered private in-holdings, the islands are held in public ownership by the US Fish and Wildlife Service, or the Commonwealth of Virginia, or are privately owned by The Nature Conservancy (TNC). TNC holdings comprise the Volgenau Virginia Coast Reserve (VCCR), recognized as a National Science Foundation (NSF) Long-Term Ecological Research (LTER) site (Hayden et al. 1991), a Man and the Biosphere Reserve, and a Western Hemisphere International Shorebird Reserve Network site (Badger 1978, 1991, 1997).

The study islands represent a variety of physiographies and vegetation structures: marsh (Chimney Pole, Fowling Point, Mink, Raccoon), grassland (Assawoman, Little Cobb, Metompkin, Myrtle, Sandy, Ship Shoal), shrubland (Cedar, Cobb, Hog, Holly Bluff, Mockhorn, Rogue, Wreck), and forested (Assateague, Chincoteague, Fishermans, Parramore, Revel, Skidmore, Smith, Wallops) islands. Cedar and Hog islands formerly supported forest, but no longer do. Given the effects of area and elevation, habitat complexity on these islands is cumulative, so that forested islands also have areas of shrubland, grassland, and marsh; shrubland islands have grassland and marsh; and grassland islands have marsh (Dueser and Brown 1980). Assateague, Chincoteague, Fishermans, and Wallops islands are connected to the Peninsula mainland by highway bridges, but all the others in this study are accessible only by crossing open tidal waters. Given the relative absence of the usual sources of anthropogenic threat on barrier islands (e.g., development pressure, livestock grazing, and wandering pets; Hice and Schmidly 2002), the Virginia islands provide an ideal natural laboratory for assessing the impacts and implications of natural processes on the structure and function of an intact coastal ecosystem.

Materials and Methods

We compiled collection information for specimens in the Mammal Collection of the Virginia Museum of Natural History (VMNH), and we searched 312 electronic museum databases using the VertNet portal on 16 August 2020. In addition to VMNH, the following institutions report specimens from Accomack and/or Northampton counties, VA: American Museum of Natural History (AMNH); California Academy of Sciences (CAS); Cornell University Museum of Vertebrates (CUMV); The Field Museum of Natural History (FMNH); University of Kansas, Natural History Museum and Biodiversity Research Center (KU); Louisiana State University, Museum of Natural Science (LSUMZ); University of California,

Berkeley, Museum of Vertebrate Zoology (MVZ); North Carolina Museum of Natural Sciences (NCSM); University of Michigan Museum of Zoology (UMMZ); United States National Museum of Natural History (USNM); and University of Washington, Thomas Burke Memorial Washington State Museum (UWBM). In addition, between 1975 and 2020, we conducted live-trapping surveys (more than 45,000 trap nights) and systematic track surveys (more than 400 observer days) on the islands and the adjacent mainland in Accomack and Northampton counties, VA (Dueser et al. 2018, Porter and Dueser 2021). The sandy substrate and generally patchy vegetation make the islands ideal for detecting identifiable tracks and scat, and the low diversity of species reduced the potential for misidentifications. We also compiled and synthesized information from publications and from unpublished reports by colleagues, including capture reports from >100,000 trap nights by USDA Wildlife Services between 2001 and 2018.

We consider a native species to be “resident” on an island based on its persistent occurrence over multiple surveys, which we interpret to be indicative of a self-sustaining population. Furthermore, in most cases we also had evidence of reproduction and recruitment for species we consider to be resident. Based on these same criteria, we consider a non-native species to be “established” on an island. We consider species that we found to be undetectable in multiple recent sampling events or that we detected only infrequently to be “absent” from an island or perhaps only transient; only further sampling can clarify the status of these cases.

Results

All species in Table 1 occur on the Virginia barrier islands and/or the adjacent mainland of the southern Delmarva Peninsula in Accomack and Northampton counties, VA. For each of these, we provide details of their occurrence. Scientific names follow Pagels and Moncrief (2015), and common, or vernacular, names follow Wilson and Reeder (2005).

ORDER DIDELPHIMORPHIA (pouched mammals)

Family Didelphidae (opossums)

Didelphis virginiana Kerr (Virginia Opossum). Specimens from the mainland: Accomack County (USNM). Specimens from Assateague Island (USNM). We have capture records from Assawoman, Metompkin, and Wallops islands, 1 report from Hog Island (Bailey 1946), and capture records from Northampton County. We consider Virginia Opossums to be resident on Assateague and Wallops islands.

ORDER SORICOMORPHA (insectivores)

Family Soricidae (shrews)

Sorex cinereus Kerr (Cinereus Shrew). Specimens from the mainland: Accomack County (MVZ, USNM). Before Moncrief and Dueser (1998) reported the first record of the Cinereus Shrew from Accomack County, there was no evidence of its presence on Virginia’s Eastern Shore. We found no specimens from the islands and have no capture records.

Blarina brevicauda (Say) (Northern Short-tailed Shrew). Specimens from the mainland: Accomack County (MVZ, USNM) and Northampton County (AMNH, USNM, VMNH). In addition, we have capture records from Raccoon Island (Dueser et al. 1979) and Wallops Island (Baker et al. 2015). We consider Northern Short-tailed Shrews to be resident on Wallops Island.

Table 1. Terrestrial mammals of the southern Delmarva Peninsula and Virginia barrier islands, including species that have been introduced (I), those that have colonized the region since European contact (C), and those that have been successfully reintroduced (R) in recent times. For each species, we indicate (1) presence (+) or absence (-) on the mainland of Accomack and/or Northampton counties, VA, in 2020 (Main.); (2) the number of islands on which we believe it to be resident or established as of 2020 (Res.); and (3) the number of islands on which it has been reported but is not resident or established as of 2020 (Rep.).

Order/species	Common name	Main.	Res.	Rep.
Didelphimorphia				
<i>Didelphis virginiana</i>	Virginia Opossum	+	2	3
Soricimorpha				
<i>Sorex cinereus</i>	Cinereus Shrew	+	0	0
<i>Blarina brevicauda</i>	Northern Short-tailed Shrew	+	1	1
<i>Cryptotis parva</i>	North American Least Shrew	+	4	1
<i>Scalopus aquaticus</i>	Eastern Mole	+	0	1
<i>Condylura cristata</i>	Star-nosed Mole	+	0	0
Lagomorpha				
<i>Lepus californicus</i> (I)	Black-tailed Jackrabbit	-	1	3
<i>Sylvilagus floridanus</i>	Eastern Cottontail	+	6	5
Rodentia				
<i>Sciurus carolinensis</i>	Eastern Gray Squirrel	+	3	2
<i>Sciurus niger</i> (R)	Eastern Fox Squirrel	-	1	0
<i>Glaucomys volans</i>	Southern Flying Squirrel	+	0	0
<i>Oryzomys palustris</i>	Marsh Oryzomys	+	25	0
<i>Peromyscus leucopus</i>	White-footed Deermouse	+	4	3
<i>Microtus pennsylvanicus</i>	Meadow Vole	+	8	8
<i>Microtus pinetorum</i>	Woodland Vole	+	1	0
<i>Ondatra zibethicus</i>	Common Muskrat	+	13	0
<i>Zapus hudsonius</i>	Meadow Jumping Mouse	+	1	0
<i>Mus musculus</i> (I)	House Mouse	+	11	2
<i>Rattus norvegicus</i> (I)	Brown Rat	+	6	6
Carnivora				
<i>Canis latrans</i> (C)	Coyote	+	0	5
<i>Vulpes vulpes</i> (C)	Red Fox	+	4	6
<i>Urocyon cinereoargenteus</i>	Gray Fox	+	1	0
<i>Procyon lotor</i>	Raccoon	+	10	15
<i>Mustela frenata</i>	Long-tailed Weasel	+	0	1
<i>Neovison vison</i>	American Mink	+	2	10
<i>Lontra canadensis</i>	North American River Otter	+	16	0
<i>Mephitis mephitis</i>	Striped Skunk	+	0	0
Artiodactyla				
<i>Cervus nippon</i> (I)	Sika	-	1	0
<i>Odocoileus virginianus</i> (R)	White-tailed Deer	+	7	13

Cryptotis parva (Say) (North American Least Shrew). Specimens from the mainland: Accomack County (MVZ) and Northampton County (AMNH, VMNH). Specimens from the following islands: Assateague (NCSM, USNM, VMNH), Chincoteague (CUMV, MVZ, NCSM, USNM), Fowling Point (VMNH), and Wallops (USNM). We have capture records from Cedar Island. We consider North American Least Shrews to be resident on Assateague, Chincoteague, Fowling Point, and Wallops islands.

Family Talpidae (moles)

Scalopus aquaticus (L.) (Eastern Mole). Specimens from the mainland: Accomack County (MVZ) and Northampton County (UMMZ, USNM). Bailey (1946) reported this species from Cobb Island. We question this report, and we consider Eastern Moles to be absent from the Virginia barrier islands.

Condylura cristata (L.) (Star-nosed Mole). Specimens from the mainland: Accomack County (USNM). We have capture records of the Star-nosed Mole from the Northampton County mainland.

ORDER LAGOMORPHA (hare-shaped mammals)

Family Leporidae (hares and rabbits)

Lepus californicus Gray (Black-tailed Jackrabbit). Specimens from the mainland: none. Specimens from Cobb (VMNH) and Little Cobb (USNM) islands. We have reliable reports (R. Boettcher, Virginia Department of Wildlife Resources, Machipongo, VA, pers. comm.) of this species on Hog Island, and Clapp et al. (1976) reported observations on Rogue Island. This species is not native to Virginia (Pagels and Moncrief 2015). We agree with the conclusion of Clapp et al. (1976) that Black-tailed Jackrabbits are established only on Cobb Island, where a shipping error led to the accidental introduction of mail-order jackrabbits from Kansas in the 1960s, rather than the mail-order cottontails that had been planned (H. Bowen, Willis Wharf, VA, pers. comm.).

Sylvilagus floridanus (J.A. Allen) (Eastern Cottontail). Specimens from the mainland: Accomack County (MVZ, USNM) and Northampton County (USNM). Specimens from the following islands: Assateague (USNM), Chincoteague (USNM), Fishermans (USNM), Hog (MVZ, USNM, VMNH), and Smith (USNM). Hanlon et al. (1989) reported 3 sightings on Parramore Island, and E. Berge (Virginia Tech, Blacksburg, VA, pers. comm.) reported 67 camera-trap photos of Eastern Cottontails on Parramore Island. Baker et al. (2015) observed this species on Wallops Island. We have track records from Assawoman, Revel, and Ship Shoal islands. Mayne et al. (1981) reported observing tracks of this species on Cedar Island. The status of the Eastern Cottontail on Fishermans Island is uncertain. Blem and Pagels (1973) reported Eastern Cottontail skulls in pellets regurgitated by *Tyto alba* (Scopoli) (Barn Owl) on Fishermans Island in 1971 and 1972. B. Truitt (The Nature Conservancy, Nassawadox, VA, pers. comm.) observed the Eastern Cottontail on Fishermans Island in 1988. Fies (1991), however, reported that this species is probably absent from Fishermans and Smith islands. Furthermore,

despite extensive fieldwork during the past 21 years, P. Denmon (US Fish and Wildlife Service, Cape Charles, VA, pers. comm.) has no recent reports of Eastern Cottontails from Fishermans Island. We consider Eastern Cottontails to be resident on Assateague, Chincoteague, Hog, Parramore, Revel, and Wallops islands.

ORDER RODENTIA (gnawing mammals)

Family Sciuridae (squirrels)

Sciurus carolinensis Gmelin (Eastern Gray Squirrel). Specimens from the mainland: Northampton County (LSUMZ, USNM, VMNH). Specimens from Chincoteague Island (VMNH). We have capture records from Assateague Island. Dueser et al. (1979) reported single sightings of this species on Parramore and Smith islands. B. Truitt (pers. comm.) reported a dead Eastern Gray Squirrel in the mouth of a *Vulpes vulpes* (L.) (Red Fox) on Parramore Island in 1977. Hanlon et al. (1989) later reported Eastern Gray Squirrels on Parramore Island. Baker et al. (2015) observed this species on Wallops Island in summer 2015, and one of us (R.D. Dueser) observed an Eastern Gray Squirrel on Smith Island in October 2015. Based on 150+ observer days of field work since 1990, we now consider the Eastern Gray Squirrel to be absent from Parramore Island, but resident on Chincoteague, Smith, and Wallops islands.

Sciurus niger L. (Eastern Fox Squirrel). Specimens from the mainland: none. Specimens from Assateague Island (VMNH). We have capture records from the mainland in Northampton County. This species was on the Federal Endangered Species List (as *S. n. cinereus* L.[Delmarva Fox Squirrel]). It was considered extirpated from Virginia at the time of listing in 1967. Later, it was reintroduced to Chincoteague National Wildlife Refuge (NWR) on Assateague Island in Accomack County (1968–1971) and to Brownsville Farm, near Nassawadox, in Northampton County (1982–1983). The Chincoteague NWR introduction was successful, while the Brownsville introduction failed (Terwilliger 2000). We consider the Eastern Fox Squirrel to be resident on Assateague Island, but, despite occasional uncorroborated reports in Northampton County, not on the mainland.

Glaucomys volans (L.) (Southern Flying Squirrel). We are not aware of any specimens from Accomack and Northampton counties, VA. We have capture records of the Southern Flying Squirrel on the Accomack County mainland, but we are not aware of any reports of captures or observations on the islands or in Northampton County.

Family Cricetidae (cricetids)

Oryzomys palustris (Harlan) (Marsh Oryzomys). Specimens from the mainland: Accomack County (MVZ, NCSM, USNM, VMNH) and Northampton County (AMNH, FMNH, UMMZ, VMNH). Specimens from the following islands: Assateague (USNM, VMNH), Cedar (MVZ, VMNH), Chimney Pole (VMNH), Chincoteague (CUMV, NCSM, USNM), Cobb (USNM, VMNH), Fishermans (VMNH), Fowling Point (VMNH), Hog (USNM, VMNH), Holly Bluff (VMNH), Little Cobb (VMNH), Metompkin (VMNH), Mink (VMNH), Mockhorn (VMNH),

Myrtle (VMNH), Parramore (USNM, VMNH), Raccoon (VMNH), Revel (VMNH), Rogue (VMNH), Sandy (VMNH), Ship Shoal (VMNH), Skidmore (USNM), Smith (USNM, VMNH), Wallops (USNM, VMNH), and Wreck (USNM, VMNH). In addition, we have capture records from Assawoman Island. We consider the Marsh *Oryzomys* to be resident on all these islands.

Peromyscus leucopus (Rafinesque) (White-footed Deermouse). Specimens from the mainland: Accomack County (MVZ, USNM, VMNH) and Northampton County (AMNH, USNM, VMNH). Specimens from the following islands: Assateague (USNM, VMNH), Cedar (VMNH), Chincoteague (NCSM, USNM), Fishermans (VMNH), Hog (MVZ, USNM, VMNH), and Wallops (USNM). In addition, we have capture records from Fowling Point Island. We consider the White-footed Deermouse to be resident on Assateague, Chincoteague, Fishermans, and Wallops islands.

Microtus pennsylvanicus (Ord) (Meadow Vole). Specimens from the mainland: Accomack County (MVZ, USNM, VMNH); Northampton County (AMNH, FMNH, NCSM, UMMZ, USNM, VMNH). Specimens from the following islands: Assateague (NCSM, USNM, VMNH), Cedar (MVZ, VMNH), Chincoteague (CUMV, MVZ, NCSM, USNM), Fowling Point (VMNH), Hog (VMNH), Metompkin (VMNH), Mockhorn (VMNH), Myrtle (VMNH), Parramore (USNM, VMNH), Revel (VMNH), Ship Shoal (VMNH), Smith (USNM, VMNH), and Wallops (USNM, VMNH). In addition, we have capture records from Holly Bluff Island. Blem and Pagels (1973) reported Meadow Voles in Barn Owl pellets collected on Fishermans Island. It is possible that the owl(s) captured the voles on the nearby Northampton County mainland, because we have never captured Meadow Voles on Fishermans Island during numerous trapping sessions from 1989 to 2015, and neither has R. Rose (Old Dominion University, Norfolk, VA, pers. comm.), who has also conducted extensive live-trapping surveys of small mammals on Fishermans Island and the Northampton County mainland. Mayne et al. (1981) reported captures of the Meadow Vole from Assawoman Island. We consider it to be resident on Assateague, Chincoteague, Fowling Point, Holly Bluff, Mockhorn, Parramore, Smith, and Wallops islands.

Microtus pinetorum (Le Conte) (Woodland Vole). Specimens from the mainland: Accomack County (KU, MVZ, USNM, VMNH); Northampton County (AMNH, UMMZ, USNM, VMNH). In addition, Baker et al. (2015) captured Woodland Voles on Wallops Island, and we consider this species to be resident on that island.

Ondatra zibethicus (L.) (Common Muskrat). Specimens from the mainland: Accomack County (MVZ, USNM) and Northampton County (VMNH). Specimens from the following islands: Assateague (USNM), Chincoteague (CUMV, USNM), and Metompkin (VMNH). We observed tracks on Cedar, Cobb, Hog, Myrtle, Parramore, Revel, Ship Shoal, Smith, and Wreck islands. We also observed multiple lodges on Hog Island (Porter 2018). Mayne et al. (1981) reported tracks of this species from Assawoman Island. We consider Muskrats to be resident on all these islands.

Family Dipodidae (jumping mice)

Zapus hudsonius (Zimmermann) (Meadow Jumping Mouse). Specimens from the mainland: Accomack County (USNM, VMNH). Specimens from the following island: Assateague (USNM, VMNH). We consider the Meadow Jumping Mouse to be resident on Assateague Island.

Family Muridae (murids)

Mus musculus L. (House Mouse). Specimens from the mainland: Accomack County (MVZ, USNM, VMNH) and Northampton County (CAS, VMNH). Specimens from the following islands: Assateague (USNM, VMNH), Cedar (MVZ, VMNH), Chincoteague (CUMV, MVZ, NCSM, USNM), Fishermans (VMNH), Fowling Point (VMNH), Hog (MVZ, USNM, VMNH), Metompkin (VMNH), Myrtle (VMNH), Parramore (USNM), Raccoon (VMNH), Revel (VMNH), Smith (USNM, VMNH), and Wallops (USNM). This species is not native to Virginia (Pagels and Moncrief 2015). We consider the House Mouse to be established on Assateague, Cedar, Chincoteague, Fishermans, Fowling Point, Hog, Metompkin, Parramore, Raccoon, Smith, and Wallops islands.

Rattus norvegicus (Berkenhout) (Brown Rat). Specimens from the mainland: none. Specimens from the following islands: Assateague (USNM), Cobb (VMNH), Hog (VMNH), Metompkin (VMNH), Parramore (USNM), and Revel (VMNH). In addition, we have capture records from Cedar, Chimney Pole, and Sandy islands. Blem and Pagels (1973) reported Brown Rat skulls from Barn Owl pellets collected on Fishermans Island, but we have no capture records to confirm the current presence of this species on the island despite extensive live trapping. It is possible that the rats were captured on the nearby Northampton County mainland. We observed tracks on Little Cobb Island. This species is not native to Virginia (Pagels and Moncrief 2015). We consider Brown Rats to be established on Assateague, Chincoteague, Hog, Metompkin, Parramore, and Revel islands.

ORDER CARNIVORA (flesh-eating mammals)

Family Canidae (dogs, foxes, and allies)

Canis latrans Say (Coyote). We found no specimens from Accomack and Northampton counties. We have capture records from Assateague, Fishermans, and Parramore islands. We have camera-trap records from the Northampton County mainland. We have observed Coyote tracks on Metompkin and Sandy islands. We do not believe Coyotes are resident on any of the Virginia barrier islands. Hogue and Hayes (2015) argued that the Coyote was not found on the Peninsula at the time of European arrival, but rather arrived through natural range expansion following the extirpation of *Canis lupus* L. (Wolf). We consider the Coyote to be a native resident of Accomack and Northampton counties as a result of natural range expansion, but we do not consider it to be resident on any of the islands.

Vulpes vulpes (L.) (Red Fox). Specimens from the mainland: Northampton County (VMNH). Specimens from the following islands: Assateague (USNM), Chincoteague (USNM), Hog (USNM), Metompkin (VMNH), and Parramore

(VMNH). In addition, we have capture records from Assawoman, Cedar, and Wallops islands. We have observed tracks on Cobb and Revel islands. Notably, one of us (R.D. Dueser) watched a Red Fox swim from Parramore Island to Revel Island on 5 November 2002. We have reliable reports from January 2018 of a Red Fox crossing the ice from Wildcat Marsh on Chincoteague Island over to Assateague Island (D. Leonard, Chincoteague, VA, pers. comm.) and of a Red Fox leaving the mainland from a small neck called “Webb’s Island” in Northampton County, heading east out onto a vast expanse of icy marsh (M. Killmon, The Nature Conservancy, Nassawadox, VA, pers. comm.). We consider the Red Fox to be resident on Assateague, Chincoteague, Parramore, and Wallops islands.

Hogue and Hayes (2015) believed that the Red Fox is not a native species on the Delmarva Peninsula, because it was not present prior to European colonization. Red Foxes in the eastern United States were long thought to be solely of European origin, introduced to the American colonies for sport hunting (Churcher 1959, Kamlar and Ballard 2002). However, recent genetic studies indicate that the history of Red Foxes on the Delmarva Peninsula is complicated. Kasprowicz et al. (2016) and Kuo et al. (2019) presented genetic evidence that native populations of North American Red Foxes underwent natural range expansion, moving southward from New England around the same time that European Red Foxes from Britain were introduced to the Delmarva Peninsula. The expanding wave of native Red Fox populations eventually reached the Delmarva Peninsula, and the native animals interbred with British foxes, producing admixed native/non-native populations on the Delmarva Peninsula (Kasprowicz et al. 2016, Kuo et al. 2019). Complicating the situation further, Kasprowicz et al. (2016) also found evidence of subsequent interbreeding between captive-bred animals (escapees from fur farms in the 1900s) and the admixed populations of wild Red Foxes on the Delmarva Peninsula. Given the prevalence of the native genotype in the region as a result of natural range expansion, even with some degree of admixture with non-native genotypes, we consider the Red Fox to be a native species on the Delmarva Peninsula.

Urocyon cinereoargenteus (Schreber) (Gray Fox). Specimens from the mainland: Accomack County (VMNH). We have capture records from the Northampton County mainland and from Wallops Island (B. Scharle, USDA-Wildlife Services, Wallops Island, VA, pers. comm.). We consider the Gray Fox to be resident on Wallops Island.

Family Procyonidae (raccoons)

Procyon lotor (L.) (Raccoon). Specimens from the mainland: Accomack County (USNM) and Northampton County (NCSM, VMNH). Specimens from the following islands: Assateague (USNM), Cedar (VMNH), Cobb (VMNH), Fishermans (VMNH), Hog (VMNH), Metompkin (VMNH), Myrtle (VMNH), Parramore (USNM, VMNH), Revel (VMNH), Smith (USNM, VMNH), and Wallops (USNM). In addition, we have capture records from Mink, Mockhorn, Rogue, and Skidmore islands. We also have observed tracks on Chimney Pole, Fowling Point, Holly Bluff, Little Cobb, Raccoon, Sandy, Ship Shoal, and Wreck islands. An article in the

Peninsula Enterprise (Neighborhood Notes: Chincoteague 1912:3) reported that “Our sportsmen (on Chincoteague Island) have had lots of fun this week, killing coons, weighing from 14 to 16 lbs., and as many as five and six a day. In the memory of the oldest inhabitants, a coon was never seen on the island before. A number of them also were found on Assateague.” A subsequent article in the *Peninsula Enterprise* (Neighborhood Notes: Wachapreague 1914:4) reported that “Tobias Jeems, Esq., the successful coon-hunter, paid Parramore's Beach L. S. Station (on Parramore Island) a visit in the great storm last Saturday and spent two days there with the boys rejuvenating, so he told us, and added that when he again visits the island and departs therefrom, we may expect him to return with a full bag of raccoons. And to cap the climax, it is said, he does the trick oftentimes without the aid of canines, running them down or pursuing them to their habitats where they fall an easy prey to his capacious reach and herculean clutch.” Truitt and Peterson (1999) reported observing tracks on Assawoman Island. We consider the Raccoon to be resident on Assateague, Chincoteague, Fishermans, Hog, Mockhorn, Parramore, Revel, Skidmore, Smith, and Wallops islands.

Family Mustelidae (weasels and allies)

Mustela frenata Lichtenstein (Long-tailed Weasel). Specimens from the mainland: Accomack County (USNM). We are not aware of any specimens from the islands; we have no capture records, and we are not aware of any reports of captures in Northampton County or on any of the islands. In addition, we have seen a taxidermied Long-tailed Weasel in the Northampton County Courthouse that is labeled as follows “Found dead on the side of the road near Locustville in Accomack Co. on September 18, 2003. Found and taxidermied by famous naturalist (and very experienced fur trapper) George W. Reiger who lives in Locustville.”

Arquilla (2007) reported “Long-tailed Weasel, *Mustela frenata*” on Cobb Island in his Table 8. However, on page 48 he says “South Cobb Island supported a large gull colony, and Least Weasel [*Mustela nivalis* L.] tracks were also observed.” We question this report of *Mustela* on Cobb Island on the basis of the meager evidence and the fact that extensive surveys on the island over the past 45 years have produced no other report of any weasel. Cobb is one of the most remote islands and perhaps the least likely to support a terrestrial mammal found nowhere else in this barrier system.

Neovison vison (Schreber) (American Mink). Specimens from the mainland: none. Specimens from Smith Island (USNM). Hogue and Hayes (2015) report that a road-killed animal was observed by a trapper in Accomack County. We have track records from Cedar, Cobb, Fishermans, Hog, Little Cobb, Metompkin, Mink, Myrtle, Parramore, Ship Shoal, and Wreck islands. We consider the American Mink to be resident on Parramore and Smith islands.

Lontra canadensis (Schreber) (North American River Otter). Specimens from the mainland: Accomack County (VMNH). Specimens from Assateague Island (UWBM). We observed animals on the Northampton County mainland and in creeks behind Parramore and Hog islands, and we observed tracks on Cedar, Chimney Pole, Cobb, Fishermans, Holly Bluff, Metompkin, Mockhorn, Myrtle,

Raccoon, Ship Shoal, Smith, and Wreck islands. Truitt and Peterson (1999) reported observing tracks of this species on Assawoman Island. We consider the North American River Otter to be a likely resident on all of these islands.

Family Mephitidae (skunks)

Mephitis mephitis (Schreber) (Striped Skunk). We are not aware of any specimens from Accomack and Northampton counties. We have no capture records of this species, and we are not aware of any reports of captures in Accomack or Northampton counties. We have a reliable report (R. Boettcher, pers. comm.) of observations of Striped Skunks on the mainland in both Accomack and Northampton counties, and we consider this species to be resident in both counties.

ORDER ARTIODACTYLA (even-toed hoofed mammals)

Family Cervidae (deer)

Cervus nippon Temminck (Sika). Specimens from the mainland: none. Specimens from Assateague Island (AMNH, NCSM, USNM). This species is not native to Virginia (Pagels and Moncrief 2015). The Sika is established on Assateague Island in Accomack County (Flyger 1960).

Odocoileus virginianus (Zimmermann) (White-tailed Deer). We are not aware of any specimens from Accomack and Northampton counties. We have observed this species on the mainland in both counties and on Assateague, Chincoteague, Cobb, Fishermans, Hog, Holly Bluff, Metompkin, Mockhorn, Parramore, Revel, Rogue, Smith, and Wreck islands. We have also observed tracks on Assawoman, Cedar, Little Cobb, Mink, Myrtle, Ship Shoal, and Skidmore islands. Paradiso and Handley (1965) reported this species from Assateague Island. We consider the White-tailed Deer to be resident on Assateague, Chincoteague, Fishermans, Hog, Mockhorn, Parramore, and Smith islands.

Discussion

The mammalian fauna of the southern Delmarva Peninsula has experienced dramatic changes in species composition through both the extirpation of native species and the introduction of non-natives. Humans have occupied the Peninsula for at least the past 13,000 years (Custer 1989, Rountree and Davison 1997). The prehistoric residents were primarily hunters and gatherers (Custer 1989) who made seasonal use of the Virginia barrier islands for fishing, shellfish gathering, and perhaps hunting. Although the evidence of this early activity has been largely erased by the wind and tides, Lowery (2003) identified >20 archeological sites in Accomack and Northampton counties, confirming the presence of humans on the islands in prehistoric times. These sites contained a variety of stone hunting tools from different eras, but none contained mammalian faunal remains. The prehistoric fauna on the southern part of the Peninsula probably included a host of species no longer found in the region, including at least *Ursus americanus* Pallas (American Black Bear), *Puma concolor* (L.) (Cougar), *Lynx rufus* (Schreber) (Bobcat), Wolf, and, perhaps, *Cervus canadensis* Erxleben (Wapiti) (Hogue and Hayes 2015, Paradiso

1969, Rountree and Davison 1997). We are unaware of any reliable record of these species ever occurring on the barrier islands. There is, however, a generic reference to “wolves” on an island (perhaps Assateague) offshore from what is now Accomack County, during the winter of 1650 (Norwood 1650:27).

Permanent European settlement on the southern Delmarva Peninsula began in 1621, when Thomas Savage was granted a tract of 3642 ha (9000 ac) of land in what would become Northampton County by Esmey Shichans, the chief of the Accomac tribe (McCartney 2021). The colonists and their descendants added another source of wildlife exploitation to the region and also introduced new species to the islands. They extirpated 4 carnivores: the Wolf, American Black Bear, Bobcat, and Cougar (Hogue and Hayes 2015). They unintentionally introduced at least 2 usually commensal rodent species (i.e., House Mouse and Brown Rat) that persist on many of the islands, even in the absence of permanent human structures. As detailed above, Europeans also purposefully introduced an English version of the native Red Fox. White-tailed Deer were introduced to Parramore Island in the 1920s, at a time when the species was almost extirpated from the entire Delmarva Peninsula through overhunting and possibly other factors (Graham 1976b, Paradiso 1969); deer are now observed frequently on many of the islands. The introduction of Black-tailed Jackrabbits to Cobb Island in the 1960s is testimony to the continuing local interest in sport hunting; their successful establishment in this harsh environment reflects their adaptability (Dunn et al. 1982). Despite sporadic captures of *Felis catus* L. (Domestic Cat) on Assateague, Parramore, and Wallops islands, we do not believe any island currently supports a population. The full impact of these introductions, both intentional and accidental, is impossible to gauge after the fact.

The extirpation of the large carnivores on the Peninsula (i.e., the Wolf, American Black Bear, and Cougar) left behind a mammalian mesopredator fauna dominated by Raccoons and Red Foxes (Hogue and Hayes 2015). Although it cannot be confirmed, it appears that these species were neither abundant nor widely distributed on the islands at the turn of the 20th century. Numerous hunt clubs operated on the islands from 1880 to 1940, producing a long history of predator removal (Graham 1976b). Some of the last residents of the village of Broadwater on Hog Island in the 1930s reported very few Red Foxes or Raccoons there (Graham 1976b). Red Foxes were seldom hunted or trapped on Smith Island, even during the early 1900s (Graham 1976b). Nevertheless, predator control was used against Raccoons and Red Foxes on islands where they were viewed as a hindrance to game stocking. For example, a specialist was hired during the 1920s to rid Parramore Island of Red Foxes to facilitate the successful introduction of game birds, but he reported that “only a few dens were ever found”, suggesting that Red Foxes were not abundant on the island at this time (Graham 1976b:51). Hunting, trapping, and poisoning of Raccoons and Red Foxes continued on an occasional basis even after the 1920s. These reports from early in the 20th century and the more recent observations of Raccoon and Red Fox movement between islands (Dueser et al. 2013, reports cited herein) suggest that mammalian carnivores are more abundant and widely

distributed on the islands today than in the past. In 2000, a new round of predator management was initiated in an effort to reverse the decline of beach-nesting and colonial waterbirds on the islands (Erwin et al. 2001). Much of what we know about current mesopredator distribution, abundance, and dispersal in this mainland-island system has been learned in connection with the predator-removal programs instituted by the current managers of the islands (Dueser et al. 2013, Moncrief et al. 2017, Porter et al. 2015). Humans have thus brought about significant changes in the mammalian fauna of the Delmarva Peninsula, including the barrier islands, reducing the number and diversity of native wildlife species, particularly predators, and introducing a number of others.

The islands also have a long history of livestock husbandry. Early European colonists introduced a host of domesticated species to the region, including *Equus caballus* L. (Horse), *Sus scrofa* L. (Domestic Pig), *Ovis aries* L. (Domestic Sheep), *Capra hircus* L. (Domestic Goat), and *Bos taurus* L. (Domestic Cow). The islands were considered good pasturage for livestock from the mid-1600s through the 20th century (Barnes and Truitt 1997, Graham 1976b). Flocks of Domestic Sheep were formerly pastured on Assateague, Chincoteague, Hog, Fowling Point, and Smith islands, and herds of Domestic Cattle on Assateague, Chincoteague, Hog, Mockhorn, and Smith islands. These animals usually were unattended, and often went feral. George Washington Parke Custis, the step-grandson of George Washington and father-in-law of Robert E. Lee, extolled the virtues of the wool of the “native sheep of Smith’s island” (Barnes and Truitt 1997). Robert E. Lee in 1832 proposed ways to improve the pasture available for Domestic Cattle and Domestic Sheep on Smith Island (Barnes and Truitt 1997). Assateague Island still supports a herd of ~150 feral ponies on Chincoteague NWR (Lowney et al. 2005, USFWS 2015). Domestic Cows and Domestic Goats were reported on Assateague Island as recently as the 1960s (Paradiso and Handley 1965). The last Domestic Sheep were removed from Hog Island in 1978 and the last Domestic Cattle in 1986 (B. Truitt, pers. comm.). The last Domestic Sheep anywhere on the islands were removed from Fowling Point Island in 1994 (J. Kelly IV, Red Bank, VA, pers. comm.). The 300-year era of livestock husbandry has ended on the islands except for the Chincoteague ponies. The ecological consequences of this long history of grazing on the islands will never be known.

We have documented 6 orders, 12 families, and 25 species of native terrestrial mammals on the Virginia barrier islands and the adjacent Delmarva Peninsula mainland. We also documented 3 orders, 3 families, and 4 species of non-native mammals that are established on the Virginia barrier islands. Pagels and Moncrief (2015) provide citations of comprehensive monographs with details of each of these species’ biology. It is noteworthy that Paradiso (1969) reported 5 native species from the northern Delmarva Peninsula that do not occur today in Accomack or Northampton counties: *Sorex hoyi* Baird (American Pygmy Shrew), *Tamias striatus* (L.) (Eastern Chipmunk), *Synaptomys cooperi* Baird (Southern Bog Lemming), *Castor canadensis* Kuhl (American Beaver), and *Marmota monax* (L.) (Woodchuck). We found no specimens of any of these species from Virginia’s Eastern Shore, and we have

reliable reports of only 2: American Beaver and Woodchuck. The American Beaver was extirpated from the entire state by 1911 (Handley and Patton 1947). It was reintroduced to a pond in central Northampton County sometime in the 1970s, but recent reconnaissance in the vicinity revealed no evidence of American Beavers (R. Dodd, Eastville, VA, pers. comm.). For the Woodchuck, we have 1 reliable observation (P. Denmon, pers. comm.) in Northampton County in the 2010s, but no reports or observations since then. Given the typical visibility of both of these species, we doubt that either is currently resident in either Accomack County or Northampton County. In addition, a non-native rodent, *Rattus rattus* (L.) (Roof Rat) occurs elsewhere in Virginia, but Paradiso (1969) did not report it from Maryland's Eastern Shore, our searches of collections databases revealed no specimens, and we have no capture records or reports for this species. Hence we do not consider the Roof Rat to be established on the southern Delmarva Peninsula.

In considering the current geographic distribution of native species in this mainland-island system, 5 patterns emerge. (1) Some species have been extirpated and are unlikely to reappear in Accomack and Northampton counties, without intentional reintroduction efforts. We place the American Beaver, Wolf, American Black Bear, Bobcat, and Cougar in this category. Of these, only American Beavers are currently resident on the northern Delmarva Peninsula (Hogue and Hayes 2015; M. Whitbeck, US Fish and Wildlife Service, Cambridge, MD, pers. comm.). (2) Some species appear to be expanding southward on the Delmarva Peninsula mainland. The Coyote has already made this journey in recent decades (Paradiso 1969) and has become well-established. Infrequent observations of the Striped Skunk and Woodchuck in Accomack and Northampton counties suggest these species may be advancing. The American Pygmy Shrew, Eastern Chipmunk, and Southern Bog Lemming may yet be found on the lower Peninsula. (3) Seven species that are resident on the Delmarva Peninsula mainland of Virginia have no representatives on the islands. It is likely that the sandy habitats on the islands are unfavorable for fossorial species such as the Eastern Mole and Star-nosed Mole and for species that den such as the Striped Skunk. The Cinereus Shrew, the Southern Flying Squirrel, and the Long-tailed Weasel appear to be rare even where they occur on the mainland and may thus be poor candidates for island colonization. (4) Many species have been reported from 1 or more islands where they appear not to be resident, likely indicating either local extinction following an early observation (e.g., Virginia Opossum and White-footed Deermouse on Hog Island; Bailey 1946) or simply occurrence of occasional transient individuals of a particularly mobile species (e.g., Coyote, Red Fox, Raccoon, and White-tailed Deer). (5) The smaller rodent species vary widely in occurrence. The Meadow Jumping Mouse and Woodland Vole each is resident on only 1 island and have never been observed on any other. In contrast, the Marsh *Oryzomys* occurs on every island we have sampled and is apparently resident on all. The White-footed Deermouse and Meadow Vole occur on only a few islands, and they are resident on only a subset of the islands where they have ever been captured. Variability among species in dispersal ability and colonization potential have undoubtedly combined with geography and variability in island physiography to

produce these complex patterns of native mammal distribution (Dueser and Brown 1980, Loxterman et al. 1998, Porter et al. 2015).

This checklist provides a foundation for future studies of mammals, especially native species, on the Virginia barrier islands. Well-documented surveys are fundamental to understanding the distribution of species, which is necessary for conservation of biological diversity and informed management decisions (Balmford and Gaston 1999, Jetz et al. 2012, Roberts et al. 2007). This need is particularly true for barrier island systems (Hice and Schmidly 2002). Our report establishes a baseline against which to measure future faunal changes during this period of changing climate and accelerated rate of sea-level rise. Given current vegetation trends (Huang et al. 2018, Wolner et al. 2013, Zinnert et al. 2019), forest- and wetland-dwelling mammals (e.g., Eastern Gray Squirrel, Eastern Fox Squirrel, White-footed Deermouse, Woodland Vole, Meadow Vole, Least Shrew, and American Mink) may be particularly sensitive to habitat changes on the islands. Changes in the distribution of island populations of mammals are likely to produce correlated changes in the genetic structure of those species (Loxterman et al. 1998, Moncrief et al. 2017). In light of declines in populations of beach-nesting and colonial waterbirds (Brinker et al. 2007, Williams et al. 2007), it will be important to monitor the occurrence and distribution of carnivores, particularly Raccoons and Red Foxes, on the islands (Dueser et al. 2013, Porter et al. 2015).

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Literature Cited

- Adkins, L.C. 1980. Contributions of habitat selection, interspecific competition, and tidal flooding to small mammal species diversity in an Assateague Salt Marsh. M.Sc. Thesis. University of Virginia, Charlottesville, VA. 78 pp.
- Arquilla, B.J. 2007. Effects of predator activity on the nesting of American Black Ducks and other birds on the barrier islands of the Mid-Atlantic coast. M.Sc. Thesis. Louisiana State University and Agricultural and Mechanical College, Baton Rouge, LA. 50 pp.
- Badger, C.J. 1978. The Atlantic barrier islands: Their preservation benefits all. *The Nature Conservancy News* 28:20–23.
- Badger, C.J. 1991. Reserve joins shorebird network. *The Islands: The Virginia Coast Reserve Spring* 1991:6.
- Badger, C.J. 1997. A generation of coastal conservation. *The Islands: The Virginia Coast Reserve. Special Edition.* 23 pp.
- Badger, C.J., and R. Kellam. 1989. *The Barrier Islands: A Photographic History of Life on Hog, Cobb, Smith, Cedar, Parramore, Metompkin, and Assateague.* Stackpole Books, Harrisburg, PA. 146 pp.
- Bailey, J.W. 1946. *The Mammals of Virginia.* Williams Printing Co., Richmond, VA. 416 pp.
- Baker, J.R., D. Adams, M. Andrews, L. Betler, T. Bracken, K. Braune, B. Frye, N. Fulton, T. Layden, K. Scott, M. Sell, S. Way, K. Yuditsky, and A.M. Haines. 2015. Rapid biological assessment of terrestrial vertebrate species at Wallops Island National Wildlife Refuge. 39 pp. Available online at <https://blogs.millersville.edu/conservation/files/2015/08/Final-USFWS-Report-CBFS-Millersville.pdf>. Accessed 6 October 2021.
- Balmford, A., and K.J. Gaston. 1999. Why biodiversity surveys are good value. *Nature* 398:204–205.
- Barnes, B.M., and B.R. Truitt. 1997. *Seashore Chronicles: Three Centuries of the Virginia Barrier Islands.* University Press of Virginia, Charlottesville, VA. 248 pp.
- Blem, C.R., and J.F. Pagels. 1973. Feeding habits of an insular Barn Owl, *Tyto alba*. *Virginia Journal of Science* 24:212–214.
- Boon, J.D., and M. Mitchell. 2015. Nonlinear change in sea level observed at North American tide stations. *Journal of Coastal Research* 31:1295–1305.
- Brinker, D.F., J.M. McCann, B. Williams, and B.D. Watts. 2007. Colonial-nesting seabirds in the Chesapeake Bay region: Where have we been and where are we going? *Waterbirds* 30:93–104
- Churcher, C.S. 1959. The specific status of the new world Red Fox. *Journal of Mammalogy* 40:513–520.
- Clapp, R.B., J.S. Weske, and T.C. Clapp. 1976. Establishment of the Black-tailed Jackrabbit on the Virginia eastern shore. *Journal of Mammalogy* 57:180–181.
- Cobb, P.R., and D.W. Smith. 1989. Soil survey of Northampton County, Virginia. United States Department of Agriculture, Soil Conservation Service, Washington, DC. 95 pp.
- Cranford, J.A., and M.S. Maly. 1990. Small mammal population densities and habitat associations on Chincoteague National Wildlife Refuge, Assateague Island, Virginia. *Virginia Journal of Science* 41:321–329.
- Custer, J.F. 1989. *Prehistoric Cultures of the Delmarva Peninsula: An Archaeological Study.* University of Delaware Press, Newark, DE. 446 pp.
- Deaton, C.D., C.J. Hein, and M.L. Kirwan. 2017. Barrier island migration dominates ecogeomorphic feedbacks and drives salt marsh loss along the Virginia Atlantic coast. *Geology* 45:123–126.
- Dueser, R.D., and W.C. Brown. 1980. Ecological correlates of insular rodent diversity. *Ecology* 61:50–56.

- Dueser, R.D., and J.H. Porter. 1986. Habitat use by insular small mammals: Effects of competition and habitat structure. *Ecology* 67:195–201.
- Dueser, R.D., and K. Terwilliger. 1987. Status of the Delmarva Fox Squirrel (*Sciurus niger cinereus*) in Virginia. *Virginia Journal of Science* 38:380–388.
- Dueser, R.D., W.C. Brown, G.S. Hogue, C. McCaffrey, S. McCuskey, and G.J. Hennessey. 1979. Mammals of the Virginia barrier islands. *Journal of Mammalogy* 60:425–429.
- Dueser, R.D., N.D. Moncrief, O. Keišs, J.D. Martin, J.H. Porter, and B.R. Truitt. 2013. Overwater movement of Raccoons (*Procyon lotor*) in a naturally fragmented coastal landscape. *Northeastern Naturalist* 20:511–528.
- Dueser, R.D., S. McCuskey, G.S. Hogue, and J.H. Porter. 2018. Survey of small mammals using trapping data on all Virginia Coast Reserve barrier islands south of Parramore Island (inclusive) 1975–1978 ver 21. Environmental Data Initiative. Available online at <https://doi.org/10.6073/pasta/0daca2db114bbfe69460a483f2bd417d>. Accessed 6 October 2021.
- Dunn, J.P., J.A. Chapman, and R.E. Marsh. 1982. Jackrabbits. Pp. 124–145, *In* J.A. Chapman and G.A. Feldhamer (Eds.). *Wild Mammals of North America*. Johns Hopkins University Press, Baltimore, MD. 1147 pp.
- Erwin, R.M., B.R. Truitt, and J.E. Jiménez. 2001. Ground-nesting waterbirds and mammalian carnivores in the Virginia barrier island region: Running out of options. *Journal of Coastal Research* 17:292–296.
- Fies, M.L. 1991. Eastern Cottontail. Pp. 578–580, *In* K. Terwilliger (Ed.). *Virginia's Endangered Species*. McDonald and Woodward Publishing Company, Blacksburg, VA. 672 pp.
- Flyger, V. 1960. Sika Deer on islands in Maryland and Virginia. *Journal of Mammalogy* 41:140.
- Forys, E.A., and R.D. Dueser. 1993. Inter-island movements of Rice Rats (*Oryzomys palustris*). *American Midland Naturalist* 130:408–412.
- Forys, E.A., and N.D. Moncrief. 1994. Gene flow among island populations of Rice Rats (*Oryzomys palustris*). *Virginia Journal of Science* 45:3–11.
- Graham, M.A. 1976a. The Virginia barrier islands: A brief history. *The Nature Conservancy News* 26:18–22.
- Graham, M.A. 1976b. Land-use history: A study of man's influence on Virginia's barrier islands. Pp. 1–86, *In* R.D. Dueser, M.A. Graham, G.J. Hennessey, C. McCaffrey, A.W. Niederoda, T.W. Rice, and B. Williams (Eds.). *Virginia Coast Reserve Study, Ecosystem Description*. The Nature Conservancy, Arlington, VA. 568 pp.
- Handley, C.O., Jr., and C.P. Patton. 1947. *Wild Mammals of Virginia*. Commonwealth of Virginia Commission of Game and Inland Fisheries, Richmond, VA. 220 pp.
- Hanlon, C.L., D.E. Hayes, A.N. Hamir, D.E. Snyder, S. Jenkins, C.P. Hable, and C.E. Rupprecht. 1989. Evaluation of a rabies recombinant vaccine for Raccoons (*Procyon lotor*): Site selection, target species characteristics, and placebo baiting trials. *Journal of Wildlife Diseases* 25:555–567.
- Hayden, B.P., R.D. Dueser, J.T. Callahan, and H.H. Shugart. 1991. Long-term research at the Virginia Coast Reserve. *BioScience* 41:310–318.
- Hice, C.L., and D.J. Schmidly. 2002. The mammals of coastal Texas: A comparison between mainland and barrier island faunas. *Southwestern Naturalist* 47:244–256.
- Hogue, A.S., and J.A. Hayes. 2015. Mammalian carnivore declines on the Delmarva Peninsula. *Maryland Naturalist* 53:2–33.
- Huang, H., J.C. Zinnert, L.K. Wood, D.R. Young, and P. D'Odorico. 2018. Non-linear shift from grassland to shrubland in temperate barrier islands. *Ecology* 99:1671–1681.

- Jetz, W., J.M. McPherson, and R.P. Guralnick. 2012. Integrating biodiversity distribution knowledge: Toward a global map of life. *Trends in Ecology and Evolution* 27:151–159.
- Kamler, J.F., and W.B. Ballard. 2002. A review of native and nonnative Red Foxes in North America. *Wildlife Society Bulletin* 30:370–379.
- Kasprowicz, A.E., M.J. Statham, and B.N. Sacks. 2016. Fate of the other redcoat: Remnants of colonial British foxes in the eastern United States. *Journal of Mammalogy* 97:298–309.
- Kirkland, G.L., Jr., and T.V. Fleming. 1990. Ecology of feral House Mice (*Mus musculus*) on Wallops Island, Virginia. *Virginia Journal of Science* 41:330–351.
- Krantz, D.E., C.H. Hobbs, III, and G.L. Wikel. 2016. Atlantic Coast and Inner Shelf. Pp. 341–380. *In* C.M. Bailey, W.C. Sherwood, L.S. Eaton, and D.S. Powars (Eds.). *The Geology of Virginia*. Virginia Museum of Natural History, Martinsville, VA. 538 pp. Available online at <https://scholarworks.wm.edu/vimsbooks/117>. Accessed 10 October 2021.
- Krim, P.M., T.L. Bashore, and G.L. Kirkland Jr. 1990. Den site characteristics and food habits of the Red Fox (*Vulpes vulpes*) on Assateague Island, Maryland. *Virginia Journal of Science* 41:340–351.
- Kuo, Y.H, S.L. Vanderzwan, A.E. Kasprowicz, and B.N. Sacks. 2019. Using ancestry-informative SNPs to quantify introgression of European alleles into North American Red Foxes. *Journal of Heredity* 110:782–792.
- Lowery, D.L. 2003. Archaeological Survey of the Atlantic Coast shorelines associated with Accomack County and Northampton County, Virginia. Virginia Department of Historic Resources, Survey and Planning Report Series, No. 7. Richmond, VA. 297 pp.
- Lowney, M., P. Schoenfeld, W. Haglan, and G. Witmer. 2005. Overview of impacts of feral and introduced ungulates on the environment in the eastern United States and Caribbean. *Proceedings of the Wildlife Damage Management Conference* 11:64–81. Available online at https://digitalcommons.unl.edu/icwdm_wdmconfproc/88. Accessed 6 October 2021.
- Loxterman, J.L., N.D. Moncrief, R.D. Dueser, C.R. Carlson, and J.F. Pagels. 1998. Dispersal abilities and genetic population structure of insular and mainland *Oryzomys palustris* and *Peromyscus leucopus*. *Journal of Mammalogy* 79:66–77.
- Mayne, K.L., R.L. Zepp, and S.D. Eckles. 1981. Fish and wildlife resources of Metomkin Island and Bay, Accomack County, Virginia. Planning Aid Report, US Fish and Wildlife Service, Annapolis, MD. 38 pp.
- McCaffrey, C.A., and R.D. Dueser. 1990. Plant associations on the Virginia barrier islands. *Virginia Journal of Science* 41:282–299.
- McCartney, M. 2021. Savage, Thomas (ca. 1595–before September 1633). *In* *Encyclopedia Virginia*. Available online at <https://encyclopediavirginia.org/entries/savage-thomas-ca-1595-before-september-1633>. Accessed 10 October 2021.
- Moncrief, N.D., and R.D. Dueser. 1998. First record of a Masked Shrew (*Sorex cinereus*) on the Eastern Shore of Virginia. *Bannisteria* 12:40–41.
- Moncrief, N.D., and R.D. Dueser. 2001. Allozymic variation in the endangered Delmarva Fox Squirrel (*Sciurus niger cinereus*): Genetics of a translocated population. *American Midland Naturalist* 146:37–42.
- Moncrief, N.D., J.H. Roberts, E.M. Hallerman, R.A. Van Den Bussche, J.H. Porter, and R.D. Dueser. 2017. Landscape genetics of a Raccoon (*Procyon lotor*) metapopulation in an undeveloped coastal island system. *Journal of Mammalogy* 98:1137–1155.
- Neighborhood Notes: Chincoteague. 1912. Peninsula Enterprise, Volume 32, Number 16, 26 October. Available online at <https://viriniachronicle.com/?a=d&d=PE19121026.1.3>. Accessed 10 October 2021.

- Neighborhood Notes: Wachapreague. 1914. Peninsula Enterprise, Volume 34, Number 22, 12 December. Available online at <https://virginiachronicle.com/?a=d&d=PE19141212.1.4>. Accessed 10 October 2021.
- Newman, W.S., and C.A. Munsart. 1968. Holocene geology of the Wachapreague Lagoon, eastern shore peninsula, Virginia. *Marine Geology* 6:81–105.
- Norwood, C. 1650. A voyage to Virginia. 52 pp. Reprinted *In* P. Force (Ed.). 1844. Tracts and other papers relating principally to the origin, settlement, and progress of the colonies in North America: From the discovery of the country to the year 1776. Volume 3, No.10. Wm. Q. Smith, Washington, DC.
- Oertel, G.F., M.S. Kearney, S.P. Leatherman, and J.H. Woo. 1989. Anatomy of a barrier platform: Outer barrier lagoon, southern Delmarva Peninsula, Virginia. *Marine Geology* 88:303–328.
- Pagels, J.F., and N.D. Moncrief. 2015. Virginia's land mammals: Past and present, with some thoughts about their possible future. *Virginia Journal of Science* 66:171–222.
- Paradiso, J.L. 1969. Mammals of Maryland. *North American Fauna* 66:1–193.
- Paradiso, J.L., and C.O. Handley Jr. 1965. Checklist of mammals of Assateague Island. *Chesapeake Science* 6:167–171.
- Peacock, C.D., and W.J. Edmonds. 1994. Soil survey of Accomack County, Virginia. United States Department of Agriculture, Soil Conservation Service, Washington, DC. 115 pp.
- Porter, J.H. 2018. Muskrat lodge locations near transect 1 on northern Hog Island of the Virginia Coast Reserve 2005–2015 ver 23. Environmental Data Initiative. Available online at <https://doi.org/10.6073/pasta/d76ff3d5dee749bbfb502b4bb9409235>. Accessed 6 October 2021.
- Porter, J.H., and R.D. Dueser. 1982. Niche overlap and competition in an insular small-mammal fauna: A test of the niche overlap hypothesis. *Oikos* 39:228–236.
- Porter, J.H., and R.D. Dueser. 2021. Hog Island, VA, small-mammal trapping 1989–2020 ver 37. Environmental Data Initiative. Available online at <https://doi.org/10.6073/pasta/87783db28896e960ac0a6ba1c4f04ce8>. Accessed 6 October 2021.
- Porter, J.H., R.D. Dueser, and N.D. Moncrief. 2015. Cost–distance analysis of mesopredators as a tool for avian habitat restoration on a naturally fragmented landscape. *The Journal of Wildlife Management*, 79:220–234.
- Roberts, R.L., P.F. Donald, and R.E. Green. 2007. Using simple species lists to monitor trends in animal populations: New methods and a comparison with independent data. *Animal Conservation* 10:332–339.
- Rountree, H.C., and T.E. Davidson. 1997. Eastern Shore Indians of Virginia and Maryland. University Press of Virginia, Charlottesville, VA. 329 pp.
- Scott, D.E., and R.D. Dueser. 1992. Habitat use by insular populations of *Mus* and *Peromyscus*: What is the role of competition? *Journal of Animal Ecology* 61:329–338.
- Svenning, J.-C., C. Fløjgaard, and A. Baselga. 2011. Climate, history, and neutrality as drivers of mammal beta diversity in Europe: Insights from multiscale deconstruction. *Journal of Animal Ecology* 80:393–402.
- Terwilliger, K. 2000. Report on the status of the Delmarva Fox Squirrel and its habitat on the Brownsville Farm, Virginia Coast Reserve. Unpublished Report produced for The Nature Conservancy. Karen Terwilliger Consulting, LLC., Locustville, VA. 35 pp.
- Truitt, B.R., and E. Peterson. 1999. Survey of mammalian predator observation on barrier islands, from VCR field notes and colonial bird surveys (1974–1999). 2 pp. Available online at https://www.vcrlter.virginia.edu/elevol/reports/1999_Truitt_Peterson.pdf. Accessed 10 October 2021.

- Turvey, S.T., and S.A. Fritz. 2011. The ghosts of mammals past: Biological and geographical patterns of global mammalian extinction across the Holocene. *Philosophical Transactions of the Royal Society* 366:2564–2576.
- US Fish and Wildlife Service (USFWS). 2015. Chincoteague National Wildlife Refuge, VA: Ponies. Available online at https://www.fws.gov/refuge/Chincoteague/wildlife_and_habitat/ponies.html. Accessed 6 October 2021.
- Williams, B., D.F. Brinker, and B.D. Watts. 2007. The status of colonial nesting wading bird populations within the Chesapeake and Atlantic barrier island–lagoon system. *Waterbirds* 30:82–92.
- Wilson, D.E., and D.M. Reeder (Eds.). 2005. *Mammal Species of the World: A Taxonomic and Geographic Reference*. Third Edition. Johns Hopkins University Press, Baltimore, MD. 2142 pp.
- Wolner, C.W.V., L.J. Moore, D.R. Young, S.T. Brantley, S.N. Bissett, and R.A. McBride. 2013. Ecomorphodynamic feedbacks and barrier island response to disturbance: Insights from the Virginia Barrier Islands, Mid-Atlantic Bight, USA. *Geomorphology* 199:115–128.
- Zinnert, J.C., S.M. Via, B.P. Nettleton, P.A. Tuley, L.J. Moore, and J.A. Stallins. 2019. Connectivity in coastal systems: Barrier island vegetation influences upland migration in a changing climate. *Global Change Biology* 25:2419–2430.