

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

Saturday, Aug. 21, 2021
9:00-9:45 a.m. via Zoom meeting

A G E N D A

- Call to order: **Dr. Art Evans**
- Roll Call: Dr. Art Evans, Dr. Tom Benzing, Dr. Carole Nash, Lisa Moerner, Melany Stowe, Mark Buss.
- May 2021 Research and Collections Committee meeting minutes (action item)
- April-June 2021 acquisitions (action item)
- Update on recent paleontological dig in Wyoming: **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
May 15, 2021**

Present at the online meeting were Dr. Art Evans, Dr. Tom Benzing, Dr. Carole Nash, Lisa Moerner, Dr. Joe Keiper, Dr. Hayden Bassett, Dr. Adam Pritchard, Dr. Kal Ivanov, Dr. Nancy Moncrief, Dr. Jackson Means, Zach Ryder, and Ben Williams. Committee member Melany Stowe was absent.

- Committee Chairman Dr. Art Evans called the meeting to order.
- The minutes were unanimously approved with no additions or corrections.
- Due to the meeting taking place online, the new acquisitions sign-off sheet is being distributed to committee members electronically. Ben Williams will submit the sheet to VMNH Registrar Jill Harris once all signatures have been collected.
- Dr. Hayden Bassett provided a brief update regarding the current state of the repatriation of the museum's Guatemalan artifacts. Dr. Bassett said he is currently waiting to get on the Guatemalan ambassador's schedule. Dr. Art Evans agreed that the museum has done all it can at this point and must simply wait.
- VMNH Myriapodologist Dr. Jackson Means provided an update on his activities in the museum's recent invertebrates lab. Dr. Means said that he and Dr. Kal Ivanov have been doing a great deal of millipede collecting in recent months, which has had a positive impact on one of his current projects: a follow-up revision of the genus *Nannaria*, the original revision of which served as his Ph.D project. The revision will add 10-15 new species to the 35 currently described species. Dr. Means said that he and Dr. Ivanov have found six new species in the field recently, five of which were collected in Virginia. He added that in addition to his multiple projects, he is currently processing a massive collection of sorted and unsorted material donated to the museum by Bill Shear.
- Dr. Art Evans thanked the curators for their hard work over the course of the past quarter, including field work, publications, and other scholarly activities. He added that collections are vitally important and reiterated that collections are the reason the museum exists.
- Dr. Carole Nash said that as more people are learning about the VMNH Waynesboro campus, she is getting increasing number of requests from members of the public who want to donate archaeological collections to the

campus. She asked Dr. Hayden Bassett if there is a process in place for dealing with such collections. Dr. Bassett said that the process is mainly done on a case-by-case basis, but generally speaking, those with un-provenanced artifacts are asked to send in photos and hold onto the artifacts, while those with artifacts that can be tied to a specific location are asked to donate them. Dr. Joe Keiper added that artifacts that do not contribute to research can often be used in education.

- Dr. Art Evans asked the curators for any updates from their work over the previous quarter.
- Dr. Hayden Bassett said that he just completed fieldwork for his five-week Smith River survey project at a campground in Stanleytown, Va. The comprehensive survey discovered two sites along the Smith River. One is a late woodland site dating to 1200-1450 AD, while the other is a transitional early to middle archaic site dating to 6000-5500 BCE. Dr. Bassett is working on a formal publication regarding these findings. The next stage of the Smith River Survey will involve using ground-penetrating radar on the floodplains of the Smith River, beginning with established well-known sites. Dr. Bassett is also doing a lot of work in the museum's Cultural Heritage Monitoring Lab, which identifies cultural heritage sites threatened by armed conflict and natural disasters. Recent projects include working with the Department of Defense and the State Department to identify threatened sites in Azerbaijan and Honduras.
- Dr. Adam Pritchard said that his paper on the gliding reptile *Weigeltisaurus* will see publication in PeerJ next week. Additionally, he will soon be appearing in a news segment regarding his Triassic fieldwork in Ashland, Va.
- Dr. Kal Ivanov said that his first paper about vertebrates — a collaboration with Dr. Nancy Moncrief regarding tree squirrel skeletal injuries — is nearing completion. He will soon be submitting a manuscript regarding subterranean insect traps, which is a collaboration with Research Associate Curt Harden. He has also been working closely with Dr. Jackson Means to collect millipedes.
- Dr. Nancy Moncrief said that she is working on multiple publications, all of which are nearing completion. The first publication that will likely see publication concerns the first records of the nine-banded armadillo in Virginia.
- Dr. Art Evans moved to adjourn the meeting.

APRIL-JUNE 2021 RECENT ACQUISITIONS FOR APPROVAL BY BOARD OF TRUSTEES RESEARCH AND COLLECTIONS COMMITTEE

RIM* No.	Collector/Donor	Date at VMNH	VMNH Dept.	Quantity	Description	Method	To Be Accessioned (Y/N)
RIM 02-2020	Liberty Hightower	12/12/2019	MAMMALOGY	1	Striped Skunk (<i>Mephitis mephitis</i>)	SALVAGE	N
RIM 15-2021	Adam Pritchard	4/28/2021	PALEONTOLOGY	~100	sandstone rocks with vertebrate bones	Field Collection	Y
RIM 16-2021	Tom Malabad - VA DCR-DNH	2/23/2021	RECENT INVERTEBRATES	65	60 alcohol preserved terrestrial isopods (Oniscidea) and 5 alcohol preserved ants (Formicidae)	Transfer	Y
RIM 17-2021	Derek Hennen	6/22/2021	RECENT INVERTEBRATES	18	pinned/pointed insects, some identified to genus/sp.	Gift	Y
RIM 18-2021	William R. Shealy, Jr	3/19/2021	RECENT INVERTEBRATES	2981	2086 pinned insects; 830 enveloped insects; 48 Cornell drawers; 10 small and 7 large storage boxes	Gift	Y
RIM 19-2021	Steven M. Roble - VA DCR-DNH	11/1/2019	MAMMALOGY	~160 lots	dry and wet vertebrate specimens including: 2 <i>Procyon lotor</i> , 2 <i>Ondatra zibethicus</i> , 1 <i>Marmota monax</i> , 1 <i>Sylvilagus</i> sp., and 1 <i>Canis</i> sp. skulls	Gift	Y
RIM 20-2021	Ray Dueser (via Nancy Moncrief)	11/18/2020	MAMMALOGY	6	2 <i>Microtus pennsylvanicus</i> , 2 <i>Mus musculus</i> , and 2 <i>Lepus californicus</i>	Field Collection	Y

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

VMNH Collections Committee and Executive Director have Approved Recent Acquisitions: RIM 02-2020, RIM 15-2021 through RIM 20-2021

APRIL-JUNE 2021 RECENT ACQUISITIONS FOR APPROVAL BY BOARD OF TRUSTEES RESEARCH AND COLLECTIONS COMMITTEE

VMNH Board of Trustees Research & Collections Committee Review of Acquisitions: RIM 02-2020, RIM 15-2021 through RIM 20-2021

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 C. Moerner

(signature) Lisa C. Moerner

Date

Carol L. Nash

(signature) Carole L. Nash

Date

Melany Stowe

(signature) Melany Stowe

Date

VIRGINIA MUSEUM OF NATURAL HISTORY RESEARCH AND COLLECTIONS EXECUTIVE SUMMARY

April-June 2020

Public outreach, fieldwork, and continued work on publications were the main focuses of VMNH Research and Collections staff in April, May, and June of 2021.

On May 1, staff participated in the “Treasures from the Vault” drive-thru show in Waynesboro, Va. The event featured seldom-seen items pulled from the museum’s collections and attracted more than 160 guests.

Additionally, VMNH Assistant Curator of Archaeology Dr. Hayden Bassett is in the direct commissioning processes to enter the U.S. Army Reserves as one of roughly 35 new “Monuments Men” Army Reserve Captains, Majors, and Lt. Colonels. This is a massive outreach operation for the museum and will position the VMNH Cultural Heritage Monitoring Lab (CHML) as the primary research lab for the Army program.

In fieldwork, Assistant Curator of Paleontology Dr. Adam Pritchard co-led the Wyoming Dinosaur Project 2021, a collaborative project involving Virginia universities and undergrad students focused on excavating Jurassic dinosaurs from a site near Greybull, WY. Meanwhile, VMNH Associate Curator of Invertebrate Zoology Dr. Kal Ivanov and other Research and Collections staff conducted fieldwork at no less than 49 different sites in 24 counties of four U.S. states during the course of this quarter.

In the category of publications, VMNH Curator of Mammalogy Dr. Nancy Moncrief’s article about the first specimens of nine-banded armadillos from Virginia as published in *Southeastern Naturalist* and has drawn considerable attention. Dr. Moncrief has three additional publications in the works.

Dr. Nancy Moncrief

- Dr. Moncrief’s article about the first specimens of nine-banded armadillos from Virginia, which are housed at VMNH, was published in *Southeastern Naturalist*
- Dr. Moncrief continued working with several colleagues on three additional manuscripts. The topics are as follows: 1) skeletal injuries in tree squirrels, 2) mammals that occur on the Virginia barrier islands, and 3) report of the whole-genome sequence of the eastern fox squirrel.
- Dr. Moncrief presented results of her research at the (virtual) annual conference of the American Society of Mammalogists.

Dr. Kal Ivanov

- Dr. Ivanov and colleagues submitted an abstract for the upcoming annual meeting of the Entomological Society of America.
- Drs. Ivanov and Means, and Biology Technician Liberty Hightower launched the “Terrestrial isopods (Crustacea: Isopoda: Oniscidea) of Virginia” project and compiled the state’s first comprehensive list.

- Drs. Ivanov and Means, along with Liberty Hightower, traveled to Virginia Beach and oversaw the acquisition and transport of 2,900+ insect specimens donated to the VMNH by Dr. William R. Shealy.

Dr. Adam Pritchard

- Dr. Pritchard collaborated with an international team of researchers on an article on a globally distributed group of Triassic reptiles called *Malerisaurus* for the journal *Papers in Palaeontology*.
- Dr. Pritchard helped co-lead the Wyoming Dinosaur Project 2021, a collaborative project involving Virginia universities and undergrad students focused on excavating Jurassic dinosaurs from a site near Greybull, WY.
- Dr. Pritchard led fieldwork in Ashland, Virginia focused on the excavation of Triassic vertebrates in collaboration with local amateur paleontologists. He also recorded an interview with a local CBS affiliate on this particular project.

Dr. Hayden Bassett

- In mid-May, Dr. Bassett delivered a comprehensive report, co-authored with VMNH Staff Archaeologist Madeleine Gunter Bassett, to the Virginia Department of Historic Resources (VDHR) on the VMNH's archaeological fieldwork in Stanleytown, VA completed in April.
- From May to June, Dr. Bassett completed ground-penetrating radar fieldwork at major terminal Late Woodland (AD 1200-1450) site in Henry County, one of seven archaeological sites included in the Smith River Survey (a 2-year VMNH archaeological survey of the Smith River in Henry County, VA). VMNH Staff Archaeologist Madeleine Gunter Bassett and Dr. Hayden Bassett used GPR to survey and identify the best locations to sample archaeologically.
- From early May through late-July, Dr. Bassett was consulted on six occasions by US federal agencies to implement his technical methods for using satellite imaging and remote sensing to document destruction of cultural heritage in conflict zones and after natural disasters. These professional services were provided to assist in efforts in Europe, Africa, and Central America.

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

**Report to the Board of Trustees
April-June 2021**

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

- Dr. Ivanov and colleagues have a manuscript in review at the American Society of Mammalogists' periodical Journal of Mammalogy.
- Dr. Ivanov and colleagues presented research findings at the [virtual] annual meetings of the American Society of Mammalogists and the Southwestern Association of Naturalists.
- Dr. Ivanov and colleagues submitted an abstract for the upcoming annual meeting of the Entomological Society of America.
- Drs. Ivanov and Means, and Biology Technician Liberty Hightower launched the "Terrestrial isopods (Crustacea: Isopoda: Oniscidea) of Virginia" project and compiled the state's first comprehensive list.
- Drs. Ivanov and Means, along with Liberty Hightower, traveled to Virginia Beach and oversaw the acquisition and transport of 2,900+ insect specimens donated to the VMNH by Dr. William R. Shealy.
- Dr. Ivanov participated in VMNH's "Treasures from the Vault" Drive-thru Experience in Waynesboro, VA and interacted with more than 160 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 are currently revising their manuscript "Survivable skeletal injuries in two North American tree squirrels (*Sciurus niger* and *S. carolinensis*)" which is in review at Journal of Mammalogy. This research was recently presented at the [virtual] annual meeting of the American Society of Mammalogists.

VMNH Research Associate and Clemson University graduate student C. Harden, L. Hightower, and Dr. Ivanov are currently drafting a manuscript (to be submitted to Environmental Entomology) on the efficiency of two subterranean trap designs for targeting hypogaeic invertebrate taxa in the eastern US. Preliminary findings indicate that these techniques are effective at sampling hypogaeic ants and beetles, including rare species not captured by traditional methods.

Drs. Dash, Zhuang, and Ivanov along with students from Hampton University and University of Texas at El Paso are drafting a manuscript on the first comprehensive account of the ant fauna of the Chihuahuan Desert. Although numerous myrmecological studies have focused on the deserts of the American Southwest, to date, limited coverage has been offered to the ant fauna of North America's largest warm desert. Preliminary data were presented at the 68th [virtual] annual meeting of the Southwestern Association of Naturalists.

VMNH myriapodologist (millipede expert) Dr. Jackson Means and Dr. Ivanov continued work on the “*Nannaria incertae sedis*” project which focuses on the diversity of the *minor* clade of the xystodesmid genus *Nannaria*, a group recently revised by Dr. Means. This research is a logical continuation of Dr. Means’ graduate work and targets a number of known, but currently undescribed, members of the group. Recent field work has resulted in the collection of at least 8 undescribed species, and is ongoing.

Dr. Ivanov, along with Dr. Means and L. Hightower initiated work on the terrestrial isopod fauna of Virginia and compiled the first comprehensive state list of this ecologically important group based on published records, museum collections, review of online databases, and original collecting. Currently, 25 species and subspecies of terrestrial isopods are reliably reported from the Commonwealth including 11 native and 14 exotic species. This list includes 9 taxa not previously known to occur in Virginia. Preliminary findings will be presented at the upcoming annual meeting of the Entomological Society of America.

Dr. Ivanov attended the (virtual) 11th International Symposium on Terrestrial Isopod Biology (ISTIB) hosted from Ghent, Belgium by Spinicornis (the Terrestrial Isopod Research Group of Belgium) and the Forest & Nature Lab of the Faculty of Bioscience Engineering of Ghent University. (July 12-14).

This quarter, Drs. Ivanov and Means visited and conducted field work at 49 sites in 24 counties of 4 US states (North Carolina, Tennessee, Virginia, and West Virginia) in support of ongoing research projects. On a number of occasions, they were joined in the field by VMNH Research Associates Dr. A. Evans and C. Harden, R&C staff (Dr. H. Bassett, L. Hightower, and B. Williams), and colleagues (Drs. S. Dash and D. Hennen).

In support of VMNH’s recently launched “Terrestrial isopods (Crustacea: Isopoda: Oniscidea) of Virginia” project, Dr. Ivanov: 1) identified and curated 60 specimens (of 9 species) recently donated to VMNH by T. Malabad (DCR-DNH Karst Program). The Virginia endemic troglobitic *Amerigoniscus henroti* and the native and widespread *Miktoniscus medcofi* represent new additions to the VMNH collection; 2) processed, identified, and curated 125 specimens (of 16 species) of terrestrial isopods from recent field work. Of these, 7 species are new to VMNH’s collection; 3) verified/completed the identification of 229 specimens (of 10 species) from the museum’s collection and is currently working on processing a large number (>200 lots) of backlogged undetermined samples.

Liberty Hightower, with help from Dr. Ivanov, databased VMNH’s cicada holdings in support of their ongoing “Cicadas (Hemiptera: Cicadidae) of Virginia” project (with VMNH Research Associate Dr. A. Evans). The 324 specimens present in the collection, represent 17 species in 7 genera chiefly of Virginia origin.

Liberty Hightower, with help from Dr. Ivanov, completed the inventory of 798 backlogged ant samples from Belize, Greece, and 21 US states which are temporarily stored in the Recent Invertebrates lab awaiting processing.

Dr. Ivanov captured data in support of Virginia Tech graduate student Morgan Malone’s work on the distribution and spread of the invasive red imported fire ant *Solenopsis invicta* in Virginia.

Dr. Ivanov responded to information requests regarding VMNH holdings: *Cotesia congregata* (Hymenoptera: Braconidae) (K. Kester; Virginia Commonwealth U).

Dr. Ivanov oversaw the acquisition of 60 ethanol-preserved terrestrial isopods (Crustacea: Isopoda: Oniscidea) and 5 ethanol-preserved ants (Hymenoptera: Formicidae) from various Virginia caves donated by T. Malabad (DCR-DNH Karst Program; RIM2021-16); 18 pinned/pointed insects, some identified to genus, from various Virginia localities donated by Dr. D. Hennen (Virginia Tech; 2021-17)

Drs. Ivanov and Means along with Liberty Hightower traveled to Virginia Beach and oversaw the acquisition and transport of 2,086 pinned/pointed and 830 enveloped insect specimens donated to VMNH by Dr. William R. Shealy, Professor Emeritus at Virginia Wesleyan University. Although the primary strength of the collection is in tropical Lepidoptera (moths and butterflies; ~ 80% of the collection), it also contains a variety of other native and exotic taxa from numerous worldwide localities.

In support of VMNH's newly established STEM Lab, Drs. Ivanov and Means, along with L. Hightower, completed the setup of the museum's newly acquired imaging station and captured the first high-resolution images of various invertebrate specimens. The now fully functional station will serve the combined research, education, and outreach needs of the entire institution.

Education & Outreach

Dr. Ivanov and museum staff presented a virtual field trip of VMNH's exhibits and collections to students from Roanoke College's non-majors Evolution course. The morning-long activities were concluded with a short Q&A session. (April 24)

Dr. Ivanov and museum staff participated in the museum's "Treasures from the Vault" Drive-thru Experience in Waynesboro, VA, the planned future location for the museum's first satellite campus. The 5-hour event was attended by 163 children and adults from Waynesboro and the surrounding areas and offered a great opportunity to promote VMNH and the museum's research and education programs. (May 1)

Dr. Ivanov provided a (virtual) workshop and training in insect identification for the Southwestern Piedmont Chapter of the Virginia Master Naturalists program. The workshop included an introductory lecture and "virtual hands-on" activities focused on order-level identification of Virginia taxa. (May 3)

This quarter, Dr. Ivanov responded to arthropod identification and information requests to individuals from North Carolina (Greensboro, Mt. Airy), Virginia (Callao, Martinsville, Stuart), and elsewhere (not specified). The majority of the requests were submitted to VMNH's FB page by museum patrons with the remainder representing taxa featured in VMNH's online series BenInNature.

Exhibits

Dr. Ivanov completed the first text draft for the museum's upcoming "Flight" exhibit and is currently working on specimen selection and preparation.

Media

Drs. Ivanov and Means recent field work and research efforts were featured in 8 posts on the museum's FB page and generated 430+ views.

Professional Service

Dr. Ivanov participated in Virginia Tech's graduate students D. Wilczek and M. Malone (virtual) Advisory Committee meetings on April 5 and April 15, respectively.

Dr. Ivanov, VMNH Executive Director Dr. J. Keiper, VMNH Administrator of Science B. Williams, and student intern V. Gray took part in the inaugural committee meeting of the "Martinsville, VA Bee City" initiative. The committee is working towards establishing, and sustaining, the City of Martinsville as one of the 141 Xerces Society Bee City USA affiliates which have already formally committed to protect and sustain native pollinator communities. The committee will be responsible in handling duties associated with improving conditions for native pollinators by providing them with healthy habitat rich in native plants, reducing the use of herbicides, pesticides, and other harmful chemicals, and by providing opportunities for educational outreach. The ultimate goal of this initiative is to engage as many people from the local community as possible in efforts to protect, and reverse the decline of, native bees and numerous other pollinators. (June 25)

Dr. Ivanov completed the copy editing of five articles for the Virginia Natural History Society's periodical *Banisteria* (Volume 55, 2021).

Dr. Ivanov served as a peer reviewer for a manuscript submitted to *Diversity* (completed May 25).

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

- Dr. Moncrief's article about the first specimens of nine-banded armadillos from Virginia, which are housed at VMNH, was published in *Southeastern Naturalist*
- Dr. Moncrief continued working with several colleagues on three additional manuscripts. The topics are as follows: 1) skeletal injuries in tree squirrels, 2) mammals that occur on the Virginia barrier islands, and 3) report of the whole-genome sequence of the eastern fox squirrel.
- Dr. Moncrief presented results of her research at the (virtual) annual conference of the American Society of Mammalogists.
- Dr. Moncrief participated in the Drive-Through Festival that was held in Waynesboro on 1 May 2021

Research and Collections

Dr. Moncrief's article about the first specimens of nine-banded armadillos from Virginia, which are housed at VMNH, was published in *Southeastern Naturalist*. Her co-authors are Mr. Seth Thompson and Mr. Michael Fies, who are Biologists in the Virginia Department of Wildlife Resources. The citation is: Moncrief, N. D., M. L. Fies, and S.D. Thompson. 2021. Recent records and range expansion of *Dasypus novemcinctus* (Nine-banded Armadillo) in Virginia. *Southeastern Naturalist* 20:N73-N78.

Dr. Moncrief also continued work on three manuscripts as follows:

- 1) She worked with her coauthors to revise and resubmit a manuscript to *Journal of Mammalogy*. It provide details about healed skeletal fractures in eastern fox squirrels and eastern gray squirrels; 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.
- 2) She submitted to *Northeastern Naturalist* an annotated checklist of mammals that live on Virginia's barrier islands and the adjacent Eastern Shore mainland. Her co-authors are VMNH Research Associates Dr. Raymond Dueser and Dr. John Porter, both whom are at the University of Virginia.
- 3) She drafted text for a manuscript that reports the first whole genome of the eastern fox squirrel, which will be submitted to the peer-reviewed journal 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.

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. The VMNH portion of funding totals about \$360,000.

In April and May Dr. Moncrief prepared and submitted a poster for the 2021 virtual conference of the American Society of Mammalogists. She presented the poster, which summarized her work on skeletal injuries in squirrels, at the conference 14-18 June 2021. Her coauthors were 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 continued working with Biology Research Technician Ms. Liberty Hightower, VMNH Collections Manager Ms. Haley Cartmell and VMNH Registrar Ms. Jill Harris to conduct and coordinate VMNH review activities of a new collections management software system (Proficio) and migration of the VMNH collections databases to that software.

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.

Dr. Moncrief responded to several inquiries for information about the vertebrate zoology collections, and she hosted several visits to the bird and herp collections.

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 serves on the Systematic Collections Committee of the American Society of Mammalogists. She met virtually with other committee members, during the annual conference of this organization, in June to discuss the business of the committee.

Dr. Moncrief is 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 identified suitable reviewers and sent the manuscript to them in June.

Scientific Programs, Exhibits, and Other Activities

Dr. Moncrief continued work on a special exhibit about flight. She worked with VMNH Research Technician Ms. Liberty Hightower to select and prepare bird and bat wings that demonstrate different types of powered flight. She met several times with VMNH Exhibits Manager Ms. Jessica Davenport and VMNH Education Manager Ms. Christy Deatherage to discuss specimens and options for displaying them.

In early April Dr. Moncrief recorded a digital lecture about mammals of Virginia and techniques used to study mammals for the Piedmont Master Naturalists' basic training course, and then she joined a live zoom session with the participants to answer their questions about the material. This presentation will also be used by the VMNH Education Department's as part of the on-line K-12 Teacher Professional Development series.

In late April, Dr. Moncrief participated with other VMNH curators and VMNH Education Manager Ms. Christy Deatherage in a live Q and A session about natural history collections for two classes at Roanoke College (taught by VMNH Foundation Board Member Dr. DorothyBelle Poli).

Dr. Moncrief participated with other VMNH scientists and educators in VMNH's Drive Thru Experience "Treasures from the Vault", which was held in Waynesboro on 1 May 2021. She displayed a variety of horns and antlers.

Dr. Moncrief continued working on a permanent exhibit about watersheds. She proofread text panels and met several times with VMNH Exhibits Manager Ms. Jessica Davenport, VMNH Education Manager Ms. Christy Deatherage, and VMNH Paleontology Research Technician Ms. Lucy Treado to discuss an interactive element that features replicas of trackways and feet of several mammals that occur in the Dan River watershed.

Adam Pritchard, Ph.D.
Assistant Curator of Paleontology

- Dr. Pritchard collaborated with an international team of researchers on an article on a globally distributed group of Triassic reptiles called *Malerisaurus* for the journal *Papers in Palaeontology*.
- Dr. Pritchard helped co-lead the Wyoming Dinosaur Project 2021, a collaborative project involving Virginia universities and undergrad students focused on excavating Jurassic dinosaurs from a site near Greybull, WY.
- Dr. Pritchard led fieldwork in Ashland, Virginia focused on the excavation of Triassic vertebrates in collaboration with local amateur paleontologists. He also recorded an interview with a local CBS affiliate on this particular project.
- Dr. Pritchard presented to a number of non-professional audiences. These included a presentation on organismal classification to a Carlisle School biology class, a fossil table display for the 'Treasures from the Vault' drive-thru event at Waynesboro, and a series of three 'Tales of Ancient Life' videos for VMNH social media.

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 article was submitted for peer review and recommended for publication with minor revisions in Q2 2021.

Dr. Pritchard helped lead the Wyoming Dinosaur Dig Project for 2021. A collaboration with University of Lynchburg Professor Dr. Brooke Haiar and VMNH technician Lucy Treado, the project focused on the Two Sisters dinosaur locality near Greybull, Wyoming. Participants in the trip for 2021 included a dozen undergraduate students from four Virginia colleges and universities and several volunteers from the general public. During the trip, Dr. Pritchard worked on transportation and care of students, equipment, and fossils; training of students and volunteers in paleontology; production of social media posts on the project; and oversight of half of the excavation site. The work began at the very end of Q2 2021 and continued into the beginning of Q3.

In late April 2021, Dr. Pritchard traveled to the Triassic vertebrate fossil site in Ashland, VA with a group of local landowners and VMNH volunteer Michael Stevens. During the trip, the team collected numerous sandstone rocks containing small vertebrate fossils, including reptile teeth and fish scales.

Dr. Pritchard collaborated with Virginia amateur paleontologist Trevor Clarke on the intake of Atlantic Coastal Plain vertebrate specimens. They also worked together on permit documents for a collecting project at the Westmoreland State Park for Q4 2021.

Dr. Pritchard submitted an abstract for the 2021 Society of Vertebrate Paleontology online conference. The abstract details his discoveries related to the gliding, lizard-like

kuehneosaurids. Dr. Pritchard's research has revealed these animals to be distant relatives of modern lizards and surprisingly closer to crocodylians and dinosaurs.

Dr. Pritchard fielded requests for VMNH paleontology specimen information from workers at the Ohio State University, the Science Museum of Virginia, the University of Illinois, Virginia Tech, the University of Lynchburg, the College of William & Mary.

Dr. Pritchard worked with Tanya Berardini, the administrator of the phylogenetic data aggregator Morphobank (www.morphobank.org). Berardini reached out to him with requests for information and feature suggestions for the site. Pritchard produced a short paragraph for the upcoming NSF proposal to continue support for the Morphobank project.

Education & Outreach

Dr. Pritchard presented a new lecture to Ms. Ashby's biology class from the Carlisle School. The program focused on the methods paleontologists and biologists use to classify organisms and place them within the tree of life.

Dr. Pritchard developed table displays and presented fossils at the Waynesboro drive-thru event "Treasures from the Vault." The paleontology table displays focused on marine animals found on the Atlantic Coast of Virginia. The drive-thru event reached 163 visitors.

Dr. Pritchard produced three 'Tales of Ancient Life' videos for VMNH social media. As of August 2021, the Q2 videos have accrued over 900 views on the VMNH Facebook page.

Exhibits

Dr. Pritchard continued to work on content for the Q1 2022 Flight exhibit with Ben Williams, Jessica Davenport, and the other curatorial staff.

Dr. Pritchard provided a loan of a *Tyrannosaurus rex* tooth and a *Triceratops horridus* horn from the VMNH collections for the Science Museum of Virginia. The specimens will be used as part of the public outreach for the SMV's temporary exhibit on tyrannosaurs.

Media

Dr. Pritchard was interviewed by a producer for a Richmond CBS affiliate for a news segment on Triassic fieldwork in the Ashland area and his collaboration with amateur paleontologist Michael Stevens. The segment aired in Q3 2021.

Hayden Bassett, Ph.D.
Assistant Curator of Archaeology

In his fourth quarter with the museum, VMNH Assistant Curator of Archaeology Dr. Hayden Bassett focused his efforts on archaeological fieldwork for VMNH's Smith River Survey (SRS), further establishing VMNH's new Cultural Heritage Monitoring Lab (CHML), and delivering the CHML's first six months of research output to key stakeholders.

Research and Collections

In mid-May, Dr. Bassett delivered a comprehensive report, co-authored with VMNH Staff Archaeologist Madeleine Gunter Bassett, to the Virginia Department of Historic Resources (VDHR) on the VMNH's archaeological fieldwork in Stanleytown, VA completed in April. In early July, Dr. Bassett published a review of *The Archaeology of Virginia's First Peoples* in the journal *Southeastern Archaeology*. He is now working on two manuscripts, with an anticipated submission next quarter.

From May to June, Dr. Bassett completed ground-penetrating radar fieldwork at major terminal Late Woodland (AD 1200-1450) site in Henry County, one of seven archaeological sites included in the Smith River Survey (a 2-year VMNH archaeological survey of the Smith River in Henry County, VA). VMNH Staff Archaeologist Madeleine Gunter Bassett and Dr. Hayden Bassett used GPR to survey and identify the best locations to sample archaeologically. This GPR fieldwork was covered by the local newspaper and served as a proof of concept for how the VMNH Archaeology Department will sample the major Virginia Indian village sites along the Smith River. In collaboration with the Smithsonian Institute, the VMNH's Cultural Heritage Monitoring Lab (CHML), under the direction of Dr. Bassett, made significant progress this quarter on projects in Armenia, Ethiopia, Ukraine, Honduras, and Afghanistan. These geospatial data production projects were initiated at the request of the US Army Reserve 38G/6V (Monuments Men) and the U.S. State Department, to support their ability to protect global cultural heritage. Through the CHML at VMNH, Dr. Bassett is leading a team of 6 cultural heritage professionals and 5 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 5,000 "objects" since May, and anticipates comparable growth in digital collections with each new quarter. Over 2,700 of these digital objects in the VMNH's CHML collections were requested/accessed by outside researchers between May and July.

Between early May and late-July, Dr. Bassett gave 17 presentations on the findings of the VMNH's Cultural Heritage Monitoring Lab (CHML). These presentations were given virtually and in person to the Smithsonian Institution, the US State Department, the US Department of Defense, University of Virginia and University of Pennsylvania faculty, the Salem Historical Society, the Rotary Club of Martinsville, the Government of Honduras, and the International Committee of the Blue Shield. Additionally, Dr. Bassett and his team delivered 12 reports of findings to key stakeholders for implementation or response. Noteworthy among these was Dr. Bassett's development of a geospatial model identifying impacts to cultural heritage in Honduras from Hurricanes Eta and Iota,

and a predictive model of archaeological sites locations across Honduras. The two data products are now being implemented in a combined US-Honduran humanitarian response to safeguard the country's cultural heritage.

Education and outreach

Dr. Bassett is currently in the direct commissioning processes to enter to the US Army Reserves as one of approximately 35 new "Monuments Men" Army reserve Captains, Majors, and Lt. Colonels. As a major outreach effort for the museum, he has positioned the VMNH's Cultural Heritage Monitoring Lab as the primary research lab for the Army's Monuments Men program.

Between May and July, the VMNH Archaeology department worked with several colleges and universities. Dr. Bassett and VMNH Staff Archaeologist Madeleine Gunter Bassett brought on seven virtual interns. Students are receiving college credit from their respective institutions to participate in this VMNH program. The U.S. Department of State has provided the CHML at VMNH an additional 8 virtual intern positions, which will begin in September. Last, Dr. Bassett and his team gave two presentations to the administration of the University of Virginia, and are in early discussions about partnerships.

In late July, Dr. Bassett participated in VMNH's annual Bug Day festival, where he set up a table demonstrating in the role of aquatic and terrestrial insects in trout ecology. He conveyed this through VMNH's mounted insect specimens, side by side with hand-tied imitations of the insect used by anglers. The table included a demonstration of fly tying, imitating mayflies commonly found on the Smith River.

Dr. Bassett responded to five public requests for identification of artifacts, all 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. In June, he was appointed to the Legislative Affairs Committee of the Council for Virginia Archaeologists (CoVA). In July, he was asked to join the doctoral committee of a William & Mary Ph.D. student studying Virginia archaeology. Last, he continued his appointments as Visiting Scholar and Adjunct Faculty at the College of William & Mary, where he will resume teaching (remotely from VMNH) in Spring 2022.

From early May through late July, Dr. Bassett organized four 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 three of the four 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. Additionally, Dr. Bassett continued his service with the publications team of the Archaeological Society of Virginia as a peer reviewer for the organization's longstanding (1945-Present) research journal.

From early May through late-July, Dr. Bassett was consulted on six occasions by US federal agencies to implement his technical methods for using satellite imaging and remote sensing to document destruction of cultural heritage in conflict zones and after natural disasters. These professional services were provided to assist in efforts in Europe, Africa, and Central America.

Research and Collections

Jill K. Harris, Registrar

Seven (7) collections acquisitions were recorded for ~3171 specimens and 160 lots of specimens. These specimens were added to the invertebrate zoology, vertebrate zoology (mammals), and paleontology collections.

Four (4) outgoing loans were recorded for 16 (sixteen) mammal, paleontology, and recent invertebrate specimens to the following institutions: Virginia Commonwealth University, Science Museum of Virginia, Waynesboro Public Library, and the Denver Museum of Nature & Science.

Re:discovery Software, Inc. (RSI) and VMNH staff completed the process of upgrading the research and collections department's collections management system from RSI Visual Re:discovery (FoxPro) to RSI Proficio Re:discovery (SQL).

Haley Cartmell, Collections Manager

Curators and staff modified/updated 9,840 existing records and added 65 new records to the VMNH collections databases, Rediscovery (for biological and archaeological collections) and EGEMS (for physical geological and paleontological collections).

The VMNH collections database software Rediscovery was upgraded to the new Proficio software. Curators and staff reviewed VMNH data using the new software during the quarter, with Ms. Harris compiling all comments and acting as "point person" with the Proficio software developers. Upgrades were marked complete in the beginning of July 2021.

Ms. Cartmell processed one (1) load of collections materials through the CO2 bubble this quarter. Processed materials included a recent donation to the Entomology collection of 2086 pinned insects, 830 enveloped insects, 48 Cornell drawers, and ten (10) small and seven (7) large storage boxes of materials.

PEOPLE SERVED DATABASE printed 8/4/2021
Summary

People Served April-June 2021

# of Activities	TYPE OF ACTIVITY	PROFESSIONALS AND 13+ STUDENTS	K-12 STUDENTS	K-12 TEACHERS	PUBLIC			TOTAL #	
2	Conference presentations (A)	440	0	0	0			440	
0	Meetings chaired (B)	0	0	0	0			0	
9	Review documents/manuscripts (B)	9	0	0	0			9	
11	Requests for information about collections (C)	0	0	0	11			11	
6	Visiting researcher (C)	5	0	0	1			6	
0	Collections tours (D)	0	0	0	0			0	
0	Lab Tours (D)	0	0	0	0			0	
0	Receptions	0	0	0	0			0	
37	Responses to requests for information about specimens at VMNH (D)	0	0	0	37			37	
4	Lectures and presentations at VMNH (D)	55	12	1	85			153	
5	Technical consultations (B, D, & E)	0	0	0	5			5	
8	Display table with specimens	0	0	0	652			652	
0	Off-site education programs	0	0	0	0			0	
3	Lectures Not at VMNH (E)	21	0	0	12			33	
0	Off-site presentations (E)	0	0	0	0			0	
3	Field trips/Field Work	31	0	0	13			44	
0	TOTALS	0	0	0	0			1390	

TOTAL # INDIVIDUALS SERVED

1390

Research & Collections Facebook Statistics April-June 2021

Total Research & Collections Post Reach

146,781

Total Research & Collections Post Reactions (Likes, Comments, Shares, etc.)

60,149

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

5,097

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

1. Armadillos in Virginia? (June 21) - 736
2. Virginia Beach Entomology Collection (May 21) - 153
3. Mt. Rogers Entomology Expedition (June 25) - 147
4. Ben In Nature: Rat Snakes Mating (June 18) - 127
5. Ben In Nature: Luna Moth (June 11) - 105

Top 5 Performing Research & Collections Posts By Total Clicks

1. Armadillos in Virginia? (June 21) - 1,510
2. Ben In Nature: Rat Snakes Mating (June 18) - 417
3. Mt. Rogers Expedition (June 25) - 203
4. North Carolina and Tennessee Entomology Expedition (May 15) - 119
5. Ben In Nature: Wolf Spider Egg Sac (May 28) - 114

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

- The total number of followers increased by 202 (from 12,895 to 13,097).
- The total number of likes increased by 183 (from 12,644 to 12,827).

Attachment

The attached article provides an example of how natural history collections can be used to answer novel questions about past and present environments. There could easily be similar stories housed right in VMNH collections! For more information, visit the following link: <https://www.reuters.com/business/environment/life-cycle-alaskan-wooly-mammoth-documented-new-analysis-his-tusk-2021-08-12/>

PALEONTOLOGY

Lifetime mobility of an Arctic woolly mammoth

Matthew J. Wooller^{1,2,*†}, Clement Bataille^{3,4,*†}, Patrick Druckenmiller^{5,6}, Gregory M. Erickson⁷, Pamela Groves⁸, Norma Haubenstock¹, Timothy Howe¹, Johanna Irrgeher⁹, Daniel Mann⁸, Katherine Moon^{10,11}, Ben A. Potter¹², Thomas Prohaska⁹, Jeffrey Rasic¹³, Joshua Reuther⁵, Beth Shapiro^{10,11}, Karen J. Spaleta¹, Amy D. Willis¹⁴

Little is known about woolly mammoth (*Mammuthus primigenius*) mobility and range. Here we use high temporal resolution sequential analyses of strontium isotope ratios along an entire 1.7-meter-long tusk to reconstruct the movements of an Arctic woolly mammoth that lived 17,100 years ago, during the last ice age. We use an isotope-guided random walk approach to compare the tusk's strontium and oxygen isotope profiles to isotopic maps. Our modeling reveals patterns of movement across a geographically extensive range during the animal's ~28-year life span that varied with life stages. Maintenance of this level of mobility by megafaunal species such as mammoth would have been increasingly difficult as the ice age ended and the environment changed at high latitudes.

The extent to which environmental changes and human activity altered woolly mammoth (*Mammuthus primigenius*) populations is key to understanding the causes of megafaunal mass extinctions after the last ice age (1–4). Because mammoths are extinct, however, we know very little about their natural history, including the size of their home ranges or lifetime movement (2, 4). Movement patterns of extant elephantids (5) and Arctic herbivores such as caribou (6) include regular movement across lifetime ranges, and it has been assumed that Arctic woolly mammoths exhibited similar behaviors.

Sequential isotopic analyses of elephantid tusks have been valuable for reconstructing life history records, including mobility (7, 8). As tusks grow, they continually incorporate ingested strontium (Sr), and the incremental record of strontium isotope ratios ($^{87}\text{Sr}/^{86}\text{Sr}$) in tusks and teeth can be used to investigate proboscidean movements (9, 10). The $^{87}\text{Sr}/^{86}\text{Sr}$ ratios in soils and plants show strong and

predictable geographic variations that primarily reflect the underlying bedrock geology and that change little at millennial time scales (10). As animals ingest local strontium, the bio-available $^{87}\text{Sr}/^{86}\text{Sr}$ patterns on the landscape are reflected in their tissues and can be used to trace an animal's movement (11, 12). Strontium isotope analyses can be augmented by stable oxygen isotope analyses to aid in determining the provenance of organisms (8, 12). To date,

studies of elephantid movement have either used bulk digestion of relatively large samples of tusks that average the isotopic variability associated with movements at low temporal resolution or have focused on incremental records of shorter duration found in teeth, short mandibular tusks, adolescent tusks, or tusk segments (7–9, 13).

The unglaciated portion of northern Alaska has a long and well-preserved mammoth paleontological record, with woolly mammoths persisting in mainland Alaska until ~13,000 calibrated radiocarbon years before present (4, 14) and more-recent survival on islands (1). Our aim is to use sequential isotopic analyses of one of these well-preserved remains, a tusk, to examine the life history of a woolly mammoth that was alive during the last ice age, when conditions likely favored woolly mammoth adaptations (15). We selected a tusk [University of Alaska Museum Earth Science (UAMES) collection catalog number 29496] from an animal that died above the Arctic Circle ~17,100 calibrated years before present (14). The well-preserved remains of our study specimen include both tusks (total length: ~2.4 m), fragments of the skull, and a complete mandible with well-preserved teeth (14). Genetic analyses of the specimen showed that it has a single copy of the X chromosome and is therefore male (14),

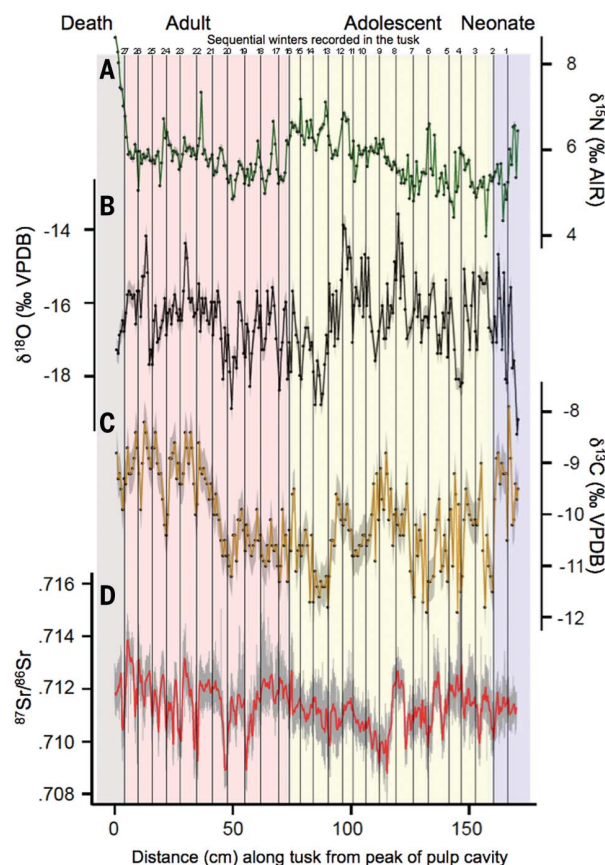


Fig. 1. Sequential isotopic analyses along an entire ~1.7-m-long transect of a mammoth tusk from Arctic Alaska. (A) Stable nitrogen, (B) oxygen, (C) carbon, and (D) strontium isotope values ($\delta^{15}\text{N}$, $\delta^{18}\text{O}$, $\delta^{13}\text{C}_{\text{carbonate}}$, and $^{87}\text{Sr}/^{86}\text{Sr}$ values, respectively). Vertical lines represent annual markers [peak winter (14)], and color shading corresponds to four main life periods (neonate, adolescent, adult, and end of life) (14). VPDB, Vienna Pee Dee Belemnite international standard; AIR, atmospheric nitrogen international standard.

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†These authors contributed equally to this work.

and analyses of its complete mitochondrial genome placed it within mitochondrial clade I (14). Macroscopic and microscopic examination of growth layers exposed on the interior surface of the bisected tusk, along with x-ray and isotope data along the entire tusk ($^{87}\text{Sr}/^{86}\text{Sr}$, $\delta^{18}\text{O}$, $\delta^{13}\text{C}$, and $\delta^{15}\text{N}$ values) (Fig. 1), established a minimum age at death of 28 years.

The ultrahigh-resolution $^{87}\text{Sr}/^{86}\text{Sr}$ (~340,000 individual $^{87}\text{Sr}/^{86}\text{Sr}$ ratio measurements) and lower-resolution $\delta^{18}\text{O}$ variations [i.e., about weekly temporal resolution (14)] along the entire tusk (Fig. 1) were used to infer the geographic range and movements of the mammoth during its main life stages (14). Our approach involved comparing the $^{87}\text{Sr}/^{86}\text{Sr}$ data from the tusk, averaged at about weekly resolution, along with the $\delta^{18}\text{O}$ values, to a set of predictive isotope maps for Alaska and northwestern Canada. We then used an isotopically informed Markov chain Monte Carlo approach to identify the most probable routes and most frequently visited areas (Fig. 2) (14) and reconstruct the mammoth's movement history (14).

The isotope data indicate four main life stages: neonate, juvenile, adult, and end of life (the last ~1.5 years) (14). Data from the first ~10 cm from the tusk tip showed minimal $^{87}\text{Sr}/^{86}\text{Sr}$ variation (Fig. 1), suggesting that the young mammoth mostly occupied a range in the lower Yukon River basin in interior Alaska (14). As a juvenile (2 to 16 years, represented by the next ~75 cm of tusk), the mammoth used a larger range spanning some of the lowlands of interior Alaska between the Alaska and Brooks ranges (Fig. 2) (14). The mammoth undertook regular north-south movements within this large core area (Fig. 2) (14) as well as several long-distance movements, sometimes reaching the eastern end of the Brooks Range and the northern Seward Peninsula in the west (Fig. 2) (14). These juvenile-age movements probably represent the movements of a herd (16–18). Living *Loxodonta* and *Elephas* species both form stable matriarchal social units comprising related females together with their juvenile male and female offspring (16–18).

With increasing maturity, our study mammoth broadened his range (Fig. 2). After ~16 years, a distinctive transition occurred involving higher variance in $^{87}\text{Sr}/^{86}\text{Sr}$ along with other isotopic changes (Fig. 1) (14). This implied change in the animal's range probably reflects a transition to reproductive maturity accompanied by long-distance travel between interior Alaska and the North Slope of the Brooks Range (Fig. 2). These movements were probably in response to seasonal changes in resource availability. Today, male individuals of *Elephas maximus* and *Loxodonta africana* tend to be more mobile than females, and they typically leave matriarchal herds to lead solitary lives or form all-male

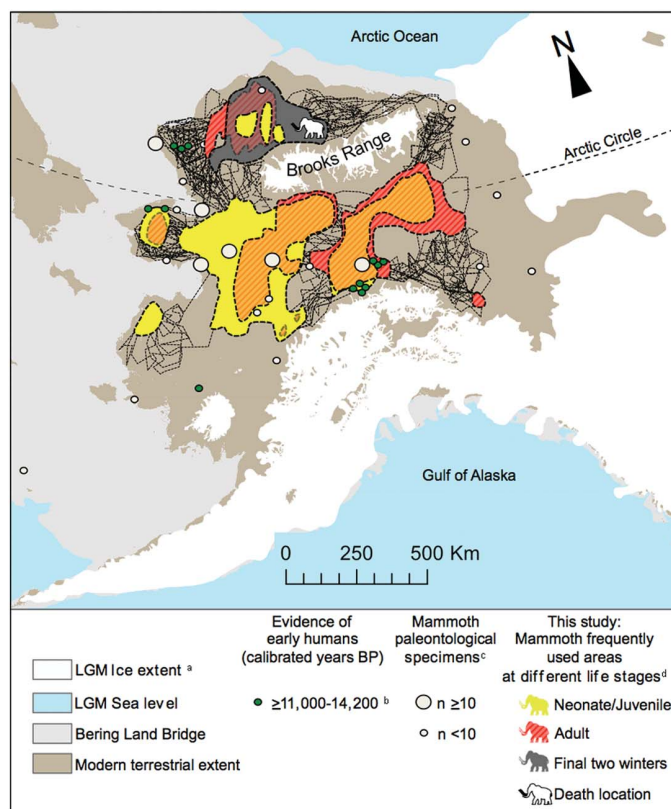
Fig. 2. Summary life history of this study's woolly mammoth within the geographic, climatic, and human dispersal context of Beringia during the Late Quaternary. The core areas correspond to those that were visited most frequently by the individual during each life stage (colored polygons) (14) (orange areas signify areas of overlap between neonate/juvenile and adult frequently used areas). The black dashed lines between the core areas represent the routes produced by the best walks (14). The white mammoth symbol indicates the area where the specimen was found (i.e., death location). Also shown are locations where the remains of other mammoths have been found and where evidence of early humans has been reported. Superscript letters indicate sources: a, (22); b, (23–25); c, compiled from Arctos and Neotoma databases (14); and d, this study. LGM, Last Glacial Maximum; BP, before present.

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groups (16–18). It is noteworthy that some of the mammoth's areas of frequent use (Fig. 2) (14) mirror those of extant caribou (6), suggesting the use of these areas by Arctic herbivores over many millennia. Holarctic mammoth distributions seem to favor habitats in mountainous settings (19). Notably, some of the areas most frequently visited by our mammoth bull are proximate to locations of higher densities of mammoth remains and some of the earliest sites of human occupation in Alaska (Fig. 2).

The isotopic proxies for movements ($^{87}\text{Sr}/^{86}\text{Sr}$ ratios and $\delta^{18}\text{O}$ values), habitat, and diet [$\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values (14)] from the final ~10 cm of the tusk, representing the last ~1.5 years of our mammoth's life, reveal that it occupied a reduced range entirely restricted to the region north of the Brooks Range (Fig. 2), where it most likely died from starvation (14). Evidence for starvation includes a substantial increase in $\delta^{15}\text{N}$ values and a corresponding decrease in $\delta^{13}\text{C}$ values (Fig. 1) (14). Death seems to have occurred in late winter or spring, after it was restricted to a small area surrounding the location of its death (Fig. 2). A winter or spring season of mortality is indicated by declining $\delta^{18}\text{O}$ values immediately before its death. Winter conditions can in-



clude a scarcity of food and low temperatures, requiring greater investments in thermoregulation by arctic mammals, and this seasonality of death is consistent with previously analyzed mammoths from Chukotka and Wrangel Island (7).

The last persisting woolly mammoth populations were geographically constrained on isolated and relatively small islands (1, 7), with no option to maintain large-scale movement patterns. Their extinctions were probably due to stochastic environmental changes and inbreeding that contributed to their eventual demise (1, 7). Our study mammoth, alternatively, moved widely across unglaciated parts of Alaska. If woolly mammoth populations on mainland Beringia maintained a similar degree of mobility during the transition from the last ice age to the warmer and wetter Holocene, this behavior could have imparted additional ecophysiological stress, in particular as the forb- and/or graminoid-dominated ecosystems diminished and forests and peatlands expanded (4, 20). This may have compounded their vulnerabilities to other stressors, including predation from humans and large carnivores (21), potentially contributing to their eventual extinction from mainland Beringia.

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SUPPLEMENTARY MATERIALS

science.sciencemag.org/content/373/6556/806/suppl/DC1
Materials and Methods
Figs. S1 to S21
Tables S1 to S7
References (26–90)
MDAR Reproducibility Checklist
Movie S1
Data S1 to S3

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A mammoth's life

Fossils have long given us glimpses of the life that came before us, but these glimpses are generally static. They tell us a bit about species that lived, but not much about how they lived. Evolving techniques are deepening our viewpoint. Wooller *et al.* examined isotopes collected from the tusk of a 17,000-year-old mammoth to elucidate its movements from birth to death. This included its time—likely with a herd—as an infant and juvenile, then as a prime-age adult, and then as a declining senior over its approximately 28-year life span.

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